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“Effect of 4 Week Expiratory Muscle Strengthening On Exercise Induced Breathlessness In Normal Adults – An Experimental Study.”

Akshata Ashok Changwani , Abhijit Diliprao Diwate , Arijit Kumar Das

Introduction

In a country like India, having a population of 1.3 billion, it is declared second in the list of most populated countries in the world[1]. However, with this population rate, only a handful amount to a normal healthy population[2]. Even though considering them to be normal, at times, even these healthy individuals complain of problems like headache, dizziness, anxiety, stress, nausea, breathlessness and general weakness. Which, in turn, reflects the in general endurance of the individual [3].

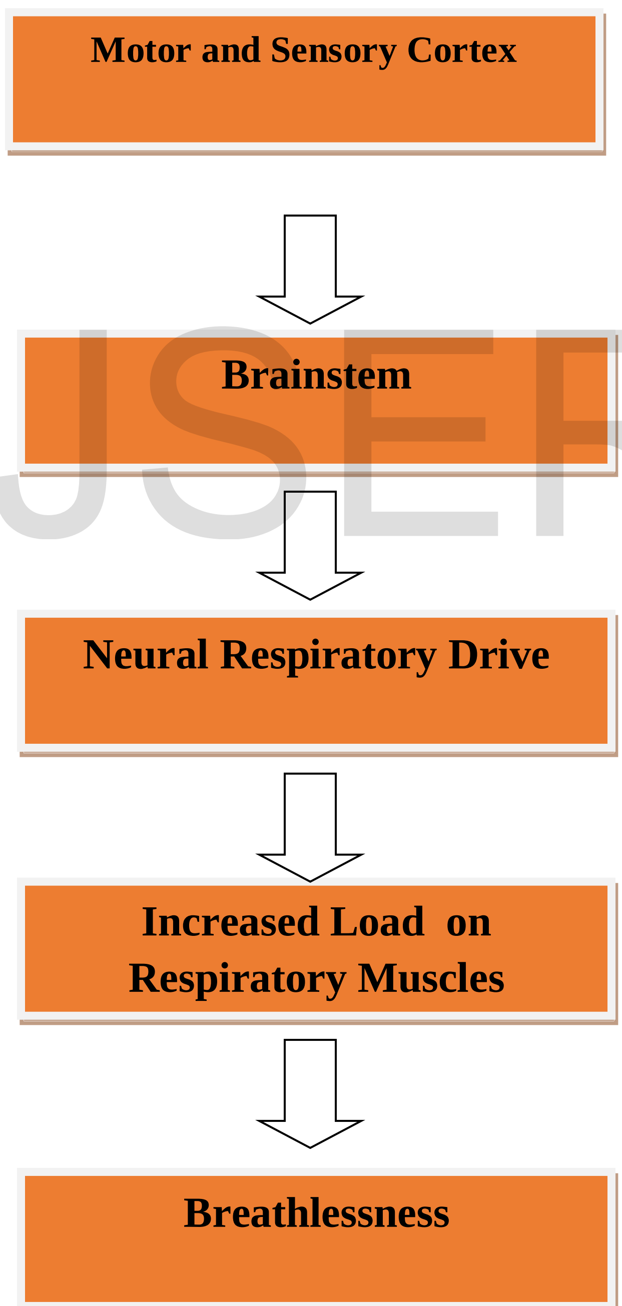
1.1 BREATHLESSNESS

Breathlessness is an unpleasant sensation of rapid or difficult breathing. Its onset may be sudden (acute) or gradual, which develops over a while (chronic) [4,5]. The reason behind the subject experiencing breathlessness is that the body demands more oxygen than it supplies[4,5]. As a result of which the brain sends signals of breathing faster in so as to improve the flow of oxygen-rich air into the lungs via which the oxygen gets into the bloodstream and is pumped around to the body via the aorta of the heart [4-6].

Associated physiology: the sensation of respiratory overload, causing breathlessness increases when the load on the respiratory muscles increases [4-6]. As a result of which the capacity of the respiratory muscles decreases or a result of the combination of both [4-6]. When load–capacity imbalance is caused, the neural drive to the respiratory muscles neural respiratory drive (NRD) from the medullary respiratory centre increases in order to make sure efficient gas exchange and respiratory homeostasis [4-6].

The individual being aware of the levels of NRD is vital for the perception of breathlessness, irrespective of the nature of the stimulus, causing activation of the sensory neural afferents. In 1963, CAMPBELL and HOWELL proposed the theory of "length-tension inappropriateness" or "efferent–afferent mismatch", which explains breathlessness in these terms (4-6). It states that the brain "expects" a particular pattern of ventilation and feedback for a given level of NRD failing which the afferent signal from that prediction causes or intensifies the sensation of breathlessness[4-6]. The sensory afferents mainly consist of the pulmonary stretch receptors and intercostal muscle spindles stimulation of which may help reduce breathlessness, as shown below (4-6).

The Flow Chart shown below explains the physiology of breathlessness in short (4-6)



Breathlessness, when perceived by normal adults, is usually on exertion(4-6). When there is no such pathological cause identified for breathlessness, the origin then is considered to be exercise-induced breathlessness which in turn creates an impact on the activities of daily living by reducing the functional capacity of the subject (4-6).

1.2 EXERCISE-INDUCED BREATHLESSNESS

A normal healthy adult breathes in and out up to 20 times a minute, which accounts for nearly 30,000 breaths a day (7). A vigorous workout or an exertional session of work may throw a kink in that pattern due to breathlessness since the lungs do not supply the increasing demand for oxygen to the body via the heart. This is what is termed as exercise-induced breathlessness (4-7).

Associated Physiology: The respiratory center of the brain mainly comprises of 3 neuron groupings in the brain: the dorsal medullary group, the ventral medullary group, and the pontine grouping (7,8). The pontine grouping is further classified into the pneumotaxic and apneustic centers. Where the dorsal medulla is responsible for inhalation, the ventral medulla is responsible for exhalation, and the pontine groupings are in charge for regulating the frequency of the medullary signals along with regulating their intensity where the pneumotaxic groups limit inhalation, and the apneustic centers prolong and encourage inhalation (7,8).

