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Inspiratory Muscle Training Effects on Respiratory Function and Coughing Ability in Men With Obesity

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Objective: Cough is a biological defense mechanism which produces sputum. Difficulties with expelling sputum can occur during decreased coughing ability caused by obesity, which increases the risk of pulmonary complications.We investigated the influence of an 8-week inspiratory muscle training (IMT) program on respiratory function and respiratory muscle strength in the sitting and supine positions of people with obesity.

Design: A randomized controlled trial

Methods: The participants were Twenty-one men with a body mass index (BMI) $\geq$ 30 kg/m^2 or more. They were randomized into a control group (CG: n=10) and an IMT group (IMTG: n=11). The threshold IMT was used at a load of 30% of the maximum inspiratory oral pressure in the IMTG; the minimum load of the threshold IMT was used in the CG. Two sets of 15 min a day were performed four times a week for 8 weeks. Respiratory function, respiratory muscle strength, and coughing ability were measured in the sitting and supine positions.

Results: Compared to baseline values, vital capacity in the supine position and inspiratory and expiratory muscle strength were significantly increased after 8 weeks in the IMTG, but not in theCG.Coughing ability did not differ significantly between the groups.

Conclusion: Eight weeks of IMT enhanced respiratory muscle strength in men with obesity and improved vital capacity in the supine position;however, itdid not improve coughing ability.

Key Words: Cough, Inspiratory capacity, Obesity, Vital capacity, Respiratory muscle training

Introduction

Obesity affects lung function[1-3]by reducing total lung capacity, functional residual capacity, preliminary expiratory volume, vital capacity (VC), and 1-second volume [4-6]. Recently, it was reported that reductions in total lung volume, previously thought to occur only in individuals with severe obesity, are also observed in those with less severe obesity [7].Furthermore, lung function is affected by the site of fat deposition. In particular, fat deposition in the thoraco-abdomen and the accumulation of visceral fat reduce ventilation efficiency and lung functionby increasing in the resistance of diaphragm contraction [4-6]. This is largely due to the loss of compliance in the chest wall and abdomen because of the deposition of fat around the ribs, diaphragm, and abdominal cavity.

In addition, lung function is generally affected by posture, and when posture is changed from a sitting to a supine position, the total lung volume, functional

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residual capacity, and VC decreasebecause the intra-abdominal organs push the diaphragm toward the head in the supine position compared with the sitting position, and compression of the back of the chest limits thorax expansion [8, 9]. Thus, in people with obesity, lung function and coughing ability are reduced in the supine position, and it is necessary to keep these functions as effective as possible to avoid the risk of secondary pulmonary complications.

Inspiratory muscle training (IMT) is commonly used to increase inspiratory muscle strength. There are reports that the effect of increasing inspiratory muscle strength is observed in the 4-week and 12-week IMT protocols [10, 11]. Therefore, we hypothesized that increasing inspiratory muscle strength in obese individuals by IMT would improve VC and coughing ability in supine position.

This research aimed to examine the influence of an 8-week inspiratory muscle training program on respiratory function and respiratory muscle strength in the sitting and supine positions of men with obesity.

2Materials and Methods

Study Design

A randomized controlled trial.

Participants

The participants included 25 men with a body mass index of ≥30 kg/m2without history of circulatory or respiratory organ conditions, sleep disorders, or sleep apnea. Before the start of the study, we performed pulmonary function tests on the participants and confirmed that there were no abnormalities (Table 1). None of the participants had been to the hospital or taken any medications at the start of the study. However, four of the 25 were excluded for scheduling reasons. Although all participants were men, we did not deliberately exclude women. All participants were class I obese according to the WHO criteria for obesity. The participants were then randomly divided into the control group (CG; n=10) and the IMT group(IMTG; n=11) by drawing numbers from envelopes. The participants were blinded to their group assignment.

This research was approved by the AINO University Research Ethics Committee (2020-003) and conducted according to the Declaration of Helsinki.Written informed consent was obtained from all participants.

Procedures

Figure 1 shows the research protocol. In the IMTG, the threshold IMTwas used at a load of 30% of the maximum inspiratory oral pressure (PImax), and in the CG, the minimum load of the threshold IMT was used; both groups performed two sets at 15 min a day,four times a week for 8 weeks. The number of breaths was twelve/minute, and breathing was

Table 1. Morphological measurement data

	IMTG(n=11)		CG(n=10)	
Variables	**Baseline**	**8-week intervention**	**Baseline**	**8-week intervention**
Age (years)	23.50±2.42	23.50±2.42	23.67±2.78	23.67±2.78
Height (m)	1.69±0.06	1.69±0.06	1.70±0.05	1.71±0.06
Weight (kg)	88.70±8.56	89.10±7.08	89.22±6.63	90.10±5.53
BMI (kg/m^2)	31.14±1.07	31.24±1.13	31.15±0.63	31.56±0.66
Waist (cm)	97.90±6.79	96.11±6.32	94.28±6.96	94.83±6.01
%VC (%)	89.82±3.52	89.63±3.6	91.70±2.45	91.40±2.27
FEV1% (%)	85.09±7.26	85.27±6.62	86.55±4.67	86.63±4.41

Data are means±SD.
Abbreviations: IMTG, inspiratory muscle training group; CG, control group; BMI, body mass index; WC, waist circumference; %VC, percentage of predicted vital capacity; FEV1%,forced expiratory volume in one second/ forced vital capacity ratio.

