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Original Article

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Effects of Inspiration and Expiration Exercise Combined with Upper Extremity Proprioceptive Neuromuscular Facilitation on Forced Volume Vital and Peak Expiratory Flow

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| Abstract |

Purpose: The purpose of this study was to examine the effects of inhalation and exhalation exercise combined with upper extremity proprioceptive neuromuscular facilitation pattern on two spirometry values: forced volume vital (FVC) and peak expiratory flow (PEF).

Methods: Thirty-two healthy adults were divided into two groups: 1) a combined group, which performed upper extremity D2 flexion pattern (shoulder flexed/abducted/external rotated, forearm supinated, wrist radial deviated, and finger extended) during exhalation and D2 extension pattern (shoulder extended/adducted/internal rotated, forearm pronated, wrist ulnar deviated, and finger flexed) during inhalation; and 2) reverse combined group, which performed the D2 flexion pattern during inhalation and the D2 extension pattern during exhalation. The inverse application of upper extremity movements during inhalation and exhalation induced selective resistance or assistance on respiration. FVC and PEF were measured at two time points, before and after four weeks.

Results: In both groups, the pre-post intervention comparison showed significant increases in FVC and PEF ($p < .05$). In the between-groups comparison, the reverse combined group showed a significantly higher PEF than the combined group at four weeks post intervention ($p < 0.05$).

Conclusion: The combined respiration exercise with reverse PNF upper extremity patterns using selective resistance showed an effective increase in PEF in healthy adults. Clinicians and researchers might consider using selective resistance as a widely applicable and cost-effective option for respiratory rehabilitation planning.

Key Words: PNF upper extremity pattern, Respiratory exercise, Spirometry values

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Ⅰ. Introduction

Chronic respiratory diseases are common conditions observed in a billion of individuals worldwide (Prince et al., 2015) and include chronic obstructive pulmonary disease (COPD), asthma or interstitial lung disease (Armstrong & Vogiatzis., 2019; Bousquet et al., 2010). These diseases can cause difficulty in breathing during physical activity such as a shortness of breath and/or chronic cough producing sputum. When the difficulties become chronic conditions, they may negatively impact on disorder and/or quality of life in those with the respiratory diseases (Carreiro-Martins et al., 2016). As a long-term effect, the difficulties in breathing could restrict a chance of participation in their physical activity (e.g. daily living) and could further result in decreased quality of life (American Thoracic Society, 1999).

A number of exercise and educational program have been developed for respiratory rehabilitation and showed positive effect on increased strength of respiratory muscles and/or capacity of respiration. The respiratory rehabilitation with positive effect includes training using physical activity (Summerhill et al., 2007), selective muscle strength exercise (HajGhanbari et al., 2013), respiratory exercise using an instrument for lung capacity (Clanton et al., 1985) and respiration re-education training (Troosters et al., 2005). Of these, the training using physical activity and selective muscle strength exercise report a maximized effect on capacity of respiration but they may not be suitable for most patients with chronic respiratory diseases since these diseases are common in old individuals. In addition, the respiratory exercise using an instrument for lung capacity and respiration re-education training leaded by experts require a higher cost than other interventions. Thus, it is essential to develop a widely applicable and cost-effective intervention for patients with chronic respiratory disease.

The applicable and cost effective respiratory rehabilitation may not require a high intensity of physical activity and/or strength exercise as well as it should be able to conduct by patients themselves. Respiratory rehabilitation using the Proprioceptive Neuromuscular Facilitation (PNF) on thorax is easy and concise intervention conducting movement patterns using joint range of motion with a low intensity of physical activity (Kim et al., 2000). Thus, it is possible to be used for patients with limitation of movement. To assist the thoracic movement, upper extremity movement is often applied during respiration in rehabilitation training. For example, Areas et al. (2013) conducted a randomized control study using upper extremity PNF pattern in healthy women for four weeks, and showed a significantly increased maximum pressure for inhalation/exhalation (effect size for maximum inhalation/exhalation pressures: 1,74/1.56). This increased capacity of respiration from the added upper extremity movement pattern may be associated with increased extension and elevation of trunk movement as the kinematic chain effect while the upper extremities are elevated and/or flexed (Stapley et al., 1998). Fayad et al. (2008) examined the amount of increased extension and elevation in trunk while arms were fully elevated using 3D motion analysis, and reported that 7° of extension and 8° of elevation in trunk.

Although the application of the PNF upper extremity pattern for thoracic movements needs assistance of experts (e.g. therapists), it requires less cost than other interventions as it can be implemented by patients themselves once trained appropriately. The other advantage of using the PNF upper extremity pattern is that the direction of resistance (flexion or extension) to thorax can be chosen during either inhalation or exhalation. To date, the PNF upper extremity pattern during respiration has shown a significant effect on capacity of respiration. However, no studies examined the effect of two different directions of resistance on capacity of respiration when it combines with inhalation and exhalation, as a widely applicable and cost-effect rehabilitation intervention. Thus, the aim of this study was to examine the effects of inhalation and exhalation exercise combined with upper extremity PNF patterns on the spirometry values including the forced volume vital (FVC) and peak expiratory flow (PEF).

