

Comparative effect of incentive spirometry and diaphragm breathing to functional capacity in COVID-19 patient in an isolated ward



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ABSTRACT

Background: COVID-19 affects the multiorgan system, mostly the respiratory system. Symptoms might vary from upper respiratory manifestation to acute respiratory distress syndrome, with the main feature being impairment of gas exchange. This pulmonary impairment might lead to a decrease in functional capacity, which cause activity limitation. Thus, COVID-19 patient requires the right pulmonary rehabilitation strategy to improve pulmonary function and prevent further pulmonary complications. This study aimed to compare the effectiveness of incentive spirometry and diaphragm breathing exercise on cardiorespiratory functional capacity in COVID-19 patients.

Methods: Subjects were divided into two groups of breathing exercises, the incentive spirometry group and the diaphragm breathing exercise group. They performed breathing exercises for 5 days, and the functional capacity was measured by a test named 4-meter gait time test (4MGT) and 30 sit-to-stand test (30STS). The test was taken before and after performing breathing exercises.

Results: These two respiratory exercises significantly affected the functional capacity in a good manner ($p < 0.05$). The incentive spirometry had improved 30STS ($P = 0.763$) and 4MGT results ($P = 0.674$), as well as diaphragm breathing exercise did to 30STS ($P = 0.456$) and 4MGS ($P = 0.441$).

Conclusion: In conclusion, diaphragm breathing exercises and incentive spirometry improved the functional capacity of COVID-19 patients. However, incentive spirometry showed a larger effect on 30STS and 4MGT compared to diaphragm breathing exercises.

Keywords: 30SST, 4MGT, COVID-19, diaphragm breathing exercise, functional capacity, incentive spirometry.

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INTRODUCTION

Coronavirus Disease 2019 (COVID-19) is transmitted disease caused by *Severe Acute Respiratory Syndrome Coronavirus 2* (SARS-Cov-2). The common symptoms of COVID-19 are respiratory symptoms, including fever, cough, and dyspnea. The clinical manifestation of this disease can be presented with no symptoms, mild disease without complication, a moderate disease with mild pneumonia, and severe disease to *Acute Respiratory Distress Syndrome* (ARDS).¹

The major complication of COVID-19 is coagulopathy, laryngeal edema, necrotized pneumonia, acute respiratory distress, also complications in the cardiovascular system, sepsis, and pulmonary embolism.² The pulmonary complications could be occurred due to

acute inflammatory response resulting in capillary and endothelial damage, or secondary lung injury promoted by prolonged mechanical ventilation leads to parenchymal consolidation and fibrosis.^{3,4} On the other hand, most COVID-19 patient experience arterial hypoxemia due to ventilation-perfusion mismatch.⁵ This causes reduced oxygen diffusion and impairment of gas exchange resulting in a decrease in functional capacity.⁶

Functional capacity is defined as the individual's ability to perform daily activities in an autonomous and independent manner.⁷ The newest assessment for functional capacity in recent studies are 4 meters gait speed test and 5 repetitions sit-to-stand test. Both assessments are easy to perform and require small spaces, short time, and minimal equipment, so that considered

to be routinely used to assess functional capacity inward.⁸

Pulmonary rehabilitation was individualized rehabilitation treatment refers to the results of a comprehensive evaluation. Pulmonary rehabilitation is beneficial to shorten the length of hospitalization periods, improving quality of life, increasing respiratory muscle function as well as the skeletal muscle of upper and lower extremities, relieving dyspnea, and reducing stress and anxiety.⁹ Pulmonary rehabilitation is critical for COVID-19 patients and preferable to begin as early as possible, particularly in a mild and moderate degree of the disease.

Breathing exercise in pulmonary rehabilitation has been effective in postoperatively improving lung expansion, breathing control, deep breathing, and diaphragmatic breathing. Specifically,

diaphragm breathing has been shown to reduce the work of breathing and improve ventilation efficiency. It also influences human postures as well.¹⁰ During diaphragmatic breathing exercises, the clients are usually instructed to put their own hands on the abdomen and upper chest to confirm visually that their movement is appropriate.¹¹

Incentive spirometry is a breathing exercise by using a device to sustain maximal inspiration. The device provides direct visual feedback when the patient inhales and sustains the inflation for at least 5 seconds. The patient is instructed to hold the spirometer in an upright position, exhale normally, and then place the lips tightly around the mouthpiece. Then the patient is asked to take slow inhalation until the ball or the piston in the chamber is raised to reach the determined target. At maximum inhalation, the mouthpiece is removed, followed by a breath hold and normal exhalation. The appropriate technique will encourage adherence to therapy.¹² The use of the incentive spirometer in respiratory muscle exercise has been shown effective in maintaining or increasing inhaled lung volume, preventing lung infection after surgery and improving sputum expectoration.¹²

METHODS

Study Design

This study was a single-blind clinical trial, with pre-post and comparative study design and consecutive sampling. The pre-post study design was used to explain the alteration of cardiorespiratory functional capacity before and after performing the incentive spirometry and diaphragm breathing exercise. The comparative study design aimed to elucidate the comparison of the effectiveness beyond both groups.

