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# The effect of 4 weeks of interval training and IMT on the return to the initial state of respiratory muscle strength in inactive people

**Fatemeh Khodadadi mian abad** *
Msc of Exercise Physiology, Faculty of Physical Education and Sport Science, Shahrood University of Technology, Semnan, Iran.

**Ali Younesian**
Associate Professor of Exercise Physiology, Department of Exercise Physiology, Faculty of Physical Education and Sport Sciences, Shahrood University of Technology, Semnan, Iran

**Ali Livani**
Ph.D. student of Exercise Physiology, Department of Physical Education and Sport Sciences, Faculty of Humanities, Tarbiat Modares University, Tehran, Iran.

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## Abstract

**Purpose:** The aim of this research was the effect of 4 weeks of interval training and Inspiratory Muscle Training (IMT) on the initial recovery of respiratory muscle strength in inactive people. **Method:** This research was semi-experimental. The statistical sample of this research consisted of 30 healthy and inactive students of Shahrood University of Technology with an average age of 30±10 years. Subjects were randomly divided into 3 groups (IMT, Interval and Sham exercises). The parametric test of one-way analysis of variance with repeated measurement and dependent t-test with 95% confidence was used with SPSS 26 softwar. **Results:** Inspiratory muscle strength showed a significant increase in IMT and interval training groups ($P<0.05$). Also, the time to return to the initial state of respiratory muscle strength decreased significantly in all three groups ($P>0.05$), the largest decrease was related to the IMT and sham exercise groups, and the interval exercise group experienced a smaller decrease than the other two groups. **Conclusions:** It seems that IMT training is more effective than interval training in increasing the strength of respiratory muscles and improving the return to the initial state of the strength of these muscles.

***Keywords**:* Interval training, recovery, respiratory muscle strength, inactive.

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[1] **Author's e-mail:** fateme.khodadadi13760@gmail.com **(Corresponding Author)**; ayounesian@shahroodut.ac.ir; alivani1371@gmail.com.

# INTRODUCTION

Physical activity is a challenging task for inactive people. In inactive healthy people, "Breathlessness" and "lack of air" are much more unpleasant than doing work or effort (Banzett, Lansing, & Binks, 2021). This feeling can be caused by any intensity of lack of air. It has been shown in a research that exercise is one of the causes of breathlessness and lack of air in inactive people (Wasserman & Casaburi, 1988). People avoid doing activities that increase their breathlessness and this will increase muscle atrophy in them. Weaker muscles have greater metabolic demands (need for oxygen) at the same workload, and the person will feel more breathlessness (Beach & Schwartzstein, 2006). This cycle is called breathlessness cycle. Sometimes the severity of breathlessness reaches a point where it makes a person incapable of doing daily tasks (Bailey, 2004). Functional and cognitive studies of the brain have shown that lack of air activates parts of the brain that are related to the feeling of pain and anxiety Interestingly, the results show that regardless of the pathophysiological differences (Banzett et al., 2000; Binks, Evans, Reed, Moosavi, & Banzett, 2014). between people, lack of air is the main cause of shortness of breath during exercise (Banzett et al., 2021). Researchers have suggested that the mechanical limitation of breathing at the end of sports activity is the only justification for these observations (McConnell, 2013). Of course, the amount of this limitation is partly rooted in the ability of the inspiratory muscles to use the available inspiratory reserve volume to increase tidal volume (Guyton & Hall, 2006). Therefore, the mechanical work of respiratory muscles can also be effective in the feeling of lack of air during exercise (Fukushi, Nakamura, & Kuwana, 2021). Understanding the effort related to any muscle action is rooted in the balance between the required force and the capacity of the muscle to provide that force (the strength of that muscle, that is, by increasing the strength of a muscle (muscle capacity), the perception of effort related to doing work in that muscle will decrease (Foster et al., 2021). In a research, it has been determined that there is a significant relationship between respiratory muscle weakness and the possibility of pneumonia (Morisawa et al., 2021). Weakness of the respiratory muscles disrupts the process of clearing the airways, which will increase the risk of respiratory system infection (Mier, Laroche, Agnew, Vora, & Clarke, 1990). Subsequently, muscle atrophy in the respiratory and skeletal systems will increase and will make swallowing difficult (Romer & Polkey, 2008). Another factor that will cause breathlessness is respiratory muscle fatigue (Welch, Kipp, & Sheel, 2019). According to the definition of the American Thoracic Society, fatigue is a decrease in the productive force of skeletal muscles that can be recovered by resting (Laveneziana et al., 2019; Society, 2002). They have also stated that the use of the MIP index in healthy and motivated people who perform their maximum respiratory effort can reflect respiratory muscle fatigue during short-term or long-term intense activities (Holland et al., 2014). Research results have shown that breathing exercises (IMT) and intervals can reduce the perception of respiratory effort during physical activity by increasing the strength of respiratory muscles and delay the onset of respiratory metaboreflex activity, which is a mechanism that causes fatigue of these muscles (Cooper, 1999). These two training methods increase the strength of respiratory muscles with different mechanisms (Suzuki, Sato, & Okubo, 1995). In fact, respiratory muscle training (IMT) refers to a method of training that a person performs using respiratory training devices (breathing devices based on the principle of gradual overload) and interval training is actually a type of aerobic exercise that The alternating form is implemented and it is in this way that the time of training or exercise is divided into two parts of activity and rest (Enright, Unnithan, Heward, Withnall, & Davies, 2006).

