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Review article

Meta-analysis of the impact of physical activity on the recovery of physical function in COVID-19 patients

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ABSTRACT

Background: The decrease in physical function resulting from COVID-19 infection exerts a substantial negative influence on the quality of life of individuals. Physical activity plays a crucial and irreplaceable role in hastening the elimination of adverse effects on the body caused by acute and chronic diseases. Nevertheless, there have been reports of unfavorable events following physical activity post-COVID-19 infection, sparking debate regarding the efficacy of physical activity as a rehabilitation method to enhance the physical function of COVID-19 patients.
Objective: The aim of this study is to investigate the impact of physical activity on promoting the restoration of physical function among individuals with COVID-19, and to offer guidance for the advancement and consideration of physical activity in the rehabilitation treatment of COVID-19 patients.
Methods: A search was conducted on the PubMed and Web of Science core collection databases, with the search period set from January 1, 2020, to February 6, 2023. The included literature was assessed for risk of bias and methodological quality according to the Cochrane Handbook for Systematic Reviews of Interventions, utilizing Review Manager 5.1 software. The outcome measures from the included studies were analyzed, and the quality of evidence for the outcome measures was graded using the GRADE classification criteria.
Results: The effect of physical activity intervention on improving the 6-Minute Walk Test score in COVID-19 patients was better than that of conventional treatment [WMD = 69.19(95%CI = 39.38, 98.99), $I^2 = 57\%(p = 0.03)$]. The effect of physical activity on improving the 30-Second Sit-to-Stand Test score was better than that of conventional treatment [WMD = 2.98(95%CI = 1.91, 4.04), $I^2 = 0\%(p = 0.56)$]. There was no significant difference between physical activity and conventional treatment in improving Grip strength in COVID-19 patients [WMD = 2.35(95%CI = −0.49, 5.20), $I^2 = 0\%(p = 0.80)$]. The effect of physical activity on improving the Timed Up and Go test score in COVID-19 patients was better than that of conventional treatment [WMD = −1.16 (95%CI = −1.98, −0.34), $I^2 = 4\%(p = 0.35)$]. The effect of physical activity on improving Forced Vital Capacity in COVID-19 patients was better than that of conventional treatment [WMD = 0.14 (95%CI = 0.08, 0.21), $I^2 = 0\%(p = 0.45)$]. The effect of physical activity on improving Forced Expiratory Volume in the first second in COVID-19 patients was better than that of conventional treatment [WMD = 0.08(95%CI = 0.02, 0.15), $I^2 = 52\%(p = 0.10)$].

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Conclusions: Physical activity plays a crucial role in facilitating the recovery of exercise capacity and pulmonary function in COVID-19 patients, helping to expedite the restoration of overall physical health. It is crucial for COVID-19 patients to undergo an accurate assessment of their physical condition before engaging in any physical activity.

1. Introduction

The COVID-19 pandemic has been an ongoing global challenge for over three years, and concerted efforts from nations around the world have yielded significant achievements in containing and managing its spread. Nevertheless, as the virus continues to evolve and mutate, it is likely to persist in the natural environment, and its associated diseases may eventually become commonplace respiratory infections. The World Health Organization (WHO) has warned that following infection with the novel coronavirus, individuals may exhibit symptoms of upper respiratory tract infections, often accompanied by varying degrees of physical function decline, including impairments to both exercise capacity and pulmonary function [1]. Vaccination is currently a crucial measure globally for preventing COVID-19 and protecting vulnerable populations. Multiple studies have confirmed the effectiveness of vaccination in preventing severe illness [2–5]. However, vaccines do not provide absolute protection against COVID-19 infection, and breakthrough infections can occur even after vaccination [6]. Moreover, even after the resolution of acute symptoms of COVID-19 infection, patients may still experience the long-term effects of persistent multi-organ damage [7]. Research has revealed that individuals with even mild symptoms of COVID-19 may experience lasting physical impairments [8–10] and a reduction in their overall quality of life [11,12]. This has caused great distress among the public. Effectively preventing and alleviating these adverse effects and aiding patients in returning to their normal work and daily lives as quickly as possible is a pressing question that demands attention [13].