Moreover, the Mechanoreceptors located in the airways, trachea, lung and pulmonary vessels are responsible for providing sensory information to the respiratory center of the brain regarding the volume of the lung space (7,8). There are two primary types of thoracic sensors (7,8). The slow adapting stretch spindles that convey only volume information and the rapid-acting receptors respond to both volumes of the lungs and chemical irritation triggers (7,8). These include such as harmful foreign agents that may be present functioning via the Vagus (X) to the brain to increase the rate and volume of breathing, along with stimulating errant coughing patterns of breathing secondary to irritants in the airway [7,8]. During exercise expiratory muscles, especially the abdominal muscles, contribute substantially to increased ventilation to meet the increasing demand for oxygen, thereby leading to an increased work of inspiratory muscles during exercise [7,8]. An increased sensation of respiratory effort during exercise may, therefore, be related to the participation of expiratory muscles, as the respiratory muscles respond to training stimuli in the same manner as the skeletal muscles [7,8]. It happens as a result of improvement in the structural and functional zones by improving strength, speed, power, endurance, peak inspiratory flow and maximal inspiratory and expiratory pressure, which in turn improves the respiratory endurance [7,8].

1.3 ENDURANCE

Talking of endurance, endurance refers to the ability of an organism to exert and remain active for an extended period of time, as well as its ability to resist, withstand, recover from and the immunity to trauma, wounds or fatigue , in order to improve the endurance of an individual, he/she need to repeatedly perform that activity so as to allow the muscles to strengthen [9] . It mainly is used in aerobic or anaerobic exercise [9,10].

1.4 AEROBIC EXERCISE

Aerobic exercise provides cardiovascular conditioning, which in turn Aimproves the cardiovascular endurance of an individual [11,12]. The term aerobic precisely means "with oxygen," which indicates that breathing controls the amount of oxygen that can make it to the muscles to help them burn fuel and move [11,12]. Therefore exercise requires the perfect matching of the respiratory and cardiovascular system, to provide the muscle with the adequate supply of energy to be transformed into mechanical work [11-14]. On the part of the cardiovascular system, an increased supply of the arterial blood to the involved skeletal muscle is required to meet the increasing demand during exercising along with continuous removal of metabolic waste that is released by exercising muscles thereby leading to an overall additional output [11-14]. The left ventricle, therefore, undergoes hypertrophy, dilatation, and sympathetic stimulation during exercise, which increases the myocardial contractility, contributing to the increase in the stroke volume [11-14].

The increased stroke volume and heart rate cause an increase in cardiac output, which is necessary to deliver more oxygen to the exercising skeletal muscle, which shows that the cardiovascular system provides a link between pulmonary ventilation and oxygen usage at the cellular level [11-14]. During exercise, the coherent supply of oxygen to working skeletal and cardiac muscles is of utmost importance to maintain the Adenosine-Tri-Phosphate (ATP) production by aerobic mechanisms [11-14]. The equine cardiovascular response to increased needs for oxygen delivery during exercise contributes largely to over 35-fold increases in oxygen uptake that occur during sub-maximal exercise [11-14]. Cardiac output during exercise increases greatly owing to the relatively high heart rates that are obtained during exercise [11-14]. The increase in the heart rate is directly proportional to the workload until the heart rates close to maximal are achieved [11-14]. It is remarkable that exercise heart rates six to seven times of resting values are not associated with a fall in stroke volume, which is maintained by the splenic contraction, increased venous return, and increased myocardial contractibility [11-14]. Despite the vast changes in cardiac output, increases in blood pressure during exercise are maintained within relatively smaller limits, as both pulmonary and systemic vascular resistance to blood flow is diminished [11-14].

1.5 MAXIMAL AND SUBMAXIMAL EXERCISE

Submaximal performance testing is a way of analysing either VO_2 max or "aerobic fitness" in individuals [15]. The test protocol is carried out in a manner where the essential parameter is that the protocol does not reach the maximum of the respiratory and cardiovascular systems [15,16]. These set of tests are usually made to be performed when observed that the maximal tests could cause some potential danger to the individuals who are not considered under the normal healthy subjects category, therefore in this type the exercise are prescribed in such a way that the tests have a predetermined endpoint, i.e., a peak heart rate of 120pm, or 70%of Maximum Hear Rate(MHR), or Metabolic Equivalents (MET) equivalent of 5 (15,16).

Maximal performance testing refers to a standardised measure that is made use of to assess, analyse and evaluate the ratio of oxygen absorption to carbon dioxide expulsion in the cardiopulmonary system during heavy workout sessions (16-18). This test compares the disparity between inadequate oxygen supply and rapid carbon dioxide accumulation in the blood affecting the intensity, performance, and duration of muscle activity (16-18). This is also referred to as a stress test (16). It relates to a practical measure using specific types of equipment to determine cardiopulmonary efficiency in terms of sufficient oxygen intake (VO_2peak) and proper carbon dioxide removal during exercise (16-18). The fitness level is correlated to the vo2peak values so obtained i.e., it reflects the relative amount of oxygen needed to exercise muscles combined with their ability to excrete waste materials simultaneously (16-18). A high-intensity workout session can cause the muscles to undergo fatigue or weakness due to a disproportion between oxygen reuptake and toxic byproducts in the blood (16-18). This is an indication that the body has reached its maximal potential to metabolise further energy (16-18).

FIELD TEST: This is a type of maximal exercise test that can only be performed by low-risk factor categorised individuals and healthy individuals (16). This is the type of maximal test, which is usually chosen for the healthy individual category to analyse their cardiorespiratory endurance and fitness (16).The most commonly used field tests are Rockport, 1.5-mile walk test, etc. out of which the 1.5-mile walk test holds a significant validity and reliability factor (16).

Mile Walk Test (16,19) **-Step 1:** note down the height and weight of each person being tested. Calculate the body mass to the nearest 0.01 kg and height to the nearest 0.1 cm. **Step 2:** Ensure that the subject completes a structured warm-up session of about 10 min. **Step 3:** Before starting the test, clearly explain that each subject is supposed to walk or run the 1.5-mile (2.4 km) distance as fast as possible. **Step 4:** Start a stopwatch at the same time that the run/walk is initiated and keep a record of the time. **Step 5:** When the subject completes the distance note the time to the nearest second sheets. **Step 6:** Every individual should perform a cool-down consisting of slow walking, followed by stretching post the regimen. **Step 7:** Use the equations **3.5 + 483/Time**(nearest hundredth of a minute) to estimate each's VO_2 max, then record the result.

