Medica Hospitalia
Journal of Clinical Medicine
Med Hosp 2025; vol 12 (3) : 305–314

OPEN ACCESS

Original Article

Correlation between Maximal Inspiratory Pressure and the Sit-to-Stand Test in Post-COVID-19 Patients

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p-ISSN: 2301-4369 e-ISSN: 2685-7898
https://doi.org/10.36408/mhjcm.v12i3.1382

Submitted: June 26th, 2025
Accepted: November 21th, 2025

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Abstract

Background : Coronavirus Disease 2019 (COVID-19) can lead to long-lasting complications such as ongoing respiratory issues and functional impairments. Damage to the alveoli and respiratory muscles, particularly the diaphragm, may result in lower maximal inspiratory pressure (MIP) and decreased physical performance. Although prior studies have examined the connection between MIP and functional tests in various respiratory conditions, research focusing on post-COVID-19 populations, particularly in Indonesia, is scarce.
Aims : To investigate the correlation between Maximal Inspiratory Pressure (MIP) and 30-second Sit-to-Stand (30s STS) test performance in adult post-COVID-19 patients.
Methods : A cross-sectional study was conducted at two tertiary hospitals in Jakarta, Indonesia, involving 40 adults post-COVID-19 patients aged 18–59 years. Participants underwent clinical screening, spirometry, MIP measurement using the MicroRPM device, and the 30s STS test. Pearson correlation analysis was used for normally distributed variables with significance set at $p < 0.05$.
Results : The average MIP was 79.03 ± 26.68 cmH_2O, while the mean score for the 30s STS test was 12.78 ± 2.47 repetitions. Spirometric measurements revealed an average FEV_1 of 2.23 ± 0.57 L, FVC of 2.84 ± 0.69 L, and an FEV_1/FVC ratio of 81.19%. A moderate positive correlation between MIP and 30s STS performance was identified (r = 0.515, $p = 0.001$).
Conclusion : There is a significant moderate correlation between MIP and 30s STS performance among post-COVID-19 patients, suggesting that simple functional tests can be effective tools for assessing respiratory muscle strength and informing rehabilitation strategies in clinical environments.

Keywords : COVID-19; Diaphragm; Maximal Inspiratory Pressure; Sit-to-Stand Test

INTRODUCTION

Coronavirus Disease 2019 (COVID-19), caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), affects not only pulmonary structures but also respiratory muscles, particularly the diaphragm.[1] COVID-19 can induce acute diaphragmatic weakness through direct viral invasion, systemic inflammation, and immobilization during hospitalization. This condition is associated with reduced Maximum Inspiratory Pressure (MIP), a recognized indicator of inspiratory muscle strength, and may influence physical performance, as reflected in functional tests such as the Sit-to-Stand (STS) test.[2,3]

Globally, up to 60–70% of COVID-19 survivors report symptoms such as dyspnea, muscle fatigue, and reduced exercise tolerance several months following recovery, with functional impairment remaining obvious even two years after the infection. In Indonesia, clinical follow-up for COVID-19 survivors remains inconsistent and objective monitoring of respiratory muscle function is rarely conducted in the framework of standard rehabilitation programs. Simple and low-cost measures, such as MIP and STS testing, represent a viable alternative for the early detection of respiratory and functional impairments, especially in resource-poor healthcare systems.[4–8]

Persistent symptoms following COVID-19, including dyspnea and fatigue, are frequently reported and differ from those observed in COPD, as they often occur in individuals without prior respiratory disease and may not follow a chronic, progressive trajectory.[9] In Indonesia, these sequelae have significant clinical implications given the high number of COVID-19 survivors, the relatively younger demographic profile compared to typical COPD populations, and contextual factors such as nutritional status, physical activity patterns, and healthcare accessibility, which may influence recovery.[10] Investigating the correlation between MIP and STS performance in Indonesian COVID-19 survivors is therefore essential to determine whether inspiratory muscle strength serves as a predictor of functional capacity in this population.

