

The Effect of Respiratory Muscle Training in Patients with Chronic Obstructive Pulmonary Disease*

— Preliminary Study —

Kim, Mae-Ja**

According to the 1983 annual report of the Korean Medical Insurance Association the majority of people utilizing the medical institutions in Korea were patients with respiratory problems.¹⁾ And the number of clinical patients with COPD is gradually increasing in Korea. Individuals with chronic obstructive pulmonary disease(COPD) develop progressive physical limitation that impinge on activities of daily living and increase financial burdens and emotional suffering. Then Various rehabilitative devices and programs are available to individuals with COPD. However, most of the devices are expensive, and difficult to use at home because they require an oxygen or compressed air sources.

In recent years numerous studies have demonstrated the beneficial effects of respiratory muscle training.²⁻⁹⁾ Though the research has been limited it suggests that respiratory muscle training will increase respiratory muscle strength and endurance and general exercise tolerance.

STATEMENT OF THE PROBLEM

What is the relationship between the respiratory muscle training and their enhancement of respiratory muscle in patient with COPD?

DEFINITION OF TERMS

Theoretical definition

COPD(chronic obstructive pulmonary disease); a condition partially or completely limited the flow of

air within the airway. Chronic bronchitis, chronic asthma, and emphysema are included in this category.

Strength training: training of inspiratory muscle for the purpose of the respiratory muscle enlargement and bulge.

Endurance training: training to increase muscle mitochondria, energy-liberating enzymes in the sarcoplasm, and electron transport capacity and enhances muscle circulation and oxidative metabolism.

Operational definition

COPD: when the subjects are selected, forced expiratory volume in one second(FEV₁) is less than 65% of predicted and the FEV₁/FVC (forced vital capacity) ratio is less than 75%.

Strength training: result of the strength training of participants in this research is measured to the centimeters of H₂O negative pressure of P_Imax(maximal inspiratory pressure) using a magnehelic pressure gauge before and after training by inspiratory muscle trainer.

Endurance training: result of endurance training of participants in this research is measured to the 1/min of MVV(maximal voluntary ventilation) using a spirometry and cm H₂O of SIP (sustainable inspiratory pressure) using a SIP device before and after 12-minute walking.

12-minute walking: training walking for 12-minute per day, 2 days per week by regular interval for 6 weeks in a measured corridor of SNUH.

* 국비 해외파견 교수 연구논문임.

** *Seoul National University, School of Nursing.*

REVIEW OF THE LITERATURE

Anatomy and physiology of the respiratory system

As yet there is no pharmacologic cure for chronic obstructive pulmonary disease. However, respiratory muscle training may be useful in preventing respiratory failure. In this section characteristics and theoretical background of strength and endurance training were discussed.

Under normal condition the inspiratory muscles alone are responsible for breathing; that is, contraction of the upper inspiratory muscles opens the pharynx and larynx so that air can enter the chest, and contraction of inspiratory muscles of the chest wall and diaphragm generates the negative pressure required to draw air into the chest. Normally, the elastic recoil of the lung and chest wall is sufficient to expel the air previously inspired, so that active contraction of chest wall and abdominal expiratory muscle is not required for expiration. Among the respiratory muscles, the diaphragm is the most important.

About half of the muscle fibers in the adult human diaphragm and intercostal muscles are slow-twitch fibers, which have a high oxidative capacity.¹⁰⁾ These have an extremely high endurance and are quite resistant to fatigue. About one quarter of fibers in the diaphragm are fast-twitch fibers with high oxidative and glycolytic capacities and good endurance. Only one quarter of the fibers in the adult human diaphragm are fast-twitch fibers with low oxidative but high glycolytic capacity. These fibers are strong but fatigue quickly. The diaphragm has an excellent blood supply, and studies in dogs show that the blood flow to the diaphragm increases markedly with inspiratory resistive loading.^{11,12)} Thus the intrinsic nature of most of the diaphragm muscle fibers and the diaphragm's blood supply enable it to sustain high ventilatory loads for long periods.¹³⁾

Pressure developed by inspiratory muscle contraction is the greatest at low volumes, between functional residual capacity(FRC) and residual volume (RV), and the inspiratory muscle pressure falls off

sharply as lung volume is increased from functional residual capacity(FRC) to total lung capacity(TLC).¹⁴⁾

The effect of lung volume on inspiratory and expiratory pressures is mediated by the effect of lung volume on the length of the respiratory muscles.^{15,16)} All kinds of muscles display a characteristic force-length relationship that is quite similar for all mammalian striated skeletal muscles and for diaphragm from different species.¹⁷⁾ The optimum resting length(L_0) of the muscle is usually the length at which the muscle begins to develop tension when it is passively stretched. In the case of the diaphragm, the length is probably attained at lung volumes at or just below FRC. When the diaphragm is stimulated to contract at its optimum resting length, maximum force (or pressure) is generated.¹⁸⁾

Contractile force is also modulated by the length of the muscle at the onset of contraction and by the velocity at which the muscle shortens during contraction. The force-velocity relationship acts in a compensatory fashion, helping the respiratory muscles cope with resistive loads.^{18,19)} In addition to these neural and mechanical factors, the strength of respiratory muscle contraction is highly dependent on the integrity of the muscle cell, including the cell membranes, excitation-contraction coupling mechanism, contractile elements, and mitochondria.¹³⁾

Training for the respiratory muscle

Training of skeletal muscles is not new. Conditioning exercises for athletes have been a vital component of training programs for many years. However, training of respiratory muscles is relatively new compared to the training of other skeletal muscles.

