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IMMEDIATE EFFECTS OF INVERSE RATIO BREATHING VERSUS DIAPHRAGMATIC BREATHING ON INSPIRATORY VITAL CAPACITY AND THORACIC EXPANSION IN ADULT HEALTHY FEMALES

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ABSTRACT

Background: The normal inspiratory to expiratory ratio is 1:2.However, the duration of inspiration can be increased voluntarily till the ratio becomes 2:1.This is called as inverse ratio breathing. The effects of inverse ratio ventilation have been studied on patients with respiratory failure and Acute Respiratory Distress Syndrome. No studies have been carried out to study the effects of inverse ratio breathing in voluntarily breathing individuals. Hence this study was carried out to find the immediate effects of inverse ratio breathing versus diaphragmatic breathing on inspiratory vital capacity and thoracic expansion.

Method: 30 healthy adult females in the age group 20-25 years were included in the study. Inspiratory vital capacity and thoracic expansion at 2nd, 4th and 6th intercostal space was measured using a digital spirometer and an inelastic inch tape respectively. Diaphragmatic breathing was administered for one minute and the same parameters were measured again. A washout period of one day was given and same outcome measures were measured before and after individuals performed inverse ratio breathing with the help of a visual feedback video for one minute.

Results: Data was analysed using Wilcoxon test. There was extremely significant difference between the mean increase in the inspiratory vital capacity and thoracic expansion at the 2nd, 4th and 6th intercostals space after inverse ratio breathing as compared to diaphragmatic breathing ($p < 0.0001$).

Conclusion: Inspiratory vital capacity and thoracic expansion increase significantly after inverse ratio breathing.

Keywords: I:E ratio, Inverse ratio breathing, diaphragmatic breathing, inspiratory vital capacity, voluntary breathing, thoracic expansion.

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INTRODUCTION

Breathing consists of two phases, inspiration and expiration. During inspiration, the diaphragm and the intercostal muscles contract. The diaphragm moves downwards increasing the volume of the chest cavity and the intercostal muscles pull the ribs up expanding the rib cage and further increasing this volume. This increase of volume lowers the air pressure in the alveoli to below atmospheric pressure. The air rushes from the high atmospheric pressure through the respiratory tract into the alveoli. In contrast to inspiration, during expiration the diaphragm and the intercostal relax. This returns the thoracic cavity to its original volume, increasing the air pressure in the lungs and forcing the air out.

Various centres in the brain like the Dorsal Respiratory Group of Neurons, the Ventral Respiratory Group of Neurons and the Pneumotaxic centre regulate these phases of breathing. Basic rhythm of respiration is generated in the Dorsal Respiratory Group of neurons which emits repetitive bursts of action potentials which are transmitted to the diaphragm and other inspiratory muscles and bring about inspiration. These bursts increase in a ramp like manner and cease during the next few seconds during which occurs the elastic recoil of the diaphragm and chest wall bringing about expiration [1].The normal ratio of inspiration to expiration during relaxed breathing is 1:2 that is the duration of expiration is twice that of inspiration [2]. The lung contains stretch receptors that transmit signals through the vagi to the Dorsal Respiratory Group of Neurons when the lungs become overstretched and this stops the emission of inspiratory signals.

When the diaphragm is working effectively as the inspiratory muscle, effective relaxed (tidal) breathing is carried out. Although the diaphragm controls breathing at an involuntary level, a person can be taught to control breathing by optimal use of the diaphragm as in the diaphragmatic breathing exercise. The person is sitting in a relaxed position. The person is asked to place his or her own hand below the anterior costal margin. Then the patient is asked to breathe in slowly and deeply through the nose allowing the abdomen to rise slightly. Then the person is told to exhale slowly through the mouth [3].

Respiration can be controlled voluntarily and one can hyperventilate or hypo ventilate till serious derangements in pCo_2 ,pH, pO_2 occur in the blood. Inspiration can be prolonged till the tidal volume increases to more than three times the normal after which the stretch receptors in the lungs are activated and the inspiratory signals are shut off. In this manner one can prolong the duration of inspiration such that it becomes double the duration of expiration. This is called as inverse ratio breathing in which the ratio of inspiration to expiration becomes 2:1 [2]. To prolong inspiration in such manner the work of the external intercostal muscles increases to further increase the volume of the thoracic cavity than relaxed breathing. The accessory muscles of inspiration may also be put to use.

Previously, studies have been carried out to find out the effects of inverse ratio breathing as a setting with different ventilator modes on cardio respiratory parameters in severe respiratory failure [4] as well as to study benefits of inverse ratio ventilation in patients with Acute Respiratory Distress Syndrome [5].

