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Original Research Article

EFFECTS OF ABDOMINAL EXERCISE ON RESPIRATORY MUSCLES AND PULMONARY FUNCTION IN HEALTHY MALES

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ABSTRACT

Background: Abdominal muscle is the major expiratory muscle and play an important role in ventilation. The purpose of this study is to examine the effects of abdominal muscle training on pulmonary function. Subjects were randomly assigned to low (n=7), moderate (n=7), and high intensity (n=7) groups and performed sit-up exercises at for 6 weeks. The intensity was set at 40% (low), and 80% (high) of the numbers of sit-ups they performed during 1-min sit-up test. Baseline and post-training measurements included pulmonary function, maximal inspiratory (PImax) and expiratory pressure (PEmax), and 1-minute sit-up test.

Results: No differences were found in post-training pulmonary function among the 3 groups. However, significant increase in maximal voluntary ventilation after training was found in low (26. 5 vs 31.4 L, $p<0.05$), moderate (29.9vs 45.0 L, $p<0.05$), and high intensity group (27.2 vs 42.2 L, $p<0.05$). Subjects in the LOW group demonstrated a significantly increase in PEmax (88.0 (66.0-96.0) vs. 104.0 (91.0-123.0) cmH2O, $p<0.05$)

Conclusions: The abdominal muscle training may enhance the ability of maximal ventilation through increasing expiratory muscle strength.

KEY WORDS: abdominal muscle, respiratory muscle training, pulmonary function, sit-up.

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INTRODUCTION

The abdominal muscles are the principle muscles of expiration among the others. During high-intensity exercise, when the minute ventilation increase, the work of abdominal muscles is required to increase expiratory flow rate and tidal volume [1]. The enhanced abdominal muscles activity during exercise helps expiration of air out of the lungs which result in decrease in the end-expiratory lung volume. This can help inspiratory muscles to produce a larger force by improving their length-tension relationship and assist with lung expansion at the beginning of inspiration through passive recoil of the chest wall [2].

Many studies have found the positive outcome of respiratory muscle training on pulmonary function and physical performance in both healthy and cardiopulmonary disease populations [3-5]. Most of these studies focused on the effects of inspiratory muscle training. Expiratory muscles have higher proportional of fast-twitch fibers and less oxidative stress than inspiratory muscles but are involved in similar proportion as inspiratory muscles during exercise or pathological conditions [6-8]. It is rescannable to suggest that expiratory muscles are prone to fatigue that subsequently impairs pulmonary function. Expiratory muscle training, especially the abdominal muscles may improve pulmonary function exercise performance.

In addition to their action in pulmonary function, abdominal muscles are also a major contributor to the trunk muscles. Consequently, the abdominal muscle plays an important role in maintaining postural stability during whole-body activities [9]. During strenuous physical activities, the abdominal muscles are facilitated, thereby increasing abdominal pressure. With such activities, the diaphragm is repeatedly involved; thus, the diaphragm strength can also be developed [10]. Thus, such non-respiratory maneuvers may have an effect on pulmonary function and respiratory muscle performance. However, few studies have explored the mechanisms of these effects.

Because respiratory muscles are morphologically and functionally skeletal muscles, their response to applied stimulus are similar as those in other skeletal muscles [11]. According to the training theory, muscle performance may not improve if the training intensities are not sufficiently high. However, when the subjects' training exceeds their capability, subjects may suffer muscle fatigue, or even injury. The sit-up exercise, in addition to its effects on the diaphragm, is also a common method of training abdominal muscles in healthy subjects and athletes [9]. Which intensity and whether the benefits from abdominal muscle exercise parallel the traditional respiratory muscle training effects on respiratory muscle strength and pulmonary function remains unclear. We hypothesis that sit-up exercise may improve respiratory muscle and pulmonary function through enhancement of abdominal muscle performance. The aims of this investigation were to assess the effects of an abdominal muscle training program on the respiratory muscle strength and pulmonary function in healthy subjects; and to determine appropriate training intensity by comparing effects of exercise at different intensities on the outcome variables.

METHODS

Subjects: Subjects were recruited from a university campus. The inclusion criteria were male subjects at 18-25 years of age, and with a normal body index (BMI) of 18-24kg/m2. Subjects were excluded if they had a history smoking, heart and lung diseases, musculoskeletal diseases, had undergone abdominal- or thoracic surgery within the past 6 months, or had regular exercise habits. The study protocol was approved by Chang Gung Hospital Human Subjects Institutional Review Board. All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All subjects gave their signed informed consent before enrolling the study.