SARS-CoV-2 is known to affect multiple organ systems, due to widespread expression of ACE2 receptors, the virus's primary cellular entry point, including in lung tissue and the diaphragm.[11] Pulmonary imaging often reveals ground-glass opacities (GGOs), consolidation, and in some cases, fibrotic changes––particularly in patients who required mechanical ventilation.[12] In addition to alveolar injury, diaphragm involvement has been increasingly recognized. Diaphragmatic weakness, likely mediated by direct viral infiltration and inflammation, can impair respiratory muscle strength and reduce ventilatory efficiency.[13]

Maximal Inspiratory Pressure (MIP) is a well-established metric for evaluating respiratory muscle strength, particularly diaphragmatic function. Studies in post-COVID-19 populations have shown a measurable decline in MIP compared to healthy controls. For instance, Plaza *et al*. reported MIP reductions of 13.5 cmH$_2$O in females and 10.9 cmH$_2$O in males post-COVID-19, suggesting a meaningful loss of inspiratory capacity.[14]

Functional performance assessments such as the Six-Minute Walk Test (6MWT), One-Minute Sit-to-Stand Test (1MSTST), and 30-Second Sit-to-Stand Test (30s STS) have been widely used to evaluate aerobic capacity and lower-limb function in respiratory and rehabilitation contexts. These tests are simple, cost-effective, and informative tools that may indirectly reflect respiratory function and overall endurance.[15]

Recent evidence has increased the understanding that COVID-19 may directly and indirectly impair respiratory muscle function. SARS-CoV-2 can induce diaphragmatic injury by viral infiltration, systemic inflammation, prolonged immobilization, and possible neural involvement, resulting in inspiratory muscle weakness and persistent dyspnea even after recovery.[4,5,16]

Respiratory muscle dysfunction persisted in a substantial number of COVID-19 survivors and most of the time paralleled peripheral muscle weakness and reduced lung function, even two years post-infection. Several functional tests, such as the Six-Minute Step Test (6MST) and the One-Minute Sit-to-Stand Test (1MSTST), have been validated as reliable, low-cost methods for the assessment of exercise capacity in patients following COVID-19, thereby supplying useful guidance for pulmonary rehabilitation programs.[17] More recently, several systematic reviews reported that RMT in patients following COVID-19 induced significant increases in inspiratory and expiratory muscle strength, reduced dyspnea, improved exercise capacity, and quality of life, although the role of targeted respiratory muscle assessment in the same context remains poorly explored.[18,19] These findings emphasize the need for the assessment of respiratory muscle strength as part of post-COVID-19 rehabilitation strategies.

Previous research has identified correlations between MIP and sit-to-stand test performance in patients with chronic respiratory diseases, particularly chronic obstructive pulmonary disease (COPD).[20] While Indonesia has a high number of COVID-19 survivors, it still lacks structured long-COVID rehabilitation services, with respiratory muscle assessment not always implemented in outpatient settings. Thus, information about the relationship between respiratory muscle strength and functional performance in post-COVID-19 patients is still scant, especially in Indonesian settings. These findings highlight the potential of incorporating MIP and 30s STS into early post-COVID screening protocols, especially in low-resource rehabilitation settings. This study provides locally relevant evidence for integrating respiratory muscle assessment into clinical practice in Indonesia.

This study presents novelty in both its methodological and contextual aspects. Conducted during the COVID-19 pandemic, when access to diagnostic facilities and procedures involving airborne transmission risk was highly restricted, this research offers a practical and safe alternative for evaluating respiratory muscle function and functional capacity using noninvasive measures. The use of Maximum Inspiratory Pressure (MIP) and the 30-second Sit-to-Stand Test (30s STS) provides a simple yet reliable approach to assess post-COVID-19 respiratory performance under limited-resource conditions.

