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The Effect of Integration Between Respiratory Muscle Training and Abdominal Drawing-in Maneuver on Decreased Pulmonary Function in Young Subjects

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Abstract

The aim of this study was to investigate the effects of respiratory muscle training (RMT) with abdominal drawing-in maneuver (ADIM) on pulmonary function. Twenty-two subjects with restrictive breathing participated in this study. All the subjects were randomly assigned to three groups (7 subjects in RMT group, 7 subjects in RMT with ADIM group, 8 subjects in control group). The first group performed the RMT by using incentive respiratory spirometer (IRS). The second group performed the RMT by using IRS and the ADIM by using a Stabilizer. The exercises were conducted over four days. The pulmonary function was evaluated using the spirometer to measure the force exploratory volume in 1 second (FEV_1) and forced vital capacity (FVC). Measurements were conducted on the first day and the last day. A paired-t test was used for pre-post changes and the change rates in FVC and FEV_1 among each group were investigated by a one-way ANOVA. The findings of the the study were as follows: 1) There were significant differences of FVC and FEV_1 between pre and post in the two training groups ($p<.05$) 2) There was no significant difference of the change ratio the FVC and FEV_1 between the RMT group and RMT with ADIM group. Therefore, it is concluded that respiratory muscle and ADIM training, combined with two methods of treatment would suggest positive evidence for improving pulmonary function.

Key Words: Abdominal drawing-in maneuver training; Pulmonary function; Respiratory muscle training.

Introduction

Respiration is a process during which an organism exchanges carbon dioxide with oxygen in order to obtain the materials necessary to sustain life. The respiratory system supplies the blood with oxygen while removing carbon dioxide. During expiration, the system passes the air through the vocal cords, generating sounds, regulating abdominal pressure, and aiding urination, defecation, and parturition. Respiration consists of inspiration and expiration. Inspiration is an active movement that contracts the diaphragm and intercostal muscles. The major inspiratory muscles are the diaphragm and external intercostal, and the auxiliary inspiratory muscles are the sternocleidomastoid, scalene, serratus anterior, pectoralis major, pectoralis mi-

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nor, trapezius, and erector spinae. Contrary to inspiration, expiration is a passive process that occurs during relaxation of the muscles that were engaged in inspiration, and brings the thorax back to its original location. During expiration, the size of the thorax decreases, increasing intrathoracic pressure. Pulmonary compliance contracts the lungs, resulting in the air pressure within them becoming greater than the atmospheric pressure and thereby releasing the air from the lungs (Kim et al, 2009).

The thorax and abdominal muscles used for respiration are divided into the major and auxiliary muscles. The auxiliary muscles include the scalene, sternocleidomastoid, pectoralis major, and the abdominal. These aid the major muscles when the demand for air increases (Bach et al, 1993; Hanayama et al, 1997; Jardins, 2002). Previous studies have noted that weakened expiratory muscles drastically lower the capacity for coughing and sputum drainage, and exercises to strengthen these expiratory muscles were conducive to reinforcing the muscular strength of the pectoralis and reducing residual volumes (Kim et al, 2008). Consequently, the strengthened respiratory muscles after exercises are linked with an enhanced capacity for coughing and sputum expectoration (Estenne et al, 1989). It is possible to utilize repetitive breathing resistance training to strengthen respiratory muscles using simple instruments, and this can also improve cardiopulmonary functionality (Roth et al, 2010). One of the methods used to train respiratory muscles is one with an incentive respiratory spirometer (IRS). The method's merits are that it is easy to learn how to use the instrument, it is economical, and patients are inspired to use it as it produces a visible achievement. Its visual feedback helps trained patients to use the instrument independently and freely (Westwood et al, 2007), and maximizes their respiratory motivation (Bartlett et al, 1973; Houge, 2001).

The four muscles in the abdomen perform the important functions of trunk flexion and rotation, pull the abdominal wall medially, and increase the pressure within the abdominal cavity. The elements of the abdomen are not actually pressurized, and therefore these muscles induce the diaphragm to move inwards toward the thoracic cavity. This movement is a result of increased pleural pressure and reduced lung capacity. These abdominal muscles are strong and play an important role in activities like coughing and deep respiration (De Troyer and Estenne, 1988). Previous studies have presented conclusive evidence that abdominal muscles are the most crucial muscles in respiration (Suzuki et al, 1991). Most important, the activation of the upper and lower fibers of the transversus abdominis muscle contributes to changes in abdominal pressure and these are essential in increasing abdominal pressure. The diaphragm helps to enhance the spinal stability; its contraction, together with the abdominal muscles' contraction, increases abdominal pressure (Bartelink, 1957; Cresswell et al, 1992; Grillner et al, 1978), and it continuously contributes to respiration and posture adjustment, along with the abdominal muscles (Hodge et al, 2000). The Stabilizer[1] is a tool developed for abdominal drawing-in maneuver (ADIM) training that increases the abdominal pressure, stabilizing the lumbar spine. This Stabilizer provides visual feedback through a pressure sensor (Cairns et al, 2000).