Procedures: At the initial screening visit, baseline data such as age, health history, and physical status were obtained from the subjects. The 1-min sit-up test, respiratory muscle strength, and pulmonary function were measured din all subjects. Subjects were then randomly assigned to low intensity (LOW), moderate intensity (MOD), and high intensity (HIGH) group. The intensity of sit-up exercise was determined by the number of sit-ups in each training sessions. Subjects in LOW group performed 40% of the total numbers of sit-ups that subjects completed during their baseline 1-min sit-up test. The MOD and HIGH groups performed 60% and 80% of the total numbers of sit-ups during their baseline tests, respectively. Every subject performed the sit-up exercise 3 sessions per day, 4 days a week for 6 weeks. Subjects performed the training at home and were asked to record the number of sit-ups their performed in every session. Subjects were asked to maintain normal diet and avoid any type of regular physical exercise during the study period. The investigator visited weekly to assess subjects' progress and the compliance to the program. After completing the 6-week training program, these measurements were repeated by the same investigator who was blinded to the subject's allocated group.

Outcome measurements: Maximal voluntary volume (MVV), minute volume (MV), and tidal volume were measured using a hand-held volume manometers (Haloscale , Ferriaris Co, Middlesex, UK). Peak expiratory flow was measured using a peak flow meter (Mini-Wright Peak flowmeter 3103, Clement Clarke Int Co, Harlow, UK). Subjects performed the test in sitting position and a single, experienced technician recorded the data. The procedures required the performance at least 3 trials, with the largest data within 5% variation accepted for analysis.

The respiratory muscle strength was measured using a hand-held pressure manometers (Inspiratory force meter, Borhringer Laboratory Inc, Norristown, PA, USA). Maximal inspiratory pressure (PImax), which was referred as an index for inspiratory muscle strength, was measured by instructing subjects to inspire forcefully against a occluded mouthpiece for 1s or more. Inspiratory efforts were initiated from residual volume. Maximal expiratory pressure (PEmax) was an index for expiratory muscle strength and measured from total lung capacity. For each test, a minimum of 3 trials were performed, and the higher values of PImax and PEmax, with 2 measures that varied by <5% were then recorded.

The 1-min sit-up test was used to evaluate the dynamic endurance of the abdominal muscles. Subjects reclined their backs with knee flexed to 90°, hips flexed to 45°, and their feet flat. The subjects elevated their back approximately 75-90° off the floor. Each subjects received verbal instructions followed by a demonstration of the 1-min sit-up test. The subjects then practiced the sit-up 2 to 3 times to ensure proper techniques and were then given a 10 to 20-min rest period before the test. Before initiating the test, subjects were told to perform as many sit-ups as they could within 60s. The total number of sit-ups performed correctly was recorded.

Statistical analysis: Data were analyzed using the statistical software package SPSS18.0 version for Windows (Chicago, IL. USA).Results were expressed as means±standard deviation for nominal distribution, while uninominal data were expressed as median (IQR) for nonparametric distribution. Differences within groups were assessed by Wilcoxon match-pair signed rank test (uninominal data) and paired t-test (nominal data). Between group baseline characteristics, pre- and post- measurements were compared with Kruskal-Wallis test. Difference was considered to be significant if p value <0.05.

RESULTS

Twenty-one subjects were recruited into the study and were randomly allocated into 3 groups (7 subjects in each group). The demographic data were shown in Table1. There were no differences between the groups with regards to age, height, weight, and body max index at the beginning of the study.