1.6 PULMONARY SYSTEM

As exercise commences pulmonary ventilation (breathing) increases in direct proportion to the intensity and metabolic needs of exercise (20-22). Talking about the pulmonary system, we shall start with the respiratory cycle (20-22). The two phases of the respiratory cycle comprise of the inspiratory phase and the expiratory phase (20-22). At rest, during the inspiratory phase when the diaphragm contracts, it shows movement inferiorly toward the abdominal cavity, providing a larger thoracic cavity and larger space for the lungs (20-22). Contraction of the external intercostal muscles produces movement of the ribs upward and outward, causing expansion of the rib cage, which increases the volume of the thoracic cavity (20-22). As a result of the adhesive force of the pleural fluid, the expansion of the thoracic cavity enforces the lungs to stretch and expand. This increase in volume leads to a reduction of intra-alveolar pressure, creating a pressure lower than that of the atmospheric pressure (20-22). As a result, a pressure gradient is formed that drives air into the lungs. Normal expiration is a passive process, meaning that energy is not required to push the air out from the lungs (20-22). Instead, the elasticity of the lung tissue produces elastic recoiling of the lungs, as the diaphragm and intercostal muscles relax the next inspiration (20-22). As a result of which the thoracic cavity and lungs decrease in volume, causing an increase in interpulmonary pressure (20-22). The inter-pulmonary pressure rises above atmospheric pressure, creating a pressure gradient that causes air to leave the lungs (20-22).

1.7 RESPIRATORY PHYSIOLOGY DURING EXERCISE

During the inspiratory phase in an aerobic exercising training process, the muscles involved are the diaphragm, the internal and external intercostals, and the accessory muscles (23). Expiration being a passive process, the muscles involved are the diaphragm, internal and external intercostals, accessory muscles and the abdominals (20,23).

During exercise, the inspiratory phase shows a higher intake of tidal volume (TV) and end-inspiratory lung volume thereby forcing the subject to breathe at higher volumes in the flat part of the pressure-volume curve and increasing the inspiratory pressure per breath [(20-23)]. Continuous recruitment of expiratory muscles during exercise in healthy humans suggested that when the expiratory flow is limited during exercise, the enforced slowing of expiratory muscle velocity of shortening increases expiratory pressure [(20-23)]. The increased expiratory work makes a useful contribution to inspiration [(20-23)]. The relaxation of expiratory muscles provides gravitational assistance to a downward movement of the diaphragm, while the relief of end-expired gas compression expands the lungs [(20-23)]. So as we can see, due to the reduction in the end-expiratory volumes the subject experiences breathlessness which we term as exercise-induced breathlessness [(20-23)].

1.8 EXERCISE-INDUCED BREATHLESSNESS

A few studies have suggested that the sensation of dyspnoea/breathlessness is determined by the magnitude of the central motor command signal, which duly increases whenever the peripheral muscles undergo exercise thereby making it weak or fatigue[7,8,23]. Respiratory muscle fatigue increases the sense of effort during loaded breathing in healthy subjects, which we call exercise-induced breathlessness [(7,8,23)]. During exercise expiratory muscles, especially the abdominal muscles, contribute substantially to increased ventilation to meet the increasing demand for oxygen, thereby leading to an increased work of inspiratory muscles during exercise [(7,8,23)]. An increased sensation of respiratory effort during exercise may, therefore, be related to the participation of expiratory muscles [(7,8,23)]. To overcome this, training the expiratory muscles will lead to an increased strengthening of the respiratory muscles [(24)]. Since the respiratory muscles respond to training stimuli in the same manner as the skeletal muscles, i.e. improvement in the structural and functional zones by improving strength, speed, power, endurance, peak inspiratory flow and maximal inspiratory and expiratory pressure, which in turn improves the respiratory endurance [(6,24)].

1.9 RESPIRATORY MUSCLE STRENGTH TRAINING

In general, Respiratory muscle strength can be defined as a technique, that aims to improve the strength and function of the respiratory muscle through specific exercises (24,25). It comprises of a set of exercises, breathing and another regimen, to improve the strength and endurance of the respiratory muscles, thereby improving pulmonary ventilation (26,27). This in turn leads to a reduction of the work of breathing and muscle fatigue, leading to an improvement in the breathing pattern and improving the oxygen uptake, which generally gets altered in healthy individuals ,when these individuals are subjected to any form of exercise/exercise training process, which leads to the development of exercise-induced breathlessness i.e- during exercise the breathlessness so perceived is termed as exercise-induced breathlessness , where there is an expiratory flow limitation, which leads to breathing at higher volumes, leading to an increased inspiratory load which further leads to a mechanical disadvantage of the respiratory muscles (20-28).

Training the expiratory muscles or the inspiratory muscles provides an increase in the strength of the respiratory muscles (28,29). Since the respiratory muscles respond to training stimuli in the same manner as the skeletal muscles, i.e. improvement in the structural and functional aspects by improving strength, speed, power, endurance, peak inspiratory flow and maximal inspiratory and expiratory pressure, which in turn improves the respiratory endurance (6,13,31). The techniques used for the training purpose consists of the resistance training and endurance training phase where, inspiratory pressure threshold loading (IPTL) and expiratory pressure threshold loading are the most commonly used, researched and validated techniques for inspiratory and expiratory muscle training respectively (27,32,33).

The expiratory phase, as we saw in the previous physiology of breathlessness, shows airflow limitation (13,8,23,34). This leads to a reduction of the end-expiratory volumes thereby causing an overload on the inspiratory muscles, failing which the inspiratory muscles require the additional help of the accessory muscles leading to a mechanical disadvantage of the respiratory muscles as a result of which the subjects start perceiving breathlessness during exercise (13,8,23). So if we aim at strengthening the expiratory muscles, it would reverse the alteration of the overload on the inspiratory muscles thereby leading to the mechanical advantage of the respiratory muscles (13,8,23)

1.10 EXPIRATORY MUSCLE STRENGTH TRAINER(EMST)

It is an exercise tool consisting of a plexiglass tube and mouthpiece. Inside the trainer is a variable tension spring controlling a 'pop-off ' valve that is calibrated in pressure(cmH_2O) which is adjustable **(35,36)**. At first, the maximum expiratory strength shall be measured using the maximum expiratory pressure (MEP) device **(35,36)**. The subject is then instructed to take a deep inspiration against a preset threshold of 75% of muscle strength **(35,36)**. Post which the subject's nose is clipped and the subject is asked to forcefully expire maximum air into the device which shall last for a few seconds **(35,36)**.

1.11 EFFECT OF EMST ON EXERCISE-INDUCED BREATHLESSNESS

This training is meant to increase the strength of the expiratory muscles as the muscles exercise against a pre-determined threshold **(35,36)**. Once the strength of the muscles has been improved, it shall help to provide a greater vo2peak to the individual while exercising since the expiratory muscles shall function better by since the muscles have been strengthened to provide a higher end-expiratory volume which in turn shall lower the perception of breathlessness of the individual while exercising **(35,36)**.