Measuring forced vital capacity (FVC) is a method of measuring the vital capacity. The forced vital capacity refers to the total capacity of air that can be blown out by maximal forced expiration after maximal inspiration. The forced expiratory volume in 1 second (FEV_1) means the capacity of air that is blown out for a single second. Most healthy adults can exhale 80% of their total capacity in 1 second during expiration (Westwood et al, 2007). Usually, in order to evaluate pulmonary functions after respiratory muscle training (RMT), measurements are taken of the pulmonary residual volume, the FVC and the FEV_1 (Roth et al, 1995). A IRS may be also used to evaluate pulmonary functions and the respiratory muscles' de-

1) STABILIZER^{TM} Pressure Bio-Feedback, Chattanooga group Inc, Hixson, U.S.A.

gree of weakness (Kim et al, 2009).

This study attempted to examine whether respiratory muscle and ADIM training was conducive to enhancing pulmonary functions. This study established a hypothesis that RMT and the ADIM training would increase abdominal pressure from the transversus abdominis muscle, improving pulmonary functions in the FVC and FEV_1. We also predicted that a integrating exercise program of conducting respiratory muscle and ADIM training would be more conducive to enhancing pulmonary functions than either of them alone, and it also surmised that activation of deep abdominal muscles like transversus abdominis muscle would be effective in enhancing respiratory capabilities. The purpose of this study was to examine the effects of a integrating exercise of respiratory muscle and ADIM training devised for internal stabilization of the spine on pulmonary functions.

Methods

Subjects

Subjects were selected by taking a pre-measurement with a spirometer; the subjects selected comprised 22 healthy male and female adults in their twenties with restricted pulmonary functions, with a vital capacity of less than 80%, or whose FEV_1 was less than 70% compared to the norm (Kagaya et al, 2009). Those who had undergone orthopedic or neurological surgeries, other thoracic surgeries, or those who received treatment due to neurological problems were excluded. Before this experiment was performed, this study was sufficiently explained to all the subjects and their consent to participate was obtained. 14 subjects were randomly allocated to either a respiratory muscle training group (RMTG, n_1=7), a integrating training group of respiratory muscle and ADIM exercises (ITG, n_2=7), or a control group (n_3=8) to which no exercise was prescribed. The three groups' general characteristics were not statistically significantly different and their FVC and FEV_1 were also not statistically significantly different (Table 1).

Figure 1. Spirometer.

Instruments

A spirometer[2)] was used to measure the subjects' FVC and FEV_1 among pulmonary function indexes (Figure 1).

Table 1. General characteristics of the subjects (N=22)

Variables	RMTG[b] (n_1=7)	ITG[c] (n_2=7)	CG[d] (n_3=8)	F[*]
Age (yrs)	20.7±3.2[a]	19.1±.9	19.8±1.6	.99
Weight (kg)	163.1±4.9	159.7±4.4	164.8±8.1	1.30
Height (cm)	50.0±4.9	51.6±6.4	52.5±7.2	.30
FVC[e] (ℓ)	1.9±.6	2.0±.4	2.4±.6	1.94
FEV_1[f] (ℓ)	1.8±.6	1.9±.4	2.3±.6	1.28

[a]Mean±SD, [b]respiratory muscle training group, [c]integrating training group, [d]control group, [e]forced vital capacity, [f]forced exploratory volume in 1 second, [*]p>.05.

2) CHESTGRAPH HI-101, CHEST M. I. INC, Tokyo, Japan.

Procedures

The RMTG received incentive spirometry training, the ITG of respiratory muscle and ADIM exercises received incentive spirometer and ADIM training, and the control group did not receive any intervention. Each group's training period spanned 4 days. For all the groups, the FVC and FEV_1 were measured prior to the exercise and they were re-measured after the exercises were carried out for 4 days.

Respiratory Muscle Training

For the RMT method using an incentive spirometer[3], a RMT method presented by Hall et al (1996) was modified and applied. The subject maintained a maximal inspiration position for 2 to 3 seconds and then performed maximal expiration. This exercise was performed for a total of 5 sets, with 10 repetitions making up one set. After each set, a one-minute resting time was allowed. When the subject complained of fatigue or felt dizzy during the respiratory exercise, they took a rest for a short while and then proceeded with the exercise. If these symptoms were severe, the subjects stopped the exercise.