Given the rising number of COVID-19 survivors experiencing prolonged symptoms, evaluating the association between MIP and functional performance is essential for early detection of residual impairments, planning interventions, and guiding pulmonary rehabilitation. Therefore, this study aims to investigate the correlation between MIP and 30s STS performance in post-COVID-19 adults in Indonesia, offering insights relevant for both local clinical practice and the global rehabilitation community.

METHODS

This observational study employed a cross-sectional design to assess the correlation between Maximal Inspiratory Pressure (MIP) and 30-second Sit-to-Stand (30s-STS) test performance among adult patients recovering from COVID-19. Participant recruitment was conducted consecutively to reduce selection bias. The study was carried out in the outpatient physical medicine and rehabilitation clinics of two tertiary referral hospitals in Jakarta, Indonesia: Dr. Cipto Mangunkusumo General Hospital (RSCM) and Persahabatan Hospital (RSP). This study got two ethical clearances, consist of EC Number KET-1339 /UN2.F1/ETIK/PPM.00.02/2023 from RSCM and EC Number 157/KEPK-RSUPP/12/2023 from RSP.

The source population consisted of individuals with a confirmed history of SARS-CoV-2 infection. The study sample comprised patients attending the rehabilitation clinics of the participating hospitals between July 2022 and June 2024. Inclusion criteria were adults aged 18–59 years, confirmed COVID-19 diagnosis by PCR testing at least three months prior to enrollment, ability to follow verbal instructions (Mini-Mental State Examination [MMSE] score ≥25), and provision of written informed consent.

Exclusion criteria included: significant structural postural deformities (e.g., severe scoliosis, kyphosis, lordosis), long-term corticosteroid use, history of mechanical ventilation during ICU admission, severe cardiopulmonary diseases (e.g., advanced COPD, severe asthma, congestive heart failure), balance impairment (Berg Balance Scale score <21), or major motor weakness (Manual Muscle Testing [MMT] score <3).

Sample size was calculated based on correlation analysis, with assumptions of a significance level (α) of 0.05 (Z_a = 1.96), power (1β) of 80% (Z_β = 0.842), and an expected correlation coefficient (r) of 0.5. The minimum required sample size was 30 participants.

The primary independent variable was MIP (cmH□O), assessed using the MicroRPM device. The primary dependent variable was lower-limb functional performance, measured by the total number of complete repetitions in the 30s-STS test. Potential confounders included age, sex, body weight, and height. Operational definitions for all variables were predefined to ensure consistency. Demographic data were collected from government-issued identification; anthropometric data were measured using calibrated equipment. All assessments were conducted by trained healthcare personnel following standardized procedures.

Eligible participants underwent clinical screening that included history taking, physical examination, and evaluation using the MMSE and Berg Balance Scale. Subjects meeting all inclusion and exclusion criteria then proceeded with pulmonary function testing. MIP was measured in a standing position using the MicroRPM, following standard respiratory muscle strength testing protocols. After a 10-minute rest period, participants performed the 30s-STS test on a standardized armless chair. Throughout testing, vital signs––including oxygen saturation, blood pressure, and perceived exertion (measured using the modified Borg scale)––were recorded pre- and post-test to monitor for adverse effects.

Data were analyzed using IBM SPSS Statistics for Windows, Version 25.0. Descriptive statistics were used to summarize participant characteristics and outcome variables. The Kolmogorov–Smirnov test was applied to assess data normality. For normally distributed variables, Pearson correlation analysis was used to evaluate the association between MIP and 30s-STS performance. If variables were non-normally distributed, Spearman's rank correlation was applied. Additional group comparisons were conducted using the Kruskal–Wallis test when appropriate. A two-tailed *p*-value <0.05 was considered statistically significant. Correlation strength was interpreted using the correlation coefficient (r) along with 95% confidence intervals.

