Journal of Advances in Medicine and Medical Research

Volume 35, Issue 21, Page 274-283, 2023; Article no.JAMMR.106436
ISSN: 2456-8899
(Past name: British Journal of Medicine and Medical Research, Past ISSN: 2231-0614, NLM ID: 101570965)

An Update of Cardiopulmonary Rehabilitative Measures in Long-COVID-19 Patients: A Systematic Review

Lubna Sattar [a*], Ngozi Amanze [b], Filagot D. Eshete [c], Ferdinand Ugwuja [d], Ahmed R. Abdelwahed [e], Chijioke Okonkwo [b], Husna Shahnoor [f], Halimah Aderinsola Adekoya [g], Durgaprasad Gadireddi [h], Olusayo Louise-Oluwasanmi [i], Sidra Shahid Mubasher [j], Agho Osamede [k], Ghulam Muhammad Humayun [l], Isabella Vittorino Mejia [m] and Patrick Batti [b]

[a] Shadan Institute of Medical Sciences, India.
[b] American University of Antigua, Barbuda.
[c] Miami Valley Hospital, USA.
[d] Richmond Gabriel University, St Vincent and the Grenadines.
[e] Menoufia University Faculty of Medicine, Egypt.
[f] Deccan College of Medical Sciences, India.
[g] Washington University of Health and Sciences, Belize.
[h] Bhaskar Medical College, India.
[i] Howard University, USA.
[j] University Medical and Dental College, Pakistan.
[k] Oba Okunade Sijuade School of Medicine, Igbinedion University, Nigeria.
[l] Allama Iqbal Medical College, Pakistan.
[m] Universidad Libre Seccional Barranquilla, Colombia.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMMR/2023/v35i215233

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/106436

**Corresponding author: E-mail: lubnashariqsattar@gmail.com;*

Systematic Review Article

Received: 15/07/2023
Accepted: 19/09/2023
Published: 27/09/2023

ABSTRACT

Background: The long-term effects of COVID-19 on patients have become an emergent concern. This systematic review aims to evaluate the effectiveness of various post-acute care interventions for COVID-19 patients.
Methods: A comprehensive literature search was conducted in accordance with PRISMA guidelines across three databases: PubMed, Scopus, and Web of Science. The studies were independently evaluated by two reviewers based on their relevance to the research question, which pertains to the effectiveness of interventions such as home-based pulmonary rehabilitation, inspiratory muscle training, pharmacological treatments, and novel technological methods.
Results: Our review included seven studies, each demonstrating improvement in physical and respiratory function, as well as in quality of life, following diverse interventions. Home-based pulmonary rehabilitation, with and without telecoaching, appeared to improve functional outcomes and decrease dyspnea and fatigue. Pharmacological interventions, such as Treamid, showed promise, particularly in women. EMG-driven rehabilitation robots demonstrated feasibility and safety, while H2 inhalation may also be a viable approach.
Conclusion: Post-acute care interventions, tailored to individual patient needs, can potentially improve health outcomes in COVID-19 patients. However, the heterogeneity of the included studies necessitates further large-scale randomized controlled trials to definitively ascertain the effectiveness of these interventions.

Keywords: COVID-19; post-acute care; pulmonary rehabilitation; inspiratory muscle training; pharmacological treatment; Telecoaching; H2 inhalation.

1. INTRODUCTION

“The SARS-CoV-2 virus, responsible for Coronavirus Disease 2019 (COVID-19), has precipitated a global health crisis due to its high transmissibility and significant morbidity and mortality” [1]. To date, nearly 768 million confirmed cases and millions of associated fatalities have been reported worldwide [2]. In response to this unrelenting pandemic, the global scientific community has rapidly mobilized to elucidate the disease’s transmission, prevention, and treatment strategies. However, as the pandemic's trajectory unfolds, a pressing need has emerged to address the long-term sequelae of COVID-19 and effective post-acute care strategies [3].

“Accruing evidence suggests that a significant subset of COVID-19 survivors, colloquially known as 'long haulers,' continue to endure persistent symptoms following the acute phase of the infection” [4]. The observed post-acute COVID-19 symptoms span multiple organ systems—including respiratory, cardiovascular, and neurological—and manifest in various forms, such as dyspnea, fatigue, cognitive impairment, and diminished exercise capacity [5]. Furthermore, patients who experienced severe COVID-19 often report functional and mental health deterioration, adversely impacting their quality of life [6,7]. These findings highlight the criticality of efficacious post-acute care interventions in mitigating COVID-19's long-term impacts and facilitating patient recovery.

