# Effect of Neuromuscular Electrical Stimulation Addition in Exercise with Expiratory Muscle Trainer on FEV1 And FVC in Untrained Healthy Subjects

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## Abstract

Coughing is a mechanism for expelling foreign particles or excess mucus in the airway by increasing high expiratory pressure. When coughing, the respiratory muscles that control cough production are the inspiratory and expiratory muscles. Weakness of the expiratory muscle can affect to the ability to generate sufficient pressure to cough. In generally, a decrease in respiratory muscle's strength can occur in patients who have experience of prolonged immobilization, elderly people who suffer from sarcopenia, to stroke patients. The untrained healthy persons were not realizing the effects of their lifestyle which can reduce the rectus abdominis muscle as an additional expiratory muscle. If it occurred in long time, it will reduce the lung function capacity of force expiratory volume (FEV1) and force vital capacity (FVC). The subjects of this study were 16 untrained healthy males with aged 18-40 years. Furthermore, they divided into 2 groups, the intervention group with Expiratory Muscle Trainer (EMT) training plus of Neuromuscular Electrical Stimulation (NMES) on the rectus abdominis muscle and the control group with exercise with Expiratory Muscle Trainer only. The outcome was measured for FEV1 and FVC by spirometry. The results of this study were indicating an increase in FEV1 and FVC in each group however. The intervention group was increase of FEV1 0.22+0.22 (p value=0.18) and the control group was 0.01+0.39 (p value=0.92). The intervention group was increase of FVC 0.50+0.48 (p value=0.02) and the control group was 0.32+0.51 (p value=0.12). The FEV1 results between the two groups were not significant difference (p value=0.21) and as well as FVC results after 4 weeks of training. In summary, this study concluded that EMT training with NMES increased FVC even though the difference between the two was not significant.

***Keywords:*** *expiratory muscle trainer, neuromuscular electrical stimulation, force expiratory volume (FEV1), force vital capacity (FVC).*

## Introduction

Coughing is a mechanism for expelling foreign particles or excess mucus in the airway by increasing high expiratory pressure. When coughing, the respiratory muscles that control cough production are the inspiratory and expiratory muscles. Weakness of the expiratory muscle can affect to the ability to generate sufficient pressure to cough. In generally, a decrease in respiratory muscle's strength can occur in patients who have experience of prolonged immobilization, elderly people who suffer from sarcopenia, to stroke patients[1]. WHO were reports 15 developing countries with the highest number of deaths due to pneumonia with the highest number from India with 158,176, followed by Nigeria with 140,520, and Pakistan in third place with 62,782 deaths[2]. Pneumonia was in the top 10 of diseases in hospitals and community health centers in East Java from 2008 to 2010. Based on Riskesdas, the incidence of pneumonia in East Java at 2013 was 1.3%[3].

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The risk of pneumonia was increased as well as the duration of the prolonged immobilization[4]. Its due to the accumulation of secretions in the lowest bronchial branches which is affected lung atelectasis and an ideal environment for pathological bacteria[5]. Fatigue in the respiratory muscles can also increase the sensation of shortness of breath and decrease lung function capacity in healthy subjects[6]. This can be caused by obstructed movement of the rectus abdominis muscle, especially as a result of wearing a belt too tight or a self-image that shows if have a flat stomach[7]. The untrained healthy person does not realize the effects of his lifestyle which can reduce the rectus abdominis muscle as an additional expiratory muscle. Therefore, if it occurred in a long time, will reduce the ability to sputum secretion, reduce pulmonary function, moreover increasing the risk of pneumonia[8,9,10].

Breathing exercises using EMT can have an effect to increase expiratory muscles strength and the frequency of breath in normal people, so that increasing the respiratory function during exercise. The patients with chronic obstructive pulmonary disease, exercise using EMT has a positive impact on respiratory function[11]. The NMES is the use of electrical stimulation of the motor nerves which causes a muscle to contract. Patients with respiratory problems, such as weakness that affects the respiratory muscles, NMES can be used to increase the ability of the respiratory muscles and to increase the function itself. The use of NMES on the abdominal muscles has been hypothesized to increase muscle mass and tone, thereby improving respiratory function[12]. Research on the effect of breathing exercises with an EMT coupled with the use of NMES on the rectus abdominis muscles was limited. Based on the problem above, this study aims to determine the effect of adding NMES to the rectus abdominis on breathing exercises with EMT in untrained healthy young male adults on their lung function.

## Methods

This study was an experimental study in untrained healthy male subjects with randomized pre-test and post-test group design.

