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Effect of expiratory muscle strength training on elderly cough function

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ABSTRACT

Age-related loss of muscle strength, known as sarcopenia, in the expiratory muscles, along with reductions in lung elastic recoil and chest wall compliance decreases the intrathoacic airway pressure as well as expiratory flow rates and velocity, greatly impacting an elderly person's ability to generate the forces essential for cough. This study examined the effects of a 4-week expiratory muscle strength training (EMST) program on maximum expiratory pressure (MEP) and cough function in 18 healthy but sedentary elderly adults. MEP significantly increased after the EMST program from 77.14 ± 20.20 to 110.83 ± 26.11 cm H_2O. Parameters measured during reflexive coughs produced by capsaicin challenge, indicated that compression phase duration significantly decreased (from 0.35 ± 0.19 to 0.16 ± 0.17 s), peak expiratory flow rate decreased (from 4.98 ± 2.18 to 8.00 ± 3.05 l/s) and post-peak plateau integral amplitude significantly increased (from 3.49 ± 2.46 to 6.83 ± 4.16 l/s s) with the EMST program. EMST seems to be an effective program to increase the expiratory muscle strength in the sedentary elderly, which contribute to an enhanced cough function.

1. Introduction

Cough plays an important role in expelling foreign substances or excessive mucus in the intrathoracic airways through production of high forced expiratory airflow velocity (Shannon et al., 1997; McCool, 2006). During cough, the coordinated activity of various respiratory muscles intricately controls cough production. The inspiratory muscles contract to increase lung volume needed to augment the high-velocity of expiratory flow. The expiratory muscles contract to build up high positive intrapleural and intra-airway pressures for development of peak expiratory flow rates (Chung et al., 2003; McCool, 2006). Weakness of the inspiratory or expiratory muscles greatly impacts an individual's ability to generate the forces essential for cough, decreasing the airway pressure critical for generating the essential cough expiratory airflow rates and velocity.

Respiratory muscle strength decreases in the elderly with muscle fiber atrophy, sarcopenia (Chen and Kuo, 1989; Tolep and Kelsen, 1993; Enright et al., 1994; Brooks and Faulkner, 1995; Berry et al., 1996; Janssens et al., 1999), by approximately 20% by age 70 years (Chen and Kuo, 1989). This age-related change in the respiratory muscles is often combined with a sedentary lifestyle. Inactivity, due to a lack of physical exercise may accelerate reductions in respiratory muscle force generating capacity resulting in a decrease in intrathoracic pressure and expiratory flow rates during cough (Beardsmore et al., 1987; Mizuno, 1991; Irwin et al., 1998; Campbell, 2001). It has been reported that the force generating capacity of the expiratory muscles (referred to here as expiratory muscle strength) is reduced more than the inspiratory muscles (Mizuno, 1991; Tolep et al., 1995). This is due to greater reductions in muscle fiber cross-sectional area of the expiratory muscles than those of the inspiratory muscles (Mizuno, 1991; Tolep et al., 1995).

Development of specific methods for increasing cough strength and timing has been limited. Limited numbers of treatment studies designed to improve cough in patients with respiratory muscle weakness have relied on procedures, such as percussion and shaking, manually assisted cough, mechanical insufflation and/or exsufflation (Bott and Agent, 2001; Sivasothy et al., 2001; Chatwin et al., 2003; Mustfa et al., 2003). These procedures improved cough efficacy with increasing peak cough expiratory flow to a small degree in patients with respiratory muscle weakness. While these methods increased peak expiratory flow rate, they did not improve respiratory muscle force generating capacity. Additionally,

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mechanical assisted insufflation/exsufflation requires a mechanical ventilator which is only available for use under medical supervision and cannot be used in the patients with mild to moderate decreases in respiratory muscle force generating capacity such as the normal sedentary elderly. Thus, it is essential to develop treatments applicable to the elderly population to reverse their regressed cough production related to respiratory muscular weakness and ameliorate their risk of respiratory diseases due to inadequate airway clearance (Gosselink et al., 2000; Baker, 2003; Chiara et al., 2006).