The improvement of the expiratory muscle strength can be checked by using MEP, which corresponds to the expiratory muscle strength **(35,36)**.

There are plenty of articles emphasizing on the inspiratory muscle training to improve the respiratory endurance but with no significant results, but as we saw in the previous physiology, the perception of breathlessness is due to the airflow limitation in the expiratory phase therefore my study aims at strengthening the expiratory muscles to improve the respiratory endurance because the expiratory phase plays an equally important role in improving the endurance by helping reduce the breathlessness induced during the exercise, by correcting the physiology which leads to the breathlessness, thereby helping improve the activity level functional capacity and exercise endurance of the individual [36-40].

Once the strength of the muscles has been improved, it shall help to provide a greater VO_2peak to the individual while exercising since the expiratory muscles shall function better as the muscles have been strengthened to provide a higher end-expiratory volume which in turn shall lower the perception of breathlessness of the individual while exercising.

Need for the study

In the normal adult population, when subjected to any exercise training program, they tend to develop exercise-induced breathlessness. During exercise the breathlessness so perceived is termed as exercise-induced breathlessness, where there is an expiratory flow limitation, which leads to breathing at higher volumes, leading to an increased inspiratory load which further leads to a mechanical disadvantage of the respiratory muscles

There have been several studies conducted on strengthening the inspiratory muscles to improve the respiratory endurance but with no significant results because according to the previous physiology, the perception of breathlessness is due to the airflow limitation in the expiratory phase due to a reduction in the end-expiratory volumes thereby causing an increasing load on the inspiratory muscles.

To overcome this, training the expiratory muscles will lead to an increased strengthening of the respiratory muscles. Since the respiratory muscles respond to training stimuli in the same manner as the skeletal muscles, i.e. improvement in the structural and functional zones by improving strength, speed, power, endurance, peak inspiratory flow and maximal inspiratory and expiratory pressure, which in turn improves the respiratory endurance.

Once the strength of the muscles has been improved, it shall help to provide a greater VO_2peak to the individual while exercising since the expiratory muscles shall function better since the muscles have been strengthened to provide a higher end-expiratory volume which in turn shall lower the perception of breathlessness of the individual while exercising.

Therefore the need of this study is to understand the effect of expiratory muscle strengthening on exercise-induced breathlessness in normal adults.

Aim and Objectives

3.1 Aim

To understand and evaluate the result of 4-week expiratory muscle strengthening on exercise-induced breathlessness in normal adults.

3.2 Objectives

3.2.1) To assess the expiratory muscle strength by using the positive expiratory pressure gauge(MEP).

3.2.2) To assess the exercise-induced breathlessness using the Rate of Perceived Exertion (RPE) using a modified Borg scale by performing a 1.5-mile walk test.

3.2.3) To check the effect of expiratory muscle strength trainer (EMST) for expiratory muscle strengthening

3.2.4) To compare the pre and post expiratory muscle strength and exercise-induced breathlessness post intervention

Hypothesis

6.1 Null hypothesis - Expiratory muscle strengthening will have no effect on the exercise-induced breathlessness.

6.2 Alternate hypothesis - Expiratory muscle strengthening will show some effect on exercise-induced breathlessness.

Material and Methodology

This study was designed to analyse the effect that expiratory muscle strength trainer would have on exercise-induced breathlessness in normal adults. Requisite permission and approval were obtained from the head of the institution and the Institutional Ethical Committee before the commencement of work.

7.1 Study design- Quasi-experimental study design to assess the effect that expiratory muscle strength trainer would have on exercise-induced breathlessness in normal adults

7.2 Study setting- Medical Educational Campus with a population of 5000

7.3 Study population- Normal adults in the range of 18-35yrs.

7.4 Study duration- One year

7.5 Sample size- sixty-two (62)

[statistical formula (A=1.00 , B=(Zα+Zβ)^2, C=(E/S( )^2] △

7.6 Sampling method- Purposive sampling

7.7 CTRI Registration – The trial was registered on Clinical Trials Registry India under the no. CTRI/2018/06/014430

7.8 Inclusion criteria: Normal Adults aging 18-35yrs (both genders)

Normal Adults with a BMI range of 18.5-24.99 kg/m^2

Normal adults willing for participation

7.9 Exclusion criteria: Subjects with any pre-diagnosed pathology.

Subject addicted to smoking

Athletes/subjects associated with sports on

7.10 Procedure

After approval from the Institutional Ethical Committee, the participants were explained about the proposed benefits, risk and procedure involved in the study, in a language best understood by them.

Participants willing to participate in the study were then screened for inclusion and exclusion criteria.

Participants meeting the inclusion criteria were included in the study.

Informed written consent was taken from all the participants included.

This was followed by achieving a medical fitness report from the hospital before the conduction of the study.
At baseline readings of the vitals, MEP(best of 3 trials), and the 1.5mile test was calculated post which the intervention was initiated, i.e. Expiratory Muscle Strength Trainer (EMST).

7.10.1) Intervention: Expiratory Muscle Strength Trainer 150 (EMST-150) [35]: It is an exercise tool consisting of a pexi-glass tube and a mouthpiece. Inside the trainer is a variable tension spring controlling a ‘pop-off’ valve that is calibrated in pressure(cmH_2O) which is adjustable (fig A). At first, the maximum expiratory strength was measured using the MEP. The subject was then instructed to take a deep inspiration against a preset threshold of 75% of muscle strength. Post which the subject’s nose was clipped and the subject was asked to forcefully expire maximum air into the device which shall last for a few seconds. This was followed by a resting period of 15-20 seconds followed by performing five repetitions of the same followed by a break of 1minute and a total of 25 training breaths were performed each day for a span of five days/week. At the end of every week, the threshold was increased by turning it one-quarter turn clockwise

FIGURE A. EMST

Manufacturer – EMST 150

Manufacturer Reference – 61779

Pressure Range – 0 – 150 cm H_20

Address - NC , United States

FIGURE B. MEP

Manufacturer – Diamond

Manufacturer Reference – C- 105366

Pressure Range – 0 – 300 mmHg

Address - Kalbadevi , Mumbai

7.10.2) Maximum Expiratory Pressure [36]: It is a positive expiratory pressure gauge (fig. B) which has been previously used in studies for a similar purpose, i.e. for calculating the expiratory muscle strength which

tested in a sitting position with a considerable amount of back support and armrest. The subject was then asked to blow maximum air post a maximum inspiration, the value of which was denoted on the device signifying the pressure level which can directly be correlated with the expiratory muscle strength, which was recorded pre and posts the intervention. The value of the best of three trials was considered.