### Subjects

The study subjects were 16 untrained healthy men who met the inclusion criteria. The inclusion criteria were untrained healthy men, ages 18-40 years, body mass index (BMI) 18.5 - 24.9 kg/m$^2$, and willing to participate in this study. Exclusion criteria were undergoing a routine aerobic exercise program twice a week, undergoing a rectus abdominis muscle strengthening exercise program, ischemic heart disease and arrhythmia, using a pacemaker, restrictive or obstructive airway disease, neuromusculoskeletal disease, and allergy to neuromuscular electrical stimulation electrode pad. The subjects were randomly divided into two groups, intervention group using EMT with addition NMES (n=8) and control group using EMT only (n=8). Baseline data was collected before the training program and post intervention data was collected 4 weeks after training. FEV1 and FVC was measured before and after the training program as an outcome in this study with spirometry. All participants were given instructions about the objectives and procedures of the study and invited to participate after signing the informed consent form. This study was approved by the institutional ethics research committee of Dr. Soetomo General Hospital, Surabaya, Indonesia.

### Intervention

In the first visit, introducing with all tests was carried out. 50% maximal expiratory pressure (MEP) is determined using Phillips EMT. The training program was initiated with warming up and ended with cooling down. Training session for intervention group, exercise was adjusted to the contraction of the NMES. The exercise were characterized by isometric rectus abdominis muscle exercise using Phillips EMT, intensity 50% MEP, 5 sets, 6 repetitions/set, five times a week with, for 4 weeks, The addition NMES using Intelect® portable NEMS follow the exercise with EMT. The detail of exercise described as follows: 1) Intervention group, exercise of rectus abdominis muscles, initiated EMT, intensity 50% MEP, 5 sets, 6 repetitions/set, five times a week (rest interval between sets is 1 minutes), and NMES electrodes placed at rectus abdominis muscle with on time 6 seconds, off time 30 seconds until visible muscle contraction for 30 minutes, 2) control group, only performed EMT training.

## Statistical Analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS v.23). Data normality assumptions was used Saphiro-Wilk test. The baseline characteristics between intervention and control groups were compared using independent sample t test. The differences between FEV1 and FVC before and after the training session of intervention and control group using paired t test. Between-group differences (delta) of FEV1 and FVC were compared using independent t-tests. The differences were considered statistically significant at $p < 0.05$.

## Results and Discussion

Total subjects of this study were 16 participants who were divided into intervention and control groups groups (8 participants in each group). None of the subjects reported any adverse effects during the strengthening exercise program. The baseline characteristics of the subjects such as age, weight, height, BMI, FEV1 and FVC value before training program did not show a significant difference between the two groups (Table 1). In both intervention and control groups groups, there was not a statistically significant increase in FEV1 ($p > 0.05$) after strengthening exercise. But in intervention group there was a statistically significant increase in FVC ($p < 0.05$) (Table 2). Comparison of the delta FEV1 and FVC revealed that there was no difference between the two groups ($p > 0.05$) (Table 3).

**Table 1. Baseline Characteristic of Subjects.**

| Variable | Intervention Group (n=8) | Control Group (n=8) | p Value |
|---|---|---|---|
| **Age (Year)** | 32.62±4.83 | 30.75±4.65 | 0.689 |
| **Weight (kg)** | 67.37±4.03 | 60.12±10.45 | 0.105 |
| **Height (m)** | 1.68±4.03 | 1.69±5.80 | 0.380 |
| **BMI (kg/m$^2$)** | 23.66±2.33 | 20.76±2.72 | 0.471 |
| **FEV1** | 3.29±0.32 | 3.53±0.32 | 0.154 |
| **FVC** | 3.48±0.36 | 3.80±0.48 | 0.159 |

*Significant if p value <0.05.

**Table 2. FEV 1 and FVC Before and After Exercise.**

| | Intervention (n=8) | | | Control (n=8) | | |
|---|---|---|---|---|---|---|
| | **Before** | **After** | **p Value** | **Before** | **After** | **p Value** |
| FEV1 | 3.29±0.32 | 3.53±0.36 | 0.18 | 3.53±0.32 | 3.55±0.19 | 0.92 |
| FVC | 3.48±0.36 | 3.99±0.50 | 0.02* | 3.80±0.48 | 4.12±0.48 | 0.12 |

*Significant if p value <0.05

**Table 3. Comparison of Delta FEV1 and FVC Before and After Exercise between Two Groups.**

| | Intervention Group (n=8) | Control Group (n=8) | p Value |
|---|---|---|---|
| FEV1 | 0.22±0.22 | 0.01±0.39 | 0.210 |
| FVC | 0.50±0.48 | 0.32±0.51 | 0.564 |

*Significant if p value <0.05

Spirometry can assess static lung function and dynamic lung function. Static lung physiology is the volume of air in a static state that is not related to the time dimension, consist of tidal volume (TV), inspiratory reserve volume, expiratory reserve volume, residual volume, inspiratory capacity, functional residual capacity, vital capacity, forced vital capacity, total lung capacity. Dynamic pulmonary physiology consists of FEV1, FVC, Forced expiratory flow, Peak expiratory flow rate, and maximum voluntary ventilation (MVV)[13].