RESULTS

A total of 52 individuals were screened for eligibility at two research sites. Of these, 12 participants were excluded: 10 due to difficulties completing the assessment procedures and 2 due to a history of knee arthritis. The remaining 40 subjects met the inclusion

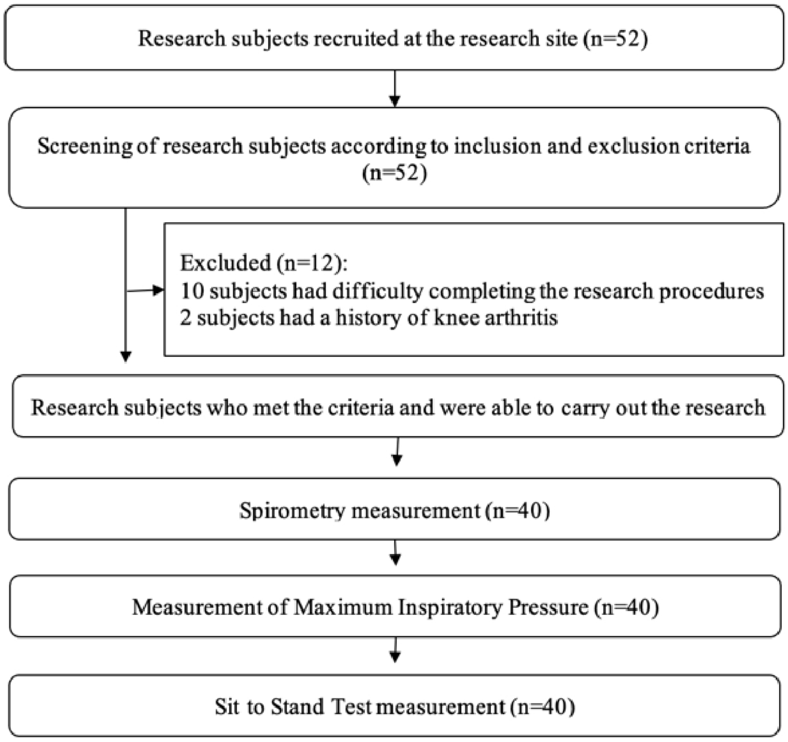

Figure 1. Research Sample Recruitment Flow

criteria and completed the study protocol, which included spirometry, maximal inspiratory pressure (MIP) measurement, and the 30-second sit-to-stand (30s-STS) test. The study received ethical approval.

Among the 40 participants, 15 were male (37.5%) and 25 were female (62.5%). The mean age was 38.80 ± 11.23 years. Nutritional status based on Asia-Pacific BMI classification revealed 2.5% underweight, 20% normal weight, 27.5% overweight at risk, 32.5% obesity class I, and 17.5% obesity class II. Regarding educational background, 72.5% of participants had completed higher education (D1–S2), and 27.5% had completed high school.

Based on time since COVID-19 infection, 5% had recovered within the last year, 47.5% within 1–2 years, and 47.5% more than 2 years prior to the study. Spirometry results indicated normal lung function in 60% of participants, with 25% showing obstructive, 12.5% restrictive, and 2.5% mixed patterns.

The average FEV$_1$ was 2.23 ± 0.57 L, and the mean FVC was 2.84 ± 0.69 L. The mean FEV$_1$/FVC ratio was 81.19%, ranging from 49% to 95%.

The mean 30s-STS score for all subjects was 12.78 ± 2.47 repetitions. Males performed an average of 13 (11–15) repetitions, while females averaged 12 (range 8–20). Participants with a COVID-19 onset <1 year prior achieved the highest average score (13 repetitions), while those with restrictive lung function recorded the highest mean score (14 repetitions) across pulmonary subgroups.

The mean MIP for all subjects was 79 cmH$_2$O (range 60–100). Males exhibited higher mean values 95 cmH$_2$O (range 80–110) cmH$_2$O compared to females 64 cmH$_2$O (range 41–144). The highest average MIP was recorded in the group with COVID-19 onset under 1 year 111 cmH$_2$O (range 91–130). Among pulmonary function groups, the mixed-type group had the highest mean MIP at 91 cmH$_2$O.

