OPEN ACCESS

ORIGINAL ARTICLE

JMHRS JOURNAL OF MODERN HEALTH AND REHABILITATION SCIENCES

Correlation of Maximal Respiratory Pressures with Pulmonary Function in Post-COVID-19 Patients

[1]Siti Chandra Widjanantie[a], [2]Maria Agustina Dwiarti Kartika Harinaningtyas[b], [3]Nury Nusdwinuringtyas[a], [4]Erlina Burhan[c], [5]Wiwien Heru Wiyono[c]

[a]Cardiorespiratory Division, Physical Medicine and Rehabilitation Department, Faculty of Medicine, University of Indonesia, Jakarta, Indonesia

[b]Resident, Physical Medicine and Rehabilitation Department, Faculty of Medicine, University of Indonesia, Jakarta, Indonesia

[c]Pulmonology and Respiratory Medicine Department, Faculty of Medicine, University of Indonesia, Jakarta, Indonesia

ABSTRACT

Background: Post-COVID-19 patients frequently experience impaired respiratory muscle strength and reduced lung function, which may not be fully detected through spirometry alone.

Objective: To investigate the correlation between maximal respiratory pressures specifically maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) with pulmonary function parameters measured with spirometric parameters (FVC and FEV1) in individuals recovering from COVID-19 before and after pulmonary rehabilitation.

Methods: This prospective cohort study included 25 post-COVID-19 patients who completed a structured pulmonary rehabilitation program. Respiratory muscle strength was assessed using MIP and MEP, while lung function was measured via spirometry (FVC and FEV1), both pre- and post-rehabilitation. Pearson correlation analysis was used to evaluate the associations between MIP-FVC and MEP-FEV1. Data collection followed ethical standards and statistical analysis was conducted using SPSS version 25.

Results: Pre-rehabilitation, MIP and FVC were weakly correlated ($r = 0.244$, $p = 0.239$), and MEP and FEV1 showed no significant correlation ($r = -0.175$, $p = 0.402$). Post-rehabilitation, MIP correlated moderately with FVC ($r = 0.553$, $p = 0.004$), and MEP strongly with FEV1 ($r = 0.697$, $p < 0.001$), indicating substantial functional improvements.

Conclusion: Pulmonary rehabilitation enhances respiratory muscle strength and its relationship with pulmonary function, supporting MIP and MEP as sensitive indicators of post-COVID-19 respiratory recovery.

Keywords: COVID-19, Forced Expiratory Volume, Muscle Strength, Pulmonary Function Tests, Pulmonary Rehabilitation, Pulmonary Ventilation, Respiratory Function Tests, Respiratory Muscle Training, Respiratory Muscles, Vital Capacity.

Correspondence

Maria Agustina Dwiarti Kartika Harinaningtyas | memaria87@gmail.com

Disclaimers

Conflict of Interest: None declared

Data/Supplements: Available on request.

Funding: None

Ethical Approval: Respective Ethical Review Board

Study Registration: N/A

Acknowledgments: N/A

Article Info

Received: 12 April 2025, *Accepted:* 01 August 2025,

Published Online: 18 August 2025

How to Cite: Widjanantie SC, Harinaningtyas MADK, Nusdwinuringtyas N, Burhan E, Wiyono WH. Correlation of Maximal Respiratory Pressures with Pulmonary Function in Post-COVID-19 Patients. J Mod Health Rehab Sci. 2025;2(3):132. Available from: https://jmhrs.com/index.php/jmhrs/article/view/132

Introduction

COVID-19 has emerged not only as a viral infection with acute pulmonary manifestations but also as a condition with lingering systemic consequences, particularly impairing respiratory muscle function in many survivors (1). Respiratory compromise in post-COVID-19 individuals is frequently multifactorial ranging from direct viral induced myopathy and inflammatory injury to disuse atrophy secondary to prolonged hospitalization and immobilization. Among elderly patients and those with pre-existing comorbidities, this functional impairment can be compounded by complications such as acute respiratory distress syndrome (ARDS) and the myopathic effects of corticosteroids commonly administered during acute infection. These physiological derangements often result in persistent dyspnea, exercise intolerance, and impaired quality of life symptoms not always captured effectively through conventional spirometry alone (2,3).