It has been found that the fatigue of the respiratory muscles affects the physical activity capacity through the accumulation of metabolites and the activation of the metaboreflex (Fernández-Rubio et al., 2021). This mechanism causes the activation of group III and IV afferents of the respiratory muscles, which increases the sympathetic tone of the lower vessels (Sheel, Boushel, & Dempsey, 2018). Increasing the contraction of lower limb vessels during exercise leads to the feeling of fatigue in people and prevents them from continuing physical activity (Sheel et al., 2018). Therefore, reducing or delaying the activation of the respiratory metaboreflex can be an important factor in improving sports performance by training the respiratory muscles (Chan et al., 2023). Research results have shown that the motivation to do work in many people is based on results (Plonczynski, 2000). This means that increasing the duration of physical activity as well as faster recovery can increase people's desire to do physical activity. In other words, the faster the fatigue of the respiratory muscles is removed and the faster they return to the state before performing physical activity, the more likely they can perform high-intensity exercises for a longer period of time and stay away from the breathlessness cycle. Few researches have been done regarding the speed of return to the initial state of respiratory muscle strength, and the present research project is the first research project in Iran that tests this hypothesis to determine whether doing breathing and interval exercises can affect the changes in the time to return to the state. Does it affect the initial strength of the respiratory muscles or not?

# METHOD

**The current research was semi-experimental.**

The statistical population of this research consisted of all inactive healthy students of Shahrood University of Technology with an age range of 20 to 40 years. Inactive meant that they had not participated in any sports activity regularly in the last 1 year. After the announcement of the call to participate in this research project, 30 undergraduate and graduate students who were within the desired age range and conditions for entering the study were randomly selected as a sample and entered the study. This research was carried out and implemented for 4 weeks in the sports physiology laboratory of the Faculty of Physical Education of Shahrood University of Technology. People were randomly divided into three groups: breathing exercises, interval exercises and sham exercises. They were based on the questionnaire of personal information and medical history of the subjects. The criteria for entering the study include the absence of cardiovascular diseases, high blood pressure, abdominal and thoracic surgery in the previous six months, exercise-induced asthma (EIB), acute and chronic muscle injuries, forced expiratory volume ratio in the first second (FEV1) had a forced vital capacity (FVC) below 70%, a history of eye surgery and respiratory diseases (such as asthma, COPD, cystic fibrosis, etc.). Exclusion criteria included any physical activity outside the framework of the exercise protocol for individuals. Also, in case of any respiratory disease or skeletal muscle damage, they were excluded from the research. At the beginning and before the implementation of the research, a separate meeting was held for each of the groups and its members in order to get to know and implement the training protocol of the groups, and the method of implementing the exercises was explained to them.