Pulmonary rehabilitation, a recognized intervention for chronic respiratory diseases, may hold promise for enhancing lung function and exercise capacity in COVID-19 survivors, given the virus's primary respiratory system involvement [8]. Home-based pulmonary rehabilitation, telecoaching, and inpatient pulmonary rehabilitation are some of the modalities being explored for managing post-COVID-19 sequelae [9].

Simultaneously, pharmacological interventions such as Treamid have been demonstrated to potentially improve lung function in post-COVID patients exhibiting lung fibrosis [10]. Non-pharmacological interventions, including inspiratory muscle training and molecular hydrogen inhalation, have also been investigated for their putative benefits in post-acute COVID-19 care [11,12].

In parallel, technologies, such as EMG-driven rehabilitation robots, have been deployed to counter post-viral fatigue syndrome—a common debilitating symptom in COVID-19 survivors [13]. Additionally, respiratory rehabilitation training has been proposed to ameliorate respiratory function, enhance quality of life, and assuage anxiety in elderly COVID-19 patients [14,15].

Given the array of interventions under investigation, there is an urgent requirement to comprehensively understand their effectiveness in managing post-acute COVID-19 scenarios. This systematic review aims to bridge this knowledge gap by compiling and critically appraising the existing literature on various post-acute care interventions for COVID-19 patients. By systematically evaluating the most recent literature, this review seeks to provide a thorough understanding of these interventions' efficacy, thereby guiding healthcare providers in informed decision-making regarding post-acute COVID-19 care management. Furthermore, the outcomes of this review will lay a robust groundwork for future research endeavors in this crucial healthcare domain.

2. METHODS

We adhered to PRISMA Statement 2020 guidelines [16]. The primary objective of this review is to conduct a comprehensive evaluation of the recent literature assessing the efficacy of various interventions in managing post-COVID complications. The research question is: What are the most effective interventions in the management of post-COVID complications?

2.1 PICO Framework

The PICO framework for this systematic review is as follows:

- Population: Patients with post-COVID complications
- Intervention: Various interventions for post-COVID care including pharmacological treatments, rehabilitation programs, and novel therapies
- Comparison: Standard care or other treatments for post-COVID complications, control groups receiving placebo or no intervention
- Outcome: Changes in clinical, functional, and quality of life measures, complications, side effects, and other relevant health outcomes post-intervention

2.2 Search Strategy

The systematic literature search focused on studies published between 2020 and 2023 to include the most recent and relevant research findings. This search was executed across three databases: PubMed, Scopus, and Web of Science, to locate pertinent studies. Keywords and MeSH terms such as 'Post-COVID Complications', 'COVID-19', 'Long COVID', 'Intervention', 'Treatment', 'Clinical Trial', 'Efficacy', 'Safety', among others, and their combinations were used for the search. No restrictions were applied based on language or geographical location, and only peer-reviewed articles were considered eligible for inclusion.

2.3 Study Selection

The articles retrieved from the initial search were independently evaluated by two reviewers based on their titles and abstracts to determine their relevance to the topic of post-COVID complications and various interventions in their management. Any disagreements between the reviewers were resolved through discussion or by consulting a third reviewer if necessary. The full texts of the shortlisted articles were procured for further in-depth review. Studies were included if they met the following criteria: original research studies published between 2020 and 2023, studies focusing on the role of various interventions in managing post-COVID complications, and studies that provided adequate data for extraction and analysis.

2.4 Data Extraction

Data from the included studies were systematically extracted by the research team. The data extracted included the following details: author names, year of publication, study design, intervention, population characteristics, main results, and clinical implications. The extracted data were then synthesized and analyzed qualitatively. The primary findings were compiled and summarized. This provided an overview of the current state of interventions in managing post-COVID complications.

2.5 Data Analysis Post-Extraction

After data extraction, the analysis was conducted qualitatively due to the heterogeneity of the included studies. The information gathered ranged from study design to clinical implications

and main results. Each study was scrutinized to understand its contribution to the research question concerning effective interventions for post-COVID complications. Given the diverse range of interventions and outcomes reported, a narrative synthesis approach was employed to compare the effectiveness of the interventions. The primary findings from each study were compiled, and patterns or themes identified were brought together to give a comprehensive overview of current knowledge in this area. While a meta-analysis was not performed due to the qualitative nature of the data synthesis, the qualitative analysis allowed for a nuanced understanding of the existing evidence, highlighting the complexities and potentials of various post-COVID care interventions.