Pearson's correlation analysis revealed a statistically significant moderate positive correlation between MIP and 30s-STS test performance ($r = 0.515$, $p = 0.001$). This indicates that individuals with higher inspiratory pressure tended to perform better on the functional sit-to-stand assessment.

DISCUSSION

The mean score for the 30-second sit-to-stand (30s STS) test in this study was 12.78 repetitions, which is substantially lower than the established cutoff of 29 repetitions for detecting functional impairment in patients with mild post-COVID-19 conditions. This finding suggests the presence of residual functional limitations, even among individuals who may not exhibit overt clinical symptoms. Given its simplicity, low cost, and minimal equipment requirements, the 30s STS test serves as a practical screening tool to identify patients who may benefit from targeted rehabilitation interventions during the recovery phase. Study by

TABLE 1
Participant Characteristics

Variable	Subjects (n = 40)
Age (years)	38.80 ± 11.23
Sex, n (%)	
Male	15 (37.5%)
Female	25 (62.5%)
Body Weight (kg)	64.5 (43–116)
Height (cm)	158.83 ± 8.875
Nutritional Status/BMI, n (%)	
Underweight	1 (2.5%)
Normal Weight	8 (20%)
Overweight	11 (27.5%)
Obesity I	13 (32.5%)
Obesity grade II	7 (17.5%)
Education, n (%)	
High School Graduate	11 (27.5%)
College Graduate (D1–S2)	29 (72.5%)
COVID-19 Onset, n (%)	
Less than 1 year	2 (5%)
1–2 years	19 (47.5%)
More than 2 years	19 (47.5%)
Lung Function, n (%)	
Normal	24 (60%)
Obstructive	10 (25%)
Restrictive	5 (12.5%)
Mixed	1 (2.5%)

Amput., *et al* (2025) show results that the 1-min-STST demonstrated outstanding test–retest reliability in post-COVID-19 patients. Lower limb muscular endurance and its contribution to functional ability are assessed using the 1-min-STST. These mechanisms show how well post-COVID-19 patients respond to rehabilitation regimens and carry out daily tasks.[17]

The Sit-to-Stand test has gained increasing attention as a safe and sensitive measure of physical performance in post-COVID-19 patients. In the prospective cohort study by Faria *et al*. (2023), post-COVID-19 patients presented with significantly lower heart rate response and oxygen saturation at the end of the 1MSTST and reduced repetition number compared to recovered patients without post-COVID symptoms. The threshold value below which HRend/HRmax ratio was suggestive of post-COVID-19 condition was established as less than 62.65%, which underlines that STS test is able to unmask subtle exercise intolerance and autonomic dysregulation even when overt pulmonary function abnormalities are absent.[7]

These findings support the inclusion of functional tests, such as STS, in standard post-COVID evaluations, given the potential early impairments of cardiovascular and muscular responses to exercise. Added to MIP, a direct indicator of inspiratory muscle strength, clinicians are able to better describe the relationship between respiratory and systemic limits. Our study indicates that even young, well-educated patients with increased body mass index are showing significant impairment of both

TABLE 2
Spirometry Results

Variable	Value (n=40)
FEV1 (L)	2.23 ± 0.57
FVC (L)	2.84 ± 0.69
FEV1/FVC (%)	81.19 (49 – 95)

TABLE 3
30s Sit-to-Stand Test Results

Variable	Sit to Stand Test (times)
Sex	
Male	13 (11–15)
Female	12 (8–20)
COVID-19 Onset	
Under 1 year	13 (11–15)
1–2 years	13 (11–15)
> 2 years	13 (11–15)
Lung Function	
Normal	13 (11–15)
Obstructive	12 (10–14)
Restrictive	14 (12–16)
Mixed	11