Various factors can influence the effect of the training. Improvement in respiratory muscle strength and endurance may result from one or more factors: learning or a true training effect,⁷⁾ amount of daily training and period of training.

Breathing is exquisitely turned to meet the body's metabolic needs. As breathing is augmented, for example by physical exercise, the inspiratory muscles of the chest wall are stimulated to more forceful contractions. During quiet breathing, the diaphragm

and a few of the intercostal muscles contract. As ventilation increases, more and more of the intercostal muscles come into play.¹⁸⁾

Muscle exercise results in immediate changes in the relative amount of various constituents in different muscle compartment and in the activity of various enzyme systems.²⁰⁾ The respiratory muscles can be characterized with regard to their strength, endurance capacity, susceptibility to fatigue, and responses to training. Leith and Bradley²⁾ showed that training could improve respiratory muscle strength and ventilatory endurance. Training regimens designed to enhance respiratory muscle strength increased maximal inspiratory pressure (P_Imax) and maximal expiratory pressure (P_Emax) by about 55%, but did not affect maximal voluntary ventilation (MVV) or sustainable ventilatory capacity (SVC). Conversely, regimens designed to increase ventilatory endurance increased MVV and SVC by about 14% to 19% without affecting P_Imax or P_Emax. The fact that strength training does not enhance endurance, and vice versa, results from the fact that strength and endurance depend on different structural and biochemical properties of muscle fibers.

Strength training produces an increase in the size and number of myofibrils, particularly in white fibers, slow twitch fibers, result in hypertrophy of the muscle fiber,²⁰⁾ i.e., muscle trained for strength enlarge and bulge.

Endurance is the property of a muscle that affords resistance to fatigue. The fibers within the highest endurance have a large part of their volume occupied by mitochondria, leaving less room for contractile elements, whereas the strongest fibers have fewer mitochondria and more contractile elements.¹⁸⁾

Endurance training produces an increase of muscle mitochondria, energy-liberating enzymes in the sarcoplasm and electron transport capacity^{21, 22)} and enhance muscle circulation and oxidative metabolism.²³⁾ Endurance training such as walking, running, swimming, bicycle ergometer and treadmill running increases the percentage of fast-twitch red fibers in lower extremity muscles.^{21, 47)} It is isocapnic hyperpneic exercise and dynamic in nature. This exercise recruits more muscle groups into action,

increasing in efficiency of training compared to static breathing exercises. It also trains expiratory as well as inspiratory muscles.

A variety of inspiratory muscle training regimens have been employed in preventing respiratory failure, some are based on overcoming resistive or elastic loads. It is important to evaluate which form of inspiratory muscle training is best.

Skeletal muscle training is three major principles: overload, specificity, and reversibility. The overload principle means that skeletal muscles must be challenged to the limit of their ability so that muscle cells increase in size and/or functional ability. The specificity principle means that training should be directed specifically to functional attributes of the muscles. For instance, a different training routine is required for strength training than is required for endurance training. In addition, only the muscles actively participating in the training benefit from it. The reversibility principle states that the effects of training are transient and reversible. The training routine must be kept up if the training effect is to be sustained.²⁰⁾ The recovery period necessary to return to a normal baseline condition after exercise training is a function of both the severity and the duration of the training program. The long-term effects are dependent on continued training and a cessation of training results in a gradual decline in performance capacity of the adapted muscle cell. Belman and Mittman⁷⁾ showed that the effect of a 6-week period of ventilatory muscle endurance training was increased substantially by the fifth to sixth week of the training.

Previous reports have suggested that there is a high prevalence of depression and/or anxiety in patients with COPD.²⁴⁻³⁰⁾ Light et al.³¹⁾ reported that the prevalence of depression in patients with moderate or severe COPD approaches 50% while the incidence of anxiety is much lower (2%).

OBJECTIVES

Persons with COPD develop progressive respiratory weakness that can limit the ability to perform activities of daily living and can increase financial

burdens and emotional suffering.

In several reports on the effect of respiratory muscle training, either one or both of strength and endurance training were performed in one group fashion. As yet there are no reports comparing which form of inspiratory muscle training is the best.

The purpose of this study is to identify the most appropriate training method for enhancement of inspiratory muscle through performing combined strength and endurance training and strength training only. And the other one is to identify validity of the measuring and evaluating method for the dissertation.

Following is the hypotheses to accomplish the above objectives.

1. Patient with COPD who receive both strength and endurance training will have a greater increase in the P_Imax, MVV, and SIP than those who receive only strength training.

2. Patient with COPD who receive both strength and endurance training will have less in the BESC than those who receive only strength training.

METHOD

Subjects

The subjects are patients with COPD as adults. Patients were recruited from the outpatient internal medicine department of Seoul National University Hospital in Korea. Subjects who diagnosed on the basis of pulmonary function test as having irreversible airway obstruction (COPD) and who consented to participate in the study were included as sample in this study. The diagnosis within 6 months was accepted as present condition.

