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# Correlation Between Chest Expansion Improvement and Functional Capacity After Breathing Exercise in COVID-19 Patient

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**Abstract**— Measuring chest expansion is considered to perform in COVID-19 patient to assess the pulmonary function impairment as its usage to other interstitial lung diseases. The decrease of pulmonary function will affect the cardiorespiratory functional capacity. These problems demand an appropriate pulmonary rehabilitation programme aimed to returning the decent quality of life. Among 43 subjects we prescribed two types of breathing exercise: incentive spirometry and diaphragm breathing exercise. The chest expansion at three levels (axillary, nipple, and xiphisternum) was measured before and after breathing exercise; then average of its improvement was recorded. The assessment of functional capacity using 4-meter gait time test (4MGT) was also performed after sequence of breathing exercises. This study showed improvement of chest expansion on majority of subjects. Based on bivariate analysis using Spearman correlation, the p value was 0,012 ($p<0,05$) and coefficient correlation was 0,381. We can conclude that there was correlation between chest expansion improvement and functional capacity measured by 4MGT after breathing exercise in COVID-19 patient.

**Key Words**: COVID-19, chest expansion, functional capacity, 4MGT, breathing exercise

## Introduction

Chest expansion measurement has been widely used to assess the therapeutic effect of different treatment techniques, including respiratory muscle endurance training and respiratory muscle stretching among various diseases(Wilson et al., 2001). Chest expansion was measured as the difference between chest circumferences at maximal inhalation and maximal exhalation. This technique was able to assessing pulmonary function impairment in easy and simple way (Pun et al., 2020)(Reddy et al., 2019).

The lack of chest mobility caused by pulmonary disease such as COPD could restrict the chest and abdominal volume increasing during exercise and lead to exercise intolerance (Kaneko et al., 2016)The changes of chest wall mobility might related to airway obstruction, hyperinflation, and mechanical disadvantage of the respiratory muscles.(Malaguti et al., 2009)In COVID patient, the significant changes were observed in lung volume, and most patients might develop obstructive or restrictive pulmonary patterns. Furthermore, these can negatively affect the functional capacity.(Frota et al., 2021)(Mo et al., 2020)Although the previous study has mentioned the correlation between chest wall mobility, lung function, respiratory muscle strength, and exercise tolerance in patients with ankylosing spondylitisand fibromyalgia, (LR et al., 1990; Ozgocmen et al., 2002)the studies on chest wall mobility in COVID-19 has been rarely discussed.

The main goals of pulmonary rehabilitation are to reduce respiratory symptoms, improving the exercise tolerance, and increasing functional capacity so thus could improve the quality of life.(Mo et al., 2020)(Frota et al., 2021)(Liu et al., 2020)It consists of respiratory muscle training and physical training. Assessment of cardiorespiratory functional capacity are required before determining the pulmonary rehabilitation programme and also to monitoring the effects of therapeutic and rehabilitation programme. 4-Meter Gait Speed (4MGS) test was an excellent marker to assess the exercise capacity in elderly and it has been correlated with other function measurement. (Kon et al., 2013)Previous study reported that4MGS correlated to quality of life, physical activity and pulmonary functional capacity in chronic obstructive pulmonary disease (COPD) patients.(Hirabayashi et al., 2020) However, there were paucity in studies showed the usefulness of 4MGS for other lung disease, particularly in COVID-19 patient.

The aim of this study was to evaluate whether there was correlation between chest expansion improvement and functional capacity measured by 4-Meter Gait Time (4MGT) test after performed specific breathing exercise.

**Material and Methods**

This study was a *clinical trial*conducted in isolated ward of Universitas Indonesia Hospital, Depok on March-August 2021. The ethical clearance was taken at Universitas Indonesia Hospital ethics committee.There were 43 subjectsincluded in this study followed the inclusion criteria. The inclusion criteria were COVID-19 patient in isolated ward, 18 years and above, cooperative, capable to walked independently and obey the command, and willing to take part in this study. The exclusion criteria were patient with neurological disorder, side-weakness in lower extremity, and had psychiatric and/or cognitive impairment. The characteristic grouping of this study based on gender, age-span categorized by WHO, BMI categorized by WHO, and comorbid or underlying disease. The types of breathing exercise were also mentioned, whether the subjects performed incentive spirometry or diaphragm breathing exercise.

