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# Volume Incentive Spirometer is more Effective than Flow Incentive Spirometer on Arterial Blood Gases in Patients with Pneumonia

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**Abstract:**Respiratory distress and poor oxygenation caused by pneumonia has long been a major concern of healthcare providersleading to respiratory distress and poor oxygenation that consequently results in poor prognosis and prolonged hospital stay. This is why physical therapists are inclined towards improving patients' symptoms and oxygenation using various therapeutic measures.This study aims at comparing the effect of flow versus volume incentive spirometers on arterial blood gases in patients diagnosed with bacterial pneumonia.Forty male patients, aged between 50 and 60 years and diagnosed with bacterial bronchopneumonia participated in this study and were randomized into two equal groups in umbers (A and B). The former used flow inventive spirometers and the latter used volume spirometers. At the end of the study duration, arterial blood gases of both groups were compared. Groups A and B both showed significant increase in $PaO_2$ and $SPO_2$ ($p \leq 0.05$) . However, the latter showed more improvement in both variables (27.1% and 6.6% respectively) compared to (14.2% and 3.1% respectively) in the former group.**Conclusion:**Volume incentive spirometers are more effective than flow incentive spirometers in improving arterial blood gases in patients with bacterial bronchopneumonia.

**Keywords:**Bacterial pneumonia, oxygen saturation, ventilation, pulmonary rehabilitation, chest physiotherapy.

**Ethical consideration:** The study was approved by the ethical committee of the faculty of physical therapy, Cairo University. And a written consent was signed by every participating patient after the study procedures has been thoroughly explained.

## Introduction

### 1.1. Pneumonia

The word "pneumonia" originates from the classic Greek synonym pneumonia. In Greek culture it means lung, so the word pneumonia points out lung disorders. Therapeutically, it's an infection of one or both lung' parenchyma usually results in an inflammation. The various causes of pneumonia include bacteria, viruses, fungi and parasites. According to recent classification of pneumonia, it's classified into: hospital-acquired (HAP), community-acquired (CAP), ventilator-associated pneumonia (VAP) and healthcare-associated (HCAP).[1]

Pneumonia produces infection of the lower portion of the lung; the alveoli and the bronchioles. The root-causes of pneumonia consist of infectious and non-infectious agents like viruses, bacteria,

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parasites, mycoplasma, and fungi mainly linked to the surroundings. Non-infectious agents include; environmental or chemical agents as well as aspiration of gastric contents.[2]

Bacterial pneumonia is often categorized based on the type of acquisition to community-acquired pneumonia (CAP), Healthcare-associated pneumonia, Ventilator-associated pneumonia (VAP) and Non-ventilator-associated hospital-acquired pneumonia (NV-HAP). [3]

Patients with pneumonia complain of chest pain, cough with or without retained secretions, fatigue, fever, nausea, vomiting or diarrhea, and shortness of breath.[4]In general, Community-acquired pneumonia (CAP) is a public health issue, resulting in high risk of morbidity that usually requires hospitalization, and a main leading reason for mortality, particularly in severe cases with sepsis or requiring ventilation support.[5]For this reason, chest physiotherapy in pneumonia has become a great concern in healthcare sector.

### 1.2. Arterial Blood Gases

Arterial blood gas (ABG) measurement is a safe inexpensive non-invasive measurement of oxygenation, ventilation and gas exchange. It is also a perfect for pulmonary function measurements as it can assess the two functions of the lung (oxygenation and CO2 removal). Another non-invasive technique is a pulse oximetry depends on blood gas analysis to verify their validity.[6]It also can assess the acid-base balance, pH, the partial pressures of carbon dioxide (PaCO2) and partial pressures oxygen (PaO2) dissolved in arterial blood.[7]
To assess the oxygenation PaO2 and arterial blood oxygen saturation (SaO2) should be measured and haemoglobin concentration by the oxy-haemoglobin dissociation curve.[8]The correlation among oxygen saturation (SO2) and partial pressure (PO2) in blood is showed by the oxygen haemoglobin dissociation curve (ODC). Oxygen saturation (SO2) means all-inclusive haemoglobin connected sites which are filled with oxygen. Each haemoglobin molecule can bond with till 4 oxygen molecules (**Figure 1).** That bonding is responsible for increasing slope of the ODC at low level of oxygenation. However at the high level of oxygenation, the curve flattens as the haemoglobin molecules reach complete saturation give the sigmoid (s-shaped) appearance.[9]