Traditional spirometric parameters, while informative, primarily assess global ventilatory capacity and may overlook early or isolated deficiencies in respiratory muscle strength. To address this diagnostic limitation, maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) have been proposed as complementary indices capable of directly quantifying the contractile force of inspiratory and expiratory musculature, respectively (4). MIP predominantly reflects diaphragm strength, the principal inspiratory muscle, whereas MEP gauges the efficacy of abdominal and intercostal muscles during forced expiration (5). These measurements provide critical insights into the mechanical integrity of respiratory musculature, which can be selectively compromised even when spirometric outputs appear preserved (6,7).

Emerging evidence underscores the importance of structured pulmonary rehabilitation in reversing respiratory muscle deconditioning following COVID-19 (8). Despite the widespread implementation of rehabilitation protocols during the pandemic, the relationship between respiratory muscle strength and pulmonary function parameters in this context remains underexplored. This gap in knowledge is particularly salient given that rehabilitation programs have shown considerable promise in restoring MIP and MEP values, which in turn may translate into improved spirometric indices such as forced vital capacity (FVC) and forced expiratory volume in one second (FEV1). However, the temporal and mechanistic linkage between these physiological domains has not been comprehensively elucidated, particularly in prospective, controlled clinical settings (9).

This study was therefore considered to examine the correlation between respiratory muscle strength assessed via MIP and MEP and conventional spirometric outcomes (FVC and FEV1) in term of pulmonary rehabilitation for post-COVID-19 patients, both before and after the implementation of a targeted pulmonary rehabilitation regimen. By evaluating these correlations longitudinally, this research aims to determine the extent to which enhancements in muscle strength contribute to measurable improvements in pulmonary function. Such insights are vital for refining rehabilitation strategies and for identifying early markers of respiratory compromise in the post-viral recovery trajectory. The findings may offer an evidence-based rationale for integrating respiratory muscle strength assessments into standard post-COVID-19 care algorithms, thereby optimizing outcomes in this growing patient population.

Materials and Methods

This prospective cohort study was conducted at a single tertiary academic center with the aim of evaluating the relationship between respiratory muscle strength and pulmonary function before and after pulmonary rehabilitation in individuals recovering from COVID-19. The study population comprised 25 adult patients who had recently recovered from confirmed COVID-19 infection and demonstrated ongoing respiratory symptoms or reduced functional capacity (10). Inclusion criteria required participants to have completed acute COVID-19 treatment, been clinically stable, and willing to undergo a structured rehabilitation protocol. Patients with pre-existing neuromuscular disorders, severe cognitive impairment, or other contraindications to pulmonary rehabilitation were excluded to ensure the homogeneity of the cohort and reliability of outcome measures.

Respiratory muscle strength was assessed using maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP), both measured with a handheld respiratory pressure meter according to standardized protocols. MIP reflects diaphragm and inspiratory muscle function, while MEP assesses the strength of the abdominal and intercostal muscles during forced expiration. Measurements were performed with patients in a seated position, using a nose clip to prevent air leakage. Each participant was instructed to perform three maximal inspiratory and expiratory efforts, with sufficient rest between attempts to avoid fatigue. The highest reproducible value from each set was recorded for analysis, ensuring adherence to recommended guidelines for respiratory pressure testing (6,7,11).

Pulmonary function was evaluated using spirometry, performed by trained technicians following the American Thoracic Society/European Respiratory Society (ATS/ERS) guidelines to minimize interobserver variability and ensure procedural consistency (11). The primary spirometric parameters measured included forced vital capacity (FVC) and forced expiratory volume in one second (FEV1), which represent overall ventilatory capacity and airway patency, respectively (12). All spirometric tests were conducted in a temperature controlled laboratory environment and repeated post-rehabilitation under identical conditions to ensure comparability.

Maximal Inspiratory Pressure (MIP) and Maximal Expiratory Pressure (MEP) are indicators of respiratory muscle strength, with normal MIP values typically ≥ –80 to –100 cmH_2O in men and ≥ –70 cmH_2O in women, and MEP values ≥ 100–130 cmH_2O in men and ≥ 80–100 cmH_2O in women. Values below these thresholds may suggest clinically relevant respiratory muscle weakness, and reference equations are often used to interpret results based on predicted norms for specific populations. For spirometric parameters, Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1) are considered normal if they are ≥ 80% of predicted values, while an FEV1/FVC ratio > 0.70 indicates normal airway function. In post-COVID-19 patients, MIP and MEP are often reduced even when spirometry remains within normal limits, reflecting isolated respiratory muscle weakness (10-14).