In addition, all subjects had to be in a stable phase of illness at the time of admission and for the duration of study. The stable state was determined by: 1) absence of any respiratory infection as evidenced by no change in sputum color or consistency for at least one month period prior to and for the duration of the study; 2) body temperature less than or equal to 37.0°C (by oral) at the time of clinic appointment and on return visits throughout the study; and 3) no change in medication or respiratory

therapy for a 2-week period prior to and for the duration of the study. Subjects receiving maintenance doses of steroids are allowed to participate in the study.

Patients hospitalized for a respiratory infection and any patient taking a psychotherapeutic drug were excluded from the study. And patients with a major cardiovascular disorder including recent myocardial infarction, angina pectoris, uncompensated congestive heart failure, or intermittent claudication and those subjects suffering from disabling musculoskeletal disorders were excluded from the study. In addition, the subject had to demonstrate an ability to perform the inspiratory muscle trainer and walking.

Four patients with COPD were finally recruited from the outpatient clinic of the Seoul National University Hospital. They were randomly assigned to 2 groups: 2 subjects in strength and endurance training (SET) and 2 subjects in strength training (ST) containing 1 woman. All patients had FEV₁ of 21~38 percent of predicted.

Two ST subjects completed only 5 weeks of training. All stopped because one subject suffered from HIVD and the other one had influenza. So these subjects excluded from analysis of the study.

Prior to start of the study a letter requesting cooperation was delivered to an administrator at Seoul National University Hospital.

Design

Types of training in this study were combined strength and endurance training, and strength training only. Period and amount of strength training was 30 minutes per day for 6 days per week, for 6 weeks. Strength training was performed using inspiratory muscle trainer at their home. Endurance training was performed for 12-minute walking 2 days per week for 6 weeks in a measured corridor of SNUH.

The strength and endurance training group was instructed regarding the use of the inspiratory muscle trainer (DHD Medical Products, Canastota, N.Y.) and 12-minute walking. The strength training group was instructed regarding the use of the inspiratory muscle trainer.

Training device

Inspiratory resistive breathing device is composed of inspiratory muscle trainer (DHD medical products, Canatota, N.Y.) which provides six different levels of fixed inspiratory resistance by the size of the inspiratory orifice. This static maximal inspiratory maneuver is quasi-isometric in nature and is carried out by a maximal inspiration against the closed glottis at a fixed lung volume.³⁾ Inspiratory resistive breathing training exercise utilizes a combination of both isometric and isotonic (dynamic) exercises and is carried out by inspiration through a narrow tube that offers an alinear airway resistance (specificity principle). In this circumstance the inspiratory muscles must contract harder and more forcefully than during regular breathing (overload principle). The size of the orifice was determined by the level of resistance that subjects could tolerate without being immediately exhausted. Jardim et al.⁴³⁾ suggested the level of inspiratory resistance to be about 30% of the subject's maximal inspiratory pressure(P_Imax), whereas the study of Pardy et al.³⁾ suggested that about 40cm H₂O/L/sec would be an optimal level of resistance for inspiratory muscle training.

To determine the level of inspiratory orifice maximal inspiratory pressure(P_Imax) was measured 3 times with four to seven-day interval for 3-week period prior to training. With these data, the level of inspiratory orifice was determined by 25~30% of the highest value of those P_Imax.

Inspiratory muscle training was done with the subject seated in a chair 2 hours after meal, using inspiratory muscle trainer wearing the noseclip.

Endurance training was conducted by 12-minute walking. Subjects were allowed to rest if necessary, but were encouraged to complete as many lengths as possible.

Measuring instruments

a) Maximal inspiratory pressure(P_Imax)

Respiratory muscle strength was assessed by maximal inspiratory pressure(P_Imax) and was measured by a magnehelic pressure gauge with a mouthpiece attached to the negative port. The patient, while

seated, was instructed to maximally inspire against a closed airway at functional residual capacity with the nose clamped. Inspiratory force was measured in centimeters of H₂O negative pressure.

b) Maximal voluntary ventilation (MVV) and sustainable inspiratory pressure(SIP)

The endurance of inspiratory muscle was assessed by maximal voluntary ventilation(MVV) and sustainable inspiratory pressure(SIP).

MVV is the maximum volume of air that can be breathed per minute upon maximal voluntary effort. The patient is encouraged to imitate the type of breathing encountered during severe exercise while choosing his own rate(MVV_P). Demonstration by the observer was usually required as is practice, coaching encouragement, and indication of rhythmic timing during the test. Hyperventilation is continued for 15 sec, and the volume is reported in liters per minute BTPS.⁴⁵⁾

In skeletal muscle, endurance cannot be inferred from measurement of strength. Because the action of the ventilatory muscle is to generate pressure, methods of evaluating ventilatory muscle function by measuring pressure would be preferable to those that measure volumes.