Considering the proposed mechanisms by which inverse ratio breathing can be beneficial and the fact that it can be carried out voluntarily, it was hypothesized that inverse ratio breathing may affect the lung capacities, thus showing changes in the inspiratory vital capacity and thoracic expansion. Inspiratory vital capacity is the maximum volume of air inspired from the point of maximum expiration.

Thoracic expansion is considered as an indirect measure of lung capacity [6]. Thoracic expansion is measured conventionally by placing an inelastic measuring tape circumferentially at the 2^{nd} intercostal space or at the axillary level, 4^{th} intercostal space and 6^{th} intercostal space or at the level of xiphoid process. Measurements are taken at the height of maximal expiration and inspiration [7].

As there are discrepant results obtained in the studies carried out previously, this study was carried out to find out the immediate effects of inverse ratio breathing in voluntarily breathing individuals on inspiratory vital capacity and thoracic expansion as well as to compare these effects with the immediate effects of diaphragmatic breathing, on the same parameters. Keeping this aim in view, the objectives of this study were to measure the inspiratory vital capacity and thoracic expansion at 2nd, 4th and 6th intercostal space immediately before and after administering diaphragmatic breathing,to measure the inspiratory vital capacity and thoracic expansion at 2nd, 4th and 6th intercostal space immediately before and after administering inverse ratio breathing and to compare between the immediate effects of inverse ratio breathing and diaphragmatic breathing.

METHOD

The study design was cross sectional and experimental. The population was selected from College students.30 female individuals were selected by incidental sampling method. Healthy female individuals in the age group of 20-25 years were included in this study. Individuals having any known respiratory, cardiovascular condition or musculoskeletal impairments of the thorax, individuals with inability to comprehend commands and individuals who smoke were excluded from this study. Inspiratory vital capacity and thoracic expansion at 2^{nd}, 4^{th}, 6^{th} intercostal space were used as the outcome measures for this study.

Procedure

Selected individuals were explained about the purpose and informed consent was obtained prior to the study.

Measurement of inspiratory vital capacity: (Figure 1) Participants were made to sit erect on a stool with their feet resting on the ground. They were instructed to hold the mouthpiece of the digital spirometer inside their mouth such that no air escapes from the corners of the mouth. The nose was occluded with the help of a nose clip. The participants were told to exhale normally before starting the test. On the command of start they were told to take a normal breath and continue breathing normally till further instructed. The therapist then instructed the participant to carry out maximal expiration when the digital spirometer displayed the command, followed by a slow maximal inhalation and then normal exhalation. The reading for inspiratory vital capacity displayed on correct completion of the test was then recorded.

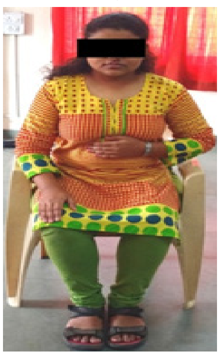
Figure 1: Measurement of Inspiratory vital capacity.

Measurement of chest expansion: **(Figure 2)** Participants were made to sit on a high plinth. Thoracic expansion was measured using an inelastic inch tape. The tape was placed circumferentially at the 2nd, 4th and 6th intercostal space respectively. Individuals were then told to first exhale maximally and then inhale maximally. Measurements were recorded at the height of maximal expiration and maximal inspiration and the difference between the two measurements was recorded in inches[7].

Figure 2: Measurement of Thoracic expansion.

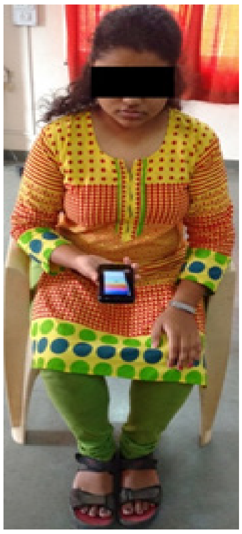
After recording both the parameters the participants were made to perform diaphragmatic breathing (Figure 3). Participants were made to sit relaxed on a chair. The participants were told to place their hand below the anterior costal margin and feel the movement occurring. Then the participants were told to breathe in slowly and deeply through the nose allowing the abdomen to rise slightly and then relax and exhale slowly through the mouth [3]. This was carried out for one minute. The measurements for inspiratory vital capacity and thoracic expansion were taken immediately after the completion of diaphragmatic breathing in the same manner as before.

Figure 3: Participants performing diaphragmatic breathing.



The same procedure was repeated on the next day at the same time before and after the participants performed inverse ratio breathing. For administering inverse ratio breathing the participants were made to sit erect in a chair (Figure 4). A visual feedback video was prepared beforehand which displayed gradual rise of a marker for 4 seconds and gradual fall for 2 seconds. The participants were instructed to carry out inspiration as the marker moves from the starting point to the end point at a constant speed and to carry out expiration as the marker moves back from the end point to the starting point. This was carried out for one minute.