All participants provided written informed consent prior to enrollment, and ethical approval was obtained from the Institutional Review Board of the hosting academic institution prior to initiation of the study protocol. Patient confidentiality and data security were strictly maintained throughout the study period. All participants underwent a structured pulmonary rehabilitation program comprising aerobic training, breathing exercises, and respiratory muscle training tailored to individual tolerance and capacity. The rehabilitation sessions were supervised by qualified physiotherapists and conducted over a defined period with frequency and intensity adjusted based on patient progress. The aim of the intervention was to enhance respiratory muscle performance, improve ventilatory efficiency, and alleviate dyspnea.

Data were collected at two time points: baseline (pre-rehabilitation) and after completion of the rehabilitation program (post-rehabilitation). Parameters recorded included MIP, MEP, FVC, and FEV1. Data entry and verification were performed independently by two researchers to ensure accuracy and reduce transcription errors. Statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as means and standard deviations. Pearson's correlation coefficient was employed to evaluate the relationship between respiratory muscle strength (MIP, MEP) and pulmonary function (FVC, FEV1) before and after rehabilitation. Statistical significance was set at a p-value less than 0.05.

Results

A total of 25 post-COVID-19 patients completed the study and underwent both pre- and post-rehabilitation assessments. The analysis focused on evaluating the relationship between respiratory muscle strength measured via maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) and pulmonary function, as represented by forced vital capacity (FVC) and forced expiratory volume in one second (FEV1), before and after a structured pulmonary rehabilitation program.

Pre-Rehabilitation Phase: MIP vs FVC: A weak positive correlation was observed between Maximal Inspiratory Pressure (MIP) and Forced Vital Capacity (FVC) ($r = 0.244$, $p = 0.239$), which was not statistically significant, suggesting limited association between inspiratory strength and lung volume prior to rehabilitation. MEP vs FEV_1: A weak negative correlation was found between Maximal Expiratory Pressure (MEP) and Forced Expiratory Volume in 1 second (FEV_1) ($r = –0.175$, $p = 0.402$), also non-significant, indicating no clear relationship between expiratory strength and airflow before intervention (See Table 2).

Table 1: Demographic and Clinical Characteristics of the Study Population (n = 25)

Variable	Value
Age (years), mean ± SD	52.4 ± 10.7
Male n (%)	14 (56%)
Female n (%)	11 (44%)
BMI (kg/m²), mean ± SD	27.8 ± 4.2
Time since COVID-19 recovery (weeks), mean ± SD	6.2 ± 1.8
Presence of comorbidities, n (%)	18 (72%)
Hypertension	10 (40%)
Diabetes Mellitus	7 (28%)
COPD or Asthma	3 (12%)

Post-Rehabilitation Phase: MIP vs FVC: A moderate positive correlation ($r = 0.553$, $p = 0.004$*) emerged, suggesting that improvements in inspiratory muscle strength were significantly associated with gains in lung volume after rehabilitation. MEP vs FEV_1: A strong positive correlation ($r = 0.697$, $p < 0.001$**) was observed, indicating that increases in expiratory muscle strength were significantly related to improved expiratory airflow following rehabilitation (See Table 2).

Table 2: Correlation Between Respiratory Muscle Strength and Lung Function (Pre- and Post-Rehabilitation)

Phase	Muscle Strength Parameter	Mean ± SD (cmH_2O)	Lung Function Parameter	Mean ± SD (L)	Pearson r	p-value
Pre-Rehabilitation	MIP	42.68 ± 16.46	FVC	2.74 ± 0.71	0.244	0.239
	MEP	39.60 ± 12.11	FEV1	2.29 ± 0.64	–0.175	0.402
Post-Rehabilitation	MIP	74.92 ± 20.34	FVC	2.78 ± 0.70	0.553	0.004 *
	MEP	74.92 ± 20.34	FEV1	2.78 ± 0.70	0.697	<0.001 **