**Breathing exercise protocol and sham**

At the beginning of the work, the subjects learned how to do diaphragmatic breathing, and then each of them individually learned how to work with the PowerBreathe breathing device, and each person did breathing exercises separately several times as a pilot to get familiar with this device. The method and frequency of exercises per week were similar for both groups, but the intensity of the exercises was different, so that the people in the breathing exercises group performed the exercises with a higher intensity. In order for the subjects of the sham group not to be suspicious of the implementation of mock exercises during the implementation of the protocol, the method of familiarizing them with the breathing exercises group was slightly different and the preconditioning method was used to familiarize them (Benedetti et al., 2016). In the group of breathing exercises, in the first two weeks, the intensity of the exercises was equal to 50% of MIP, the frequency of training was increased to 4 days per week, and in the last two weeks, the intensity of the exercises was increased to 60% of the new MIP, and the frequency of training was increased to 5 days per week. The exercise frequency of the sham group was chosen as the breathing exercise group, but the intensity of the exercises was set equal to 10% of MIP in the first two weeks and 15% in the last two weeks. The subjects of both groups performed 30 breathing efforts with the intensities mentioned above in each training session.

**Interval training protocol**

Interval exercises were performed submaximal. First, the subjects' resting heart rate was calculated for one minute in a sitting position after 5 minutes of inactivity. Then, using Fox's formula (220-age), the maximum heart rate of each person was calculated and finally, the intensity of the subjects' physical activity was determined based on the target heart rate. In the first two weeks, the training intensity was increased to 60% of the reserve heart rate and in the last two weeks to

70% of the reserve heart rate. The frequency of training was 3 days in the first two weeks and 4 days in the last two weeks. The interval training protocol consisted of a 5-minute warm-up with an intensity equivalent to 40% of the reserve heart rate, 20 minutes of the main body of the exercise, which included 4-minute and one-minute periods of exercise and rest, and finally a 5-minute cool-down. In the 4-minute intervals of the first two weeks, the intensity of running was equal to 60% of the reserve heart rate, and the intensity was reduced to 40% during the one-minute rests in between. In the second two weeks, these values increased to 70% for 4-minute intervals and 50% for rest intervals in between. The cool-down protocol consisted of 3 minutes of running at an intensity equivalent to 40% of the reserve heart rate at the beginning and two minutes of static stretching at the end of this period.

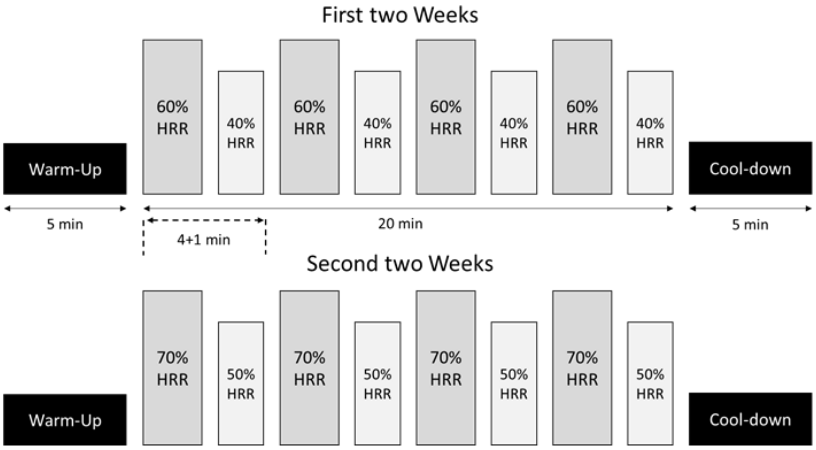


**Figure 1:** How to implement the 4-week training protocol that was implemented in two different weeks. (HRR: Heart rate reserve)

## How to measure the strength of respiratory muscles

Respiratory muscle strength was measured using a pulmonary manometer (hand gas manometer) according to the protocol proposed by the American Thoracic and European Respiratory Society (Laveneziana et al., 2019; Society, 2002).

## How to measure the recovery time of respiratory muscle strength

The time to return to the initial state of respiratory muscle strength was determined after performing the maximal laboratory test. At the beginning and at the end of the 4-week training protocol, the subjects performed the maximum bulk test on the h/p/cosmos treadmill, and after the test, in order to check the effectiveness of the above training protocols, at 2, 10, 15, and 30 minutes after performing the bulk test, performed the MIP breathing maneuver to record the time it took to return to the initial state of their respiratory muscle strength. The pre-test and post-test interval with the training protocol was considered 48 hours.