Figure 4: Participant performing inverse ratio breathing.



The difference between the measurements recorded before and after both the breathing techniques was calculated. The increase in the parameters after diaphragmatic breathing and inverse ratio breathing was compared statistically using the Wilcoxon matched- pairs signed-ranks test using the software GraphPad InStat (version 3.06). Level of significance was set at 0.05 and confidence interval of 95%.

RESULT

The differences in the pre and post measurements of inspiratory vital capacity and thoracic expansion at the 2nd, 4th and 6th intercostal space were calculated after diaphragmatic breathing and compared with inverse ratio breathing. The results obtained were as shown in table 1.

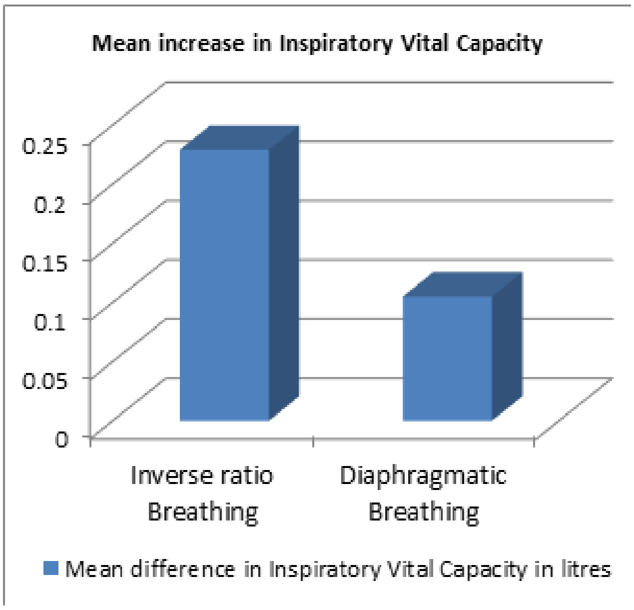
Table 1: Pre and Post measurements of inspiratory vital capacity and thoracic expansion

Mean increase in inspiratory vital capacity (litres) (Graph 1)		**Diaphragmatic Breathing**	**Inverse ratio Breathing**	**p value**
		0.10	**0.23**	**< 0.0001**
Mean increase in thoracic expansion (inches)	At 2nd Intercostal space (Graph 2)	0.16	0.69	< 0.0001
	At 4th intercostal space (Graph 3)	0.16	0.71	< 0.0001
	At 6th intercostal space (Graph 4)	0.13	0.49	< 0.0001

DISCUSSION

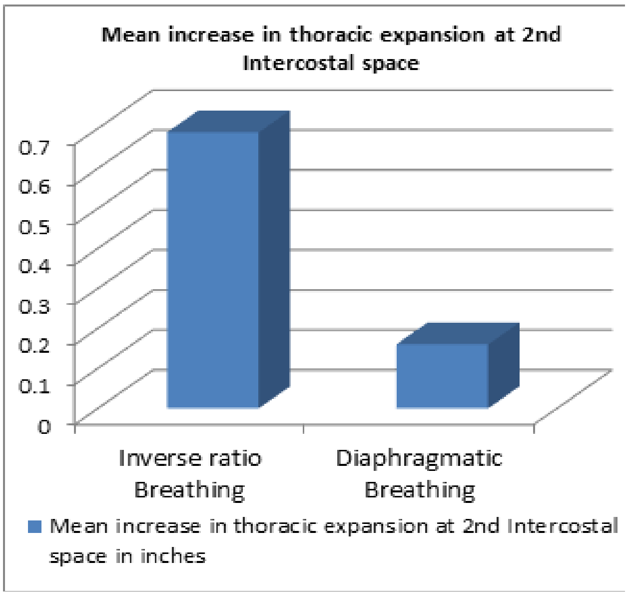
This study included 30 healthy female individuals in the age group of 20-25 among which majority were 22 years of age. All the individuals performed diaphragmatic breathing and inverse ratio breathing as instructed. For preparing the visual feedback video used during inverse ratio breathing, a chart was used having colours from light to dark. A marker was used which moved at a constant speed from light to dark in 4 seconds and back to light in 2 seconds. Participants were instructed to perform inspiration as the marker moved from light to dark and expiration as it moved back to light. Participants found that this method was easy to follow. There was an increase in their inspiratory vital capacity and thoracic expansion after performing both the exercises. However, the mean increase in inspiratory vital capacity after diaphragmatic breathing was 0.10 litres while that after inverse ratio breathing was 0.23 litres (Graph 1). These values reflect a greater increase after inverse ratio breathing. The p value was less than 0.0001 proving its statistical significance. Thus, it can be concluded that there was a greater increase in inspiratory vital capacity of the participants after they performed inverse ratio breathing.