STS performance and MIP values post-COVID-19, reinforcing the concern that post-COVID sequelae are not limited to severe cases or aged individuals. This emphasizes the importance of early, personalized rehabilitation protocols, particularly those utilizing RMT, to enhance ventilatory efficiency, reestablish functional capacity, and prevent long-term deconditioning among all post-COVID-19 survivors, whatever baseline risk.[7]

The average maximal inspiratory pressure (MIP) in this study was 79.03 cmH□O (males 94.6 cmH□O, females 64 cmH□O), which is substantially lower than normative values for healthy young adults, typically exceeding 128 cmH□O in males and 97 cmH□O in females. This reduction reflects persistent inspiratory muscle weakness likely related to post-COVID-19 sequelae such as diaphragmatic or intercostal dysfunction, deconditioning, or direct viral muscle injury, consistent with previous reports showing lingering MIP deficits in recovered patients.[6,21] Similar reductions in MIP have been reported in recent studies showing persistent respiratory muscle weakness months to years after COVID-19 recovery, with inspiratory pressures in the lower range in about 40% of survivors and impaired diffusion capacity.[4,5] Numerous interconnected mechanisms, such as systemic inflammation, microvascular damage, and critical illness-related myopathy, are probably responsible for the reported decrease in respiratory muscle strength. Further factors that may impair muscular contractility and endurance include oxidative stress and ventilator-induced diaphragmatic dysfunction. According to a study by Verduri *et al*. (2024), the use of noninvasive ventilation (NIV), which seems to serve as an independent risk factor, was linked to both MIP and MEP dysfunction. Long-term inspiratory muscle performance may deteriorate because to diaphragmatic deconditioning brought on by prolonged NIV exposure. Overall, these results imply that the cumulative effects of supportive respiratory therapies during the acute phase as well as the direct impacts of the infection itself are reflected in post-COVID-19 respiratory muscle dysfunction.[4] In this respect, direct diaphragmatic

TABLE 4
Maximal Inspiratory Pressure Results

Variable	Maximal Inspiratory Pressure (cmH$_2$O), Median (IQR)
Sex	
Male	95 (80–110)
Female	64 (41–144)
COVID-19 Onset	
Under 1 year	111 (91–130)
1–2 years	75 (60–90)
> 2 years	79 (60–100)
Lung Function	
Normal	74 (41–144)
Obstructive	74 (60–90)
Restrictive	76 (60–95)
Mixed	91

TABLE 5
Correlation Between Maximal Inspiratory Pressure and 30s Sit-to-Stand Test

Variable	Mean ± SD	Correlation Coefficient (r)	*p*-value
Sit to Stand Test	12.78 ± 2.47	0.515	0.001
Maximal Inspiratory Pressure	79.03 ± 26.68		

involvement, as well as systemic myopathy, is likely to be responsible for muscle weakness.[16]

Accumulating evidence indicates that COVID-19 impairs respiratory muscles through a combination of direct viral and secondary systemic mechanisms. SARS-CoV-2 may infect diaphragmatic myofibers via ACE2 receptors, provoking inflammatory and fibrotic remodeling that compromises contractility. In concert, systemic inflammation, microvascular injury, protracted immobilization, and ventilator-associated diaphragm dysfunction promote muscle atrophy and weakness. Additional neural involvement, including phrenic neuropathy and possible injury to central respiratory control pathways, may further contribute to persistent dysfunction. The interaction between these factors yields continued inspiratory muscle weakness, decreased ventilatory efficiency, and chronic exertional dyspnea even in individuals with spared pulmonary parenchyma. Recognition of these mechanisms underlines the clinical relevance of routine respiratory muscle assessment and specific rehabilitation during follow-up care after COVID-19.[16]