Subjects

The sample of this study was patients in isolated wards of Universitas Indonesia hospital with moderate and severe degrees of COVID-19. Since there was no pilot study that mentioned about spirometry incentive exercise in COVID-19 patients, we used the same determination to count the number of samples as a study done on COPD patients who had undergone the diaphragm breathing exercise.

The subject criteria followed the inclusion and exclusion criteria. The inclusion criteria included a COVID-19 patient who was over 18 years old, a conscious and cooperative patient, and was able to walk independently without any assisted devices. The exclusion criteria were intubated patients, patients with systolic blood pressure >140mmHg and diastolic blood pressure > 90mmHg, hemiparesis of the lower limb, psychiatric and cognitive disorders, and those who suffered pain with VAS>5. The incentive spirometry group was instructed to perform 10 breaths per session twice a day, while the diaphragm breathing exercise group performed the exercise for 30 minutes each day. Both exercises were performed for 5 days. Subjects who did exercise for less than 5 days and were discharged to a home or incentive care unit (ICU) were excluded from this study.

Statistical Analysis

The data were analyzed using IBM SPSS Statistics software version 26. The Shapiro-Wilk test was performed to investigate whether the variable was normally distributed. For the descriptive analysis, mean and standard error values were calculated for the numerical variables, if the variable is normally distributed, and proportions were calculated for the categorical variables. We used two-way repeated measurement of ANOVA to compare the 30STS and 4MGS between incentive spirometry and diaphragm breathing group before and after exercise. To estimate the effect size of incentive spirometry and diaphragm breathing exercise on 30STS and 4MGT results, we used the Partial Eta squared (η_p^2) on a repeated measure of ANOVA. The use of η_p^2 (P) has been widely used and recommended to improve the comparability of effect sizes.¹³

RESULTS

Table 1 showed that male subjects were greater in number (53,3%) than female subjects (46,7%) in both groups. The average age of the subjects performing incentive spirometry was 47.0 (SD = 11.4), while the diaphragm breathing group was 47.4 (SD = 14.5). The majority of subjects (66,7%) had a comorbid or underlying

disease. However, only 11 subjects (33,3%) reported not having any comorbid. On the degree of severity, slightly more than half of the subjects had moderate disease (75,6%), whereas 24,2% suffered from severe disease of COVID-19.

Based on the two-way repeated measures ANOVA analysis, there was a significant difference in mean 30STS between incentive spirometry and diaphragm breathing before exercise [$F(1,20) = 12.66; P = 0.000$] shown in Table 2. There was also significant difference between each group after performing exercise [$F(1,20) = 5.59; P = 0.028$].

The results of two-way repeated measures ANOVA in Table 3 also showed that there was significant difference in mean 4MGT before and after exercise between incentive spirometry [$F(1,20) = 32.01; P = 0.000$] and diaphragm breathing [$F(1,20) = 6.26; P = 0.021$].

Based on two-way repeated measure ANOVA performed in Table 4, incentive spirometry and diaphragm breathing caused changes in 30STS and 4MGT. The 30STS was improved in the incentive spirometry group ($P = 0.763$) and diaphragm breathing group ($P = 0.674$). Meanwhile, the 4MGT result was decreased as a shorter duration required to walk through 4 meters after incentive spirometry ($P = 0.456$) as well in the diaphragm breathing group ($P = 0.441$).

DISCUSSION

The most common and main cause of hospitalization in COVID-19 patients is a pulmonary impairment which could affect the functional capacity and quality of life. Prolonged hospitalization is also associated with cardiorespiratory function and reduces the ability to perform daily activities. So that the COVID-19 patient will need pulmonary rehabilitation in order to manage dyspnea, improve functional capacity, and prevent pulmonary complications.^{14,15} pulmonary rehabilitation commonly consists of respiratory muscle training.¹⁶

Incentive spirometry is commonly used for reducing the pulmonary complications of a patient with chronic obstructive pulmonary disease. This device provides a slow, deep long breath to achieve total lung capacity and sustain the inflation

to extend the alveolar open.^{17,18} Recent studies showed significant improvement of pulmonary function parameters such as FVC, FEV, and PEFR on subjects using incentive spirometry for 8 weeks. The improvement of pulmonary function is suspected to be influenced by the

visual feedback directly provided by the incentive spirometer. It might encourage the subjects to promote a sustained maximal inspiration that enhances the lung volume and optimize the use of respiratory muscles.¹⁹