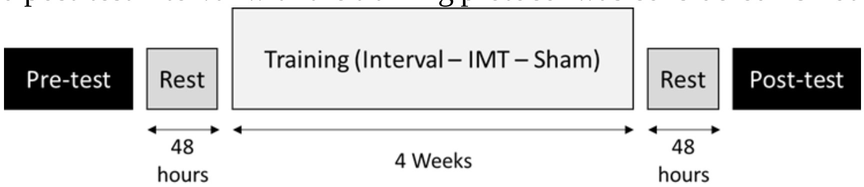


**Figure 2:** How to implement the research plan

### Statistical method

Kolmogorov-Smirnov statistical test was used to check the normality of the data distribution and it was found that the data distribution is normal. After ensuring the normality of the data, the statistical test of one-way analysis of variance with repeated measurements was used to check the difference between the different times of measuring the MIP maneuver compared to before the test. The dependent t-test statistical test was used to check the change in respiratory muscle strength compared to the pre-test. All calculations were done using SPSS version 26 statistical software and at a significance level of $p \leq 0.05$.

## RESULTS

In Table 1, the descriptive information of the subjects is given.

**Table 1:** Descriptive information of training groups.

| **Variables** | **Mean and standard deviation** | | |
|---|---|---|---|
| | **Interval group** | **Respiratory group** | **Sham group** |
| **height (cm)** | 174.5 ± 1.6 | 178.5 ± 1.38 | 174.8 ± 2.53 |
| **weight (kg)** | 81.43 ± 2.87 | 78.51 ± 4.19 | 74.65 ± 3.4 |
| **Age** | 23.9 ± 2.02 | 23.8 ± 1.68 | 24.8 ± 2.34 |
| **BMI (kg/cm$^2$)** | 26.04 ± 2.75 | 24.86 ± 4.18 | 24.34 ± 2.31 |
| **Respiratory muscle strength (cmH2O)** | 3.94 ± 100 | 93.5 ± 4.71 | 6.2 ± 99 |
| **The time frame of return to the initial state** | 30 minutes | 30 minutes | 30 minutes |
| **FVC (Liter)** | 4.97 ± 0.62 | 4.66 ± 0.57 | 4.48 ± 0.67 |
| **FEV1 (Liter)** | 3.94 ± 0.64 | 3.97 ± 0.55 | 3.9 ± 0.72 |

The result of one-way analysis of variance with repeated measurements is given in the table. The results show that the time frame for returning to the initial state of respiratory muscle strength in the IMT and sham groups decreased from 30 minutes to 10 minutes (P<0.05). In the interval group, the time frame decreased significantly from 30 minutes to 15 minutes (P<0.05).

**Table 2.** Comparison of the difference in respiratory muscle strength between different times with the time before running in the pre-test.

| Variable | group | | levels: The difference in the average strength of respiratory muscles compared to the initial state $M \pm SE$) | Significance level (P-value) |
|---|---|---|---|---|
| Respiratory muscle strength IMT group | Pre-MIP | MIP 2 min | 19.50 ± 2.63 | 0.000 |
| | | MIP 10 min | 11.50 ± 2.89 | 0.032 |
| | | MIP 15 min | 8.00 ± 1.10 | 0.000 |
| | | MIP 30 min | -1.00 ± 1.24 | 1.000* |
| Respiratory muscle strength Interval group | Pre-MIP | MIP 2 min | 18.00 + 2.49 | 0.000 |
| | | MIP 10 min | 10.50 ± 2.73 | 0.040 |
| | | MIP 15 min | 9.50 ± 2.16 | 0.018 |
| | | MIP 30 min | 1.00 ± 1.00 | 1.000* |
| Respiratory muscle strength Sham group | Pre-MIP | MIP 2 min | 23.00 ± 1.52 | 0.000 |
| | | MIP 10 min | 11.50 ± 2.11 | 0.004 |
| | | MIP 15 min | 9.00 ± 1.79 | 0.007 |
| | | MIP 30 min | -1.00 ± 1.00 | 1.000* |

*Significant difference at P≤0.05 level

**Table 3.** Comparison of the difference in respiratory muscle strength between different times with the time before running in the post-test.