3. RESULTS

Of the 227 studies identified, 19 were removed before screening. In the screening phase, 208 were screened for titles and abstracts. Of these, 179 were excluded for lack of relevance. In total, 29 studies were assessed for full-text eligibility, of which 7 were included in the systematic review.

The characteristics of the included studies are tabulated and presented in Table 1.

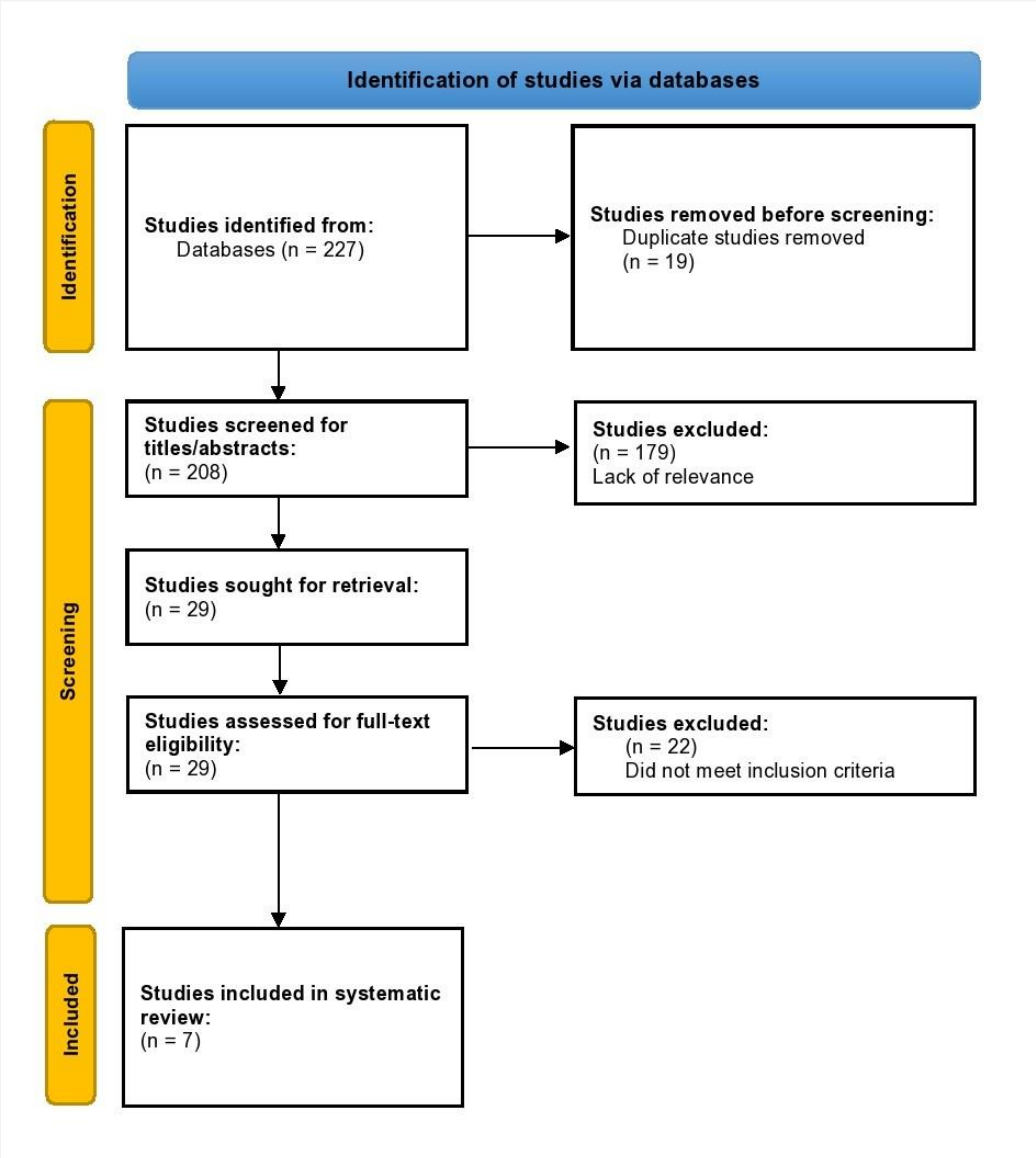

Fig. 1. PRISMA flowchart depicting the study selection process

Table 1. Characteristics of all the included studies

Author, Year	Title	Study Design	Intervention	Population Characteristics	Main Results	Implications for Post-COVID-Care
Şahın, 2023	Effects of a home-based pulmonary rehabilitation program with and without telecoaching on health-related outcomes in COVID-19 survivors: a randomized controlled clinical study	Randomized control trial	Home-based pulmonary rehabilitation (PR) program with and without telecoaching	42 COVID-19 patients who completed medical treatment	-Both groups improved FVC, six-minute walk distance, right and left deltoid muscle strength, Saint George's Respiratory Questionnaire activity and impact domain scores, and SF-36 scores (P< 0.05) -Decreases in daily-life dyspnea, exertional dyspnea, and exertional fatigue were significant in the study group (P< 0.05) -The improvement in SF-36 social functioning domain scores was greater in the study group (P<0.05)	Home-based PR with telecoaching can lead to improved social functioning and decreased dyspnea and fatigue in post-COVID patients
Vallier, 2023	Randomized controlled trial of home-based vs. hospital-based pulmonary rehabilitation in post COVID-19 patients	Randomized control trial	Comparison of inpatient pulmonary rehabilitation (IPR) and home-based pulmonary rehabilitation (HPR)	17 post-COVID-19 patients randomized into two groups for IPR or HPR	Both groups improved 6MWT distance (IPR +95 m vs. HPR +72 m, P<0.001), with no significant interaction between time and group (P=0.420)	Home-based pulmonary rehabilitation could be as effective as inpatient rehabilitation in alleviating physical sequelae in post-COVID-19 patients
Bazdyrev, 2022	Efficacy and safety of Treamid in the rehabilitation of patients after COVID-19 pneumonia: a phase 2, randomized, double-blind, placebo-controlled trial	Phase 2, randomized, double-blind, placebo-controlled clinical trial	Comparison of Treamid 50 mg or placebo peroral administration for 4 weeks	Post-COVID patients with lung fibrosis and decreased lung function randomized into two groups to receive Treamid or placebo	-The Treamid group (41%), compared to the placebo group (17%), showed significantly improved FVC and/or DLCO (P=0.036) -The modified Borg scale showed a significant reduction in dyspnea in the Treamid group (- 0.9 0.7 vs. - 0.4 0.8, P=0.018) -Exploratory analysis showed superior improvement in the female population in the Treamid group	Treamid might be a promising pharmacological treatment for long-term sequelae in post-COVID patients, particularly in women. This finding supports further investigation in future clinical trials