FEV1 and FVC required strong additional expiratory muscles to release expiratory gas volume[14]. Weakness in the expiratory muscles will cause a decrease FEV1 and FVC in chronic diseases such as chronic obstructive pulmonary disease[14,15].

FEV1 and FVC results depend on the amount of chest pressure generated during exhalation. Both of these examinations are very dependent on the abdominal muscle's strength, power of abdominal muscles, and the greater pressure generated. When the abdomen muscle contraction, it increases abdominal pressure and pushes the diaphragm toward to the chest cavity. This will be decreasing of lung size and an increasing pleural pressure on both tests[16].

Lung function was influenced by respiratory muscle strength, compliance with the thoracic cavity, airway resistance, and recoil elasticity of lung tissue[17]. Changes in FEV1 before and after exercise showed an increase although not significant in the intervention group (p value 0.18) and the control group (p value 0.92). The FVC before and after exercise showed a significant increase in the intervention group (p value 0.02) after undergoing 4 weeks of training. But in the control group was showed insignificant improvement (p value 0.12). This is similiar with research from Sasaki (2005) who reported that exercise using an EMT in 16 healthy young subjects for 2 weeks showed insignificant results before and after exercise. This is caused by strengthening exercises on the respiratory muscles cannot affected to the function of the lungs, but can reduce the feeling of shortness of breath in the subjects[18].

Research from Sapienza (2011) which reported exercise with an EMT for 4 weeks reported an increase in Maximal Expiratory Pressure (MEP) which indicates an increase in expiratory muscle strength but not effected for lung function[19]. Research Zhao[20] reported giving NMES for 4 weeks in patients with chronic obstructive pulmonary disease also did not give a significant increase in FEV 1 and FVC[20].

Research by McLachlan[21] reports that giving NMES increases FVC after 4 weeks. These is more about improving in strength and mass of the abdominal muscles rather than improving in lung function[21]. The increase in strength could be come from neurological and morphological adaptations. Therefore, the possibility of performance improvement mainly supported by changes in intra- and inter-muscle coordination wich the NMES works on recruiting muscle fiber type II that quickly but ease to fatigue. While using Expiratory Muscle Trainer works on recruiting muscle fibers type I that are slow but not to fatigue easily. A systematic review shows an increase in blood flow and changes in muscle fibers in the muscle[12, 20].

The two exercise groups showed a positive effect in increasing FEV 1 and FVC, but there was no significant difference between the two groups (p value ΔFEV1=0.210 and p value ΔFVC=0.564). Suzuki[6] and Sasaki[18] also reported similar results, where there was

no significant difference between before and after 4 and 2 weeks of exercise using the EMT in healthy people[6,18]. Likewise, the research of Laciuga[11] and Woodberry[23] which showed an increase in each group, but there were no significant differences between groups on FEV 1 and FVC. This is because strengthening exercises on the expiratory muscles cannot affect the condition of lung function, but increase the strength of the expiratory muscles and functional capacity[11,20,23,24].

The results of research from Kucio[24] and Zhao[20] which provided NMES for 4 weeks also found no significant difference to FEV 1 and FVC before and after exercise, but there was an increase in expiratory muscle strength, physical performance and functional capacity of the study subjects[20,23]. This study has limitation that physical activity of subjects outside the exercise program cannot be controlled so that could be affect the results of the study.

## Conclusion

In summary, exercise with EMT with the addition of NMES increase FVC in untrained healthy subjects. There is no difference in the FEV1 and FVC between both groups.