The relationship between physical activity and health is closely linked. Physical activity is considered a good way to improve physical function and has a positive effect on the prevention and treatment of chronic diseases [14]. Simultaneously, physical activity has been recommended as a standard therapy in clinical practice for pulmonary diseases such as pulmonary fibrosis or pulmonary hypertension, heart failure, renal diseases, and muscular dystrophy [15]. In response to the COVID-19 pandemic, medical groups have embraced the "Exercise is Medicine" approach to support public health and mitigate the negative impacts of COVID-19 sequelae on patients. This approach advocates for the use of moderate physical activity as a means of promoting disease recovery. For instance, WHO recommends that adults who are healthy or have asymptomatic infections engage in at least 150 min of moderate-intensity physical activity per week. For children and adolescents, the recommendation increases to at least 300 min of physical activity per week [16].

However, there have been frequent reports of adverse events associated with engaging in physical activity after COVID-19 infection [17–19]. These reports have sparked controversy and raised concerns regarding the effectiveness of physical activity in promoting the recovery of COVID-19 patients. Evidence suggests that myocardial cells have a high concentration of ACE2 receptors on their membranes, making the heart susceptible to COVID-19 infection. This can lead to viral invasion of myocardial cells, excessive immune activation, and the production of inflammatory cytokines, ultimately resulting in heart failure and cardiac arrhythmias in patients [20]. During the acute phase of COVID-19 infection, if patients have evident or subtle myocardial injury symptoms, engaging in vigorous exercise can potentially accelerate viral replication within the heart, intensify inflammatory responses, and increase myocardial cell necrosis. This can lead to cardiac discomfort in patients and, in severe cases, even sudden cardiac death [19]. Additionally, there is a significantly increased risk of developing pulmonary fibrosis in COVID-19 patients [21]. On one hand, the progression of pulmonary fibrosis can lead to a decrease in the diffusion capacity of carbon monoxide in the lungs, impairing exercise tolerance and the ability to withstand maximum exercise loads while increasing the risk of exercise-related injuries [15]. On the other hand, the multi-organ dysfunction caused by viral infection reduces the patients' ability to recover after exercise. It is due to these risks that an increasing number of patients have concerns about engaging in physical activity after COVID-19 infection.

In light of the COVID-19 pandemic, the conventional concept of "Exercise is Medicine" has been called into question. Given the rapid and widespread transmission of the virus among the general public, and the fact that many individuals are experiencing their first infection, the efficacy of physical activity in promoting the recovery of COVID-19 patients' physical function remains uncertain. As a result, there is a need for systematic research to assess the value of physical activity in rehabilitating COVID-19 patients. This study aims to address this issue by conducting a meta-analysis of existing literature to determine the effectiveness of physical activity in promoting the recovery of COVID-19 patients' physical function. The findings of this study provide valuable insight into the potential of physical activity as a therapeutic approach for COVID-19 rehabilitation and may serve as a basis for the promotion of physical activity in the treatment of COVID-19 patients.

2. Information and research methods

2.1. Search strategy

To identify relevant studies for this meta-analysis, a comprehensive literature search was conducted on February 6th, 2023, using the Web of Science (WOS) Core Collection and PubMed databases. The search terms used included "Physical activity", "Physical exercise", "Exercise", "COVID-19″, "SARS-Cov-2″, and "Randomized Control Trial". The search was limited to studies published between January 1st, 2020 and February 6th, 2023, with the literature type set to "Article" and the language to "English". The search terms were cross-checked and supplemented with manual searches and a review of the reference lists of relevant articles. This rigorous approach enabled us to comprehensively identify relevant studies for inclusion in our meta-analysis.

2.2. Study selection

To ensure the quality and relevance of the included studies, the principles of the Patient/Population, Intervention, Comparison, Outcome, and Study design (PICOS) framework were followed when defining the inclusion and exclusion criteria. Two researchers independently reviewed all search results and cross-checked them. In case of discrepancies, a third researcher was consulted to decide whether to include the literature. The final inclusion criteria for the original literature were as follows:

Inclusion criteria:(1) Study type: randomized controlled trials; (2) Participants: COVID-19 infected individuals; (3) Intervention: physical activity only; (4) Control group: blank control or standard treatment; (5) Outcome indicators: physical function-related indicators; (6) Statistical data are publicly available and the complete data is visible.

Exclusion criteria: (1) Non-randomized controlled trials; (2) Participants with other serious underlying diseases; (3) Experimental groups without physical activity as the only intervention or not included; (4) Literature without statistical data available; (5) Conference abstracts or reviews; (6) Duplicate literature.

These rigorous inclusion and exclusion criteria ensured that only high-quality studies meeting the specific requirements of this meta-analysis were included in the final analysis.