Graph 1: Mean increase in Inspiratory vital capacity

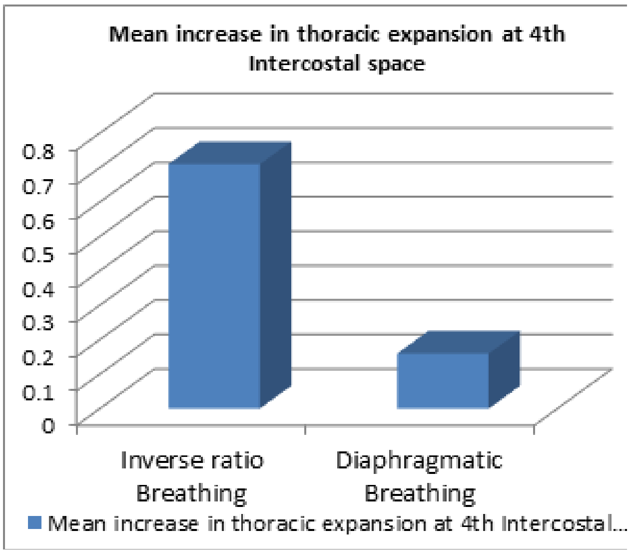


The mean increase in thoracic expansion at 2nd, 4th and 6th intercostal space was 0.16 inches, 0.16 inches and 0.13 inches respectively after performing diaphragmatic breathing and it was 0.69 inches, 0.71 inches and 0.49 inches after performing inverse ratio breathing (Graphs 2, 3 and 4). These values reflect that the increase in thoracic expansion was more after inverse ratio breathing than after diaphragmatic breathing. Its statistical significance is reflected by the p values which are less than 0.0001 for the mean increase at all the three levels. Thus, it can be concluded that there was a significant increase in thoracic expansion of all the participants at all the three levels after inverse ratio breathing than after diaphragmatic breathing.

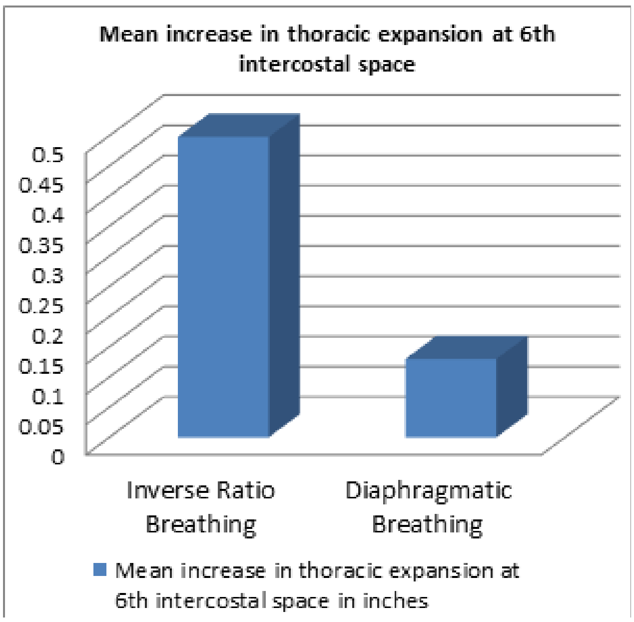
Graph 2: Mean increase in thoracic expansion at 2nd Intercostal space



Graph 3: Mean increase in thoracic expansion at 4th intercostal space



Graph 4: Mean increase in thoracic expansion at 6th intercostal space



In the study carried out by Elizabeth Zavala et al on the patients with ARDS, the following mechanisms for the benefits of inverse ratio breathing were proposed [5]:

1) During inverse ratio breathing, an intrinsic PEEP is generated in the alveoli due to short expiratory phase thus increasing the end expiratory volume.
2) The prolonged inspiratory phase recruits long time constant alveoli which take a longer than average to get recruited.
3) There is improved intrapulmonary distribution of inspired air.
4) Higher Mean airway pressure.

The increase in the inspiratory capacity and thoracic expansion of individuals carrying out inverse ratio breathing in this study can be also attributed to these mechanisms. However further research is needed on a larger sample size including both the genders so that the beneficial effects can be generalised to the population. Also, there is a need for further studies which confirm these benefits in patients with known respiratory conditions. At the same time, newer methods should be developed for providing visual feedbacks to patients for carrying out inverse ratio breathing as an exercise which are easy to comprehend and follow.

CONCLUSION

Inspiratory vital capacity and thoracic expansion increase significantly after performing inverse ratio breathing. Thus inverse ratio breathing can be used as an adjunct to other forms of exercises in individuals who have reduced lung volumes and capacities.

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Citation

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