SIP device is converted by Nickerson et al.⁴⁶⁾ This method is to measure how long subjects can breathe at a given inspiratory pressure. The mechanics of the device ensure that the subject must generate a certain threshold pressure(P_{th}) to generate significant inspiratory flow. The apparatus consists of a two-way Hans-Rudolph valve with the inspiratory port connected to a chamber. Inside the chamber is a plunger mounted over a large opening. When the pressure difference between the chamber and atmosphere is greater than P_{th}, the plunger lifts and air enters, allowing the subject to take a breath. Elementary physics predicts

$$P_{th} = M \cdot g / A$$

where P_{th} is the difference in pressures between the inside and outside of the chamber, M is the mass of the plunger, g is the gravitational constant, and A is the area where the plunger rests on the base. P_{th} can be varied by adding weights to the plunger. A mouthpiece is connected at the end of a

large-bore tubing about 4cm long which attached to mouthpiece tube of Hans-Rudolph valve.

c) Bronchitis-Emphysema Symptom Checklist(BESC)

The Bronchitis-Emphysem Symptom Checklist was composed of 89 items within 10 symptom categories and developed by kinsman. Individual's mean score was obtained by dividing the sum of individual scale scores within 10 categories of symptom items and by the total number of answered items within 10 category. One item was reverse scored within the BESC (e.g., 5=1 : 1=5). For each patient, the raw symptom category mean scores were converted to standard (T[Z]) score (mean=50; SD=5) : using the normative mean and standard deviation :

$$T[Z] = \left(\frac{\bar{X} - \bar{X}}{SD} \right) 10 + 50$$

The category T[Z] score of the BESC could be utilized when broken down into 3 levels: High (Z score >55), Low (Z score <45), and Moderate (between these extremes).

Collection of data

PImax, SIP, MVV, and BESC were measured before the training, and once every week for 6 weeks using inspiratory muscle trainer and 12-minute walking. At that time vital signs and routine pulmonary function test (PFT) were also performed for checking subject's general health status. PFT and MVV were measured using a Collins Survey Spirometer CAT No. 06031. SIP was measured using SIP device. SIP was the highest pressure that can generate in each breath for 10 min.

Subjects were contacted by telephone 2~3 times weekly to ensure whether they keep training correctly and how their general conditions are.

Analysis of data

PImax, MVV, SIP, and BESC were represented by the score of each patient measured before the training, and once every week for 6 weeks.

Difference of pretraining and posttraining was calculated by percent and mean and standard deviation.

Statistical analysis of the hypothesis used the paired t-test for intragroup analysis, and the standard t-test for intergroup analysis with the obtained scores of PImax, MVV, SIP and BESC.

RESULTS

The characteristics for all subjects are shown in (Table 1).

In (Table 2), mean and percent differences of the pretraining-and 6th week posttraining results of the tests are presented for both groups of the patients. There were no significant differences in PImax and MVV between pretraining and 6th week posttraining. However SIP of the ST group significantly increased in the 6th week post-training (pretraining 41±14, posttraining 70±15, comparing with the pretraining at 5% level.

Although mean percent differences of PImax(maximal inspiratory pressure) in the ST group (27%),

(Table 1) Characteristics of Subjects Undergoing Inspiratory Muscle Training.*

Group	Subject No.	Sex	Age	Ht(cm)	Wt(kg)	FEV ₁ (%pred)	MVV(1/min, %pred)
S E T	1	M	67	163	56	37	65.7
	2	M	60	165	64	21	22
mean±SD							48.85±19.85
S T	1	M	52	169.5	72.5	38	46
	2	F	51	147.2	37	33	27
mean±SD							36.50± 9.50

SET : Strength and Endurance Training

ST : Strength Training Only

FEV₁ and MVV : values of pretraining

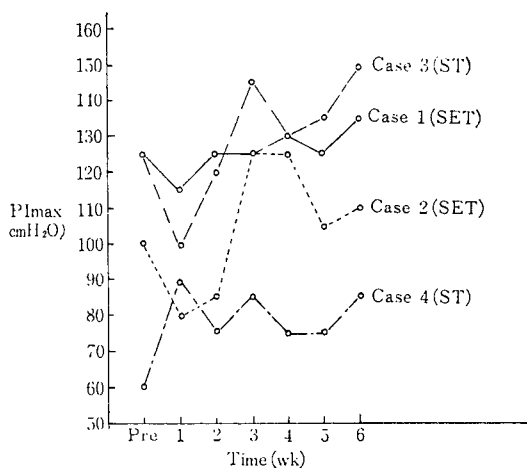
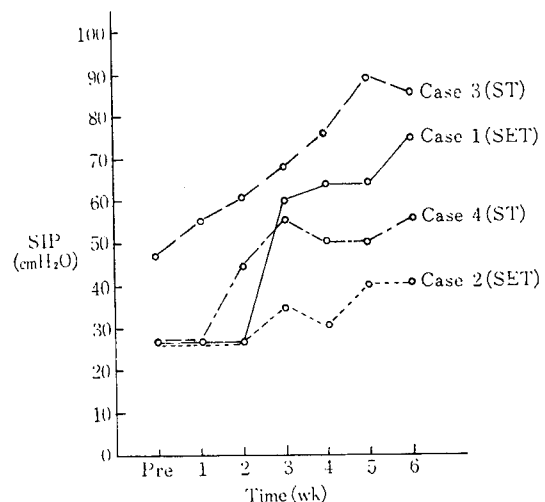
* : Baseline value

〈Table 2〉 Comparison of the P_Imax, SIP, MVV for Pretraining and 6th week post-training.