Systematic reviews also suggest that RMT significantly improves MIP and MEP and reduces dyspnea and enhances exercise performance in post-COVID-19 patients. These findings support the clinical applicability of inspiratory training as a core component of rehabilitation programs.[19] These findings align with randomized controlled trial evidence demonstrating that structured inspiratory muscle training (IMT) can significantly improve respiratory muscle strength and alleviate breathlessness in long-COVID patients. Collectively, these data underline the reality of sustained inspiratory muscle impairment after COVID-19 and the clinically meaningful benefits of integrating IMT into rehabilitation protocols to restore ventilatory function and reduce exertional dyspnea.[22]

RMT, both inspiratory (IMT) and combined inspiratory-expiratory modality, has emerged as an effective rehabilitation intervention in COVID-19 survivors with persistent dyspnea, fatigue, and reduced exercise capacity. Post-COVID-19 respiratory muscle weakness is multifactorial, resulting from diaphragmatic dysfunction, systemic inflammation, microvascular injury, and prolonged inactivity. RMT directly addresses these mechanisms by applying targeted resistance to breathing, thus stimulating adaptive remodeling of the diaphragm and accessory inspiratory muscles. These adaptations result in enhanced strength, endurance, and ventilatory efficiency through physiological mechanisms similar to skeletal muscle training. Randomized controlled trials and systematic reviews report significant gains in maximal inspiratory and expiratory pressures (MIP and MEP), inspiratory endurance, and functional capacity following a structured RMT program.[19,23,24]

Recent studies further confirm that moderate-intensity, individualized RMT improves respiratory performance and patient self-reported outcomes without untoward effects. Supervised training for six to eight weeks has been shown to enhance inspiratory muscle strength and endurance, decrease perceived breathlessness, and enhance the dyspnea component of quality-of-life instruments such as the Chronic Respiratory Disease Questionnaire. Strengthened inspiratory and expiratory muscles reduce the proportion of maximal effort required during daily activities, decreasing respiratory drive and neural activation and translating to lower dyspnea intensity. Combined inspiratoryexpiratory protocols yield greater improvements in expiratory flow and airway clearance, key components for restoring effective ventilation and reducing respiratory effort during exertion.[19,23,24]

Besides physiological recovery, RMT significantly contributes to functional restoration and the regain of general health in patients post-COVID-19. Participants receiving RMT demonstrate significant improvement in six-minute walk distance, a reduction in exertional dyspnea, and improved health-related quality of life. While spirometric parameters such as FEV□ and FVC usually remain unaltered, these functional and perceptual improvements reflect improved respiratory efficiency and oxygen utilization. Importantly, RMT provided in home-based or telerehabilitation formats has shown excellent adherence and safety, supporting its feasibility in long-term recovery programs. Altogether, these data suggest that RMT is a safe, evidence-based, widely available intervention to promote respiratory muscle reconditioning and reduce dyspnea, thus facilitating the resumption of daily activities in patients with persistent post-COVID-19 sequelae.[19,23,24]

A statistically significant moderate positive correlation was observed between MIP and 30s STS performance (r = 0.515, p = 0.001), indicating that individuals with greater inspiratory strength tended to demonstrate better lower-limb functional capacity. This relationship aligns with previous studies showing a strong association between respiratory muscle strength and functional performance in post-COVID-19 populations. Motta *et al*. reported that more than half of long-COVID patients presented with maximal inspiratory pressures below 80% of predicted values, which were significantly correlated with reduced six-minute walk distance, thereby underscoring the impact of inspiratory weakness on exercise tolerance.[6,25,26] Clinically, this suggests that the 30s STS test may serve as a surrogate marker for inspiratory muscle strength, particularly in resource-limited settings where direct MIP measurement is not feasible. The Sit-to-Stand (STS) test can serve as a functional surrogate because it reflects lower limb strength, endurance, and indirectly respiratory muscle performance. This is based on the physiological link: inspiratory muscles contribute significantly to trunk stabilization during STS movements, and reduced respiratory muscle strength has been shown to correlate with poorer STS performance in post-COVID and chronic respiratory disease patients. Such a surrogate could enhance early identification of patients requiring respiratory rehabilitation.