| Variable | group | | levels: The difference in the average strength of respiratory muscles compared to the initial state $M \pm SE$) | Significance level (P-value) |
|---|---|---|---|---|
| Respiratory muscle strength Interval group | Pre-MIP | MIP 2 min | 17.00 ± 2.26 | 0.000 |
| | | MIP 10 min | 8.50 ± 2.11 | 0.030 |
| | | MIP 15 min | 4.50 ± 1.57 | 0.187* |
| | | MIP 30 min | 1.00 ± 1.00 | 1.000* |
| Respiratory muscle strength IMT group | Pre-MIP | MIP 2 min | 17.22 + 2.22 | 0.001 |
| | | MIP 10 min | 5.00 ± 2.35 | 0.667* |
| | | MIP 15 min | 1.66 ± 2.35 | 1.000* |
| | | MIP 30 min | - 0.55 ± 0.55 | 1.000* |
| Respiratory muscle strength Sham group | Pre-MIP | MIP 2 min | 16.00 ± 2.21 | 0.000 |
| | | MIP 10 min | 10.00 ± 3.07 | 0.099* |
| | | MIP 15 min | 3.00 ± 1.33 | 0.510* |
| | | MIP 30 min | 0.5 ± 0.5 | 1.000* |

*Significant difference at P≤0.05 level

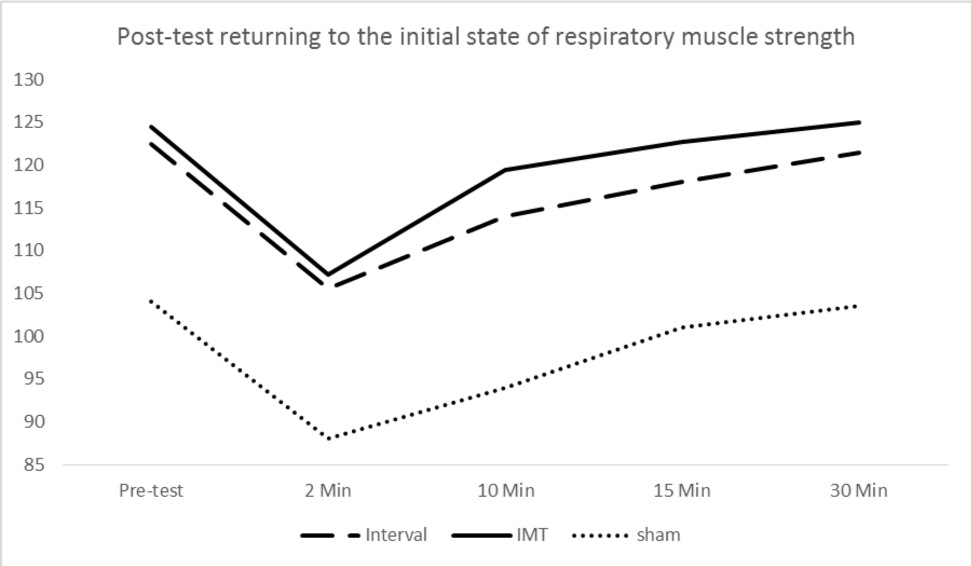


**Figure 3**: Time to return to the initial state of respiratory muscle strength in the post-test

You can see the result of the correlated t-test about the MIP index in Table (4). As it can be seen, two groups of interval and IMT have made significant progress compared to the pre-test (P<0.05).

**Table 4:** Descriptive information of training groups.

| variable | group | pre-test (M±SD) | post-test (M±SD) | t-statistic | significance level (P-value) |
|---|---|---|---|---|---|
| **MIP (cmH2O)** | **interval** | 100 ± 12.47 | 122.5 ± 10.86 | -5.58 | 0.000 |
| | **IMT** | 93.5 ± 4.71 | 124.4 ± 18.1 | -8.56 | 0.000 |
| | **sham** | 99.00 ± 19.69 | 104 ± 19.55 | -1.34 | 0.213 |