Diaphragm breathing exercise could be performed in sitting or laying position. Subject was positioned in a 45° relaxed sitting position. Then the subject was instructed to places hand on the upper abdomen. Have the subjects inhale through the nose letting the hand on the abdomen rise during inspiration. Then have the patient exhale through pursed-lips, while the hand presses inward on the abdomen. The exercise repeated in 5 repetitions each session, three times a day. During exercise, patient should relax upper chest and shoulders.(Respiratory & Services, n.d.)

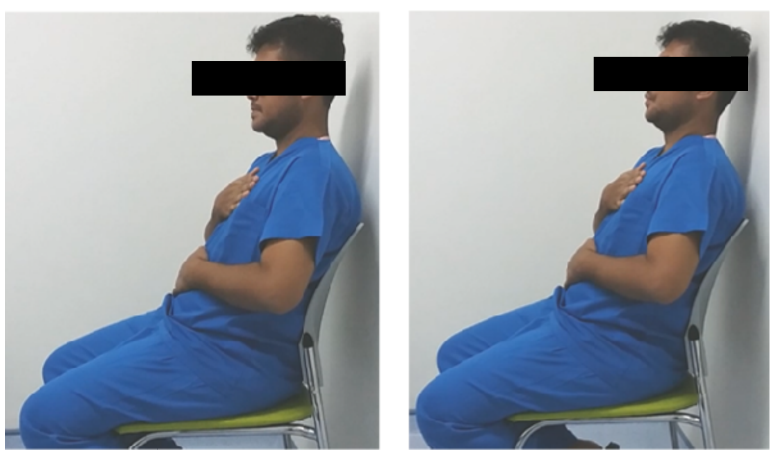

**Figure 1a.** Diaphragm breathing exercise: inhale **1b.** exhale

An incentive spirometer is a device that measures the volume of the air inhaled into the lungs during inspiration.The subject was instructed to hold the spirometer in an upright position, exhale normally, and then place the lips tightly around the mouthpiece. When inhaled through an incentive spirometer, a piston volume rose inside the device and measures the volume of the inspired air. Inhalation should be sustained for 5 seconds, then the mouthpiece was removed, followed by a normal exhalation.(Restrepo et al., 2011) The exercise was performed three times a day with number of repetition was about 5 times in each session.

**Figure 2.** Incentive Spirometry exercise

The chest expansion was measured at three levels (axillary, nipple, xiphisternum) before and after performed breathing exercise and the average of improvement was recorded. The average of the three level readings were used as difference between maximum and minimum chest circumferences(Pun et al., 2020). Improvement of chest expansion was explained by the difference between average of chest circumferences before and after breathing exercise.

The assessment of functional capacity using 4-meter gait time (4MGT) test was performed to see theduration taken to walking 4 meters in second. Subjects were instructed to walk at usual pace from standing position behind he starting line. Timing started as the first foot step forward and end when a foot completely reached the finish line. The time needed to taken 4 meters walking was recorded.(Maggio et al., 2016)

Data analysis was conducted by using SPSS version 26.0. The significant level was set at $p < 0.05$ for all statistical procedures. Univariate analysis was used to describe the characteristics of the subjects, the average of chest expansion improvement, and 4MGT test result. The bivariate analysis was conducted to see the correlation between each subject's characteristic to chest expansion improvement; and to assess the correlation between chest expansion improvement to 4MGT.

**Results**

Table 1. Demographic features of COVID-19 patient in Isolated Ward Universitas Indonesia Hospital during March - August 2021

| Demographic Features of COVID-19 Patient | | | | |
|---|---|---|---|---|
| | Frequency | Percent | Minimum/ Maximum | Mean ± St. Deviation |
| **Gender** | | | | |
| Male | 21 | 48.8 | | |
| Female | 22 | 51.2 | | |
| **Age** | | | | |
| < 40 years old | 10 | 23.3 | 18/ | 47.6047 ± |
| 40-60 years old | 27 | 62.8 | 67 | 12.35418 |
| > 60 years old | 6 | 14.0 | | |
| **BMI (WHO)** | | | | |

| | | | | |
|---|---|---|---|---|
| Underweight (<18.5 kg/m2) | 1 | 2.3 | | |
| Ideal (18.5-24.9 kg/m2) | 15 | 34.9 | 16.22/ | 28.1101 ± |
| Overweight (25.0-29.9 kg/m2) | 16 | 37.2 | 52.12 | 7.38046 |
| Obese (>30 kg/m2) | 11 | 25.6 | | |
| **Comorbid** | | | | |
| Yes | 29 | 67.4 | | |
| No | 14 | 23.6 | | |
| **Type of Breathing Exercise** | | | | |
| Diaphragm Breathing | 21 | 48.8 | | |
| Incentive Spirometry | 22 | 51.2 | | |