Group	Subject No.	P _I max(cm H ₂ O)			SIP(cm H ₂ O)			MVV(l/min, %pred)		
		pre	post	% diff	pre	post	% diff	pre	post	% diff
SET	1	125	135	8	26	75	188.64	65.7	67	1.97
	2	100	110	10	27	40	48.14	26	22	-15.38
mean±SD		112.5 ±12.5	122.5 ±12.5	8.00	26.5 ±0.5	57.5 ±17.5	116.98	45.85 ±19.85	44.5 ±22.5	2.94
ST	1	125	150	20	55	85	54.54	46	46	0
	2	60	85	41.66	27	55	103.70	27	35	29.62
mean±SD		92.5 ±32.5	117.5 ±32.5	27.00	41 ±14	70 ±15*	70.73	36.5 ±9.5	40.5 ±5.5	10.95

SET : Strength and Endurance training
P_Imax : Maximal inspiratory pressure
MVV : Maximal voluntary ventilation
pre : pretraining
post : 6th week posttraining

ST : Strength training
SIP : Sustainable inspiratory pressure
% diff : percent change from pretraining value
* : p<0.01 (paired t-test=-29)

〈Fig. 1〉 Individual P_Imax values before and after training.

〈Fig. 2〉 Individual SIP values before and after training.

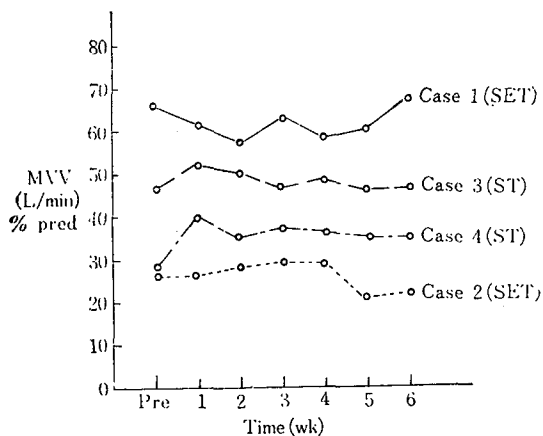
and SIP in the SET(strength and endurance training) group (116.98%) and ST group (70.73%) increased, there were no statistical differences between the mean value of each of this group and that of the opposite group at 6th week posttraining in any of the 3 tests for trainings. This was probably due to the large variation between individual patients.

There are individual figures for P_Imax〈Fig. 1〉 SIP〈Fig. 2〉 and MVV〈Fig. 3〉 of pretraining and post-training weekly.

P_Imax increased relatively in the SET group and one subject of ST group when the value compared the change of pretraining with those of posttraining, but one subject of ST group (Case 4) decreased in that value of last week rather than first week of posttraining.

The values of SIP gradually increased in all of them.

In the MVV all of them did not markedly increase, and especially one subject of SET group decreased



(Fig. 3) Individual MVV values before and after training.

from the value of fifth week.

The values of the categories for bronchitis-emphysema symptom checklist(BESC) are shown in the Table 3-1, 3-2, and 3-3.

In the SET group the mean of the category T[Z] score of BESC of pretraining were moderate or low. Their 6th week posttraining mean of the category T[Z] score of BESC decreased in the categories of

(Table 3-1) Differences in Group of Strength and Endurance Training on BESC

BESC Symptoms	pre T[Z] (mean)	6th week post T[Z] (mean)	t	p value
Helplessness-Hopelessness	47.75	40.75		
Decathexis	47.80	41.95		
Fatigue	48.15	33.50		
Poor memory	53.85	49.40		
Sensory-Perceptual	51.15	44.95		
Airways Obstruction/Congestion	33.30	33.40	1.95	p>0.05
Sleep Disturbance	54.70	42.05		
Irritability	29.10	35.70		
Anxiety	34.25	37.25		
Alienation	43.15	43.15		

High : Z score >55 Low : Z score <45
 Moderate : Z score 45~55
 BESC : Bronchitis-Emphysema Symptom Checklist

helplessness-hopelessness, decathexis, fatigue, poor memory, sensory-perceptual and sleep disturbance, and airways obstruction/congestion and alienation were not changed, whereas irritability and anxiety increased. These results were no significant differences.

In the ST group the means of helplessness-hopelessness, decathexis, poor memory, sensory-perceptual and irritability of pretraining were high and the means of fatigue, airways obstruction/congestion, sleep disturbance, anxiety and alienation of pretrain-

(Table 3-2) Differences in Group of Strength Training on BESC.

BESC Symptoms	pre T[Z] (mean)	6th week post T[Z] (mean)	t	p value
Helplessness-Hopelessness	55.60	36.35		
Decathexis	56.50	37.65		
Fatigue	53.50	33.50		
Poor memory	61.50	48.15		
Sensory-Perceptual	58.50	44.95		
Airways Obstruction/Congestion	45.65	31.55	11.14	p<0.001
Sleep Disturbance	52.20	38.25		
Irritability	59.35	33.05		
Anxiety	45.90	32.85		
Alienation	49.40	38.45		

(Table 3-3) Differences in BESC for the Two Groups.