7.10.3) 1.5 Mile test [16]: The Rate of Perceived Exertion (modified Borg scale), was calculated by performing the 1.5mile walk test. In this test, all the subject were pre-instructed for all the do's and don'ts about the exercise training. On the day of the exercise training, the subject's vitals were recorded, post which all the subject were made for walking a uniform distance of 1.5miles, where the subject had to pace on an even cemented ground. In case the subject was tired midway, he could rest but

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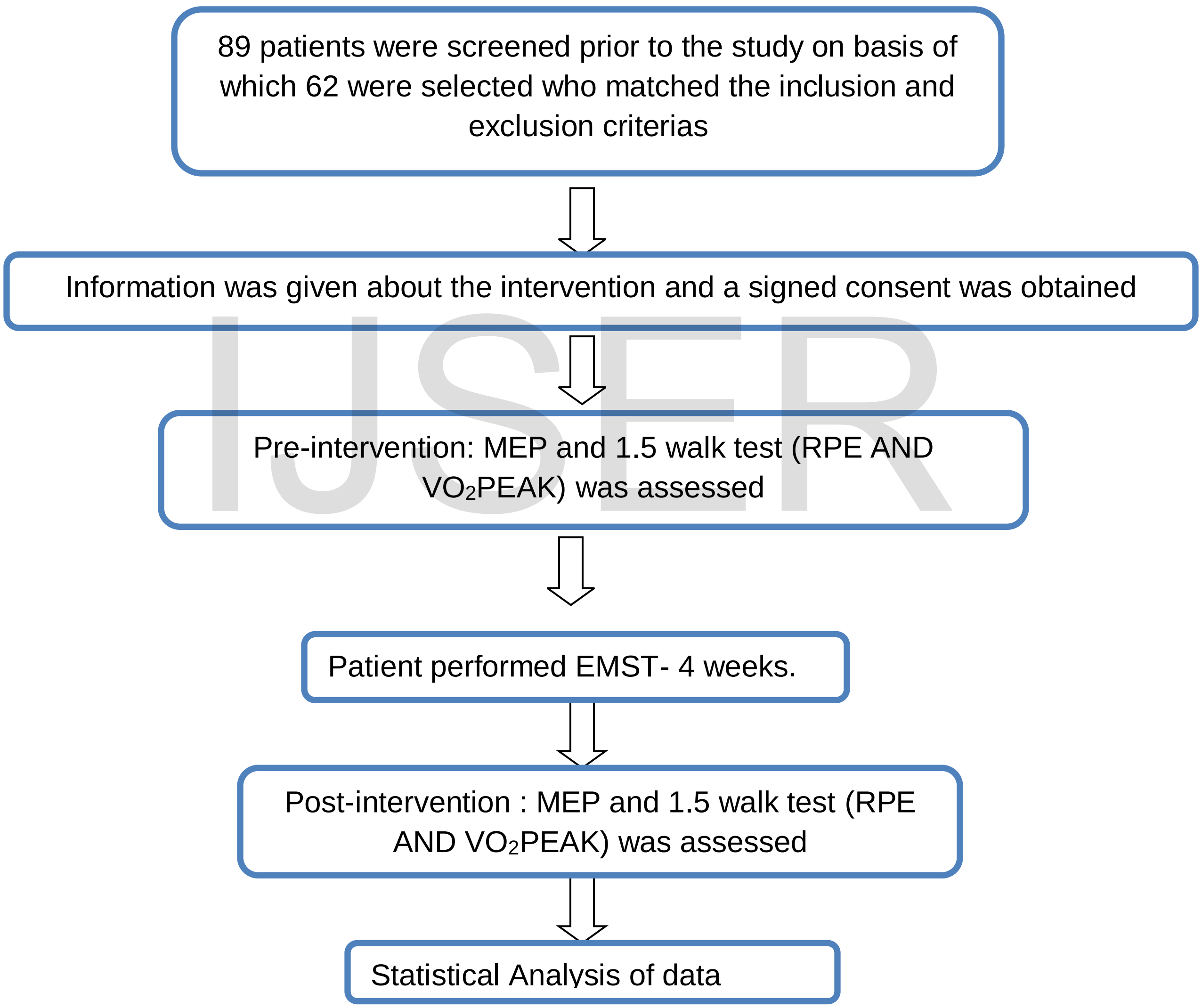
mandatorily had to complete the 1.5mile distance. On completion of the test, the RPE(modified Borg scale) was calculated which would give us the value of exercise-induced breathlessness in the subject along with VO_2peak by using the formula 3.5 + 483/ Time.

Flow-chart of procedure



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Statistical Analysis

Statistical Analysis: The analysis of the statistics was performed using **SPSS software Version 16.0.** To calculate the normality of the data for which the Shapiro-Wilk test was used. The Graph Pad instant software was then used where the two-tailed nonparametric Wilcoxon signed rank test was used to analyse the pre and post results of MEP, RPE and 1.5-mile walk test results since the normality test was not passed. There was no statistical difference noted in terms of demographic data in the pre-interventional period.

Table: 1A Depicting the Statistical tests used for the study

Comparison	**Normality Test (Shapiro Wilk)**	**Test Used**
Within the group analysis	Not Passed	Wilcoxon Signed Rank Test

RESULTS

The results obtained are as follows:

The baseline data were assessed before the intervention :

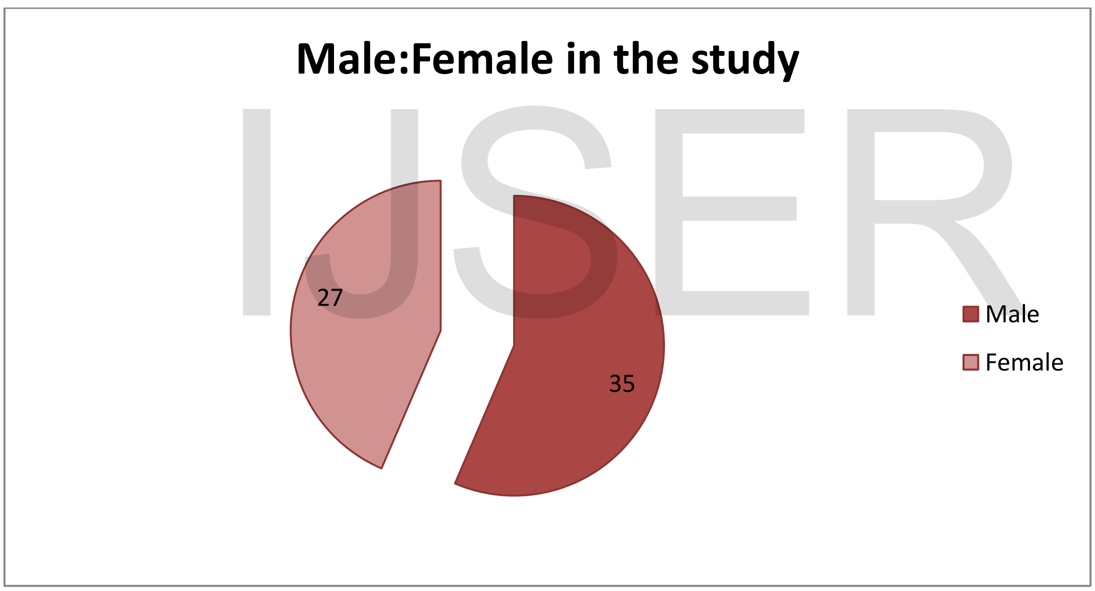
Table.1 B Shows the demographic data of the subjects assessed at baseline :