There were 22 female subjects (51,2%) and 21 male subjects (48,8%) included in this study. The majority of subjects was between 40-60 years old (62,8%). Based on WHO categories of Body Mass Index (BMI), 16 subjects were overweight (37,2%); 15 subjects were ideal (34,9%); 11 subjects were obese (25,6%) and 1 subject was underweight (2,3%). More than half subjects had comorbid (67,4%).Based on randomized selection, 22 subjects (51,2%) were prescribed the incentive spirometry and 21 subjects performed diaphragm breathing exercise (48,8%).

Table 2. Correlation between subject characteristics and chest expansion improvement

| | **Chest expansion improvement** | |
|---|---|---|
| | **R** | **P** |
| **Gender** | 0.118 | 0.450 |
| **Age** | 0.073 | 0.642 |
| **BMI** | -0.097 | 0.534 |
| **Comorbid** | 0.121 | 0.440 |
| **Type Of Exercise** | 0.326* | 0.033 |

Based on Spearman correlation, the p value of variable type of exercise was 0,033 (p < 0,050) and the corelation coefficient was 0.326. While other variable such as gender, age, BMI, and comorbid showed value above 0,050.

Table 3.Effect of each breathing exercise to chest expansion improvement

| **Effect of breathing exercise to chest expansion improvement** | |
|---|---|
| | **R** |
| **Breathing Exercise** | 0,150 |

The subjects received breathing exercisehad improved chest expansion 15% times than subject who didn't received breathing exercise (R = 0,150).

Table 4. Correlation between chest expansion improvement and 4-meter gait time after performed breathing exercise

| | 4 meters gait time | |
|---|---|---|
| | **R** | **p** |
| **Chest Expansion Improvement** | -0.381* | 0,012 |

Based on Spearman correlation, the sig p value of chest expansion to 4-meter gait time was 0,012 ($p<0,050$) with the corelation coefficient was -0,381.The negative correlation means that the greater improvement, the lesser duration taken to walking 4 meters.

**Discussion**

As expected, the majority of subjects showed improvement in chest expansion after performing specific breathing exercise. There were two groups of breathing exercise performed in this study; diaphragm breathing exercise and incentive spirometry. The previous study has mentioned that CCE (Core Conditioning Exercise; the stretching exercise of core muscles) showed significant improvement to the upper level of chest expansion measurement. This is resemble to the recent study that examined the effects of CCE on chest expansion in healthy elderly people.(Kim et al., 2015). It also reported on other study, that the six weeks duration of diaphragmatic breathing exercise group has improved the forced expiratory flow rate (FEFR) and chest expansion, and also relives the symptoms and significantly improve the quality of life in patient with bronchial asthma. (Pillai & Shaik, 2018)Diaphragm breathing exercise is useful to strengthen the diaphragm and decrease work of breathing by reducing rate of breathing with less effort. This technique had successfully increased tidal volume, decreased functional residual capacity, and enhance optimal oxygen uptake in COPD patient(Budiman & Garnewi, 2021)

Incentive spirometry has been effective as therapy in management of pre-operative atelectasis. Patient with COPD, asthma, bronchitis and bronchiectasis often characterized by mucus hypersecretion and airflow limitation. These results in atelectasis which increases the work of breathing and gas change impairment so thus the exercise intolerance might be occurred. The recent study suggested that incentive spirometry was potential to improve collateral ventilation and air entry to the alveolus by keeping the lungs at high volumes during breath. There was also significant difference in chest and abdominal expansion representing the larger inspiratory lung volume while using specific incentive spirometry device. (Ho et al., 2000)Furthermore, the visual feedback shown on incentive spirometry device while practicing deep breathing exercise encourages patient compliance(Franklin & Anjum, 2021).

The degree of chest expansion and contraction of the lungs depends on several factors including the mobility of skeletal muscles, the elasticity of surrounding soft tissues, chest shape, and the intensity of respiratory muscles. It's not only influenced by rib cage movement and the intercostal muscle action in transverse dimensions, it also associated with contraction of diaphragm and expanding of vertical dimension of the chest cavity. (Padkao & Boonla, 2020) The chest expansion is considerably related and might be a representing marker of respiratory function and impact the lung volume. The chest shape, age, gender, body mass index (BMI) also affected the degree of chest expansion (Jalayondeja et al., 2014).

