Original Article:  
Comparison of Diaphragmatic Excursion During Diaphragmatic Breathing Exercise, Volume and Flow Oriented Incentive Spirometer in Healthy Subjects: A Randomized Cross Over Trial

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Abstract: Objective: To compare the diaphragmatic excursion of healthy subjects (males and females) during rest and three different types of breathing exercises: Volume-Oriented Incentive Spirometer, Flow-Oriented Incentive Spirometer and Diaphragmatic Breathing. Methods: One Hundred and eleven healthy volunteers (62 male and 49 female) participated in the study. Diaphragmatic excursion was measured using ultrasound, during rest, Diaphragmatic Breathing Exercise and the use of the Volume-Oriented Incentive Spirometer and the Flow-Oriented Incentive Spirometer. Results: Diaphragmatic excursion was significantly greater during the Volume-Oriented Incentive Spirometer (6.3±1.4) than Flow-Oriented Incentive Spirometer (5.4±1.4) and Diaphragmatic Breathing exercise (5.2±1.3). During all three types of breathing exercises, males showed a higher diaphragmatic excursion than females. Conclusions: The Volume-Oriented Incentive Spirometer promoted greater diaphragmatic excursion than the Flow-Oriented Incentive Spirometer and the Diaphragmatic Breathing Exercise.

Key Words: Diaphragmatic excursion, Diaphragm breathing exercises; Volume-Oriented Incentive Spirometer, Flow-Oriented Incentive Spirometer.

Introduction:  
Patients who have undergone upper abdominal surgery or thoracic surgeries frequently have a high incidence of post-operative pulmonary complications. Such as hypoxemia, pneumonia and atelectasis. Such complications can increase the risk of morbidity and mortality, prolong hospital stay and raise health care cost. The mechanism of these pulmonary complications is related to modifications of compartmental displacement, specifically diaphragmatic dysfunction, decreased lung compliance, impaired mucociliary clearance, and a monotonous breathing pattern without periodic sighs. Respiratory therapeutic measures such as Diaphragmatic Breathing Exercises (DB), positive pressure exercises, Incentive Spirometer (IS), and thoracic mobility exercise are used for prevention and treatment of post-operative pulmonary complications (PPC). Diaphragmatic Breathing Exercises involve inspiring to total lung capacity with particular emphasis on the use of the diaphragm. This had been shown to inflate alveoli and reverse post-operative hypoxemia. Diaphragmatic breathing exercises also improve the efficiency of ventilation, decrease the work of breathing, increase the expansion of the diaphragm, and improve gas exchange and oxygenation. Incentive Spirometer employs visual feedback in order to encourage the performance of reproducible, sustained maximal inspiration, until total lung capacity has been achieved. Maximal inspirations cause an increase in trans-pulmonary pressure and consequently an increase in lung volume. An end inspiratory pause maintains this increase in trans-pulmonary pressure and ensures alveolar stability. Several studies have been conducted to evaluate the efficacy of the Incentive Spirometer for the prevention and treatment...
of post-operative pulmonary complications after thoracic, abdominal or cardiac surgery, and to compare this technique with other treatment programs. However, the results obtained in these studies are been conflicting.(5-8) Despite the widespread use of the Incentive Spirometer, some systematic reviews have found little evidence that the use of this technique is beneficial in terms of preventing post operative complications, this lack of evidence could be attributed to methodological flaws. At present, the Incentive Spirometer continues to be used as part of the routine prophylactic and therapeutic regimen for respiratory care.(6) Some studies have shown that the use of the Incentive Spirometer with a Volume-Oriented device requires less respiratory effort than does the use of the Incentive Spirometer with a Flow-Oriented device.(9,10) Other authors have observed that there is greater abdominal motion, lower accessory respiratory muscle recruitment, and higher tidal volume during the use of a Volume-Oriented Incentive Spirometer than during the use of Flow-Oriented Incentive Spirometry.(3,4,11,12) Studies have also shown that Diaphragmatic Breathing Exercises encourage maximum diaphragmatic movement.(13) However there is scarcity of evidence to conform the difference between different types of Incentive Spirometers (Volume And Flow) and the Diaphragmatic Breathing Exercise on diaphragmatic excursion in healthy subjects. There are a lack of retrievable studies which compare the efficacy of Incentive Spirometer (volume and flow) and that of the diaphragmatic breathing exercise on diaphragmatic excursion in healthy subjects. The aim of the study is to compare diaphragmatic excursion in a state of rest, with that during Diaphragmatic Breathing Exercise, Volume-Oriented Incentive Spirometer and Flow-Oriented Incentive Spirometer, in healthy subjects.

Material and Methods
Inclusion criteria
- Normal subjects between 21 to 70 years.
- Body mass index (BMI) 18.5 to 25kg/m².
Exclusion criteria
- History of smoking.
- History of cardio respiratory diseases.
- Subjects who have had previous experience with the devices tested
- Those who were unable to perform the assessment tests or breathing exercises proposed in this protocol.