Botek, 2022	Molecular Hydrogen Positively Affects Physical and Respiratory Function	Randomized, single-blind, placebo-controlled study	Inhalation of molecular hydrogen (H2) for 14 days; twice for a total of	Acute post-COVID-19 patients (26 males, 24 females) randomized into	In comparison to placebo, H2 therapy increased 6MWT distance by 64 ± 39 m, FVC	H2 inhalation may be a safe, effective approach for improving physical and

Author, Year	Title	Study Design	Intervention	Population Characteristics	Main Results	Implications for Post-COVID-Care
	in Acute Post-COVID-19 Patients: A New Perspective in Rehabilitation		one hour each per day	two groups, one receiving H2 and the other receiving a placebo	by 0.19 ± 0.24 L, and FEV1 by 0.11 ± 0.28 L (all P≤0.025)	respiratory function in acute post-COVID-19 patients
Palau, 2022	Effect of a home-based inspiratory muscle training programme on functional capacity in postdischarged patients with long COVID: the InsCOVID trial	Single-center, blinded assessor, randomized controlled trial	Home-based inspiratory muscle training (IMT) programme	26 patients with long COVID and a previous admission due to SARS-CoV-2 pneumonia randomly assigned to receive either a 12-week IMT or usual care alone	-The IMT group significantly improved their peak oxygen consumption (peak VO2) compared with the usual care group (P<0.001) -Positive findings were also observed in the chronotropic index and some quality-of-life dimensions	IMT improved exercise capacity and quality of life in long-term COVID patients with SARS-CoV-2 pneumonia
Zasadzka, 2022	Application of an EMG-Rehabilitation Robot in Patients with Post-Coronavirus Fatigue Syndrome (COVID-19)-A Feasibility Study	Pilot study	EMG-driven rehabilitation robot	Patients with Post-Viral Fatigue (PVF) syndrome after COVID-19 randomly assigned to two groups, one with and one without the intervention	-Both groups improved in most measured parameters except for muscle fatigue -Muscle fatigue scores presented non-significant improvement in the intervention group and non-significant deterioration in the control group	Using an EMG rehabilitation robot in patients with PVF can be feasible and safe; more evidence is required to corroborate findings
Liu, 2020	Respiratory rehabilitation in elderly patients with COVID-19: A randomized controlled study	Observational, prospective, quasi-experimental study	Six-week respiratory rehabilitation training	72 elderly patients with COVID-19 with 36 of them undergoing respiratory rehabilitation and the rest receiving no intervention	-The intervention group showed significant improvements in FEV1(L), FVC(L), FEV1/FVC%, DLCO%, and 6-min walk test -SF-36 scores, in 8 dimensions, and SAS anxiety scores were statistically significant within the intervention group and between the two groups -SDS depression scores showed little significant improvement	Six-week respiratory rehabilitation improves elderly COVID-19 patients' respiratory function, quality of life, and anxiety, but not depression