Sr. No.	Variables	Mean ± SD
01	AGE	24.04 ± 1.84
02	BMI	22.47 ± 1.83
03	MEP	73.45 ± 4.24
04	RPE	3.58 ± 0.49
05	1.5 MILE WALK(VO_2PEAK)	35.91 ± 2.25

Table.2 Depicting male to female ratio of the study

Sr. No.	Gender	Total No. (62)
01	Male	35
02	Female	27

Graph . 1 Depicting the Male: Female ratio of the study wherein the total sample size of 62 subjects, 35 were male, and 27 were female.



This was followed by checking for the normal distribution of the data.

Table.3 Depicts the normality test of the data in order to analyse the homogeneity of the data

	Shapiro – Wilk		
Outcomes	Statistic	Df.	Significance
PRE-MEP	.919	62	.001
POST MEP	.932	62	.002
PRE-RPE	.627	62	.000
POST RPE	.671	62	.000
PRE 1.5	.875	62	.000
POST 1.5	.933	62	.002

The **Shapiro-Wilk test** was used to check for the normal distribution of data because the elements for analysis were less than 2000. As portrayed in the above table, the p-value obtained for all the pre and post variables is less than 0.05 thereby proving the data to be a nonhomogenous one, which shall require the use of nonparametric tests for the analysis of the pre-interventional and post-interventional outcome measures

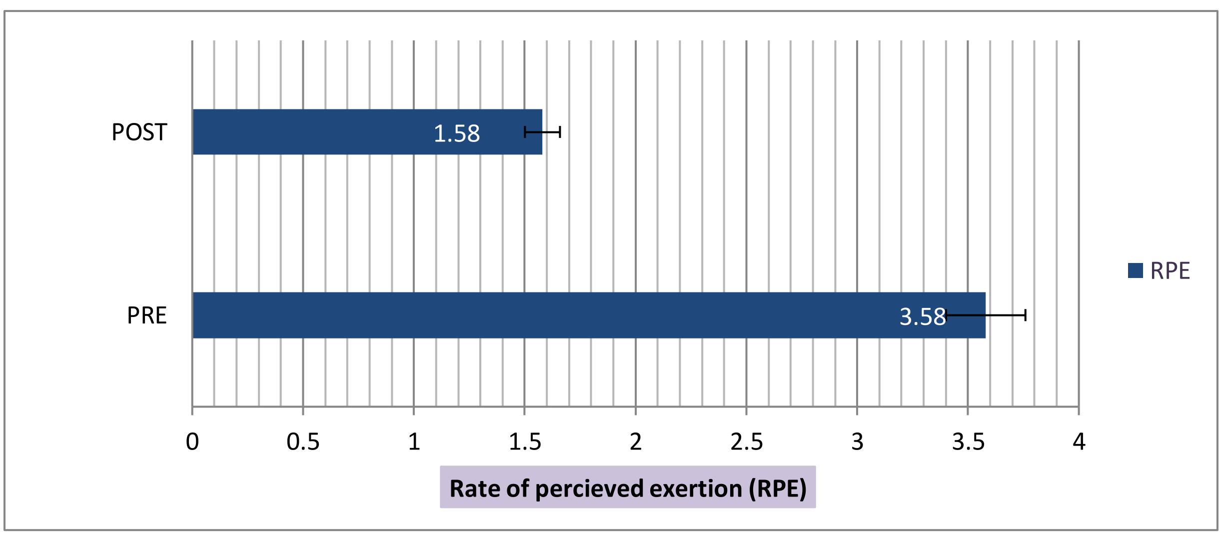
9.1) RPE(MODIFIED BORG): The table below depicts the numerical data of the RPE which was assessed before the intervention and four weeks post the intervention using the nonparametric - Wilcoxon signed rank test since the analysis was a within-group analysis

Table 4: Table depicting results of a comparison of RPE pre and post-intervention results using Wilcoxon signed rank test

	RPE (mean ±SD) PRE	RPE (mean ±SD) POST	Mean Difference	% Reduction	Nonparametric spearmen correlation coefficient (r)	P – value
1	3.58 ±0.49	1.58 ±0.52	2.0	55.75 %	0.83	0.0001

Table 6 depicts that the RPE values show a statistically significant decrease post the 4-week interventional protocol, with a p-value of 0.0001, proving it to be extremely significant.

Graph 2: Graph depicting results of RPE pre and post-intervention



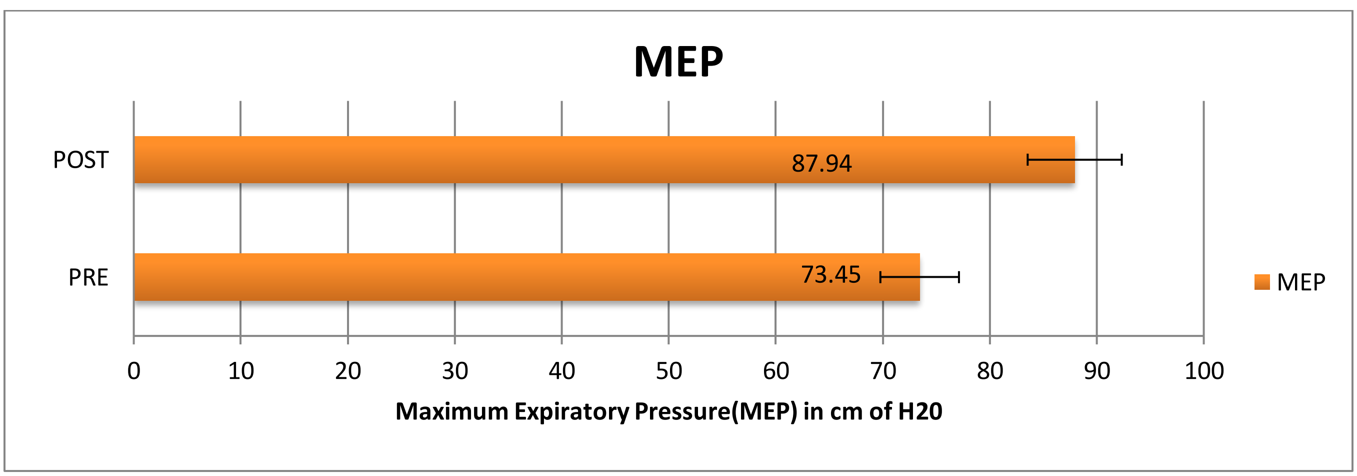
9.2) MEP: The table below depicts the numerical data of the maximum expiratory pressure which was assessed before the intervention and four weeks post the intervention using the nonparametric - Wilcoxon signed rank test since the analysis was a within-group analysis.