BESC Symptoms	Difference score of SET	Difference score of ST	t	p value
Helplessness-Hopelessness	-7	-19.85		
Decathexis	-5.85	-18.85		
Fatigue	-14.65	-20.00		
Poor memory	-4.45	-13.35		
Sensory-Perceptual	-6.20	-13.55		
Airways Obstruction/Congestion	0.10	-14.10	4.55	p<0.001
Sleep Disturbance	-12.65	-13.95		
Irritability	6.60	-26.30		
Anxiety	3.0	-13.05		
Alienation	0	-10.95		

ing were moderate. Their 6th week posttraining mean scores of the category T[Z] score of BESC decreased in all categories. And these results were significant differences. (Table 3-2, paired t-test=11.14, $p < 0.001$).

The Table 3-3 is shown differences of the pretraining and 6th week posttraining results in the category T[Z] score of BESC in the two groups. In both groups 6th week posttraining results of the category T[Z] score of BESC decreased in all categories, especially the values in the ST group decreased more than the values of SET group. This result was significant differences in the 2 values, all results are the mean of differences before training and after 6 week of the training (Table 3-3, $t=4.55$, $p < 0.01$).

DISCUSSION

The changes in the SET group with those in the ST group were compared in 4 indicators that were most likely to be affected by training. These were P_{lmax}, SIP, MVV and BESC. In the ST group SIP significantly increased and BESC decreased. And BESC of both groups, the SET and ST significantly decreased (Table 2, 3-2, 3-3).

There was no significant differences in P_{lmax} in both group. In several previous studies P_{lmax} increased after strength training.^{3,4,42,43} In contrast, Parady et al.⁹ found no increase in P_{lmax} after inspiratory resistive breathing exercises. However, one can infer from these studies that inspiratory muscle training with increased inspiratory load generally improves the strength of respiratory muscles.

In one of each of both group considerable increase of SIP occurred in the training, however another occurred small increase (Fig. 2). Sixth week posttraining results of SIP increased in 70 ± 15 in the ST group. This was significant increase. SET group were however not significant (Table 2). An improvement in exercise performance may result from one or more factors, including increased motivation, learning or a true training effect.⁴³ If the improvement resulted from increased motivation and effort, one would expect to see a rapid improvement once

the technique has been mastered. In fact, wide fluctuations would occur, depending upon the individual's effort on any particular occasion.

In previous study for the effect of a 6-week period of ventilatory muscle endurance training, after the initial small improvement during the baseline period, the rate of improvement was initially slow and only increased substantially by the fifth to sixth week of the training.⁷

Nickerson et al.⁴⁶ converted a method for measuring ventilatory muscle endurance as the sustainable inspiratory pressure (SIP). They had obtained SIP of 82 ± 6 cm H₂O and P_{lmax} of 122 ± 8 cm H₂O from the normal subjects. They argued that this method is to measure ventilatory muscle endurance, not strength. If so, in my study, these results would be probably due to the large variation between individual patients, small number of subjects and training amount per week of endurance training.

There was no significant increase in the MVV after training. MVV is a complex test and is influenced by several factors, including airway mechanics, muscular strength and the patient's motivation and cooperation.⁴⁶ Even in a previous study in COPD, MVV was not increased.⁹ Leith et al.² reported that endurance training increased their MVV by 14% only. Belman et al.⁷ found small significant increase in the MVV after training. They, therefore, concluded that endurance is probably a less important component of the MVV. On the other hand, the MSVC/FEV₁ ratio increased significantly after training.

In the SET group, 6th week posttraining mean of the category T[Z] score of BESC indicated no significant difference. However, significant difference between categories of BESC was found within the ST group and improvement was found between both group (Table 3-2, 3-3). This is in partly agreement with Lanson's study that was demonstrated in the self-reported ratings of clinical signs and symptoms in patients with COPD.

The effect of inspiratory muscle training on ADL was not tested. However, 3 of 4 subjects reported an increased ability to perform activities of daily living. Several studies also reported an increased

ability to perform ADL.^{8,9,42)}

The ST using inspiratory muscle trainer for 30 minutes session of training daily, performed at home with inexpensive device, was more effective in improving exercise performance in patients with COPD than the SET program used in this study. The method is cheap, effective, acceptable to patients and requires few supervisory personnel.

SUMMARY

The effect on strength and endurance training (SET) (2 patients) were compared with those of strength training (ST) (2 patients) in patients with chronic obstructive pulmonary disease. The result of training was assessed by 4 tests: maximal inspiratory pressure (P_Imax), sustainable inspiratory pressure (SIP), maximal voluntary ventilation (MVV) and bronchitis-emphysema symptom checklist (BESC). Measurements were repeated before and after training per week for 6 weeks. The SET group performed inspiratory muscle training, using a inspiratory muscle trainer 30 minutes per day, 6 days per week and performing endurance training-12-minute walking-2 days per week for 6 weeks, whereas the ST only group trained for 30 minutes daily, 6 days per week using inspiratory muscle trainer. SET was no significant increase in exercise performance, whereas ST produced an increase in SIP and a decrease in BESC. There was significant change in BESC between the two groups.

A simple at home training program using inspiratory muscle trainer was more effective than that of SET program in improving exercise performance of some patients with COPD.