Abdominal Drawing-in Maneuver

For the ADIM training, a ADIM training method presented by Richardson et al. (2004) was modified and applied. The subject lay in a prone position and the Stabilizer was placed horizontally, right under the abdomen and the anterior superior iliac spine (ASIS) so that the instrument did not touch the ASIS. The pressure biofeedback unit was inflated to 70 ㎜Hg and the subject was instructed to perform an ADIM. The pressure biofeedback unit's pressure was then lowered by 6∼10 ㎜Hg, and this was maintained for 10 seconds. The subject rested for 2 to 3 seconds after the 10-second maintenance. This exercise was conducted for a total of 5 sets with 10 repetitions making up one set. For each set, a one-minute rest was allowed. Prior to the exercise, the functions of the deep abdominal muscles were explained, and the subjects performed a preliminary exercise through feedback and reinforcement about whether the exercise was properly applied.

Statistical Analysis

Data were analyzed using Statistical Package for the Social Sciences software version 18.0 software. Before the exercise, a one-way ANOVA was conducted in order to verify the statistical significance of the differences in the groups' general characteristics and pulmonary functions. Then, a paired t-test was performed in order to verify the significance of the differences in each group between the measurements taken prior to the experiment and after the

Table 2. Comparisons of the FVC and FEV_1 before and after the intervention between groups (Unit: ℓ, N=22)

	RMTG[b] (n_1=7)	ITG[c] (n_2=7)	CG[d] (n_3=8)
FVC[e]			
Pre-test	1.77±.45[a]	2.06±.24	2.28±.71
Post-test	1.95±.47	2.39±.23	2.23±.68
t	-3.46*	-8.21*	-.69
FEV_1[f]			
Pre-test	1.68±.50	1.92±.30	2.26±.71
Post-test	1.93±.45	2.26±.26	2.22±.68
t	-4.42*	-5.99*	.65

[a]Mean±SD, [b]respiratory muscle training group, [c]integrating training group, [d]control group, [e]forced vital capacity, [f]forced exploratory volume in 1 second, *$p<.05$.

3) Tri-ball Incentive Spirometer 600-1200cc, Ark Therapeutic, Lugoff, U.S.A.

Table 3. Comparisons of improvement rate of the FVC and FEV_1 after the intervention (N=22)

	RMTG[b] (n_1=7)	ITG[c] (n_2=7)	CG[d] (n_3=8)	F
FVC[e] improvement rate (%)	16.86±11.64[a**]	18.55±10.62[***]	-1.28±7.95	9.07[*]
FEV_1[f] improvement rate (%)	11.10±9.57[**]	15.98±6.02[***]	-1.41±8.47	9.14[*]

[a]Mean±SD, [b]respiratory muscle training group, [c]integrating training group, [d]control group, [e]forced vital capacity, [f]forced exploratory volume in 1 second, [*]p<.05, [**]significant difference between RMGT and CG, [***]significant difference between ITG and CG.

experiment. Furthermore, in order to examine the significance of the change ratio of FVC and FEV_1, a one-way ANOVA was carried out. Tukey's honestly significant difference test was also applied as a post-hoc test. The significance level was set at .05 in order to analyze statistical significance.

Results

1. Comparison of pulmonary functions in accordance with the training methods

1.1. The Forced Vital Capacity

A comparison of the FVC prior to the exercise and after the exercise showed that this significantly increased in the RMTG and ITG (p<.05) (Table 2). FVC after the exercise was compared among the three groups; results from those in the RMTG and ITG were significantly different from the results of the control group (p<.05) (Table 2), but there was no significant difference between the RMTG and ITG (p>.05) (Table 3).

1.2. The Force Exploratory Volume in 1 second

The FEV_1 prior to the exercise and after the exercise were compared and results from participants in the RMTG and ITG significantly increased after the exercise (p<.05) (Table 2). Comparison of the FEV_1 among the three groups after the exercise showed that the RMTG and ITG had a significantly larger volume than the control group (p<.05) (Table 2). However, there was no significant difference between the results from the RMTG and ITG (p>.05) (Table 3).

1.3. Change ratio of forced vital capacity and forced expiratory volume in 1 second after the exercise

After the exercise, the FVC of the RMTG and ITG increased by an average of 16.86% and 18.55%, respectively; on the contrary, that of the control group decreased by an average of 1.28%. In addition, the FEV_1 of the RMTG and ITG rose by an average of 11.10% and 15.98%, respectively, while that of the control group reduced by an average of 1.41% (Table 3).

1.4. Comparison of the change ratio of forced vital capacity and forced expiratory volume in 1 second among the three groups

After the exercise, the RMTG and ITG's FVC and FEV_1 significantly increased in comparison with the control group (p<.05) (Table 3). After the 4-day exercise, the ITG and RMTG's FVC and FEV_1 increased further by an average of 1.69% and 4.88%. However, this was not statistically significant (p<.05) (Table 3).