Ⅱ. Methods

1. Participant

A four weeks intervention trial was performed in Busan city, South Korea. Participants were recruited from a university in the city through advertisements, social media, word of mouth, and email contact. Eligible participants included 32 healthy adults between 20 and 30 years old. They were provided information of the study and decided to participate. Participants were included if they did not have i) a history of malformation or deformation of spine, ii) a medical issue on respiratory system, or iii) acute or chronic pain in any other body. All participants were noticed that they were able to withdraw their participation at any point of the study with or without personal reason or discomfort.

2. Intervention

Participants were divided into two groups: Combined group and Reverse combine group. Both groups conducted a 15 minutes intervention every day for four weeks. For upper extremity PNF movement, the bilateral PNF diagonal 2 pattern (D2) was chosen to drive synergistic upper body movement during respiration. The D2 pattern is a technique that encompasses the shoulder, elbow, wrist and fingers movements in two directions including D2 flexion and D2 extension patterns. The D2 flexion pattern starts in shoulder extension, adduction and internal rotation, forearm pronation, and wrist and finger flexion, and ends in shoulder flexion, abduction, and external rotation, forearm supination, wrist and finger extension. The D2 extension pattern reverses the D2 flexion pattern. Intervention for Combined group consisted of PNF D2 flexion pattern during inhalation and PNF D2 extension pattern during exhalation, which provided selective support to trunk movement while respiration. On the other hand, intervention for Reverse combine group consisted of PNF D2 extension pattern during inhalation and PNF D2 flexion pattern during exhalation, which provided selective resistance to trunk movement while respiration. During the intervention, a physiotherapist assisted speed of PNF patterns for patient to maximize the amount of inhalation and exhalation, and applied manual resistance to facilitate correct upper extremity movement if needed. To minimize muscle fatigue, one minute rest was provided after every five minutes intervention.

3. Outcome measurements

A pulmonary dynamometer (SP-260 Pneumotacho Sensor, SCHILLER, Swiss) was used to measure FVC and PEF before and after four weeks intervention. Participant was provided information of how to use the dynamometer with an additional demonstration from an examiner. Two measurements were conducted for each test position for sitting and standing and the average value from the two measurements were used for analysis.

4. Analysis

All analyses were performed using the SPSS version 25.0 (SPSS Inc., Chicago, USA). Independent t-test was used for comparison of demographic information and PEF after four weeks intervention between two groups. Paired t-test was used to identify effect of intervention in each group between pre- and post-intervention. The statistical significant level α was set at 0.05.

Ⅲ. Results

1. Demographic information, FVC and PEF at pre-intervention

No significant difference was reported in demographic information including age, height and weight between two groups ($p>0.05$). No significant difference was also reported in FVC and PEF measured before intervention between two groups ($p>0.05$) (Table 1).

2. FVC and PEF at four weeks post intervention

When comparing two groups after four weeks of intervention, for FVC, no significant difference was reported between groups ($p<0.05$). For PEF, Reverse combined group reported a significantly higher PEF compared to Combined group ($p<0.05$) (Table 2).

3. Pre vs post intervention in each group

Both groups showed a significant increase in FVC and PEF after four weeks of intervention compared to pre

Table 1. General characteristics of subjects at pre intervention

	Reverse combined group (mean±SD)	Combined group (mean±SD)	t	*p*
Age (years)	22.12±1.31†	21.62±1.20	-1.12	0.27
Height (㎝)	173.68±4.25	174.81±3.76	0.79	0.43
Weight (㎏)	71.18±2.37	70.31±2.08	-1.10	0.27
FVC (ℓ)	3.83±0.34	3.98±0.33	1.25	0.21
PEF (ℓ/s)	5.45±0.49	5.70±0.57	-1.34	0.19

FVC: forced vital capacity, PEF: peak expiratory flow
†Mean ± SD

Table 2. Comparison of FVC and PEF between two groups at post intervention

	Reverse combined group	Combined group	T	*p*
FVC (ℓ)	4.45±0.65†	4.83±0.50	1.81	0.80
PEF (ℓ/s)	6.46±0.41	5.92±0.43	-3.62	0.00*

†Mean ± SD, *p<0.05

Table 3. Comparison of FVC and PEF between pre and post measurement

		Pre	Post	t	*p*
Reverse combined group	FVC (ℓ)	3.83±0.34†	4.45±0.65	-5.55	0.00*
	PEF (ℓ/s)	5.70±0.57	6.46±0.41	-7.68	0.00*
Combined group	FVC (ℓ)	3.98±0.33	4.83±0.50	-7.09	0.00*
	PEF (ℓ/s)	5.45±0.49	5.92±0.43	-5.30	0.00*

†Mean ± SD, *p<0.05

intervention ($p<0.05$) (Table 3).