References

1. Korean Nurses' Association Newspaper, Seoul, Feb., 2, 1984.
2. Leith DE, Bradley M: Ventilatory muscle strength and endurance training J. Appl. Physiol 41 : 508, 1976.
3. Larson M., Kim M.J.: Respiratory muscle training with the incentive spirometer resistive breathing device. Heart and Lung, 13 : 341, 1984.
4. Gross D., Ladd H.W., Riley EL., Macklem P.T., Grassino A.: The effect of training on strength and endurance of the diaphragm in quadriplegia. Am. J. Med. 68 : 27, 1980.
5. Keens T.G., Krastens I.R.B., Wannamaker E.M., Levison H., Crozier D.N., Bryan A.G.: Ventilatory muscle endurance training in normal subjects and patients with cystic fibrosis. Am. Rev. Respir. Dis. 116 : 853, 1977.
6. Belman M.J.: Respiratory failure treated by ventilatory muscle training, A report of two cases, Eur. J. Respir. Dis. 62 : 391, 1981.
7. Belman M.J., Mittman C.: Ventilatory muscle training improves exercise capacity in chronic obstructive pulmonary disease patients. Am. Rev. Respir. Dis., 121 : 273, 1980.
8. Pardy R.L., Rivington R.N., Despas P.J., Macklem P.T.: The effect of inspiratory muscle training on exercise performance in chronic air-flow limitation. Am. Rev. Respir. Dis. 123 : 426, 1981b.
9. Sonne L.J., Davis J.A.: Increased exercise performance in patients with severe COPD following inspiratory resistive training, Chest 81 : 436, 1982.
10. Lieberman D.A., Faulkner J.A., Craig A.B.Jr., Maxwell L.C.: Performance and histochemical composition of guinea pig and human diaphragm. J. Appl. Physiol. 34 : 233, 1973.
11. Robertson C.H. Jr., Foster G.H., Johnson R.L. Jr.: The Relationship of respiratory failure to the oxygen consumption of, lactate production by, and distribution of blood flow among respiratory muscles during increasing inspiratory resistance. J. Clin. Invest. 59 : 31, 1977.
12. Rochester D.F., Bettini G.: Diaphragmatic blood flow and energy expenditure in the dog: Effect of inspiratory airflow resistance and hypercapnia. J. Clin Invest 57 : 611, 1976.
13. Rochester D.F.: Respiratory muscle function in health. Heart and Lung, 13 : 349, 1984.
14. Agostoni E.: Chapter III. In Campbell E.J.M., Agostoni E., Davis J.N., editors: The respiratory

- muscles. Philadelphia, 1970, W.B. Saunders Co., pp. 48~79.
15. Kim M.J., Druz W.S., Danon J., Machnach W., Sharp J.T.: Mechanics of the canine diaphragm. *J. Appl. Physiol.* 41 : 369, 1976.
 16. Braun N.M.T., Arora N.S., Rochester D.F.: Force-length relation of the normal human diaphragm. *J. Appl. Physiol.* 53 : 405, 1982.
 17. McCully K.K., Faulkner J.A.: Length-tension relationship of mammalian diaphragm muscles. *J. Appl. Physiol* 54 : 1681, 1983.
 18. Gal T.J., Arora N.S.: Respiratory mechanics in supine subjects during progressive partial curarization. *J. Appl. Physiol* 53 : 57, 1982.
 19. Lopata M., Önal E., Ginzburg A.S.: Respiratory muscle function during CO₂ rebreathing with inspiratory flow-resistive loading. *J. Appl. Physiol.* 54 : 475, 1983.
 20. Kim M.J.: Respiratory muscle training: implications for patient care. *Heart and Lung*, 13 : 332, 1984.
 21. Sharp J.T. Hyatt R.E.: Mechanical and Electrical Properties of Respiratory Muscles, Lecture Note.
 22. Hollozy J.: Biochemical adaptation in muscle. *J. Biol Chem* 242 : 2278, 1967.
 23. Rochester D.F., Goldbergs S.K.: Techniques of respiratory physical therapy. *Am. Rev. Respir. Dis.* 122 (part 2 of 2) : 133, 1980.
 24. Agle D.P., Baum G.L., Chester E.H., Wendt M.: Multidiscipline treatment of chronic pulmonary insufficiency, I, Psychologic aspects of rehabilitation. *Psychosomatic Med.* 35 : 41, 1973.
 25. Dudley D.L., Glaser E.M., Jorgenson BN., Logan D.L.: Psychological concomitants to rehabilitation in chronic obstructive pulmonary disease. Part 2, Psychosocial treatment, *Chest* 77 : 544, 1980.
 26. Kass I., Dyksterhuis J.E., Rubin H., Patil K.D.: Correlation of psychophysiological variable with vocational rehabilitation outcome in patients with chronic obstructive pulmonary disease. *Chest.* 67 : 433, 1975.
 27. Lustig F.M., Haas A., Castillo R.: Clinical and rehabilitation regimen in patients with chronic obstructive pulmonary disease. *Arch. Phys. Med. Rehabil* 53 : 315, 1972.
 28. Morgan A.D., Peck D.F., Buchanan D.R., McHardy G.J.R.: Effect of attitudes and beliefs on exercise tolerance in chronic bronchitis. *Brit. Med. J.* 286 : 171, 1983.
 29. Oswald N.C., Wallis R.E., Drinkwater J.: Relationship between breathlessness and anxiety in asthma and bronchitis: A comparative study. *Brit. Med. J.* 2 : 14, 1970.
 30. Rutter B.M.: Some psychological concomitants of chronic bronchitis. *Psychological Med.* 7 : 459, 1977.
 31. Light R.W., Merrill E.J., Despars J.A., Gordon G.H., Mutalipassi L.R.: Prevalence of depression and anxiety in patients with COPD: Relationship to functional capacity, *Chest* 87 : 35, 1985.
 32. Muller N., Gulston G., Cade D., Whitton J., Froese A.B., Bryan M.H., and Bryan A.C.: Diaphragmatic muscle fatigue in newborn, *J. Appl Physiol* 46 : 688~695, 1979.
 33. Muller N., Volgyesi G., Bryan M.H., and Bryan A.C.: The consequence of diaphragmatic muscle fatigue in the newborn infant, *J. Pediat* 95 : 793~797, 1979.
 34. Roussos C.S., Macklem P.T.: Diaphragmatic fatigue in man, *J. Appl. Physiol* 43 : 189~197, 1977.
 35. Roussos C. Macklem P.T.: The respiratory muscles, *N. Engl J. Med* 307 : 786, 1982.
 36. Roussos C., Fixley M., Gross D., Macklem P.T.: Fatigue of inspiratory muscles and their synergic behavior, *J. Appl. Physiol* 46 : 897, 1979.
 37. Braun N: Respiratory muscle dysfunction, *Heart & Lung*, 13 : 327, 1984.
 38. Edwards R.H.T.: Physiological analysis of skeletal muscle weakness and fatigue. *Clin. Sci. Molec. Med.* 54 : 463, 1978.
 39. Braun N.M.T., Rochester D.F.: The respiratory muscles, In Baun G.L., Wolinsky E. editors: *Textbook of pulmonary medicine*, Boston, 1983, Little, Brown & Co., p. 37.
 40. Arora N.S., Rochester D.F.: Effects of body weight and muscularity on human diaphragm muscle mass, thickness, and area. *J. Appl. Physiol* 52 : 64, 1982.