Table 5: Table depicting results of a comparison of MEP pre-and post-intervention results using Wilcoxon signed rank test

	MEP (mean ±SD) PRE In cm of H_2o	MEP (mean ±SD) POST In cm of H_2o	Mean Difference	% Improvement	The nonparametric spearmen correlation coefficient (r)	P – value
1	73.45 ±4.24	87.94 ±4.26	14.49	16.47	0.43	0.0002

Table 4 depicts that the MEP values show a statistically significant increment post the 4-week intervention protocol, with a p-value of 0.0002, proving it to be extremely significant.

Graph 3: Graph depicting results of MEP calculated pre and post-intervention



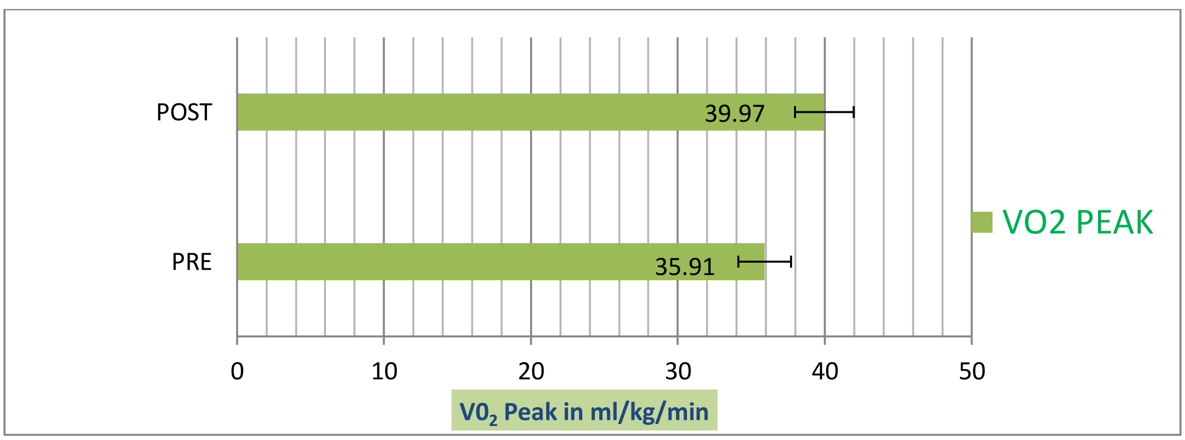
9.3) 1.5 MILE WALK (VO_2 PEAK): The table below depicts the numerical data of the VO_2Peak which was assessed before the intervention and four weeks post the intervention using the nonparametric - Wilcoxon signed rank test since the analysis was a within-group analysis

Table 6: Table depicting results of the Comparison of VO_2 Peak pre and post-intervention results using Wilcoxon signed rank test

	VO_2 Peak (mean ±SD) PRE In ml/kg/min	VO_2 Peak (mean ±SD) POST In ml/kg/min	Mean Difference	% Improvement	Nonparametric spearmen correlation coefficient (r)	P – value
1	35.91 ±2.25	39.97 ±2.49	4.06	10.15	0.85	0.0001

Table 5 depicts that the VO_2 Peak values show a statistically significant increment post-4-week interventional protocol, with a p-value of 0.0001, proving it to be extremely significant.

Graph 4: Graph depicting results of VO_2 Peak pre and post-intervention



DISCUSSION

A normal healthy adult breathes in and out up to 20 times a minute, which accounts for nearly 30,000 breaths a day. When subjected to any kind of vigorous workout or an exertional session of work, this breathing pattern may show a kink in that pattern due to breathlessness since the increasing demand of oxygen isn't supplied by the lungs to the body via the heart which as mentioned earlier is termed as exercise-induced breathlessness.

In order to overcome this perception of breathlessness , this study was conducted so as to understand the effect of expiratory muscle strengthening on exercise-induced breathlessness as a result of which our study found a reduction in the value of RPE so assessed post the 1.5 mile walk test where Modified Borg Scale was used to analyze the RPE, thereby indicating an improvement in the level of endurance due to reduction in the level of dyspnea where the pre-intervention value for RPE was 3.58 and post-intervention the values obtained were 1.58 with a p-value of 0.0001 with a mean difference of 2.0 from baseline which was analyzed using the Wilcoxon signed-rank test, thereby proving it to be statistically significant.

Similar results of reduction in the breathlessness level were found by **Jirakrit level Arungrayub** [52] in his study, he checked for the "Effectiveness of a Simple Prototype Respiratory Muscle Trainer Device on the Strength of the Respiratory Muscles, Quality of life, Dyspnea, and Oxidative Stress in patients with COPD" which was a preliminary study,where he concluded that a simple prototype device could be made use of clinically in COPD patients as a quality device to train the respiratory muscles thereby improving lung function along with reducing the sensation of dyspnea and providing an improvised quality of life of people suffering from COPD, which support the results obtained in our study, i.e., improvement in the level of the VO_2peak as a result of a reduction in the sensation of dyspnea, thereby improving the endurance.

Similarly, **Bahareh Haj Ghanbari** [45] conducted a systemic review of the "Effects of Respiratory Muscle Training on Performance in Athletes". The meta-analysis demonstrated a significant positive effect of RMT on sports performance outcome of time trials, exercise endurance, and respiratory muscle strength thereby supporting our study by proving that respiratory muscle strengthening(inspiratory as well as expiratory) helps in reducing the perception of dyspnoea and provides improvement in the endurance levels.