Table2 showed the values of pulmonary function measurement in the 3 groups at baseline and at the end of the 6-weeks training period. There were no significant differences at baseline between the 3 groups. Completion of the training program, resulted in a significantly increase in LOW (26. 5 (21.8- 28.4) vs. 31.4 (30.0-42.0) L, p<0.05), MOD (29.9(28.2 - 31.8) vs. 45.0(41. 6 -51.0) L, p<0.05), and HIGH group (27.2(23. 0 -36.1) vs. 42.2(39.5 -56.3) L, p<0.05). The percentage of improvement were 44% in LOW, 39.2% in MOD, and 60.9% in HIGH group. There were no significant changes in post-training tidal volume, respiratory rate, and peak expiratory flow among the LOW, MOD, and HIGH groups. In the measurements of respiratory muscle strength, no significant differences were found between groups after training period (Fig 1, Fig 2). Neither group showed significant difference in PImax after training. Subjects in the LOW group demonstrated a significantly increase in PEmax (88.0 (66.0-96.0) vs. 104.0 (91.0-123.0) cmH2O, p<0.05) (Fig 2). The number of sit-ups in 1 min sit-up test increase in each group after training period (Table2). However, no statistic difference were found within group. When pooling data of the 3 groups, a significant increase in PEmax (94.6±24.2 vs. 104.6±26.2cmH2O, p<0.05) and 1-min sit-up tests (43.4±10.6 vs. 46.5±10.1 times/ min, p<0.05) were found after the training program among all subjects (Tab 3).

Table 1: Baseline demographic data for subjects in 3 groups (Median (IQR)).

Group	LOW	MOD	HIGH
Number of subjects	7	7	7
Age (years)	21.0(4.0)	21.0(2.0)	20.0(3.0)
Body height (cm)	169.0(13.0)	175.5(5.0)	170.0(6.0)
Body weight (kg)	68.0(7.0)	62.0(5.0)	65.0(8.0)
BMI (kg/m2)	21.8(1.9)	20.3(1.4)	23.1(3.9)

Table 2: Pulmonary function measurements and 1-min sit-up test in subjects at pre- and post-training program (median(IQR)).

	LOW	MOD	HIGH
MVV (liter)			
pre	26.5 (21.8- 28.4)	29.9 (28.2 - 31.8)	27.2 (23.0 -36.1)
post	31.4 (30.0-42.0)*	45.0 (41.6 -51.0)*	42.2 (39.5 -56.3)*
MV (liter)			
pre	21.5 (13.0-38.3)	15.0 (9.1 -24.2)	12.1 (9.8 -13.6)
post	18.8 (15.9-29.8)	19.2 (8.2 -20.5)	15.5 (14.3 -18.6)
RR (bpm)			
pre	23.0 (16.0-50.0)	21.5 (18.8 -23.5)	19.0 (16.0 -22.5)
post	22 (17.5-37.5)	22.5 (18.3 -26.3)	22.0 (17.0 -26.0)
VT(ml)			
pre	793.7 (732.5-937.6)	715.6 (527.5 -1022.6)	587.0 (480.9 -811.1)
post	800.0 (758.7-1019.1)	753.0 (503.4 -829.5)	796.4 (681.3 -839.9)
PEF(ml/s)			
pre	580.0 (505.0-590.0)	520.0 (507.5 -567.5)	545.0 (490.0 -625.0)
post	560.0 (550.0-585.0)	545.0 (540.0 -560.0)	560.0 (475.0 -600.0)
1-min sit-up test (number of sit-ups /min)			
pre	35.0 (28.0-44.0)	42.0 (33.8-53.8)	48.0 (45.0-57.5)
post	39.0 (31.5- 45.5)	49.5 (37.0-52.3)	53.0 (45.0- 59.0)

MVV: maximal voluntary ventilation; MV: minute volume; RR: respiratory rate; VT: tidal volume; PEF: peak expiratory flow. *Pre- vs Post- measurement comparison, $p < 0.05$

Table 3: Changes of respiratory muscle and abdominal function when pooling data from 3 groups (mean±SD).

	Pre-training (n=21)	Post-training (n=21)
PImax (cmH2O)	76.0±31.0	84.0±26.5
PEmax (cmH2O)	94.6±24.2	104.6±26.2*
1 min sit-up (number of sit-ups /min)	43.4±10.6	46.5±10.1*

PImax: maximal inspiratory pressure
PEmax: maximal expiratory pressure
*Pre- vs Post- measurement comparison, $p < 0.05$

Fig. 1: Changes of maximal inspiratory pressure (PImax) in subjects at pre- and post-training program.