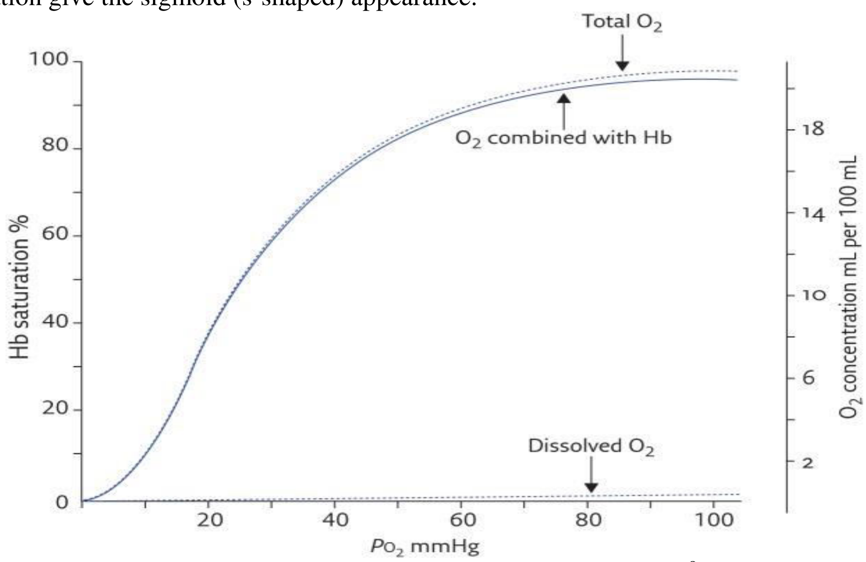


***Figure 1:*** *Oxygen hemoglobin dissociation curve (ODC).*[9]

When the rate and depth of ventilation increase or even inhale oxygen supplementations, the partial pressure oxygen (PaO2) increased and also the oxygen saturation as well. Since the shape of the dissociation curve is half s-shaped appearance **(Figure 1),** the corresponding rise is very hard. Also since the dissociation curve is almost flat when the oxygen saturation rises to 90%, any rises in PO2 have small change on saturation.[9]

### 1.3. Incentive spirometers

Incentive spirometer is a device for lung expansion technique. It assists in yawning or sighing by allowing the patient to take long slow and deep breath. It also safe and can treat atelectasis as well as

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prevent its occurrence in conscious patients who have vulnerability for shallow breathing. Incentive spirometer commonly includes Volume (Coach 2) Devices and Flow dependent devices (Triflo).[10]

Incentive spirometry is a mechanical device allowing patients to take elongated, gently, slow and deep inspirations to have maximal inhalation pressure and volume in the alveoli, and improve the competency of the airway. IS can eliminate hypoxemia and fatigue, also provide low-level resistance training to the diaphragm, increase lung inflation.[11]

The IS devices are consists of plastic flexible tube attached to a mouthpiece for patient inhalation. Flow or volume differs in aim and number of chambers. The flow oriented device has three chambers while volume device has one chamber. In flow-oriented IS when the patient inhales, the three balls raise through negative pressure created by air flow. In volume-oriented IS, when patient inhale, a piece in chamber called piston rises to indicate a volume. This volume can be measured by degrees on the side of the column, accompanied by maximal inspiratory effort by holding the breath.[12]

## 2. Materialand Methods

### 2.1. Sample and Randomization

**Sample:**Forty male patients, aged between 50 and 60 years who were admitted to El-Kateb Hospital's in-patient ward after being diagnosed with bronchopneumonia based on sputum cultures, ABG and radiology.

**Randomization:** Patients were assigned to one of two groups based on their enrolment number. All patients with even enrolment numbers were assigned to group A, while those with odd numbers were assigned to group B.

### 2.2. Inclusion criteria:

Patients who met the following criteria were included:

- Male patients with bacterial bronchopneumonia.
- Moderate stage with same symptoms (dyspnea, chest pain, productive cough, fever and fatigue)
- Age ranges from 50-60 years.
- BMI between 20 and 25 (kg/m²).
- Pneumonia severity index (PSI) shows category III or IV of patients need hospitalization.

### 2.3. Exclusion criteria:

Patients with one or more of the following criteria were excluded:

- Instability of patient's medical condition including respiratory failure.
- Association with another medical problem (liver, kidney, heart, tumors, vascular).
- Presence of malignant disease and sepsis.
- Any other physical disorders may affect the result as obesity or cardiac disease.
- Patient with viral pneumonia including confirmed COVID-19.
- Atypical and usual interstitial pneumonia (UIP).