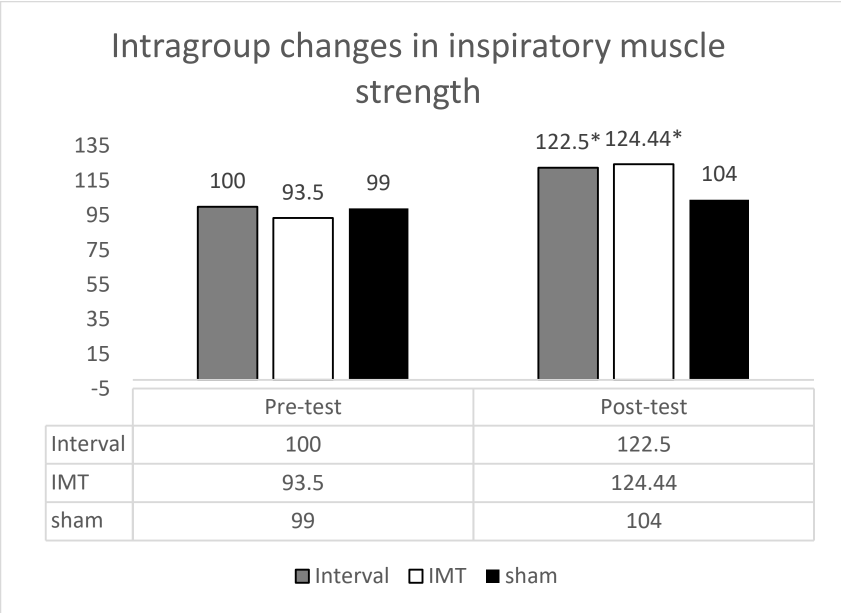


**Figure 4:** Intragroup changes in respiratory muscle strength

# DISCUSSION

Regarding the return to the initial state of the strength of the respiratory muscles, or in other words, the time it takes for these muscles to get tired, the American Thoracic Society has stated that the time it takes for these muscles to regain their original strength as the recovery time for these muscles in It is considered (Laveneziana et al., 2019; Society, 2002). The current research showed that performing breathing exercises (IMT) can change the time frame of returning to the initial state or in other words, speed up the recovery time of these muscles. In the group of breathing exercises, people were able to reduce their time frame from 30 minutes to 10 minutes. Also, the results indicate the effectiveness of interval training in improving the return to the initial state of respiratory muscle strength, but the amount is not as high as that of breathing exercises.

According to our observations, there was no research related to the effect of interval training and IMT on the time to return to the initial state of respiratory muscle strength in non-athletes. Only the following 3 studies have investigated the effectiveness of these exercises on the recovery time of respiratory muscles, all of which were conducted on athletes. Romer et al., in a research titled "Inspiratory muscle fatigue in trained cyclists: effects of inspiratory muscle training" investigated the effectiveness of these exercises on improving the recovery time of inspiratory muscles strength (Romer, McConnell, & Jones, 2002). They concluded that respiratory muscle fatigue affects exercise tolerance in healthy young adults. In other words, they have stated that by delaying the activation time of the respiratory metaboreflex, people can improve running time and also sports performance. For this reason, they investigated the time to return to the initial state of respiratory muscle strength to determine whether reducing the recovery time of respiratory muscle strength can have a positive effect on improving the running time of cyclists. In their research work, they chose 2, 10 and 30 minutes to check the effectiveness of their training protocol. Their results indicated that the time to return to the initial state of muscle strength of none of the athletes, in the initial and final test of this research project, was not in the time range specified by the researchers. These results can be interpreted that despite the effect of IMT training on improving the speed of recovery of the strength of the respiratory muscles of the athletes, they still could not return to their pre-training values even after 30 minutes. One of the possible reasons for such a result is the society under study. The statistical population of Romer et al.'s research project was professional athletes who are close to the ceiling of their cardio-respiratory-muscular adaptations and probably these exercises did not cause significant changes in them as the researchers expected. Among the other possible reasons that can cause this disparity in the present study and the above study, it is possible to mention the type of maximum test (treadmill and bicycle) and the frameworks for measuring the strength of respiratory muscles. The American Thoracic Society emphasizes that the resolution of respiratory muscle fatigue may last from minutes to hours and even days after its occurrence. Research has also shown that respiratory muscles play a structural role in addition to their respiratory role (Kocjan et al., 2018). According to the above reasons, perhaps this disparity between the results can be explained.