The intensity of respiratory muscle strength and vital capacity of lung can be reflected by maximum expiratory pressure (MEP) and maximum inspiratory pressure (MIP). Previous study has mentioned that men has higher MIP then women at all age groups and decreases by the ages of 65 and 85 years, with larger age-related declines seen in men (Sharma & Goodwin, 2006). It was supported by the study of Adedoyin that reported the chest expansion being increased with age until 3rd decade of line, then steadily declines after the periods.(Adedoyin & Adeleke, 2012)Therewere structural changes in rib cage by aging, lead to reduction in chest wall compliance. The age-related osteoporosis results to calcification of thoracic cage causing the reduced height of thoracic vertebrae and decrease the ability to expand during inspiration and generate effective contraction. (Sharma & Goodwin, 2006). The chest expansion also fount to be significantly significantly correlated with height and weight.(Pun et al., 2020). One of the reasonsfor respiratory muscle weakness related to obesity is the increased of adiposity that cause the muscles around the chest wall become inefficient. The previous study has showed a weak negative correlation between the chest level expansions (at axilla level) with BMI in the office workers only. It might be due to prolonged sitting in the office workers that affect their breathing pattern (Mahajan, 2019). Patients with obesity and chronic disease also reduced in respiratory muscle strength as a result of changes in airway resistance and chest wall mechanics.(Sood, 2009)

In lung acute disease such as acute respiratory distress syndrome, the pressure required to breathe increases. Individuals sustaining an acute viral infection can experience further imbalances between respiratory muscle capacity and high demands required for spontaneous breathing. (Mehta, 2015). Some COVID-29 patients suffered from severe acute respiratory distress syndrome and respiratory failure and required the mechanical ventilation to gain the respiratory muscle function. However, mechanical ventilation has been shown to induce rapid atrophy and respiratory muscle weakness(Berger et al., 2016)(Mehta, 2015). The systemic inflammatory response syndrome (SIRS) or sepsis and barotrauma-volutraumacontributes in eliciting the atrophy on ventilated patients. It should be associated with an inflammatory-cell infiltrate or increased proinflammatory cytokines(Belperio et al., 2006) It was proposed that SARS-CoV-2 infection triggers an excessive immune response known as a cytokine storm. A cytokine storm is characterized by the high-level activation of immune cells and excessive production ofinflammatory cytokines and chemical mediators(Feng et al., 2020). These patterns showed that inflammatory response in COVID-19 infection might have played role in respiratory muscle weakness, thus furthermore affecting the chest expansion.

Our study describes that there was no correlation between gender, age, BMI and comorbid to chest expansion improvement after performed the breathing exercise as pulmonary rehabilitation programme in COVID-19 patient. These findings was supported by the study on patient with chronic lung disease that reported thesuccess of pulmonary rehabilitation was not correlated with age, sex, chronic hypoxemic respiratory failure or other chronic conditions.(Scott et al., 2010)Although obesity was related to baseline condition of pulmonary function, it did not appear to affect pulmonary rehabilitation on COPD patient as well.(Ramachandran et al., 2008)There was also study mentionedthat BMI was not related to improvement infunctional capacity and 6MWT following pulmonary rehabilitation(Garrod et al., 2006). However, the correlation between those variables on pulmonary rehabilitation outcomes on COVID-19 patient is never been discussed.

Chest wall expansion, diaphragmatic movement, and functional capacity are positively associated to respiratory muscle strength in healthy participants. Weakness of respiratory muscles has previously reported to be related to exercise limitation in healthy individuals, athletes, and patients with heart failure (Amann, 2012)(Janssens et al., 2013)(Okrzymowska et al., 2019). Respiratory muscle weakness is also correlated with low functional capacity in chronic obstructive pulmonary disease. (Singer et al., 2011). It is resembled to our study results that chest expansion as the respiratory muscle strength marker has significantly correlated with functional capacity measured by 4MGT after performing breathing exercise. In addition, the respiratory muscle training has been proven to reduced respiratory muscle fatigue, and increased blood flow to the muscles involved thereby subject could performed a greater walking distance. (Wüthrich et al., 2013). As this study result, the improvement of chest expansion produced the shorter duration required to walk 4 meters in COVID-19 patient.

## Conclusion

The chest expansion improvement was correlated to functional capacity in COVID-19 patient. The improvement achieved after performing specific breathing exercise such as diaphragm breathing exercise and incentive spirometry. The breathing exercise could enhance the respiratory muscle strength thus improve chest expansion,thereby subjects could performed 4MGT well.

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