Diaphragm breathing was reported

to be effective in improving respiratory function in patients with the chronic obstructive pulmonary disease by increasing respiratory muscle strength and endurance. Recent studies have mentioned that diaphragm breathing exercises showed exhalation resistance and higher improvement of forced vital capacity (FVC) because of the use of the diaphragm.²⁰ Diaphragm breathing exercise allows the alveoli to open and production of surfactant through deep breathing into full vital capacity and minimize the use of accessory muscles.¹⁸ It was also reported that diaphragm breathing exercise increased tidal volume, decreased functional residual capacity, and enhanced optimal oxygen uptake in COPD patients, thus could promote exercise capacity.²¹

By the measurement of the 30STS test, the baseline number of repetitions in the incentive spirometry group was 8.63 times (SD = 2.48). In comparison, the baseline number of 30STS in diaphragm breathing exercises was 12.14 times (SD = 3.76). These results showed that both groups performed 30STS below normal limits, which were set by 17 times. This cut-off point referred to normative data published before in moderately active older adults.²² The assessment of muscle strength by a sit-to-stand test is in accordance with aerobic capacity and clinically important to assess cardiorespiratory fitness and quality of life.²³ Previous study has mentioned that COVID-19 patient could have a low number of repetitions in a 1-minute sit-to-stand test, even after discharge from the hospital.²⁴ It also reported the correlation between STS results with knee muscle strength as maximal force capacity required the standing phase of STS transition.²⁵ As we know that COVID-19 patients might experience muscle weakness associated with muscle hypoxia due to impairment in peripheral muscle perfusion, prolonged immobility, and also high accumulation of IL-6 and IL-10 as a result of the cytokine storm in the acute phase.²⁶⁻²⁸

Before performing incentive spirometry, the average 4MGT baseline was 5.40 (SD = 2.06). Even all the subjects in the diaphragm breathing exercise group also had an average baseline of 3.57 (SD = 2.11). It showed that all subjects in both

Table 1. Patient demographics (n=45).

| Variables | Incentive Spirometry (n=24) n (%) | Diaphragm Breathing Exercise (n=21) n (%) | Total n (%) |
|--------------------------------|--------------------------------------|--|--------------------------|
| Gender | | | |
| Male | 11 (45.8) | 13 (61.9) | 24 (53.3) |
| Female | 13 (54.2) | 8 (38.1) | 21 (46.7) |
| Age (years)^a | 47.0 (11.4) | 47.4 (14.5) | 47.2 (12.8) ^a |
| Comorbid | | | |
| Yes | 13 (54.2) | 17 (81.0) | 30 (66.7) |
| No | 11 (45.8) | 4 (19.0) | 15 (33.3) |
| Severity | | | |
| Moderate | 17 (70.8) | 17 (81.0) | 34 (75.6) |
| Severe | 7 (29.2) | 4 (29.0) | 11 (24.2) |

Notes: ^aMean (SD)

Table 2. Comparison of 30STS between incentive spirometry and diaphragm breathing exercise in relation to time (pre-post).

| Time | Mean (SD) ^a | | F-statistic (df1, df2) ^a | P-value ^a |
|----------------|-----------------------------|----------------------------|-------------------------------------|----------------------|
| | Incentive spirometry (n=24) | Diaphragm Breathing (n=21) | | |
| Baseline (pre) | 8.81 (0.56) | 12.14 (0.82) | 12.66 (1, 20) | 0.000 |
| After (post) | 13.52 (0.54) | 16.76 (1.21) | 5.59 (1, 20) | 0.0028 |

Notes: ^aTwo-way repeated measure ANOVA, p-value < 0.05

Table 3. Comparison 4MGT between incentive spirometry and diaphragm breathing exercise in relation to time (pre-post).

| Time | Mean (SD) ^a | | F-statistic (df1, df2) ^a | P-value ^a |
|----------------|-----------------------------|----------------------------|-------------------------------------|----------------------|
| | Incentive spirometry (n=24) | Diaphragm Breathing (n=21) | | |
| Baseline (pre) | 5.51 (0.47) | 3.57 (0.46) | 32.01 (1, 20) | 0.000 |
| After (post) | 3.45 (0.10) | 2.65 (0.25) | 6.26 (1, 20) | 0.021 |

Notes: ^aTwo-way repeated measure ANOVA, p-value < 0.05

Table 4. Comparison of 30STS and 4MGT changes in incentive spirometry and diaphragm breathing exercise groups.