Equipment used
- Incentive Spirometer-volume oriented-Coach-2 Device. (Coach 2 Device, Smiths Medical International Ltd, USA)
- Incentive Spirometer –flow oriented-Triflo Device. (Triflow Device, IGNA Medical Devices, Mumbai)
- Ultra-sonography machine (voluson 730)

Study Procedure
The study protocol was approved by the Scientific Research Committee and institutional Ethics Committee of Kasturba Medical College hospitals, Mangalore, Manipal University. The subjects were selected based up on the inclusion and an exclusion criterion, the purpose was explained and the subjects who were volunteering were included in study after they had signed an informed consent. The subjects were randomized to undergo one of the three exercise sequences in order to maintain the same proportional sequences. Finally the order in which the three types of breathing exercises performed is determined by random drawing.

The assessment of the diaphragmatic excursion was made by an experienced radiologist who used ultra-sunography in M-Mode.(13) Diaphragmatic excursion was measured, at rest, during Diaphragmatic Breathing Exercises, as well as during the use of a Volume-Oriented Incentive Spirometer and a Flow-Oriented Incentive Spirometer with an interval of one minute rest between successive test conditions. The subjects were in a half lying position with the head end of the bed elevated to 45 degrees. All subjects were instructed about how to perform Diaphragmatic Breathing Exercises and how to use the Incentive Spirometer before the assessments. Each type of breathing exercise was performed once.

Description of outcomes measures
For measuring diaphragmatic mobility
The probe was placed between the midclavicular and anterior axillary lines, in the sub-costal area, and directed medially, cranially and dorsally, so that the ultrasound beam reached the posterior third of the right hemi diaphragm perpendicularly. Diaphragm movements were recorded in M-Mode. This manoeuvre began at the end of normal expiration, and the volunteers were asked to inhale in as deeply as they possibly could do.(13,14)

Procedure for volume and flow oriented incentive spirometer
The device used for Volume-Oriented Incentive Spirometer is the Triflo and for Flow-Oriented Incentive Spirometer is the Coach-2 device. The exercise was performed according to the guidelines of the American Association for Respiratory Care; the individuals inhale deeply and slowly, hold their breath at maximal inspiration for at least 3 seconds, and exhale normally.(15,16)

Procedure for Diaphragmatic Breathing Exercises
Subjects were in a relaxed and comfortable position in which gravity assists the diaphragm, such as a semi-fowler's position. The hand was placed on rectus abdominis just below the anterior costal margin keeping the shoulders relaxed and upper chest quiet, allowing the abdomen to rise slightly. The subjects were asked to breathe in slowly and deeply through the nose and exhale slowly through the mouth.(17)

Data analysis
Data analysis was done by using Statistical Package for Social Sciences (SPSS) version: 13. Repeated measures of ANOVA was used to compare diaphragmatic excursion, at rest, during Diaphragmatic Breathing Exercise, Flow and Volume-Oriented Incentive Spirometer

Results
The anthropometric data of the subjects (male and female groups), Mean and standard deviation (Mean ± S.D) for age, height, weight, body mass index are presented in [Table 1]. Comparison between male and female for all age groups (21 to 30, 31 to 40, 41 to 50, and 51 to 60 and 61 to 70), in terms of Diaphragmatic Excursion during the rest and three types of breathing exercises are shown in [Table 2]. It was observed that the males performed better on three types of breathing exercises than did females.

Table 1: Anthropometric data of the subjects (male and female groups).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (Mean ± S.D)</th>
<th>Female (Mean ± S.D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>42.5 ± 13.9</td>
<td>41.8 ± 16</td>
</tr>
<tr>
<td>Height, cm</td>
<td>163.41 ± 6.1</td>
<td>160.47 ± 5.5</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>56.67 ± 4.8</td>
<td>53.35 ± 8.3</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>23 ± 2.1</td>
<td>22.2 ± 2.1</td>
</tr>
</tbody>
</table>
A Comparison of Diaphragmatic excursion during rest and the three different types of Breathing Techniques are shown in [Table 4]. Diaphragmatic excursion was significantly greater during use of the Volume-Oriented Incentive Spirometer (6.3 ± 1.4) than Flow Oriented Incentive Spirometer (5.4 ± 1.4) and Diaphragmatic Breathing exercise (5.2 ± 1.3).