### 2.4. Evaluation procedures

Before patients were considered into the study, a sputum culture was taken to confirm the presence of bacterial pneumonia; chest x-ray was obtained as well as arterial blood gases in order to confirm the diagnosis. When the rehabilitation program was commenced, all patients demonstrated the following criteria:

- Oxygen saturation in room air 90-92%
- Patients on supplemental oxygen no more than 1-4 Litres per minute, on nasal cannulae, then patients were gradually weaned during the study.
- Complete subsidence of fever.
- Respiratory rate less than 30 breaths/min

### 2.5. Intervention

Patients included in the study received breathing control to normalize breathing patterns, slower respiratory rate, reduce the ventilation rate as well as longer expiration process. Nasal breathing is

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stressed rather than mouth breathing. Abdominal muscles are frequently used alternatively with the upper-chest and accessory muscles of respiration in resting breathing.[13]

In addition to breathing control, patients performed incentive spirometer training as follow:

**Group A:** Incentive spirometry using flow-oriented incentive spirometers.

**Group B:** Incentive spirometry using volume-oriented incentive spirometers.

In both groups, patients were positionedat 45°to the horizontal position, on the edge of a chair or bed. The incentive spirometer was held upright. The patient breathed out normally. Then, mouth piece was placed in the mouth and lips were sealed around it.Then placed lips tightly around mouthpiece, Inhaled slowly through the device. This procedure was repeated in 2 sets of 5 repeated deep breaths and the exercise was done every waking hour for 8 hours. The patient was instructed to perform the same exercises for one week.[10]

**Statistical analysis**

- Statistical analyses were performed using SPSS software (version 20).

1. Descriptive statistics:The mean and standard deviation will be calculated for demographic characteristics including (Age, BMI, Weight, and Height).
2. Inferential statistics: Paired T- test will be used to compare the outcome measures oxygen saturation (SpO2) and arterial blood gases (ABGs) within each group before and after intervention. Paired T- test will be used to compare the outcome measures oxygen saturation (SpO2) and arterial blood gases (ABGs) within each group before and after intervention. Un-Paired T-test will be used to compare the outcome measures oxygen saturation (SpO2) and arterial blood gases (ABGs) between both groups before and after intervention. The level of significance < 0.05.

## 3. Results

**General Characteristics of the Subjects:**

The mean values of age, BMI in group (A) were 54.25± 3.19yr and 23.11± 1.60Kg/m² respectively and in group (B) were 55.50± 2.71yr and 22.86± 1.96Kg/m² respectively.Comparison of the mean values of age, BMI and sex distribution in between groups revealed no significant differences (p=0.48 and 0. 58 respectively) (table 1)

**Table (1):** General characteristics of patients in both groups (A&B)

| *Variable* | *A* | *B* | *P-value* |
|---|---|---|---|
| ***Age(yr)*** | 54.25± 3.19 | 55.50± 2.71 | 0.48 |
| ***BMI(kg/m²)*** | 23.11± 1.60 | 22.86± 1.96 | 0.58 |
| ***Variable*** | A | B | P-value |
| ***Age(yr)*** | 54.25± 3.19 | 55.50± 2.71 | 0.48 |
| ***BMI(kg/m²)*** | 23.11± 1.60 | 22.86± 1.96 | 0.58 |

Data are expressed in means, BMI: body mass index, P>0.05:Non-significant.

**Between groups comparison of pre- and post- ABG values:**

a) **Comparison of pre and post study mean values of PaO2 in both groups:**

The mean values of PaO2 pre and post study in group (A) were 60.25± 6.68 and 70.25±11.4 mmHg respectively. There was a significant increase (p=0.002). The percentage of improvement was 14.2%.The mean values PaO2 pre and post study in group (B) were 58.70± 5.93 and 80.6±7.13 mmHg respectively. There was a significant increase (p<0.001). The percentage of improvement was 27.1 (Table 2 and fig.2)

**Table (2):** Comparison of pre and post study mean values of PaO2 within groups

| **PaO2 (mmHg)** | A | | B | |
|---|---|---|---|---|
| | **Pre** | **Post** | **Pre** | **Post** |
| **Mean±SD** | 60.25± 6.68 | 70.25±11.4 | 58.70± 5.93 | **80.6±7.13** |
| **Mean difference** | 10 | | **21.9** | |
| **Percentage of improvement** | 14.2 | | **27.1** | |

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| | | |
|---|---|---|
| **t-value** | 3.6 | **9.7** |
| P-value | **0.002*** | **<0.001*** |

Data are expressed in means, SD: Standard Deviation, PaO2: partial pressure of arterial oxygen, *Significant: p≤0.05.