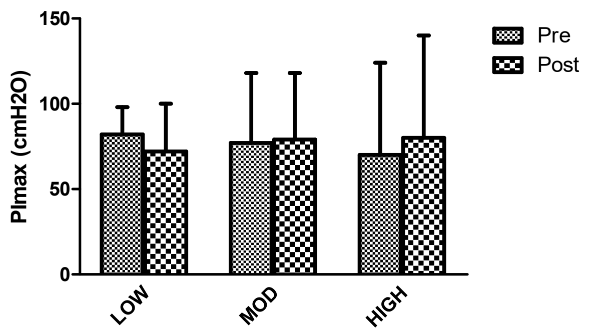
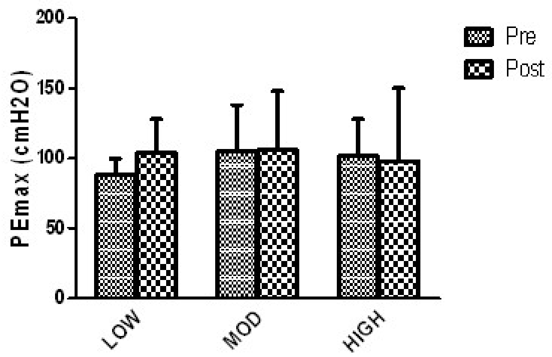


Fig. 2: Changes of maximal expiratory pressure (PEmax) in subjects at pre- and post-training program.



DISCUSSION

The main finding of the present study was that 6-week sit-up exercise training significantly improved abdominal muscle function and PEmax in healthy male subjects. Subjects had a significantly higher MVV after training in all groups.

In our study, the improvement in the 1-min sit-up test (from 43.4±10.6 to 46.5±10.1 times/min) was associated with an increase of PEmax (from 94.6±24.2 to 104.0±26.2 cmH2O) after the 6-week sit-up exercise training. Sit-up, an exercise that requires forceful contraction of abdominal muscles, has been reported to significantly increase both abdominal muscle strength and endurance [9]. Teyhen et al used ultrasound imaging to assess the changes of abdominal muscle thickness under different trunk movements and found a significant increase in the abdominal muscle thickness when healthy subjects performed sit-ups [12]. Childs et al examined the effects of sit-up training in US army soldiers and reported a significant improvement in sit-up test after the sit-up training program [13]. Our study showed that sit-up exercises improve abdominal muscle strength and endurance. This finding is similar to that of previous studies. In addition, because abdominal muscles are the major expiratory muscles, the benefits of abdominal muscle training may influence respiratory muscles, resulting in increased respiratory muscle strength (i,e., PEmax). After training, significantly increases in MVV were found in the 3 groups in our study. MVV is the volume expired in a certain period during repetitive maximal breathing effort. MVV reflects the entire lung function, which includes lung compliance, airway patency, and inspiratory and expiratory muscle strength and endurance [14]. Abdominal muscles, as part of expiratory muscles, are usually silent during quiet breathing. During high-levels of ventilation, the forceful contraction of expiratory muscle not only helps to expire more air out of the lungs, but also acts as an accessory muscle of inspiration by maintaining an optimum position at end of expiration [15]. Previous studies have suggested that abdominal exercises may not only improve abdominal muscle strength, but also affect the diaphragm and inspiratory muscles [9, 12, 13]. DePalo found that abdominal exercise significantly increases transdiaphragmatic pressure that results in an increase in PImax and PEmax in healthy adults [10]. Summerhill found that active elderly subjects have higher PEmax and PImax compared to those in sedentary subjects [16]. Moreover, they speculated that physical activity involving the trunk and abdominal muscles might raise the intra-abdominal pressure; thus, enhancing respiratory muscle strength. In our study, the forceful abdominal muscle contraction during sit-up training resulted in an increase in intra-abdominal pressure and then the diaphragm is recruited to decrease the transmission of high intra-abdominal pressure into the thorax. Although the present study failed to demonstrate a significant increase in PImax, which may be due to small sample size, the significant increase in MVV may indicate that sit-ups improve the efficiency of ventilation by increasing respiratory muscle strength. Prior studies have reported that respiratory muscle training improve pulmonary function [17, 18]. However, these improvements were produced by a traditional respiratory muscle-training device. To our knowledge, our study is the first to demonstrate significant improvement in MVV through abdominal muscle exercise training. In a study examining the effects of respiratory muscle training on pulmonary function, healthy subjects received r espiratory muscle training by a hand-held respiratory resistance-training device, and a 16% increase in MVV was reported [19]. Our study used a method that is no need of specific respiratory-training device, and had significant increase in MVV ranged from 39% to 60%, which is higher than that in previous study [19]. This raises the possibility that, besides the traditional device-aided respiratory muscle training, physical activity involving trunk and abdominal muscle may improve respiratory muscle strength and pulmonary function. This is important for patients with respiratory muscle dysfunction such as chronic obstructive pulmonary disease or cystic fibrosis when they performing whole-body exercise [20, 21]. Further studies will be required to confirm this issue.