2.3. Assessment of risk of bias

Two researchers independently assessed each included article using the "Risk of Bias Assessment" tool from the Cochrane Handbook. To evaluate inter-rater agreement, a weighted Cohen's kappa coefficient was employed. In cases where discrepancies arose between the two researchers' assessments, a third researcher was consulted to reach a consensus. The evaluation criteria are as follows:

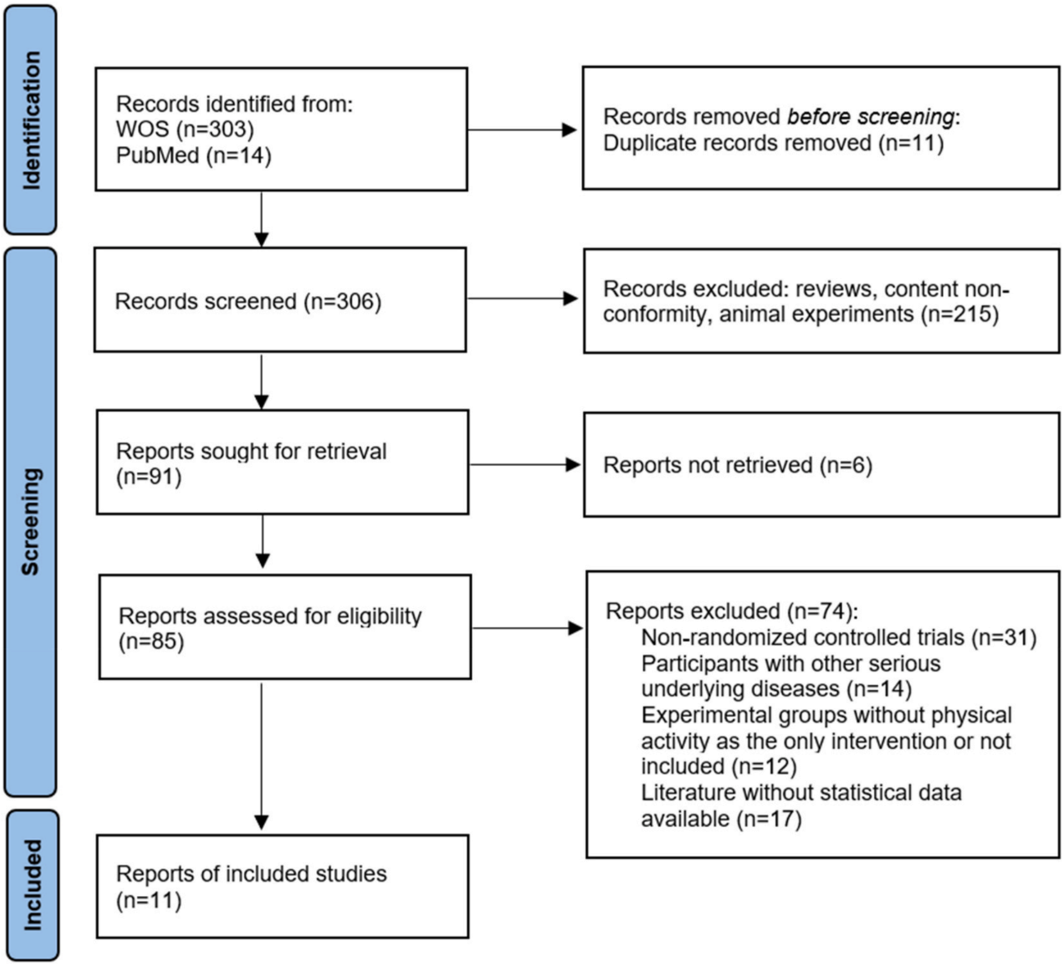

Fig. 1. PRISMA flow chart for inclusion and exclusion of studies.

(1) Random sequence generation; (2) Random sequence generation; (3) Blinding of participants and personnel; (4) Blinding of outcome assessment; (5) Incomplete outcome data; (6) Selective reporting; (7) Other bias.

2.4. Data extraction

Import all literature filtered from the database into Zotero software and download the full text. Data extraction for article information is performed independently by two researchers. Extracted information includes: (1) External characteristics of the literature, including article title, author name, journal information, and publication year; (2) Intervention characteristics of the study, including

Table 1
Summary of basic features of included literature.