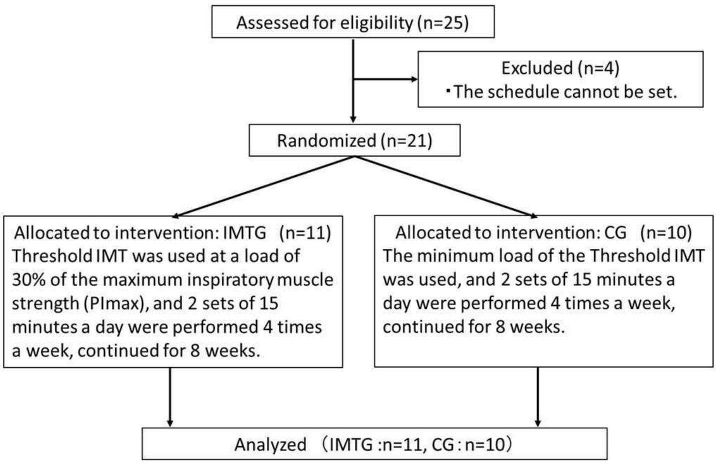

Figure 1. Protocol of this study

performed according to a metronome, because of specifying the breathing rate used to ensure consistency and reproducibility. Two weeks before the start of the experiment, morphological measurements were obtained in the standing position. Respiratory function, respiratory muscle strength, and coughing ability were measured in the sitting and supine positions, and the values were set as baseline values. These were measured again after 8 weeks.

Outcome Measures(Morphological measurement)

Height and weight were measured with participants wearing only underwear. Abdominal circumference was measured using a tape at the height of the navel during resting exhalation. Measurements were performed by a physiotherapist.

(Evaluation of respiratory function, respiratory muscle strength, and cough peak flow (CPF))

Respiratory function was evaluated using a spirometer (AS-507; Minato,Japan), and parameters such as tidal volume, inspiratory reserve volume, inspiratory capacity (IC), expiratory reserve volume (ERV), and VC were extracted. The maximum expiratory and inspiratory (PImax) pressures in the oral cavity[12]were also evaluated using a sthenometer (AAM337, Minato, Japan) attached to a spirometer, according to the method by Black and Hyatt and were considered as the surrogate indices of inspiratory and expiratory muscle strength, respectively [12]. To measurePImax, a nose clip was worn, and maximum intake was determined from the residual air volume. To measure maximum expiratory pressure, one full inhalation to the full lung volume and forced exhalation was performed.

For the CPF, a spirometer (AS-507, Minato, Japan) was used to determine the total lung volume level, maximum voluntary coughing was performed, and the peak flow value at that time was measured.

VC, respiratory muscle strength, and CPF were measured three times, and the maximum values were used. The reproducibility of measurements of respiratory function, respiratory muscle strength, and coughing ability has been proven [13,14,15].

To consider the influence of posture, the rate of change in respiratory function and coughing ability was calculated using the following formula:

Rate of change (%) = (supine position value - sitting position value) / sitting position value × 100.

Data Analyses

All statistical analyses were performed with EZR [16]for R-software(version 1.61, Saitama Medical Center, Jichi Medical University, Saitama, Japan). More precisely, it is a modified version of the R commander designed to add statistical functions frequently used in biostatistics.

All values were presented as means ± standard deviation (SD). The sample size was determined by sampling calculations done from data collected during a pilot study with eightvolunteers, which established a sample of nine individuals for each group. The EZRwas considered a power (1–β) of 80% and an α of 5% for the inspiratory muscle strength outcome based on the average and standard deviation of maximum inspiratory pressure (PImax) of the IMTG and CG after the intervention.

The normality of variables was evaluated with the Shapiro–Wilk test. Subsequently,Comparisons of each data within a group were performed using a paired t-test, and comparisons of each data between both groups were performed using an unpaired t-test. A significance level of α = 0.05 was adopted.