Abbreviations: 6MWT stands for Six-minute walk test; COVID-19 is an abbreviation for Coronavirus Disease 2019; DLCO represents Diffusing Capacity of the Lung for Carbon Monoxide; EMG is short for Electromyography; FEV1 refers to Forced Expiratory Volume in 1 second; FVC stands for Forced Vital Capacity; H2 is an abbreviation for Molecular Hydrogen; HPR represents Home-based Pulmonary Rehabilitation; IMT is an abbreviation for Inspiratory Muscle Training; IPR stands for Inpatient Pulmonary Rehabilitation; L is short for Liter; M refers to Meter; PR represents Pulmonary Rehabilitation; PVF is an abbreviation for Post-Viral Fatigue; SAS stands for Self-Rating Anxiety Scale; SDS is short for Self-Rating Depression Scale; SF-36 refers to 36-Item Short Form Survey; VO2 is an abbreviation for Oxygen Consumption

The study by Şahın [17] implemented "a randomized control trial design to test a home-based pulmonary rehabilitation (PR) program both with and without telecoaching on 42 post-COVID patients" [17]. Notably, both intervention groups showed improvements in Forced Vital Capacity (FVC), six-minute walk distance, right and left deltoid muscle strength, Saint George's Respiratory Questionnaire activity and impact domain scores, and SF-36 scores. However, the telecoaching group demonstrated more significant improvements in social functioning and decreased daily-life dyspnea, exertional dyspnea, and exertional fatigue. These findings suggest that home-based PR with telecoaching can lead to improved social functioning and decreased dyspnea and fatigue in post-COVID patients.

Next, a study by Vallier [18] randomized "17 post-COVID-19 patients into two groups to receive either inpatient pulmonary rehabilitation (IPR) or home-based pulmonary rehabilitation (HPR)" [18]. Both groups improved 6-minute walk test (6MWT) distance (IPR +95 m vs. HPR +72 m, $P<0.001$), with no significant interaction between time and group ($P=0.420$). These results suggest that home-based pulmonary rehabilitation could be as effective as inpatient rehabilitation in alleviating physical sequelae in post-COVID-19 patients.

Bazdyrev [19] conducted a Phase 2, randomized, double-blind, placebo-controlled clinical trial to evaluate the effect of Treamid, a drug given orally for four weeks, on post-COVID patients with lung fibrosis and decreased lung function [19]. The Treamid group (41%), compared to the placebo group (17%), showed significantly improved FVC and/or Diffusion Capacity for Carbon Monoxide (DLCO) ($P=0.036$). The modified Borg scale showed a significant reduction in dyspnea in the Treamid group, and superior improvement was observed in the female population in the Treamid group. This indicates that Treamid might be a promising pharmacological treatment for long-term sequelae in post-COVID patients, particularly in women, and supports further investigation in future clinical trials.

In another randomized, single-blind, placebo-controlled study by Botek [20], acute post-COVID-19 patients were assigned to receive either molecular hydrogen (H2) inhalation for 14 days or a placebo [20]. Compared to the placebo group, the H2 therapy group experienced an increased 6MWT distance by 64 ± 39 m, FVC by 0.19 ± 0.24 L, and Forced Expiratory Volume in 1 second (FEV1) by 0.11 ± 0.28 L (all $P\leq0.025$). The study concluded that H2 inhalation may be a safe, effective approach for improving physical and respiratory function in acute post-COVID-19 patients.