The combined use of 30s STS and MIP measurements provides a comprehensive yet accessible method for monitoring physical recovery in post-COVID-19 patients. These tools offer valuable insights into both systemic muscle function and respiratory capacity, enabling clinicians to tailor rehabilitation programs according to individual needs. Notably, our study population included younger individuals with relatively high education levels and increased BMI, yet still demonstrated significant reductions in functional and respiratory parameters. This reinforces the need for proactive rehabilitation strategies, even in populations perceived to be at lower risk of severe post-COVID sequelae.[8]

Despite these findings, several limitations must be acknowledged. The sample size was relatively small, and classification of participants based on the severity of initial COVID-19 infection was not performed, limiting generalizability. Moreover, no imaging studies (e.g., chest radiographs or CT scans) were conducted to objectively assess pulmonary pathology, which may have influenced respiratory performance outcomes. The study also faced challenges in participant recruitment, partly due to the evolving public perception of COVID-19 as a commonplace illness. Lastly, a subset of participants initially demonstrated difficulty performing the test procedures correctly; however, this was mitigated through standardized instruction and demonstration by trained assessors. Given the limited access to specialized pulmonary rehabilitation centers in Indonesia, the adoption of MIP and STS assessments in primary care settings could improve early identification of post-COVID functional impairment. Future research is recommended to employ larger, multicenter cohort designs to improve generalizability and allow stratification of participants by the severity of their initial COVID-19 infection. Outcome measures may include maximal inspiratory pressure, sit-to-stand performance, six-minute walk distance, diaphragm excursion, and patient-reported assessments of dyspnea and fatigue. Study populations should encompass post-COVID patients across varying degrees of disease severity, from those managed in the community to ICU survivors, along with healthy control groups, to strengthen external validity.

CONCLUSION

This study demonstrated a moderate but statistically significant correlation between maximal inspiratory pressure (MIP) and 30-second sit-to-stand (30s STS) performance among post-COVID-19 patients, indicating that respiratory muscle strength is closely linked to functional capacity in this population. Although spirometric parameters were generally within normal limits, both inspiratory strength and lower-limb functional performance were notably reduced, suggesting residual respiratory and peripheral muscle dysfunction despite apparent pulmonary recovery. These findings support the clinical utility of the 30s STS test as a simple, reliable, and low-cost surrogate for evaluating inspiratory muscle strength, particularly in settings where direct measurement of MIP is not feasible.

The persistence of respiratory muscle weakness underlines the multifactorial consequences of COVID-19: direct involvement of the diaphragm, systemic inflammation, deconditioning, and potential neural impairment. Thus, the integration of respiratory muscle assessment and targeted interventions, such as respiratory muscle training or inspiratory muscle training, in post-COVID rehabilitation programs may be an important requisite for restoring ventilatory efficiency and reducing exertional dyspnea and improving exercise tolerance. Functional performance tests coupled with respiratory strength measures can provide a more comprehensive approach to monitoring recovery, guiding individualized rehabilitation, and enhancing the quality of life among COVID-19 survivors.

Besides the clinical applications, this study further underscores the need for community-oriented rehabilitation approaches that would enable patients to engage more actively in their own process of recovery. A promotion of self-monitoring of breathing effort and progressive physical reconditioning could lead to even better post-COVID outcomes in daily life.

Future studies should explore longitudinal changes in MIP and STS performance following structured respiratory rehabilitation to determine the extent of reversibility of inspiratory muscle weakness. Establishing normative recovery trajectories could guide the timing and intensity of therapeutic interventions, ultimately improving outcomes for COVID-19 survivors.

ACKNOWLEDGMENT

We thank all study participants and the research team for their contributions. Appreciation is also extended to the staff who supported the study process, and to those who assisted during writing, review, and publication.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

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