| Variable | Mean (SD) (n=45) | | F-statistic (df1, df2) ^a | P-value ^a |
|----------------------|------------------|---------------|-------------------------------------|----------------------|
| | Pre-exercise | Post-exercise | | |
| 30STS | | | | |
| Incentive spirometry | 8.81 (0.56) | 13.52 (0.54) | 74.16 (1, 23) | 0.000 |
| Diaphragm breathing | 12.14 (0.82) | 16.76 (1.21) | 41.30 (1, 23) | 0.000 |
| 4MGT | | | | |
| Incentive spirometry | 5.51 (0.47) | 3.45 (0.10) | 19.27 (1, 23) | 0.000 |
| Diaphragm breathing | 3.57 (0.46) | 2.65 (0.25) | 15.76 (1, 20) | 0.001 |

Notes: 30SST, 30 Sit to Stand Test; 4MGT, 4 Meter Gait Time; ^atwo-way repeated measure ANOVA, ^a p-value < 0.05

groups took more than 2.8 seconds to cover 4 meters distance. The use of 2.8 seconds as the normal time reference of 4MGT was the result of dividing the 4-meters distance by the normal speed, which is 1.4 m/s. A recent study has mentioned that older people must be able to walk at speed greater than 1.4 m/s to be active in an environment. It was the minimum speed required at least to safely cross an intersection.²⁹ The slow 4MGS identified the reduction of exercise capacity and poor quality of life.³⁰ In the present study, long immobilization produced several consequences in both older and young populations, such as a reduction in total lean mass and a decrease in quadriceps muscle and strength as well.³¹ It explained that prolonged hospitalization and immobilization in COVID-19 patients might contribute to slow duration in 4MGT results.

The baseline results in this study showed that COVID-19 patient had decreased their functional capacity in general. The study conducted at Universitas Indonesia Hospital reported that COVID-19 patients with moderate disease had low functional capacity measured by 4MGT.³² The impairment of ventilatory muscle function is considered to play a principal role in limiting exercise tolerance and functional capacity in patients with chronic respiratory disease. A recent study suggested that COVID-19 patients, particularly those with persistent dyspnea, showed greater impairment in pulmonary gas exchange. It was suspected that the limitations of tidal volume expansion, hypoxemia, and the rapid breathing pattern had increased respiratory neural drive, resembling features of another restrictive lung disease. The restrictive pattern in these patients has contributed to reducing of functional capacity and increased leg fatigue during the cardiorespiratory clinical testing.^{33,34} Recent studies also confirmed a correlation between maximal expiratory pressure (MEP) and trunk control.³⁵ This suggests that respiratory muscle training might improve postural stability, which plays a key role in doing functional tasks such as sitting and walking independently.

After performing incentive spirometry and diaphragm breathing, the test results

were changed in a positive manner. The number of repetitions after performing incentive spirometry had increased with $P = 0.763$. In the diaphragm breathing group, the repetitions also increased with $P = 0.674$. This means that both incentive spirometry and diaphragm breathing exercises improve the 30STS results. However, incentive spirometry showed greater improvement in 30STS.

Incentive spirometry and diaphragm breathing also caused improvement in the 4MGT result. The subjects who performed the incentive spirometry had reduced the duration required to walk 4 meters compared to the condition before performing an exercise with $P = 0.456$. Meanwhile, the diaphragm breathing group also showed the same reduction with $P = 0.441$. The Partial Eta squared values (P) represent the effect of incentive spirometry on 4MGT results was greater than diaphragm breathing did.

Some studies have reported the limitation of a maximum rate of oxygen consumption (VO_{2max}) caused by reduction of lung function in COPD patients.³⁶ Since the VO_{2max} represents the functional capacity, so the improvement of pulmonary function will respectively increase the level of functional capacity as well. It had been reported in the previous study that respiratory muscle training improved not only lung function but also showed a significant effect on functional capacity measured by the 6-minute walking test.¹⁹

The incentive spirometry was suggested to be more physiologic to pulmonary function than diaphragm breathing exercise because it provided a low level of resistance training and minimized the potential fatigue of the diaphragm.¹² In addition, to attain the improvement of lung volume, sustained and prolonged inspiration is required to extend the collapsed alveoli. The use of incentive spirometry allows the patient to adjust the inspiratory flow rate and sustain the inflation through visual feedback provided by the device.³⁷

CONCLUSION

Diaphragm breathing exercises and incentive spirometry improve functional capacity in COVID-19 patients measured

by 30STS and 4MGT. However, incentive spirometry shows a greater effect rather than diaphragm breathing exercises on functional capacity.

CONFLICT OF INTEREST

The author reports no conflicts of interest in this work.

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AUTHOR CONTRIBUTION

All the authors were responsible for the literature search, data analysis, statistical analysis, manuscript preparation, editing, and review.

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