A training program targeting expiratory muscles, called expiratory EMST, is known to improve expiratory muscle force generating capacity and result in increased expiratory driving force during cough (Smeltzer et al., 1996; Gosselink et al., 2000; Baker, 2003; Saleem, 2005; Chiara et al., 2006) in young subjects. However, the effects of EMST in the elderly for improving cough function is unknown (Tolep and Kelsen, 1993). Furthermore, the effect of EMST on cough function, has only been studied during maximum voluntary cough production (Baker, 2003; Saleem, 2005; Chiara et al., 2006). Cough is typically a reflexive event to clear the airway (McCool, 2006), therefore, it is needed to evaluate how EMST impacts on a reflexive cough function. Capsaicin is a commonly used irritant for investigation of human cough. Capsaicin reproducibly elicits cough in most subjects (Ertekin et al., 1995; Dicpinigaitis, 2003; Nieto et al., 2003; Dicpinigaitis and Alva, 2005; Prudon et al., 2005). Hence this study was designed to investigate the effects of a 4-week EMST program with the sedentary healthy elderly on reflexive cough parameters induced by capsaicin. We hypothesized that expiratory muscle strength in the sedentary elderly would increase after the 4 weeks of the EMST program. This enhanced expiratory muscle force generating capacity was further hypothesized to increase expiratory muscle force, as measured by MEP and cough parameters during reflexive cough. It was reasoned that there would be a correlation between MEP and measures of cough intensity demonstrating that increases in expiratory muscle force would result in enhancing cough efficacy. We further hypothesized that the enhanced cough efficacy would not be related to cough sensitivity to capsaicin in sedentary elderly subjects.

2. Subjects and methods

2.1. Subjects

Eighteen healthy sedentary individuals over 65 years participated in this study (4 males and 14 females). Sedentary was defined as a person with 24-h of maximum exertion time (MET) less than 50 in physical activity as described in the physical activity questionnaire (Aadahl and Jorgensen, 2003). Subjects' ages ranged from 68 to 89 years. Subjects were recruited from the local community of Gainesville, FL, US. All experimental procedures and risks were explained to the subjects and the subjects signed an informed consent approved by the University of Florida, Institutional Review Board. All subjects had no history of chronic and acute cardiac, pulmonary, neuromuscular or immune system disease, and/or history of smoking or tobacco use within the last 5 years as well as no acute upper respiratory infection at the time of the baseline measurements. All subjects' pulmonary function measures of forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC) and FEV_1/FVC were obtained by a computerized Master Screen Pulmonary Function Test (PFT) system (Jaeger Toennies, Erich Jaeger Gmbh, Leibnizstrasse 7, D-97204 Hoechberg, Germany) and were within the normal range for the predicted normative values. All subjects were asked to report any significant changes in their level of physical activity during their participation in the study. If subjects had significant change in activity level, they were discontinued in the study. Baseline demographic and spirometric characteristics of subjects are presented in Table 1.

Table 1
Demographic and pulmonary function measures of subjects in the study.

	Men (mean ± SD)	Women (mean ± SD)
Subject (*n*)	4	14
Age (years)	78.25 ± 7.80	76.64 ± 5.27
Height (cm)	175.90 ± 2.43	160.16 ± 6.11
Weight (kg)	84.41 ± 18.80	68.05 ± 10.87
MET	28.46 ± 13.74	31.03 ± 8.56
FEV_1% pred	87.76 ± 17.19	102.43 ± 17.91
FVC % pred	87.46 ± 10.92	108.29 ± 16.95
FEV_1/FVC ratio	73.36 ± 4.86	78.54 ± 6.43

% pred: percentage of the predicted value.