Discussion

RMT using an incentive spirometer is conducive to enhancing pulmonary functions (Bartlett et al, 1973). According to recent studies, deep abdominal muscles such as transversus abdominis muscle and multifidus muscle (Wilke et al, 1995) contribute not only to stabilization of the spine (Creewell et al, 1994) and adjustment of posture (Hodge et al, 2000), but also to significant improvement in pulmonary functions when ADIM training is applied (Kim et al, 2009). Studies have verified the respective effects of RMT and ADIM training and their relationships to improvement in pulmonary functions, but there has been no research examining the relationship between a integrating training program of respiratory muscle and ADIM exercises and improvement in pulmonary functions. Accordingly, this study attempted to investigate how a integrating exercise program of RMT and ADIM training affected improvement in pulmonary functions.

This study's subjects are 22 males and females in their twenties; due to this limited sample, future research on patients with restrictive, obstructive, and mixed pulmonary functions is necessary. The subjects were randomly allocated to either a RMTG, ITG, or a control group. The tests on the subjects' pulmonary functions were conducted with a spirometer. The test on their pulmonary functions was performed by the subjects putting on a nose clip. If the subjects coughed or made a mistake, their numerical value was not recorded (Kim et al, 2001). The test results are affected by technological differences, biological differences unrelated to diseases, differences in testing equipment, performance process, examiners and subjects, and diseases themselves. The most important concern when conducting and analyzing a pulmonary function test is to minimize technological differences, consider biological differences, and discover and analyze differences originating from the diseases themselves. In determining differences in pulmonary functions, the most crucial elements are an subject's gender, body size, and age; these factors affect the results by 30%, 22%, and 8% respectively. Race and technological differences affect the results by 20% and 3% respectively, and the remaining 27% are individual differences that have yet to be explained (Becklake, 1986).

The rate of FVC is represented as a percentage of forced vital capacity; this is an index that approximately evaluates the degree of air obstruction. The FEV_1 and FVC are indexes that are used to judge a relative reduction in ventilation capacity in case the subject has restrictive or obstructive ventilation disorders. Therefore, they are measured a lot in the clinical field (Jeon et al, 2010; Kreitzer et al, 1978). They have lower variability than other indexes and are often used to evaluate a prognosis and observe progression (Harber et al, 1985). Based on prior studies, this study evaluated major respiration indexes such as FVC and FEV_1.

An incentive respiratory spirometer was used in order to apply RMT, for which a RMT method presented by Hall et al. (1996) was modified. For ADIM training, the Stabilizer was used to improve factors that were associated with decreased pulmonary function and the training was performed by modifying a ADIM training method presented by Richardson et al (2004).

FEV_1 may be affected by variables that may influence an expiration test such as expiratory effort, time of day, or whether the measurement was made before or after a meal (Kim et al, 2009). Both the RMTG's and ITG's pulmonary functions significantly improved after the respiratory muscle and ADIM training. Measurements taken on the fourth day of the experiment showed significant enhancement. The increase in FEV_1 on the fourth day after the experiment was judged to be because the subjects became accustomed to respiratory muscle and ADIM training and having their pulmonary functions measured (Kim et al, 2009). However, the control group did not show a statistically significant result, which means that there was no learning effect from repeated measurement and testing of pulmonary functions. The FVC and FEV_1 increased significantly for the RMTG and ITG. The two groups' pulmonary functions also improved significantly compared with the results from the control group. Although the integrating group's change ratio was higher than the RMTG's, their differences were not statistically significant.

Kim et al (2009) reported on a five-day period of ADIM training that was performed, and noted that the subjects' pulmonary functions started to decline on the second to third day of the training, began to improve on the fourth day, and significantly improved from the fifth day. Therefore, they concluded that significant improvement in pulmonary functions required ADIM training for at least five days. In this regard, the four-day exercise period of this study was insufficient to prove significant differences between the two groups.

This study has the following limitations. Firstly, the four-day exercise period applied in this study is judged to be insufficient to examine whether RMT and ADIM training are statistically significantly different in improving pulmonary functions. Therefore, future research considering this factor is necessary. Furthermore, additional research to further investigate the relationship between pulmonary functions and deep abdominal muscles is needed. Secondly, a single measurement may be hard to obtain a reliable result. In the future, a more precise and reliable method will be necessary.

Conclusion

This study looked at the effects of a integrating exercise program of respiratory muscle and ADIM training on pulmonary functions by conducting experiments on 22 subjects with restricted pulmonary functions. For both the RMTG and ITG, pulmonary functions significantly improved in comparison with the results from the control group. The ITG's average change ratio of pulmonary functions was larger than the RMTG's, but they were not statistically significantly different. In conclusion, RMT alone, or a integrating exercise program of respiratory muscle and ADIM training, is conducive to enhancing the pulmonary functions of patients whose FVC and FEV_1 have been reduced due to restrictive pulmonary diseases.

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