Similar results were obtained by **Illi et al.** [31] who conducted a systemic review on the "Effect of Respiratory Muscle Training on Exercise Performance in Healthy Individuals". They were able to provide evidence of improved strength and reduced sensation of respiratory effort and improved endurance post the treatment regimen.

As seen above this study proves that expiratory muscle strengthening helps in reducing of the perception of breathlessness while performing any kind of exercise which ideally could be as a result of increase in the strength of the expiratory muscles. As the articles suggest during exercise the inspiratory phase shows a greater intake of tidal volume (TV) due to increased oxygen demands and end-inspiratory lung volume thereby forcing the subject to breathe at higher volumes thereby leading to an increase in the inspiratory pressure per breath. Progressive recruitment of expiratory muscles during exercise in healthy humans suggested that when the expiratory flow is limited during exercise, the enforced slowing of expiratory muscle velocity of shortening increases expiratory pressure. The increased expiratory work makes a useful contribution to inspiration. The relaxation of expiratory muscles provides gravitational assistance to a downward movement of the diaphragm, while the relief of end-expired gas compression expands the lungs. So as we can see, due to the reduction in the end-expiratory volumes the subject to experiences breathlessness.

Similarly the results of this study show that the MEP values showed a significant improvement where a mean difference of 14.49 from baseline was obtained with a p-value of 0.0002 which proves it to be extremely significant suggesting that expiratory muscle training with a threshold trainer increase the strength of the expiratory muscles thereby improving the endurance by reducing the breathlessness induced as a result of exercising.

The efficiency of expiratory training at low load has been previously reported in individuals with COPD. But there was no such study conducted on the normal adults to check the effect of expiratory muscle strengthening on exercise-induced breathlessness. Our study proves that expiratory muscle strengthening improves the expiratory muscle strength as the pre MEP values so obtained were 77.53 and post values so obtained were 88.06 with a p-value of 0.0019 thereby proving the results to be statistically significant.

Similar results were obtained by **Illi et al.** (31) who conducted a meta-analysis on the Effect of Respiratory Muscle Training on Exercise Performance in Healthy Individuals

They were able to provide evidence of improved strength and reduced sensation of respiratory effort and improved endurance post the treatment regimen.

Another study was conducted by **Susana Mota et al.** (37) on "Clinical Outcomes of Expiratory Muscle Strengthening in Severe COPD Patients", and found positive results for increased muscle strength and lung volumes and found a significant reduction in the levels of dyspnoea along with a significant improvement in quality of life scores,the results of which are similar to those obtained in this study thereby supporting the positive effect of expiratory muscle strengthening on MEP(maximum expiratory pressure).

Ernesto Crisafulli (46) also conducted a study on "Respiratory Muscle Training in Patients Recovering Recent Open Cardiothoracic Surgery: A Randomized-Controlled Trial" and concluded by stating that an additional expiratory training helped in faster recovery of subjects undergoing open cardiothoracic surgeries by improving the expiratory muscle strength thereby reducing the chances of associated lung pathologies and complication.

The increment in the values of the maximum expiratory muscle strength as a result of EMST can be explained **Leith and Bradley (38)** who studied Ventilatory Muscle

Strength and Endurance Training demonstrated that ventilatory muscle training increased ventilatory muscle strength by the adapting to the cardio-respiratory training intensity, which provides recruitment and better function of oxidative muscle fibers, unlike the statement by **Lacasse et al** [56] who claimed that physical activity improves peripheral and respiratory muscles without specific training of the muscles, although the literature is emphatic on the need for standardizing physical training.

As a result of reduction in the perception of breathlessness due to increased expiratory muscle strength , Our study found similar results of increment in the level of 1.5 mile walk test thereby indicating an improvement in the endurance level where the pre-intervention value for 1.5 mile walk test (vo2 peak) was 35.81 and post-intervention the values obtained were 39.83 with a p-value of 0.0001 with a mean difference of 4.064 from baseline, thereby proving it to be statistically significant.

Similar results were obtained by **Illi et al.** [31] who studied the "Effect of Respiratory Muscle Training on Exercise Performance in Healthy Individuals: A Systematic Review and Meta-Analysis" where they were able to provide evidence of improved strength and reduced sensation of respiratory effort and improved endurance post the treatment regimen.

I thereby conclude that expiratory muscle strengthening reduces the perception of exercise-induced breathlessness by improving the maximum expiratory strength, thereby leading to an improvement in the endurance level as well.

Patliel Weiner et al. [40] studied the "Effect of Specific Expiratory Muscle Training(SEMT) in COPD". In this study, the experimental group was given SEMT for expiratory muscle training, and the control group was given the same with a lower load. The outcome was assessed by checking for muscle strength and endurance. They concluded that the expiratory muscles could be specifically trained with the improvement of both strength and endurance in patients with COPD, which strongly support the improvement in the endurance level so obtained in our study.

Another study showed similar results of improved endurance level conducted by **Tarik Ozmen** (54) who_studied the “Effect of Respiratory Muscle Training on Pulmonary Function and Aerobic Endurance in Soccer Players” where the author concluded by stating that the Respiratory Muscle Training (RMT) can increase the strength of the muscles, i.e. better results for MEP and MIP thereby improving tolerance to high-intensity exercise causing an improvement in endurance level.

Similarly, **Bahareh Haj Ghanbari** (40) conducted a systemic review on “Effects of Respiratory Muscle Training on Performance in an Athlete”. The meta-analysis demonstrated a significant positive effect of RMT on sports performance outcome of time trials, exercise endurance, and respiratory muscle strength thereby supporting our study by proving that respiratory muscle strengthening(inspiratory as well as expiratory) helps in reducing the perception of dyspnoea and provides improvement in the endurance levels by strengthening the respiratory muscles.

Thereby concluding that expiratory muscle strength trainer helps in reducing exercise-induced breathlessness by increasing the strength of the expiratory muscles, which in turn helps in improving the levels of exercise endurance of the individuals.

CONCLUSION

Therefore the study concludes that Expiratory muscle strengthening reduces the exercise-induced breathlessness as a result of an increase in the expiratory muscle strength, in turn leading to an improvement in the exercise endurance of the subject as well.

Suggestions

- The study can be conducted for a greater duration, and further long term effect of the same can be analyzed.

Clinical Implication

- As this study proves that expiratory muscle strength training improves the endurance level by reducing the perception of breathlessness on exercise, this training can be used in general by the population living a sedentary lifestyle to improve their endurance

- This can also be used by athletes to improve their athletic performance which might be facing hindrance as a result of exercise-induced breathlessness

Limitation of the study

- The environmental weather control

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