2.2. Procedures

2.2.1. Training protocol

The study was a 7-week experimental protocol. Weeks 1 and 2 included two pre-training baseline measurement conditions. Subjects participated in the EMST training program during weeks 3 through 6. Post-training measurement occurred during week 7. Measures of maximum expiratory pressures were obtained for each subject every week of the 7-week study period. Cough measures were recorded in weeks 1, 2, and 7.

After completion of the two pre-training baseline sessions (weeks 1 and 2), each subject was given an expiratory pressure threshold trainer. The expiratory pressure threshold trainer was a custom-modified positive end expiratory pressure (PEEP) valve that consisted of a mouthpiece and an adjustable one-way spring-loaded valve (Fig. 1). This device allowed the pressure threshold to be adjusted up to a maximum PEEP of 150 cm H_2O. The valve blocked expiratory airflow until the subject generated sufficient expiratory pressure to exceed the valve threshold pressure and open the spring-loaded valve.

The subjects' MEP was measured at the initiation of the study and following each week of training as well as post-training (the procedure measuring MEP will be discussed later). The daily training protocol consisted of the subject exhaling for 3–4 s through the training valve with the pressure threshold set at 75% of the subject's MEP at the time of measurement (Baker, 2003; Chiara, 2003; Saleem, 2005; Wingate et al., 2007). To prevent possible air-leak, the individual was instructed to place his/her lips tightly around the device mouthpiece and place one of his/her hands firmly on the cheeks. The individual was then instructed to blow as forcefully as possible into the device's mouthpiece from total lung capacity (TLC). The subject performed five sets of five breaths per set with a 2 min rest period between sets. The subjects performed this 25 breath training session for 5 consecutive days per week and did not train for 2 consecutive days. Each week readjustment of the device occurred by measuring the subject's MEPs and resetting the device to 75% of the newly measured average MEP.

To insure subject's compliance with the training protocol, they were provided with written and verbal instructions for the use of their devices and the EMST protocol. During the 4 weeks of home treatment with the device, subjects recorded the completion of their training sets on a log sheet, which was checked at each week when the readjustment of the device occurred.

2.2.2. MEP

The expiratory muscle force generating capacity was measured using MEPs (Ringqvist, 1966; Black and Hyatt, 1969; Chen and Kuo, 1989; Enright et al., 1994; Karvonen et al., 1994; Berry et al., 1996). The MEP was recorded using a disposable mouthpiece connected to a Smart 350 series pressure manometer (Meriam Process Technologies, Cleveland, OH, USA) by 50 cm of 6 mm inner diameter tubing with a 20-gauge (2 mm) needle air-leak at the mouth to prevent the subject from sustaining pressure with a glottal closure (Enright et al., 1994; Karvonen et al., 1994; Berry et al., 1996). Before every measurement of MEP, the manometer was calibrated. Repeated measures were taken with a 1–2 min rest between trials for

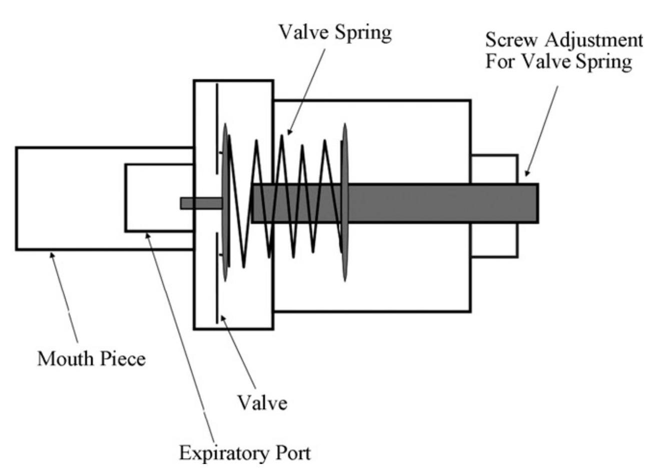

Fig. 1. Schematic representation of the expiratory pressure threshold training device.