**Conflict of Interest:** The authors declare that they have no conflict of interest.

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## References

1. McCool FD. Global Physiology and Pathophysiology of Cough. ACCP Evidence-Based Clinical Practice Guidelines. Chest. 2006; 48-53.
2. McAllister DA, Liu L, Shi T, *et al*. Global, regional, and national estimates of pneumonia morbidity and mortality in children younger than 5 years between 2000 and 2015: A systematic analysis. Lancet Global Health. 2019; 1-11.
3. Susanti S. Pemetaan Penyakit Pneumonia di Jawa Timur. Jurnal Biometrika dan Kependudukan. 2016; 5(2): 117-124.
4. Akbar R, Ermayanti S, Harminarti N. Hubungan kejadian pneumonia terhadap lama perawatan pasien kanker paru di RSUP Dr M Djamil Padang. Jurnal FK Unand. 2018; 513.
5. Teasell R, Dittmer DK. Complication of immobilization and bed rest. Canadian Physical Family Journal. 1993; 1140-1146.
6. Suzuki S, Sato M, Okubo T. Expiratory muscle training and sensation of respiratory effort during exercise in normal subject. Thorax. 1995; 50(4): 366-70.
7. Peper E, Booiman A, Lin M, Harvey R, Mitose J. 2015. Abdominal SEMG feedback for diaphragmatic breathing: A methodological note. Biofeedback. 44: 42-49.
8. 44. Widdicombe JG, Addington WR, Fontana GA, *et al*. Voluntary and reflex cough and expiration reflex implication for aspiration after stroke. Pulm Pharmacol Ther. 2011; 24: 312-317.
9. Komatsu R, Okazaki T, Ebihara S, *et al*. Aspiration pneumonia induce muscle atrophy in the respiratory, skeletal, and swallowing systems. Journal of Cachexia, Sarcopenia, and Muscle. 2018.
10. Chebib N, Cuvelier C, Malezieux-Picard A, *et al*. Pneumonia prevention in the elderly patients: The other sides. Journal of Aging Clinical and Experimental Research. 2019; 1-10.
11. Lacigua H, Rosenbek JC, Davenport P, *et al*. Functional outcomes associated with expiratory muscle strength training: Narrative review. JRRD. 2014; 51: 535-546.
12. McCaughey E, Borotkancis R, Gollee H, *et al*. Abdominal functional electrical stimulation to improve respiratory function after spinal cord injury: A systematic review and meta-analysis. Journal of Spinal Cord. 2015; 1-12.
13. Dweik RA, Carthy KM; Pulmonary Function Testing. Available at: www.emedicine.com; 2004.
14. Silanpaa E, Stenroth L, Bijlsma AY, *et al*. Association between muscle strength, spirometric pulmonary function and mobility in healthy older adults. Journal of Age. 2014; 36: 9667.
15. Buchman AS, Boyle PA, Wilson RS, *et al*. Pulmonary function, muscle strength, and mortality

in old age. Journal of Mechanism of Aging and Development. 2008; 129: 625-631.

16. 52. Cheng YJ, Macera CA, Addy CL, *et al*. Effect of physical activity on exercise test and respiratory function. Br J Sports Med. 2003; 37: 521-528.
17. 53. Basavaraj R, Satish M, Begaum NJ, *et al*. A study of pulmonary functions among swimmers – descriptive study. J of Evolution of Med and Dent Sci. 2014; 2680-2686.
18. 54. Sasaki M, Kurosawa H, Kohzuki M. Effects of inspiratory and expiratory muscle training in normal subjects. Journal Of The Japanese Physical Therapy Association. 2005; 8: 29-37.
19. 55. Sapienza CM, Davenport PW, Martin AD. Expiratory muscle training increases pressure support in high school students. J Voice. 2011; 16(4): 495-501.
20. 56. Zhao Z, Wang X, Sun W, *et al*. Inspiratory plus expiratory neuromuscular electrical stimulation versus diaphragma pacing for rehabilitation in severe COPD patients: Randomized controlled trial. J of Research Square. 2020; 1-18.
21. 57. McLachlan AJ, McLean AN, Allan DB, *et al*. Changes in pulmonary function measures following a passive abdominal functional electrical stimulation training program. Journal of Spinal Cord Medicine. 2013; 36: 1-7.
22. 58. Nevez LF, Reis MH, Plantz RDM, *et al*. Expiratory and expiratory plus inspiratory muscle training improves respiratory muscle strength in subject with COPD: Systematic review. Respiratory Care Journal. 2014; 59(9): 1-8.
23. 59. Woodberry N, Slesinski J, Herzog M, *et al*. The effects of expiratory muscle strength training on lung function and musical performance in collagiate wind instrumentalists. Journal of Research in Music Performance. 2016; 1-24.
24. 60. Kucio C, Niesporek J, Kucio E, *et al*. Evaluation of the effects of neuromuscular electrical stimulation of the lower limb combined with pulmonary rehabilitation on exercise tolerance in patients with chronic obstruction pulmonary disease. Journal of Human Kinetics. 2016; 54: 75-82.