When comparing the effects of the three difference training intensities on respiratory muscle strength and pulmonary function, there was no significant differences between the three groups at completion of the 6-week training period. Generally, the training theory suggests that gains in respiratory muscle strength can be achieved at intensities of 80% to 90% of PImax and/or PEmax, whereas endurance gains can be achieved at appropriately 60% of PImax and/or PEmax [22]. However, earlier studies have suggested that improvements in pulmonary function following inspiratory muscle training program, can occur with intensities as low as 40% of peak pressure [20, 23].

Enright et al compared the effects of different inspiratory muscle training intensities on pulmonary function, and found that subjects in the high intensity group (80% of PImax) showed the highest PImax and vital capacity compared to those for subjects in the middle intensity (60% of PImax) and low intensity (40% of PImax) groups after 8 weeks training program [24]. Unlike previous studies, our study failed to demonstrate a difference between the 3 groups, which may be due to the different mythology and short intervention period (6 weeks). It is possible that differences between groups can be observed after a longer training duration. In addition, a small sample size and insufficient statistical power may be another reason for failing to demonstrate the differences between groups

Limitations: The present study examined the effect of different abdominal muscle training intensities on pulmonary function; however, there were limitations in our study. First, our sample size was too small and lacked statistical power. Furthermore, the addition of a control group would better determine the effectiveness of abdominal muscle training on pulmonary function. Another limitation may have been the duration of the intervention. It may have been too short to identify differences between groups. Considering the specificity of abdominal muscle exercise training, further studies with a longer training duration may provide more insights about the effects of different training intensities on pulmonary function. Lastly, we measured tidal volume, MV, MVV, and peak expiratory flow with use of a simple device that was convenient and common in clinical environment such as hospitals or clinics. However, due to the limitation of devices, we failed to obtain other parameters such as total lung capacity, transdiaphragmatic pressure and diaphragm thickness, which are more specific to indicate respiratory muscle and pulmonary function. Studies have reported that respiratory muscle training significantly increase transdiaphragm pressure [10], diaphragm thickness and total lung capacity [24]. Future studies should include more sensitive measurements to obtain valid data.

CONCLUSION

In conclusion, our study suggests that abdominal muscle training through sit-up exercise resulted to the increase in abdominal muscle endurance and expiratory muscle strength in healthy male subjects. In addition, the abdominal muscle training significantly increased in maximal voluntary ventilation in low-, moderate-, and high-intensity groups. The mechanism of improvement may through the repetitive trunk movement that stimulated both inspiratory (diaphragm) and expiratory (abdominal) muscles. This suggests that individuals may benefit from performing non-respiratory activity such as sit-up exercise that may improve pulmonary function. Further studies are needed to investigate the best intensity at which abdominal muscle training can be performed to ensure the best result in the improvement of pulmonary function.

ABBREVIATIONS

BMI - Body Mass Index

LOW - Low Intensity Group

MOD - Moderate Intensity Group

HIGH - High Intensity Group

MVV - Maximal Voluntary Volume

MV - minute volume

Conflicts of interest: None

REFERENCES

[1]. De Troyer A, Estenne M, Ninane V, Van Gansbeke D, Gorini M. Transversus abdominis muscle function in humans. Journal of applied physiology (Bethesda, Md : 1985). 1990;68(3):1010-6.

[2]. Taylor BJ, How SC, Romer LM. Exercise-induced abdominal muscle fatigue in healthy humans. Journal of applied physiology (Bethesda, Md : 1985). 2006;100(5):1554-62.

[3]. Esposito F, Limonta E, Alberti G, Veicsteinas A, Ferretti G. Effect of respiratory muscle training on maximum aerobic power in normoxia and hypoxia. Respiratory physiology & neurobiology. 2010;170(3):268-72.

[4]. Forbes S, Game A, Syrotuik D, Jones R, Bell GJ. The effect of inspiratory and expiratory respiratory muscle training in rowers. Research in sports medicine (Print). 2011;19(4):217-30.