Ⅳ. Discussion

This study examined the effect of a respiratory exercise combined with PNF upper extremity bilateral symmetric D2 flexion and extension patterns on FVC and PEF in healthy young adults. The novelty of this study is the effect of respiratory intervention that combines respiration with reverse direction of PNF upper extremity patterns to provide selective resistance during the intervention. The application of the technique showed a significantly higher PEF in Reverse combined group, compared to Combined group. These results may indicate that the combined respiration with the reverse direction of PNF upper extremity pattern is effective in increasing respiratory capacity.

The interesting finding of this study was that two different directions of upper extremity movements showed the selective effect of assistance or resistance as they were designed. Use of the selective resistance in Reverse combined group showed a significantly higher increase in PEF, compared to Combined group. This may indicate that the reverse direction of upper extremity movement against to natural synergetic movement between upper extremity and thorax may provide respiratory muscles with an additional resistance, which resulted in higher PEF value in Reverse combined group. The PEF is defined as a maximum speed of expiration when an individual has a maximum inhalation. The maximum speed is determined by elasticity or volume of lung, diameter of trachea, and/or inhalation muscle. The additional resistance in Reverse combined group may strengthen the inhalation muscles. Thus, the reverse application of upper extremity movement during respiration can be considered for patients with decreased PEF that is associated with tracheal adhesion, which is a sign of deterioration in asthma or other lung diseases (Slavin et al., 2002).

Using selective resistance in respiratory rehabilitation would also be beneficial for elders or patients with lung diseases. Han and Kim (2018) examined effect of combined upper extremity exercise with therapeutic resistant bands on respiratory capacity in patients with COPD. Consistent with our findings, they did report increased FVC after intervention. However, PEF did not show significant increase after intervention in the study. This may be due to the difference in physiological factors between two groups, however, if selective resistance and assistance may apply depending on the purpose and patient’s ability to cope, positive outcome as shown in our study could be achieved in patient group. Costaet al. (2011) have suggested reverse application of inhalation and exhalation to elevation of upper extremity movement that drives selective resistance, as a new respiratory intervention strategy in older aged group (mean aged 65.3 ± 7.3). Therefore, future study may need to test effect of this selective resistance through the reverse respiratory pattern on FVC and PEF in clinical population such as patients with lung diseases or older aged group.

Strengthening respiratory muscles using upper extremity exercise has been considered an important intervention to increase respiratory capacity. This study also found increased FVC and PEF after four weeks intervention using combined respiration and PNF upper extremity patterns. Consistent with our findings, Moreno et al. (2017) applied PNF upper extremity patterns to healthy adults for four weeks and reported increased maximum inspiratory pressure (101cmH2O to 140cmH2O) and maximum expiratory pressure (107cmH2O to 155cmH2O) after four weeks. Similarly, Areas et al. (2013) examined a 4 weeks randomized control trial and reported that a combined PNF upper extremity patterns with therapeutic resistant bands showed increased strength in respiratory muscles in healthy women. This increased strength in respiratory muscles may result from the involvement of accessory respiratory muscles (e.g. sternocleidomastoid, scalene, pectoralis, serratus anterior, or serratus posterior) during upper extremity movements (Reid & Dechman, 1995). In addition, trunk extension and elevation during PNF upper extremity patterns has been reported to provide mechanical advantages to assistive respiratory muscle (Culham & Peat, 1993).

The combined respiration with PNF upper extremity pattern used in this study does not require high intensity physical activity and cost, so that it can be widely applicable and cost-effective for a wide range of patients with respiratory diseases. In addition, combined respiration exercise with upper extremity movements has been considered safe and sustainable, that can be applied for old patients with COPD or stroke (Singh et al., 2011). Future research needs to test the effect of this technique in clinical population with limitation of physical activity.

There are a few limitations in this study. This study tested healthy adults, which may show different effect compared to clinical population. To identify effect of our intervention, FVC and PEF were measured an indirect respiratory capacity rather than measurement of respiratory muscles. Thus, future studies need to test effect of this intervention on various index of respiratory capacity in elderly or clinical population.

Ⅴ. Conclusion

The combined respiratory exercise with PNF upper extremity patterns showed a significant increase in both FVC and PEF after four weeks of intervention in healthy adults. Especially, a significantly higher increase in PEF was identified in Reverse combined group using selective resistance resulted from reverse PNF upper extremity patterns during inhalation and exhalation, compared to Combined group using selective support. These results may provide applicability of selective resistance through combined respiration with reverse PNF upper extremity patterns and suggest the technique as a widely applicable and cost effective option for respiratory rehabilitation for clinical population in future research.

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