Results

A total of 21 participants completed the 8-week program. Table 2 shows the values before and after

Table 2. Respiratory function, respiratory muscle strength, and cough ability in the IMTG and CG

	IMTG(n=11)		CG(n=10)	
Variables	**Baseline**	**8-week intervention**	**Baseline**	**8-week intervention**
VCsit (L)	4.00±0.37^{C}	4.12±0.37	3.98±0.27^{C}	4.03±0.29^{C}
VCsup (L)	3.71±0.36	3.89±0.38^{AB}	3.51±0.32	3.51±0.30
Change in VC (%)	-7.26±6.42	-5.34±7.69^{B}	-11.89±3.69	-12.86±5.25
ICsit (L)	2.87±0.29	2.90±0.22	2.88±0.24	2.80±0.24
ICsup (L)	3.01±0.43	3.14±0.45^{A}	2.92±0.30	2.97±0.28
Change in IC (%)	5.05±11.25	8.11±13.81	2.06±13.91	6.26±8.34
TVsit (L)	0.63±0.09	0.66±0.08	0.67±0.14	0.62±0.15
TVsup (L)	0.64±0.10	0.61±0.08	0.65±0.13	0.66±0.09
Change in TV (%)	4.09±20.79	-6.20±10.41	2.01±35.41	12.23±35.59
IRVsit (L)	2.25±0.31	2.25±0.26	2.21±0.34	2.18±0.33
IRVsup (L)	2.37±0.42	2.52±0.48^{A}	2.27±0.25	2.31±0.29
Change in IRV (%)	6.08±14.02	12.73±19.18	4.52±17.40	7.16±12.39
ERVsit (L)	1.13±0.31^{C}	1.22±0.40C	1.09±0.35^{C}	1.23±0.25^{C}
ERVsup (L)	0.69±0.23	0.76±0.29	0.58±0.10	0.54±0.10
Chainge in ERV (%)	-35.32±26.73	-24.74±63.09	-40.36±25.55	-54.94±10.06
PImax sit (cmH_2O)	99.75±23.47	112.41±24.20^{A}	88.3±12.36	90.09±14.62
PImax sup (cmH_2O)	93.85±22.4	109.49±23.35^{A}	84.67±10.7	85.50±13.16
Change in PImax (%)	-5.99±7.67	-2.63±6.05	-3.92±3.74	-4.96±3.50
PEmax sit (cmH_2O)	83.65±26.88	94.24±30.07^{A}	85.52±13.53	89.09±17.22
PEmax sup (cmH_2O)	79.83±24.73	90.90±26.93^{A}	82.26±11.88	86.24±13.72
Change in PEmax (%)	-4.47±10.60	-3.58±8.40	-3.47±4.99	-2.55±4.64
CPFsit (L/sec)	7.10±0.93^{C}	7.31±1.12^{C}	6.39±0.53^{C}	6.58±0.61^{C}
CPFsup (L/sec)	6.67±0.90	6.98±1.19	6.01±0.42	6.15±0.54
Change in CPF (%)	-6.06±3.77	-4.55±6.27	-5.76±2.09	-6.37±3.83

Data are means±SD. Abbreviations: IMTG, inspiratory muscle training group; CG, control group; TV, tidal volume; IRV, inspiratory reserve volume; IC, inspiratory capacity; ERV, expiratory reserve volume; VC, vital capacity; CPF, cough peak flow; PImax, maximal inspiratory pressure; Pemax, maximal expiratory pressure; sit, in sitting position; sup, in supine position.

^{A}: $p < 0.05$ vs Baseline. ^{B}:$p<0.05$ vs. CG. ^{C}:$p<0.05$ vs. insupine position.

the IMT intervention. None of the baseline items showed significant differences between the CGs and IMTGs.

(Morphological measurement)

There were no significant differences within or between the groups before and after IMT intervention.

(Changes in respiratory function, respiratory muscle strength, and coughing ability)

Compared to the baseline values, the rates of change in supine IC, inspiratory reserve volume, and VC were significantly increased after 8 weeks in the IMTG,but not in the CG. Furthermore, the rate of change in VC was higher in the IMTG compared with the CG. Compared with baseline values, inspiratory and expiratory muscle strength showed significant increases in the IMTG after 8 weeks,although there were no significant differences in the CG. CPF did not show a significant difference among groups.

(Changes in posture for respiratory function, respiratory muscle strength, and coughing ability)

In both the CG and IMTG, the ERV and CPF were higher in the sitting position compared with the supine position. VC showed a high value in the sitting position at baseline and 8 weeks later in the CG, whereas, in the IMTG, VC showed a high value in the sitting position only at baseline. Respiratory muscle strength was unaffected by postural changes.

Discussion

We have shown that 8-week inspiratory muscle strength training increases respiratory strength and VC in the supine position in men with obesity.