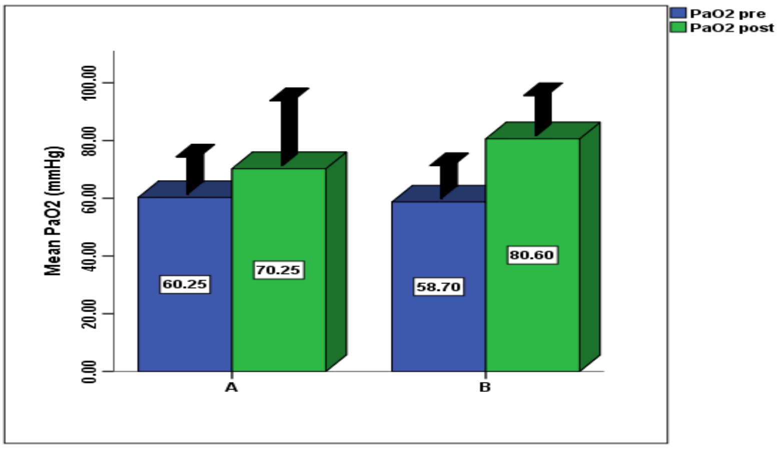


**Figure (2):** Comparison of post study mean values of PaO2 between groups.

**b) Comparison of pre and post study mean values of PaCO2 in both groups:**

The mean values of PaCO2 pre and post study in group (A) were 38.7± 3.5 and 39.6±3.54 mmHg respectively. There were no significant differences (p=0.4). The mean values PaCO2 pre and post study in group (B) were 40.3± 3.3and 40.65±2.7 mmHg respectively. There were no significant differences (p=0.7) (Table 3)

**Table (3):** Comparison of pre and post study mean values of PaCO2 within groups

| **PaCO2 (mmHg)** | A | | **B** | |
|---|---|---|---|---|
| | **Pre** | **Post** | **Pre** | **Post** |
| **Mean±SD** | 38.7± 3.5 | 39.6±3.54 | 40.3± 3.3 | **40.65±2.7** |
| **Mean difference** | 0.9 | | 0.3 | |
| **Percentage of change** | 2.2 | | 1 | |
| **t-value** | 0.7 | | 0.3 | |
| P-value | **0.4** | | **0.7** | |

Data are expressed in means, SD: Standard Deviation, PaCO2: partial pressure of carbon dioxide, P >0.05: Non-significant.

**c) Comparison of pre and post study mean values of SpO2 in both groups:**

The mean values of SpO2 pre and post study in group (A) were 90.35± 3.6 and 93.25±4.7% respectively. There was a significant increase (p=0.002). The percentage of improvement was 3.1%.

The mean values SpO2 pre and post study in group (B) were 89.75± 4.3 and 96.1±2.5% respectively. There was a significant increase (p<0.001). The percentage of improvement was 6.6%. (Table 4 fig.3)

**Table (4):** Comparison of pre and post study mean values of SpO2 within groups

| **SpO2 (%)** | A | | **B** | |
|---|---|---|---|---|
| | **Pre** | **Post** | **Pre** | **Post** |
| **Mean±SD** | 90.35± 3.6 | 93.55±4.7 | 89.75± 4.3 | **96.1±2.5** |
| **Mean difference** | 3.2 | | **6.35** | |
| **%of improvement** | 3.1 | | **6.6** | |

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| t-value | 2.1 | **5.8** |
|---|---|---|
| **P-value** | **0.04*** | **<0.001*** |

Data are expressed in means, SD: Standard Deviation, SpO2: Saturation of peripheral oxygen, *Significant: p≤0.05.