41. Bergström J., Hermansen L., Hultman E., Saltin B.: Diet, muscle glycogen and physical performance, *Acta Physiol Scand* 71 : 140, 1967.
42. Martin L.L.: Respiratory Muscle Function: A Clinical Study. *Heart and Lung*, 13 : 346, 1984.
43. Belman M.J., Wasserman K.: Exercise training and testing in patients with chronic obstructive pulmonary disease. *Basics R.D.* 10 : 1, 1981.
44. Jardim J.R., Mayo S.V., Godoy I., Fernandes A. L.G., Afonso J.E.: Inspiratory muscle conditioning training in chronic obstructive pulmonary disease(COPD) patients. *Am. Rev. Respir. Dis.* 125 (part 2 of 2) : 132, 1982.
45. Epidemiology Standardization Project. III. Recommended standardized procedure for pulmonary function testing. *Am. Rev. Respir. Dis.* 1978 : 118 (part 2) : 55~88.
46. Nickerson B.G., Keens T.G.: Measuring ventilatory muscle endurance in human as sustainable inspiratory pressure, *J. Appl. Physiol.* 52 : 768, 1982.
47. Kim K.W.: Exercise and muscle fiber, *The Korean Journal of Sports Medicine*, 2(2) : 46~58, 1985.
48. Shepherd R.J.: Learning, habituation and training, *Int. Z. Angew physiol* 28 : 38~48, 1969.
49. Higgins, M.: Epidemiology of COPD state of the art, *Chest, Supplement*, 85 : 3~8, 1985.

* 국비 해외파견 교수 연구논문임

** 서울대학교 의과대학 간호학과

국 문 초 록

만성 폐쇄성 폐질환 환자에 있어서 호흡근육 훈련의 효과에 관한 실험적 연구*

김 매 자**

내과외래를 내방한 만성폐쇄성 호흡기질환환자를 대상으로 호흡근육훈련이 호흡근육에 미치는 효과를 조사하기 위해서 자료수집을 하였다.

근력+근지구력훈련과 근력훈련을 각각 두군에게 6주동안 실시하였다. 근력훈련은DHD Medical Products 사 제품의 흡기근육훈련도구로 매일 30분씩 대상자의 가정에서 실시하였고, 근지구력훈련은 일정한 기온이 유지되는 서울대학교병원복도를 12분동안 걷게하는 운동을 주 2회 시행하였다. 이 훈련들의 효과를 평가하기 위하여 매주 최대흡기력(PImax), 참을 수 있는 흡기력(SIP), 최대환기량(MVV) 및 기관지염-폐기종 증상 체크목록(BESC)과 환자의 건강상태와 계속 훈련여부를 결정하기 위해서 폐기능검사와 vital signs을 매주 검사하였다. 그리하여 다음과 같은 성적을 얻었다.

근력+근지구력훈련군은 훈련전에 비해서 훈련후에 유의한 차이가 없었으나 근력훈련군은 SIP가 증가되고 BESC는 감소되었으며, 두군간의 비교에서는 BESC에서 훈련후에 유의한 차이가 있었다. 호흡근육훈련은 가정에서 간편하게 시행할 수있는 근력훈련이 근력+근지구력훈련보다 효과가 좋았다. 그러나 측정도구들의 타당도, 신뢰도의 평가, 더많은 수의 연구대상자, 더 효과적인 근지구력훈련의 개발에 관한 연구가 이루어져야겠다.