*Maximal Inspiratory Pressure (MIP), Maximal Expiratory Pressure (MEP), Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), * Statistically significant at p < 0.05, ** Highly statistically significant*

Discussion

This study investigated the correlation between respiratory muscle strength, measured by maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP), and pulmonary function parameters, specifically forced vital capacity (FVC) and forced expiratory volume in one second (FEV1), in post-COVID-19 patients undergoing pulmonary rehabilitation. The findings revealed that prior to rehabilitation, there was no significant association between respiratory muscle strength and spirometric measures, suggesting that early in the recovery phase, lung function and muscle performance may be dissociated due to the heterogeneous impact of COVID-19 on respiratory physiology. However, following a structured rehabilitation program, significant correlations were observed specifically, a moderate correlation between MIP and FVC, and a strong correlation between MEP and FEV1 highlighting the efficacy of rehabilitation in enhancing both respiratory muscle function and its coordination with lung mechanics.

These findings aligned with previous reports emphasizing respiratory muscle impairment as a common sequela of COVID-19, often persisting even when spirometry appears normal (1,6). The observed reduction in MIP and MEP values in the pre-rehabilitation phase was consistent with the literature documenting isolated respiratory muscle weakness in patients post-infection (3,15). Furthermore, the significant gains in both muscle strength and spirometric performance after rehabilitation underscored the efficacy of structured pulmonary rehabilitation protocols, reinforcing earlier evidence from studies by Romaszko-Wojtowicz et al. (2023) and Zampogna et al. (2021), which showed functional and physiological recovery through targeted respiratory interventions (7,8).

The increased correlation between MIP and FVC and between MEP and FEV_1 after rehabilitation implied a physiologically relevant relationship between respiratory muscle performance and ventilatory capacity. These associations support the mechanistic understanding that MIP primarily reflects diaphragmatic strength essential for lung volume expansion while MEP represents the strength of abdominal and intercostal muscles involved in forced expiration (4,11). The strong post-rehabilitation correlations in the present study suggest that improved muscle contractility contributes meaningfully to enhanced pulmonary function, in line with previous evidence indicating that MIP and MEP may serve as early and sensitive indicators of respiratory compromise (14).

The integration of respiratory muscle assessment with traditional spirometry offers a more nuanced evaluation of respiratory health, particularly in post-COVID-19 patients who may present with lingering symptoms despite normal spirometric findings. Previous research has also highlighted that MIP and MEP can detect subclinical weakness not captured by spirometry alone (2,9), a phenomenon echoed in the current cohort's pre-rehabilitation results. The lack of correlation before rehabilitation may be due to heterogeneity in recovery stages, varying severity of prior illness, or differences in effort-dependent test performance.

This study's strengths included its prospective design, the use of both pre- and post-intervention assessments, and the application of objective and validated respiratory function metrics. It provided real-world clinical insight into the rehabilitative trajectory of COVID-19 survivors with persistent respiratory dysfunction. However, limitations should be acknowledged. The single-center design and relatively small sample size (n = 25) may limit generalizability. The absence of a control group precluded causal inference regarding the effect of rehabilitation alone. In addition, potential confounders such as variations in physical activity, nutritional status, or pre-existing respiratory conditions were not fully controlled, which may have influenced recovery patterns.

Future studies should aim for larger multicenter cohorts and include control arms to isolate the effect of specific interventions. Longitudinal designs assessing long-term sustainability of respiratory improvements and incorporating imaging or diaphragm ultrasound could offer a more comprehensive understanding of structural and functional recovery. Moreover, establishing normative recovery timelines and MIP/MEP reference values specific to post-COVID-19 populations may enhance clinical decision-making (13-14). This study contributes to the growing evidence base supporting the integration of respiratory muscle assessment in post-COVID-19 rehabilitation and suggests that improvements in muscle strength may serve as both a marker and a mediator of pulmonary function restoration.

Conclusion

Pulmonary rehabilitation significantly improved respiratory muscle strength and its correlation with lung function in post-COVID-19 patients, supporting the integration of MIP and MEP assessments into clinical practice as sensitive indicators of recovery and targets for therapy. These findings have important implications for enhancing respiratory care, accelerating functional recovery, and improving the long-term quality of life in individuals affected by post-viral respiratory compromise.