[5]. Sutbeyaz ST, Koseoglu F, Inan L, Coskun O. Respiratory muscle training improves cardiopulmonary function and exercise tolerance in subjects with subacute stroke: a randomized controlled trial. Clinical rehabilitation. 2010;24(3):240-50.

[6]. Johnson BD, Saupe KW, Dempsey JA. Mechanical constraints on exercise hyperpnea in endurance athletes. Journal of applied physiology (Bethesda, Md : 1985). 1992;73(3):874-86.

[7]. Kyroussis D, Mills GH, Polkey MI, Hamnegard CH, Wragg S, Road J, et al. Effect of maximum ventilation on abdominal muscle relaxation rate. Thorax. 1996;51(5):510-5.

[8]. Roth EJ, Stenson KW, Powley S, Oken J, Primack S, Nussbaum SB, et al. Expiratory muscle training in spinal cord injury: a randomized controlled trial. Archives of physical medicine and rehabilitation. 2010;91(6):857-61.

[9]. Childs JD, Teyhen DS, Casey PR, McCoy-Singh KA, Feldtmann AW, Wright AC, et al. Effects of traditional sit-up training versus core stabilization exercises on short-term musculoskeletal injuries in US Army soldiers: a cluster randomized trial. Physical therapy. 2010;90(10):1404-12.

[10]. DePalo VA, Parker AL, Al-Bilbeisi F, McCool FD. Respiratory muscle strength training with nonrespiratory maneuvers. Journal of applied physiology (Bethesda, Md : 1985). 2004;96(2):731-4.

[11]. Sperlich B, Fricke H, de Marees M, Linville JW, Mester J. Does respiratory muscle training increase physical performance? Military medicine. 2009;174(9):977-82.

[12]. Teyhen DS, Rieger JL, Westrick RB, Miller AC, Molloy JM, Childs JD. Changes in deep abdominal muscle thickness during common trunk-strengthening exercises using ultrasound imaging. The Journal of orthopaedic and sports physical therapy. 2008;38(10):596-605.

[13]. Childs JD, Teyhen DS, Benedict TM, Morris JB, Fortenberry AD, McQueen RM, et al. Effects of sit-up training versus core stabilization exercises on sit-up performance. Medicine and science in sports and exercise. 2009;41(11):2072-83.

[14]. Beachey W. Respiratory Care Anatomy and Physiology : Foundations for Clinical Practice 2nd: Elsevier Science Health Science; 2007.

[15]. Hopkinson NS, Dayer MJ, Moxham J, Polkey MI. Abdominal muscle fatigue following exercise in chronic obstructive pulmonary disease. Respiratory research. 2010;11:15.

[16]. Summerhill EM, Angov N, Garber C, McCool FD. Respiratory muscle strength in the physically active elderly. Lung. 2007;185(6):315-20.

[17]. Ray AD, Pendergast DR, Lundgren CE. Respiratory muscle training reduces the work of breathing at depth. European journal of applied physiology. 2010;108(4):811-20.

[18]. Edwards AM, Wells C, Butterly R. Concurrent inspiratory muscle and cardiovascular training differentially improves both perceptions of effort and 5000 m running performance compared with cardiovascular training alone. British journal of sports medicine. 2008;42(10):823-7.

[19]. Watsford M, Murphy A. The effects of respiratory-muscle training on exercise in older women. Journal of aging and physical activity. 2008;16(3):245-60.

[20]. Belman MJ, Mittman C. Ventilatory muscle training improves exercise capacity in chronic obstructive pulmonary disease patients. The American review of respiratory disease. 1980;121(2):273-80.

[21]. Enright S, Chatham K, Ionescu AA, Unnithan VB, Shale DJ. Inspiratory muscle training improves lung function and exercise capacity in adults with cystic fibrosis. Chest. 2004;126(2):405-11.

[22]. Powers SK, Criswell D. Adaptive strategies of respiratory muscles in response to endurance exercise. Medicine and science in sports and exercise. 1996;28(9):1115-22.

[23]. Aldrich TK, Karpel JP. Inspiratory muscle resistive training in respiratory failure. The American review of respiratory disease. 1985;131(3):461-2.

[24]. Enright SJ, Unnithan VB. Effect of inspiratory muscle training intensities on pulmonary function and work capacity in people who are healthy: a randomized controlled trial. Physical therapy. 2011;91(6):894-905.

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