The study by Palau [21] applied "a single-center, blinded assessor, randomized controlled trial design to test a home-based inspiratory muscle training (IMT) programme on 26 patients with long COVID and a previous admission due to SARS-CoV-2 pneumonia" [21]. The IMT group significantly improved their peak oxygen consumption (peak VO2) compared with the usual care group ($P<0.001$), and positive findings were also observed in the chronotropic index and some quality-of-life dimensions. These findings suggest that IMT improved exercise capacity and quality of life in long COVID patients with a previous admission due to SARS-CoV-2 pneumonia.

An experimental pilot study by Zasadzka [13] used an EMG-driven rehabilitation robot on patients with Post-Viral Fatigue (PVF) syndrome after COVID-19 [13]. While both intervention and control groups improved in most measured parameters, except for muscle fatigue, the intervention group demonstrated non-significant improvements in muscle fatigue scores, while the control group showed non-significant deterioration. Thus, using an EMG rehabilitation robot in patients with PVF can be feasible and safe; however, more evidence is required to corroborate these findings.

Lastly, an observational, prospective, quasi-experimental study by Liu [22] applied a six-week respiratory rehabilitation training to 72 elderly COVID-19 patients [22]. The intervention group showed significant improvements in FEV1(L), FVC(L), FEV1/FVC%, DLCO%, and 6-min walk test, as well as SF-36 scores in eight dimensions and SAS anxiety scores. These results suggest that six-week respiratory rehabilitation can improve the respiratory function, quality of life, and anxiety of elderly patients with COVID-19. However, the intervention had little significant improvement on SDS depression scores.

4. DISCUSSION

This systematic review synthesized and critically appraised the most recent literature on post-acute care interventions for COVID-19 patients.

The evidence examined encompassed a diverse array of interventions, each contributing uniquely towards a more comprehensive understanding of post-acute COVID-19 care.

The results indicate that pulmonary rehabilitation programs, both inpatient and home-based, can significantly improve physical and respiratory function in post-acute COVID-19 patients [23]. This aligns with the long-established role of pulmonary rehabilitation in managing chronic respiratory conditions [24]. Additionally, the role of telecoaching in enhancing the effects of home-based pulmonary rehabilitation programs is notable, especially considering the importance of remote healthcare delivery in the ongoing pandemic scenario [25]. However, more high-quality studies are needed to assess the long-term effects and the optimal duration of these interventions.

Pharmacological interventions, particularly Treamid, exhibited promising results in improving lung function in post-acute COVID-19 patients with lung fibrosis [10,19]. These findings underscore the potential role of Treamid in managing long-term sequelae in post-COVID patients, particularly in women [19]. Given the preliminary nature of these results, future trials are required to further evaluate the safety and efficacy of Treamid in broader populations and over extended periods [19].

Non-pharmacological interventions like inspiratory muscle training (IMT) and molecular hydrogen inhalation demonstrated promising outcomes, improving exercise capacity and quality of life [26]. These findings suggest that such interventions could be incorporated into the comprehensive management of post-acute COVID-19 patients [27]. Still, more rigorous, randomized controlled trials are necessary to substantiate these initial findings.

Novel interventions, such as EMG-driven rehabilitation robots, were found to be feasible and safe for patients with post-viral fatigue syndrome after COVID-19, though the evidence supporting their effectiveness remains limited [13]. This novel approach has the potential to aid in post-COVID-19 rehabilitation, especially considering the technological advancements and the shift towards digital health solutions.

Respiratory rehabilitation training in elderly COVID-19 patients appears to have a substantial positive effect on respiratory function, quality of life, and anxiety [22]. This aligns with the increasing focus on personalized medicine and the importance of considering patient demographics when formulating intervention strategies. However, the impact of this intervention on depression scores was negligible, highlighting the need for integrated psychosocial support in post-acute COVID-19 care [28].

While the current review provides important insights into post-acute care interventions for COVID-19 patients, it is imperative to consider the potential limitations. Heterogeneity across the included studies in terms of patient characteristics, intervention protocols, and outcome measurements precludes a direct comparison of results and warrants careful interpretation. Furthermore, the novelty of COVID-19 and the emergent understanding of its long-term effects make it challenging to draw definitive conclusions.