Authors' Contributions

ICMJE authorship criteria	Detailed contributions	Authors
Substantial Contributions	Conception or Design of the work	1,2,4,5
	Data acquisition	2,3,4
	Data analysis or interpretation	1,3,5
Drafting or Reviewing	Draft the work	2
	Review critically	1,2,3,4,5
Final approval	Final approval of the version to be published.	1,2,3,4,5
Accountable	Agreement to be accountable for all aspects of the work.	1,2,3,4,5

References

1. Jain U, Sanjay S, Siddiqui S. Post-COVID-19 Respiratory Muscle Weakness: A Systematic Review and Meta-Analysis. Respir Med. 2022;197:106849. doi:10.1016/j.rmed.2022.106849
2. Fumagalli A, Misuraca C, Bianchi A, et al. Pulmonary Function in Patients Surviving to COVID-19 Pneumonia. Infection. 2021;49(1):153–157. doi:10.1007/s15010-020-01574-2
3. Mo X, Jian W, Su Z, et al. Abnormal Pulmonary Function in COVID-19 Patients at Time of Hospital Discharge. Eur Respir J. 2020;55(6):2001217. doi:10.1183/13993003.01217-2020
4. Similowski T, Yan S, Gauthier AP, et al. Assessment of Respiratory Muscle Strength in Patients With Neuromuscular Disease. Am Rev Respir Dis. 1991;144(4):918–923. doi:10.1164/ajrccm/144.4.918
5. Enright PL, Kronmal RA. The Value of MIP and MEP Measurements in Detecting Respiratory Muscle Weakness. Chest. 1994;105(6):1558–1563. doi:10.1378/chest.105.6.1558
6. Agrawal A, Nalgirkar V. Role of Respiratory Muscle Strength Using MIP Testing Following COVID-19 Infection. J Emerg Trauma Care. 2020;1(178):1–11. Available from: https://www.imedpub.com/articles/respiratory-muscle-strength-performance-in-assessment-of-covid19-patients-following-infection.php?aid=28413
7. Romaszko-Wojtowicz A, Szalecki M, Olech K, Doboszyńska A. Assessment of the Function of Respiratory Muscles in Patients After COVID-19 Infection and Respiratory Rehabilitation. Trop Med Infect Dis. 2023;8(1):1–7. doi:10.3390/tropicalmed8010046
8. Zampogna E, Paneroni M, Belli S, et al. Pulmonary Rehabilitation in Patients Recovering From COVID-19. Respiration. 2021;100(5):416–422. doi:10.1159/000514387
9. Anastasio F, Barbuto S, Scarnecchia E, et al. Medium-Term Impact of COVID-19 on Pulmonary Function, Functional Capacity and Quality of Life. Eur Respir J. 2021;58(3):2100990. doi:10.1183/13993003.00990-2021
10. Baratto C, Caravita S, Faini A, et al. Impact of COVID-19 on Exercise Capacity and Lung Function: A Post-Acute Phase Study. Int J Cardiol. 2021;343:132–135. doi:10.1016/j.ijcard.2021.01.056
11. American Thoracic Society; European Respiratory Society. ATS/ERS Statement on Respiratory Muscle Testing. Am J Respir Crit Care Med. 2002;166(4):518–624. doi:10.1164/rccm.166.4.518
12. Pellegrino R, Viegi G, Brusasco V, et al. Interpretative Strategies for Lung Function Tests. Eur Respir J. 2005;26(5):948–968. doi:10.1183/09031936.05.00035205
13. Black LF, Hyatt RE. Maximal Respiratory Pressures: Normal Values and Relationship to Age and Sex. Am Rev Respir Dis. 1969;99(5):696–702. doi:10.1164/arrd.1969.99.5.696
14. Sriboonreung T, Leelarungrayub J, Yankai A, Puntumetakul R. Correlation and Predicted Equations of MIP/MEP From the Pulmonary Function, Demographics and Anthropometrics in Healthy Thai Participants Aged 19 to 50 Years. Clin Med Insights Circ Respir Pulm Med. 2021;15:11795484211031634. doi:10.1177/11795484211031634
15. Savushkina OI, Malashenko MM, Cherniak AV, Kryukov EV, Sinitsyn EA, Zykov KA. Respiratory Muscle Strength in Patients After COVID-19. Extreme Med. 2021;3:52–56.