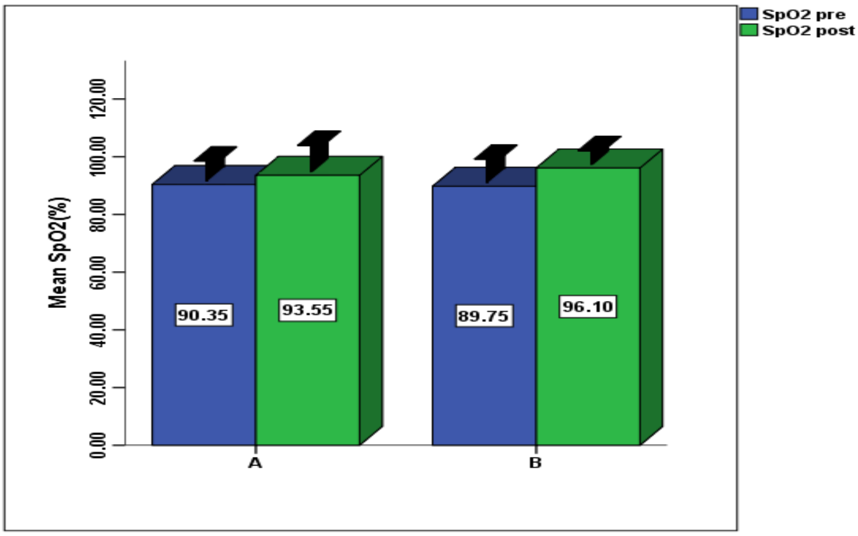


Figure (3): Comparison of post study mean values of $SpO_2$ between both groups.

**Comparison of Post-intervention values of ABG:**

| *Variable* | *Post study* | | |
|---|---|---|---|
| | **A** | **B** | **P-value** |
| ***PaO2 (mmHg)*** | 70.25±11.4 | 80.6±7.13 | 0.03* |
| ***SpO2 (%)*** | 93.55±4.7 | 96.1±2.5 | 0.04* |
| ***$PaCO_2$ (mmHg)*** | 39.6±3.54 | 40.65±2.7 | 0.29 |

*Level of Significance P value ≤ 0.05*

## 3. Discussion

One of the most common acute respiratory infections is pneumonia. The primary parts affected are the alveoli and the distal airways. Pneumonia is a vital health issue with high morbidity and mortality rate among all ages all over the world.[14]

The present study was conducted to compare the efficacy of flow-oriented spirometer and volume-oriented spirometry on patients with pneumonia. Forty patients with pneumonia participated in this study. They were enrolled from chest and internal inpatient department at El Kateb hospital in Giza governorate in the period from February 2021 to July 2021.

The patients were assigned randomly into two equal groups in number. The first group (A) included 20 patients who used flow-oriented spirometry with deep breathing exercise inform of breathing control for one week. The second group (B) included 20 patients who used volume-oriented spirometer with deep breathing exercise in form of breathing control for one week. All the patients were evaluated before and after the study by measuring the partial pressure of oxygen (PaO2), partial pressure of carbon dioxide (PaCO2) and saturation of peripheral oxygen. (SpO2).

In the present study, patients' age ranged from 50-60 years old. Adult patients with 50 years old and older are more susceptible to pneumonia. They are also at higher risk for hospitalization, complications, and death. It was believed that aging process reduce lung function and debilitate the immunity. Other health conditions in older adults also can worsen pneumonia include; chronic obstructive pulmonary disease (COPD), asthma and cardiac disease.[15]

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Patients with body mass index more than 25 Kg/m$^2$were excluded from this study. It can be hypothesized that obese patients may be more susceptible to develop pneumonia and have a great risk for morbidity and mortality. Obesity is linked to worse outcomes in those who develop pneumonia.[16]

Within both groups (A and B), the results of the present study proved that there was a significant increase in PaO2 (p=0.002 and 0.001 respectively), SpO2 (p=0.04 and 0.001 respectively) with no significant change in PaCO2 (P=0.4 and 0.7 respectively).

Flow-oriented spirometry has many benefits. Mainly, it can boost pulmonary ventilation, improve the ultimate inspiration volume and lung compliance, enhance oxygenation, prevent and treat atelectasis.[17]Additionally, it can master anaesthesia andhypoventilation complications, release respiratory secretions, assist in respiratory gas exchange and re-expand collapsed alveoli. Also, it can reduce tidal volume which is very crucial in preventing pneumonia. Flow incentive spirometer also provides visual feedback for the respiratory effort.[18]

Diaphragmatic exercises are used to increase diaphragmatic elevation while expiration and diaphragmatic falling during inhalation. The advantages of diaphragmatic breathing are to open the shrinkage and collapsed alveoli, enhance the ventilation and oxygenation of alveoli, decrease the work load of breathing and improve the diaphragmatic excursion.[19]

Another study was applied on 30 patients having coronary bypass surgery lately to assess the effect of flow spirometry (IS) on arterial blood gases. It was concluded that there is a significant effect of flow spirometry on arterial blood gases examination in CABG surgery patient by remarkable enhancement in PaO2 and SaO2.[20]