4.1 Limitations of the Systematic Review

The limitations of this systematic review are several-fold. Firstly, the inclusion of only peer-reviewed articles may have excluded relevant data from preprints or ongoing studies, potentially introducing selection bias. Secondly, the review did not employ meta-analysis due to the qualitative nature of data synthesis, thus hindering the ability to draw robust, quantifiable conclusions. Thirdly, despite using multiple databases, the review may still be subject to publication bias, given that studies with negative findings are less likely to be published.

4.2 Limitations in the Evidence Base

Regarding the evidence base, there were intrinsic limitations that impact the generalizability and robustness of the findings. Most of the studies included in the review were randomized controlled trials, which, while rigorous, might not be wholly representative of the broader population due to stringent eligibility criteria. The relatively small sample sizes in some studies could also limit statistical power. Furthermore, the diversity of interventions assessed in these studies makes it challenging to compare their effectiveness directly, limiting the conclusions that can be drawn about the superiority of one approach over another. The varying duration of follow-up across studies also complicates the long-term assessment of these interventions.

5. CONCLUSION

This systematic review has provided a comprehensive evaluation of the current literature on post-acute care interventions for COVID-19 patients. Our findings indicate that diverse interventions, including pulmonary rehabilitation, inspiratory muscle training, pharmacological treatment, and even novel technological methods, show promising potential in addressing the physical and respiratory sequelae in post-acute COVID-19 patients. Specifically, it appears that a comprehensive, multifaceted approach that is tailored to individual patient needs can significantly improve health outcomes and quality of life.

However, given the heterogeneity in study designs, patient populations, and outcome measures across the included studies, the findings must be interpreted with caution. As our understanding of COVID-19 and its long-term effects continue to evolve, it is crucial to conduct further high-quality, large-scale randomized controlled trials. This will help to more definitively ascertain the effectiveness of these interventions and thereby inform future guidelines for post-acute care for COVID-19 patients. In this rapidly evolving field, continued research and systematic reviews of emerging evidence are imperative for optimizing care for post-acute COVID-19 patients.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Halaji M, Farahani A, Ranjbar R, Heiat M, Dehkordi FS. Emerging coronaviruses: First SARS, second MERS and third SARS-CoV-2: epidemiological updates of COVID-19. Infez Med. 2020;28(suppl):6–17.
2. WHO Coronavirus (COVID-19) Dashboard | WHO Coronavirus (COVID-19) Dashboard With Vaccination Data [Internet]. [cited 2022 Feb 4]. Available:https://covid19.who.int/
3. Scarpino I, Zucco C, Vallelunga R, Luzza F, Cannataro M. Investigating topic modeling techniques to extract meaningful insights in Italian long COVID narration. BioTech. 2022;11(3):41.
4. Hayes JP. Considering the long-term respiratory effects of Covid-19. Occupational Medicine. Oxford University Press UK; 2021;71:325–7.
5. Ramakrishnan RK, Kashour T, Hamid Q, Halwani R, Tleyjeh IM. Unraveling the mystery surrounding post-acute sequelae of COVID-19. Front Immunol. 2021;12:686029.
6. El Sayed S, Gomaa S, Shokry D, Kabil A, Eissa A. Sleep in post-COVID-19 recovery period and its impact on different domains of quality of life. Egypt J Neurol Psychiatry Neurosurg. 2021;57:1–10.
7. Shanbehzadeh S, Zanjari N, Yassin M, Yassin Z, Tavahomi M. Association between long COVID, functional activity, and health-related quality of life in older adults. BMC Geriatr. 2023;23(1):40.
8. Dixit S, Borghi-Silva A, Bairapareddy KC. Revisiting pulmonary rehabilitation during COVID-19 pandemic: a narrative review. Rev Cardiovasc Med. 2021;22(2):315–27.
9. Cetisli-Korkmaz N, Bilek F, Can-Akman T, Baskan E, Keser I, Dogru-Huzmeli E, et al. Rehabilitation strategies and neurological consequences in patients with COVID-19: part II. Phys Ther Rev. 2021;26(3):222–34.
10. Sgalla G, Comes A, Lerede M, Richeldi L. COVID-related fibrosis: Insights into potential drug targets. Expert Opin Investig Drugs. 2021;30(12):1183–95.
11. Fedorowski A, Olsén MF, Nikesjö F, Janson C, Bruchfeld J, Lerm M, et al. Cardiorespiratory dysautonomia in post-COVID-19 condition: Manifestations, mechanisms and management. J Intern Med; 2023.
12. Singh SJ, Baldwin MM, Daynes E, Evans RA, Greening NJ, Jenkins RG, et al. Respiratory sequelae of COVID-19: Pulmonary and extrapulmonary origins, and approaches to clinical care and rehabilitation. Lancet Respir Med; 2023.
13. Zasadzka E, Tobis S, Trzmiel T, Marchewka R, Kozak D, Roksela A, et al. Application of an EMG-rehabilitation robot in patients with post-coronavirus fatigue syndrome (COVID-19)—A feasibility study. Int J Environ Res Public Health. 2022; 19(16):10398.