Previous studies of IMT in people with obesity reported a clear increase in peak inspiratory pressure in the 4-week and 12-week IMT protocols [10, 11], and our results support these studies.It was determined that the 8-week IMT program also affected the inspiratory muscles of men with obesity, suggesting that IMT for enhancing inspiratory muscle strength is effective for individuals with obesity. Since the activation intensity of the internal oblique and transversus abdominis reportedly occurs by applying the inspiratory load [17],we considered that simultaneous contraction of the abdominal muscle group was initiated during the 8-week IMT program, leading to enhanced expiratory muscle strength.

In addition, it is generally reported that respiratory muscle strength is also affected by posture [18];however, we did not observe this in our study. To obtain the maximum PImax, it is recommended that the measurement of PImax be performed at the maximum expiratory phase based on the theory of the length-tension relationship [19]. The maximum expiratory position is determined by the equilibrium between the contractile force of exhalation and the elastic expansion pressure of the lungs and thorax [20]. At this point, the expiratory muscle group is the most contracted, and the inspiratory muscle group is the most stretched in the respiratory cycle. It is reported that when an inspiratory effort is performed at this maximum expiratory position, the generated pressure becomes the strongest owing to the shape of the diaphragm, elastic expansion pressure of the lung and thoracic system, and length-tension relationship of the lengthened inspiratory muscle group [19, 20]. In our study, the measurement of inspiratory strength started from the maximum expiratory position, suggesting that inspiratory strength is not affected by posture. However, in terms of expiratory muscle strength, the pressure is considered the strongest at the maximum inspiratory position due to the length-tension relationship of the expiratory muscle group.VC is higher in the sitting position than in the supine position, which indicates that the lung air content is higher in the sitting position [8]. Therefore, this suggests that expiratory muscle strength may be stronger in the sitting position than in the supine position. In this research, significant difference did not show in expiratory muscle strength despite the decrease in VC in the supine position. We considered that the pressure was applied to the posterior surface of the thorax in the supine position [8], movement to the cranial side by the abdominal internal organs assisted the exhalation, and exhalation muscle strength was not affected by posture.

There was no change in VC in the sitting position, although the VC values of the IMTG in the supine position increased significantly, possibly because the diaphragm moved downward in the sitting position [6, 8, 9]; therefore, even if the inspiratory muscle strength increased,the downward movement of the diaphragm and VC were not affected. Conversely, VC in the supine position was significantly improved after 8 weeks of IMT compared with baseline. In the supine position, the abdominal internal organs move to the cranial side, and the diaphragm is pushed up to the cranial side, which reduces VC [6, 8, 9]; inspiratory muscle strength is enhanced, which indicates that VC in the supine position has improved. Our results showed no change in ERV after 8 weeks in the IMTG, suggesting that the position of the diaphragm in the resting expiratory position in the supine position did not change, although the IC increased significantly. Accordingly, the increase in the amount of inspiratory air in the supine position led to an improvement in VC. Therefore, the increase in inspiratory muscle strength in the IMTG made it possible to push the abdominal internal organs to the caudal side in the supine position, increase the IC in the supine position, and increase the VC.

Many reports have shown that cough capacity correlates with VC[9,21], and our hypothesis was that with an increase in inspiratory muscle strength, lung and cough capacities increase in the supine position. However, the IMTG showed no change in coughing ability, although VC increased after 8 weekscompared with baseline. Therefore, it may be necessary to consider the effect of fat deposition location in individuals with obesity. Previous studies have pointed out that fat deposits in the necks of people with obesity may cause airway narrowing [11], suggesting that inspiratory muscle strength may be increased and coughing ability may not be improved simply by increasing VC.

Finally, we believe that the decrease in respiratory function in people with obesity in the supine position is an importantproblem in clinical care, and the fact that IMT improved lung capacity in the supine position in this research is an important finding, as it may lead to preventing secondary pulmonary complications.Furthermore, although IMT improved VC in people with obesity, coughing ability did not improve, suggesting the need to add other exercise therapy in addition to IMT in people with obesity.

There were limitations in this research. First, the present study reported results in a small number of participants, which may have biased the findings. Second, since all our participants were men. The same results may not be obtained for women, since the types of obesity in men and women are different [22]. Third, we did not investigate the site of fat deposition and the effect of the fat deposition site on respiratory function. In addition, it was estimated that there was no change in the resting expiratory position based on the results of respiratory function regarding the diaphragm position. Future studies should examine the diaphragm position using an ultrasonic diagnostic device.

In conclusion, 8 weeks of IMT enhanced respiratory muscle strength in men with obesity and improved VC in the supine position but did not improve coughing ability.

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ConflictofInterest

The authors declare no conflicts of interest.

Author Contributions

Study concept and design: Yoshihiro Yamashina; analysis and interpretation of data: all authors; drafting of the manuscript: all authors; and critical revision of the manuscript: all authors.

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