The results of the present study also approved the finding of **Karcz et al.,** who conducted a recent, small, controlled interventional study (n = 58) to identify the effect of flow spirometry on ABGin patients after coronary artery bypass surgery (CABG).(19) The results introduced difference between the study and control groups in the amount of arterial blood oxygen and oxygen saturation. It was concluded that utilizing flow spirometry is consequentially effective in the refinement blood arterial gas parameters.[21]

These results are subsequent with **Sum et al., (2019)**who investigated the effect of flow spirometer on pulmonary function and complication rates in 50 patients with different fractures at ribs. There was a marked development in pulmonary function which assessed by pulmonary function test, particularly %FVC and %FEV.(Sum et al. 2019)So, **Sum et al.**,concluded that the utilizing of incentive spirometer enhanced PFT and decreased pulmonary complications in patients. The flow spirometer has clinical advantages without harmful effects and is a cost-essential device for patients with rib fractures.[22]

The results of another study conducted to examine the effect of flow incentive spirometer on arterial oxygen saturation (SaO2) level, hypoxemia, and pulmonary complications after bariatric surgery. Spirometer had not any effect onpost-operative hypoxemia, SaO2 level, or postoperative pulmonary complications. This contradiction may be as a result of study may be attributed to the small sample size (10 Participants only) and the short duration (2 weeks only) of their study.[23]

Another study also showed after taking a deep inhalation by the flow incentive spirometer with constant few seconds breath hold, the intra pleural pressure, intra alveolar pressure and the trans-pulmonary pressure gradient increased. This can prevent atelectasis and expand the alveoli.[24]
Examination how volume-oriented incentive spirometry practiced with patients after a stroke was done at a study which adjusts sectional and whole chest wall volume variations. It concluded that volume incentive spirometer improved whole chest wall expansion; therefore, it should be considered as a tool for rehabilitation.[25]

A comparative study was conducted on 30 volunteer patients (22 males and 8 females) who underwent coronary artery bypass surgery (CABG) to identify the efficacy of volume incentive spirometry (IS) compared to continuous positive airway pressure (CPAP) on arterial blood gases (ABG) in the incentive care unit. The study showed that there was statistical remarkable improvement in PaO2 following two hours using incentive spirometer, which indicated incentive spirometry has a long-term effect. Additionally, there was no statistical enhancement in arterial blood gases (ABG) after two hours of using CPAP.[26]

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On contrary, Volume incentive spirometer increase blood oxygenation through forced ventilation in non-ventilated and collapsed alveoli. Therefore, volume incentive spirometer is very valuable for post-operative pulmonary rehabilitations since it forces the alveoli to open and ventilate probably.[27]

Evaluation of thoraco-abdominal motion when using volume incentive spirometer compared to flow incentive spirometer in healthy adults showed that volume incentive spirometer produced higher chest wall expansion in comparison with flow incentive spirometer.[28]

In the present study's findings, the efficacy of volume-oriented incentive spirometer in comparison with flow-oriented spirometer on thoraco-abdominal mechanics and the activity of the respiratory muscle were conducted on 20 healthy subjects. Volume IS improved chest wall volume more than flow IS and produced a large dimension in the upper and lower rib-cages as well as abdomen. So, concluded that volume IS induces lower respiratory muscle activity and a larger enhance in chest wall capacity than flow IS.[29]

Another study was conducted to compare volume and flow-oriented incentive spirometer on the volumes of the chest wall, inspiratory muscle activity, and thoraco-abdominal synchrony in the 16 old subjects. After 6 weeks, it isfound that flow incentive spirometer induced lower synchrony than did volume incentive spirometer. Flow-oriented incentive spirometry required more muscle activity in old subjects to produce an enhancement in the volumes of the chest wall.[30]

Also, the study on effectiveness of flow incentive spirometer and volume incentive spirometer on pulmonary function and diaphragmatic excursion was conducted within 20 patients who had laparoscopic surgery. After 4 weeks, pulmonary function and diaphragm movement values were found to be higher in the volume incentive spirometer group than flow-oriented incentive spirometer group.[10]

## 4. Conclusion

Based on the findings of this study,Volume-oriented spirometry is more effectiveflow-oriented spirometry in improving oxygenationin patients with pneumonia.

## 5. Acknowledgment

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**Conflict of Interest:** The corresponding author reports no conflict of interest on behalf of all authors.

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