14. Chuang HJ, Lin CW, Hsiao MY, Wang TG, Liang HW. Long COVID and rehabilitation. J Formos Med Assoc; 2023.
15. Chen AT, Ge S, Cho S, Teng AK, Chu F, Demiris G, et al. Reactions to COVID-19, information and technology use, and social connectedness among older adults with pre-frailty and frailty. Geriatr Nurs (Minneap). 2021;42(1):188–95.
16. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ. 2021;372.
17. Şahın H, Naz İ, Karadeniz G, Süneçlı O, Polat G, Ediboğlu O. Effects of a home-based pulmonary rehabilitation program with and without telecoaching on health-related outcomes in COVID-19 survivors: a randomized controlled clinical study. J Bras Pneumol. 2023;49.
18. Vallier J-M, Simon C, Bronstein A, Dumont M, Jobic A, Paleiron N, et al. Randomized controlled trial of home-based vs. hospital-based pulmonary rehabilitation in post COVID-19 patients. Eur J Phys Rehabil Med. 2023;59(1):103.
19. Bazdyrev E, Panova M, Brachs M, Smolyarchuk E, Tsygankova D, Gofman L, et al. Efficacy and safety of Treamid in the rehabilitation of patients after COVID-19 pneumonia: a phase 2, randomized, double-blind, placebo-controlled trial. J Transl Med. 2022;20(1):1–13.
20. Botek M, Krejčí J, Valenta M, McKune A, Sládečková B, Konečný P, et al. Molecular hydrogen positively affects physical and respiratory function in acute post-COVID-19 patients: A new perspective in rehabilitation. Int J Environ Res Public Health. 2022;19(4):1992.
21. Palau P, Domínguez E, Gonzalez C, Bondía E, Albiach C, Sastre C, et al. Effect of a home-based inspiratory muscle training programme on functional capacity in postdischarged patients with long COVID: the InsCOVID trial. BMJ Open Respir Res. 2022;9(1):e001439.
22. Liu K, Zhang W, Yang Y, Zhang J, Li Y, Chen Y. Respiratory rehabilitation in elderly patients with COVID-19: A randomized controlled study. Complement Ther Clin Pract. 2020;39:101166.
23. Gloeckl R, Leitl D, Jarosch I, Schneeberger T, Nell C, Stenzel N, et al. Benefits of pulmonary rehabilitation in COVID-19: a prospective observational cohort study. ERJ open Res. 2021;7(2).
24. Varkonyi-Sepp J, Freeman A, Ainsworth B, Kadalayil LP, Haitchi HM, Kurukulaaratchy RJ. Multimorbidity in difficult asthma: The need for personalised and non-pharmacological approaches to address a difficult breathing syndrome. J Pers Med. 2022;12(9):1435.
25. Pimenta S, Hansen H, Demeyer H, Slevin P, Cruz J. Role of digital health in pulmonary rehabilitation and beyond: Shaping the future. ERJ Open Res. 2023;9(2).
26. Barreiro E, Bustamante V, Cejudo P, Gáldiz JB, Gea J, de Lucas P, et al. Guidelines for the evaluation and treatment of muscle dysfunction in patients with chronic obstructive pulmonary disease. Arch Bronconeumol (English Ed. 2015;51(8):384–95.
27. Fugazzaro S, Contri A, Esseroukh O, Kaleci S, Croci S, Massari M, et al. Rehabilitation interventions for post-acute COVID-19 syndrome: a systematic review. Int J Environ Res Public Health. 2022;19(9):5185.
28. Giurgi-Oncu C, Tudoran C, Pop GN, Bredicean C, Pescariu SA, Giurgiuca A, et al. Cardiovascular abnormalities and mental health difficulties result in a reduced quality of life in the post-acute COVID-19 syndrome. Brain Sci. 2021; 11(11):1456.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/106436