**Table 4: Comparison between Diaphragmatic Excursion during rest and during three different types of breathing exercises**

<table>
<thead>
<tr>
<th>N</th>
<th>Rest, cm (Mean±S.D)</th>
<th>Diaphragmatic Breathing Exercise, cm (Mean±S.D)</th>
<th>Volume Oriented Incentive Spirometer, cm (Mean±S.D)</th>
<th>Flow Oriented Incentive Spirometer, cm (Mean±S.D)</th>
<th>p' value</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>2.5 ± 1.2</td>
<td>5.2 ± 1.3</td>
<td>6.3 ± 1.4</td>
<td>5.4 ± 1.4</td>
<td>0.000 [HS]</td>
</tr>
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**Discussion**

To the best of our knowledge this is the first study assessing diaphragmatic excursion during rest as against that during the use of three different types of breathing exercises. We studied subjects of age groups between 21 to 70 years (21 to 30, 31 to 40, 41 to 50, 51 to 60, and 61 to 70), in order to assess the difference in diaphragmatic excursion with three different types of breathing exercises.

The reported mean value for diaphragmatic excursion in males is as follows: Rest is 2.5 ± 1.2 cm; Diaphragmatic Breathing Exercise is 5.4 ± 1.3 cm; Volume-Oriented Incentive Spirometer is 6.7 ± 1.3 cm; and Flow-Oriented Incentive Spirometer is 5.7 ± 1.3 cm. Diaphragmatic excursion in females: Rest is 2.4 ± 1.2 cm, Diaphragmatic Breathing Exercise is 5.2 ± 1.3 cm, and Volume-Oriented Incentive Spirometer is 5.3 ± 1.3 cm. Flow-Oriented Incentive Spirometer is 5.1 ± 1.4 cm.

In the present study diaphragmatic excursion during rest and that during three different types of breathing exercises was shown to be less in females than in males, and the difference was statistically significant in Diaphragmatic Breathing Exercise, Volume-Oriented Incentive Spirometer, and Flow-Oriented Incentive Spirometer. The probable reason would lie in the respiratory movement and breathing pattern of males and females during normal deep breathing. It was found that there was less abdominal motion in females, suggesting decreased diaphragmatic excursion in females as compared to that in males.(3)

In our study females show less diaphragmatic excursion during Diaphragmatic Breathing Exercise 12%, Volume-Oriented Incentive Spirometer 16%, and Flow-Oriented Incentive Spirometer 12% respectively when compared to males. Several studies have reported that females show 11-20% less diaphragmatic excursion during deep breathing in comparison to males.(4,9,13,14) A study carried out in Brazil reported that females showed less diaphragmatic mobility than males during Flow-Oriented Incentive Spirometer and Volume-Oriented Incentive Spirometer that is 5% and 8% respectively.(3)

Upon comparing diaphragmatic excursion via ultrasound during three different types of breathing exercises, Volume-Oriented Incentive Spirometer was shown to produce better diaphragmatic excursion than Flow-Oriented Incentive Spirometer and Diaphragmatic Breathing Exercise. The reason would be less use of accessory respiratory muscles which facilitates more diaphragmatic movement in Volume-Oriented Incentive Spirometer as compared to that produced by Flow- Oriented Incentive Spirometer and Diaphragmatic Breathing Exercise.(3,4,9,18)

For patients who underwent thoracic, cardiac and abdominal surgery the post-operative pulmonary complications are as follows: for thoracic surgery between 19% and 59%; for cardiac surgery 3% to 16%, up to 80% for upper abdominal surgery(12) and 5% to 30% for upper abdominal surgery.(10) The major causes of post-operative pulmonary complications may be related to shallow breathing and monotonous tidal volume in post-operative patients. However,
other causes such as anesthesia,(2) opioid analgesia, and postoperative pain also seem to contribute to this ventilation pattern without spontaneous deep breaths that occurs every 5 or 10 minutes.(6) As a result, physical therapy techniques of lung re-expansion have been recommended as strategies to prevent and/or to treat the post-operative pulmonary complication as well as to recover the ventilatory function in the post-operative period.(6) techniques such as Diaphragmatic Breathing Exercise, Flow-Oriented Incentive Spirometer and Volume-Oriented Incentive Spirometer are recommended.

Our results suggest that Volume-Oriented Incentive Spirometer promotes greater diaphragmatic excursion than does Flow-Oriented Incentive Spirometer and Diaphragmatic Breathing Exercise. Therefore, when the therapeutic goal is to increase diaphragmatic excursion, Volume-Oriented Incentive Spirometer seems to be more effective than Flow-Oriented Incentive Spirometer and Diaphragmatic Breathing Exercise, in the treatment of respiratory alterations. This criterion should be considered for the correct indication of the type of breathing exercise to be used in clinical practice. Finally, we also found that males performed better than did females on all three types of breathing exercises.

The limitations of our study lie in the fact that we assessed healthy subjects. Therefore, the relationship between our findings and clinical practice remain to be established. In addition, the cumulative effects of the use of the three different breathing exercises had no influence on the results, since the order in which the approaches were assessed was randomized. Further studies have to be conducted to assess diaphragmatic excursion during all different types of breathing exercises in patients at a risk of pulmonary complications.

**Conclusion**

Volume-Oriented Incentive Spirometer generates greater diaphragmatic excursion than Flow-Oriented Incentive Spirometer and Diaphragmatic Breathing Exercise.

**References**