In another similar article published in this regard by Nicks et al. with the title " The influence of respiratory muscle training upon intermittent exercise performance", their research team sought to answer the question whether by shortening the time to muscle fatigue breathing after exercise, can professional athletes return to their training without losing performance quality (Nicks, Morgan, Fuller, & Caputo, 2009)? Researchers showed that performing IMT exercises on professional athletes increases the strength of their respiratory muscles. Also, after increasing the strength of the respiratory muscles, they showed a significant improvement in performance after performing the exercise test. However, despite the improvement in sports performance, it was found that breathing exercises have no effect on improving the time to resolve the fatigue of the respiratory muscles of athletes. Nicks et al. have evaluated the recovery time in 2 and 10 minutes after finishing the training. Maybe this short period is not the right time to evaluate the time to return to the initial state of respiratory muscle strength. Also, their target community has been professional athletes. According to the above two reasons, perhaps this difference in result was not far from expected.

Samuel Verges et al. in a research titled "Increased fatigue resistance of respiratory muscles during exercise after respiratory muscle endurance training" investigated the effectiveness of respiratory muscle endurance training and its effect on the time it takes to return to the initial state of respiratory muscles (Verges, Lenherr, Haner, Schulz, & Spengler, 2007). This research team measured the recovery of respiratory muscle strength in three time frames. They did their measurements immediately after finishing test, 30 minutes and 60 minutes. It was found that the recovery rate of the muscle strength of the participants in the breathing exercise group was higher than that of the control group, but none of the two groups were able to fully return to their pre-training values. The statistical population of this study, like the previous two studies, was athletes. One of the reasons for the discrepancy between our observations and this research is probably the difference in the type of breathing exercises, the statistical population, and the type of maximal executive test.

Regarding the return to the initial state of the respiratory muscle strength of the interval group, the findings indicate that this group had the slowest time to return to the initial state in this research plan. The reason why this group did not see significant changes in the recovery of their respiratory muscles in spite of the increase in their breathing strength compared to the breathing exercise group is probably because the people in the interval group, when performing their own exercises, in addition to engaging their breathing muscles, Other organs are also involved in some way and the oxidative enzymes of both muscle groups (respiratory and other organs) increase and oxygen uptake increases in both muscle groups, so there may be a competition in oxygen uptake between the respiratory and muscle groups. Other organs are created, and the same thing causes the interval group to not be more efficient in improving the return to the initial state of the strength of the caudal muscles compared to the strength group of the respiratory muscles with the respiratory system.

Perhaps the most surprising result that can be obtained from this study is why the people in the sham group showed a similar response to breathing exercises in terms of returning to the initial state. Despite the fact that MIP did not increase significantly in this group, they were able to recover the strength of their respiratory muscles faster than before and also compared to the interval group.

**The strength and weakness of this research**

There are some strengths and weaknesses points in this research. One of the strengths of this research may be that it was performed on non-athletes for the first time. Another positive point of this research is the effect of breathing exercises on increasing the speed of recovery of respiratory muscles and increasing the speed of people's return to resuming exercises. Another positive point of this research was the implementation of the breathing exercises of the sham group, in which the greatest placebo effect was implemented on the subjects of this group. Perhaps the weak point of the current research is that it was conducted during 4 weeks, and more time may be needed for more effect.

## CONCLUSIONS

As it can be seen from the results of the present research, breathing and interval exercises have been able to increase the strength of the respiratory muscles and subsequently reduce the recovery time of these muscles in non-athletes. The results of previous studies consider metaboreflex as one of the most important causes of respiratory muscle fatigue. Perhaps it is not far from expected that the early inactivation of the metaboreflex and also the lack of sports adaptations (due to being non-athletes) of the target population caused such a result. It is suggested to investigate the simultaneous effect of both types of exercise on the time to return to the initial state of respiratory muscle strength. It is also recommended that, this research be studied on people who have weakness of these muscles to test its effectiveness on these communities.

## Declarations

### Ethics approval and consent to participate

This study was approved by the Research Ethics Committee of Shahrood University of Technology, ID: IR.SHAHROOD.REC.1401.006.


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### Contribution of authors

All authors have participated in the design, execution and writing of all parts of this research.

### Competing interests

According to the authors of this article, there is no conflict of interest.


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