Studies	Total sample size (Experimental group/ Control group)	Intervention	Content	Main outcome
C Rodriguez-Blanco [28], 2022	77 (55/22)	Telerehabilitation	Respiratory training and resistance training. 2weeks, 7/ week	6MWT、30STST
Do Amaral V T [29], 2022	32 (12/20)	Telerehabilitation	Resistance training consisted of nine exercises targeting both multi-joint and single-joint movements. The selection of aerobic exercise modalities was determined based on patient preferences and the availability of equipment. 12 weeks, 5/week	6MWT、GS、PFTs、TUG
Gonzalez-Gerez J J [23], 2021	38 (19/19)	Telerehabilitation	Respiratory exercises involved the implementation of active cyclic breathing techniques. 1 week, 7/week	6MWT、30STST
Li J [25], 2022	118 (58/60)	Telerehabilitation	Respiratory exercises included breath control and chest expansion techniques. LMS movements included wall squats. Aerobic exercise, the intensity was determined based on heart rate reserve. Over time, the difficulty and intensity gradually increased. The exercise plan consisted of sessions lasting 40–60 min each. 6 weeks, 3–4/week	6MWT、PFTs
Liu K [30], 2020	72 (36/36)	Pulmonary Rehabilitation	Respiratory exercises involved the use of handheld resistance devices. Coughing exercises entailed active coughing techniques. Diaphragmatic muscle training was performed in supine position with weighted anterior abdominal wall for maximal spontaneous diaphragmatic contraction. Stretching exercises focused on respiratory muscle stretching. Home exercises included pursed-lip breathing and coughing exercises. 6 weeks, 2/week	PFTs、6MWT
Rodriguez-Blanco C [24], 2021	36 (18/18)	Telerehabilitation	The physical therapist provided remote guidance for ten non-specific resistance-based and strength exercises. 1 week, 7/week	6MWT、30STST
Jimeno-Almazán A [32], 2022	38 (19/19)	Tailored and supervised multidimensional exercise program	Resistance training consisted of two days of strength exercises incorporating moderate-intensity variable training. One day was dedicated to low-intensity continuous training. 8 weeks, 3/week	GS、PFTs
Llurda-Almuzara L [26], 2022	70 (35/35)	Structured therapeutic exercise online program	Warm-up activities included respiratory exercises, joint mobilization, and walking exercises. The training consisted of upper and lower body strength exercises using resistance, as well as balance exercises. Cool-down activities involved muscle stretching, walking, and respiratory exercises. Additionally, there was a weekly video call follow-up for monitoring and support. 8 weeks, 3/week	GS
Corna S [31], 2022	32 (16/16)	Conventional standard inpatient rehabilitation program with aerobic exercise	The interventions included upper and lower limb strengthening exercises, balance training, walking exercises, respiratory muscle training, and aerobic training using a hand ergometer. 2 weeks, 5/week	GS、30STST、TUG
Rutkowski S [33], 2022	32 (16/16)	Virtual reality-based pulmonary rehabilitation program	Using virtual reality technology, respiratory exercises, aerobic training, and resistance training were conducted on a stationary exercise bike. 3 weeks, 5/week	6MWT
Pehlivan E [27], 2022	34 (17/17)	Telerehabilitation	Respiratory exercises involved active breathing techniques. The aerobic exercise component included rhythmic running or self-paced walking. 6 weeks, 3/ week	TUG

Attention: 6MWT = Six-Minute Walk Test; 30STST = 30-Second Sit-to-Stand Test; GS = Grip strength; PFTs = Pulmonary Function Tests; TUG = Timed Up and Go test.

sample size of each group, age and gender of subjects, intervention plan, intervention period, intervention frequency, etc.; (3) Outcome indicator data.

2.5. Evidence quality assessment

Applying the GRADE system for recommendation grading [22], the evidence quality of outcome measures can be assessed and classified into four levels: high, moderate, low, and very low. This categorization takes into account five aspects: limitations, inconsistency, indirectness, imprecision, and publication bias. The evidence quality assessment can be conducted using the GRADEpro online tool (https://gdt.gradepro.org/app/).

2.6. Statistical analysis

This study employed Review Manager 5.1 and Microsoft Excel 2016 software to process the data. The data were organized and summarized in Excel, and Review Manager was used for data merging, quality assessment, publication bias risk assessment, heterogeneity testing, and the generation of funnel plots and forest plots. After conducting heterogeneity analysis on the included literature, a fixed-effects model was used for meta-analysis when $I^2 < 50\%$, while a random-effects model was used when $I^2 \geq 50\%$. The outcome measures for the included literature were continuous variables, and the weighted mean difference (WMD) was used for data processing when consistent measurement methods and units were employed for the same outcome measure. The standardized mean difference (SMD) was used when inconsistent methods or units were used.

3. Result

3.1. Study selection

A preliminary database search retrieved 317 articles. After applying the inclusion and exclusion criteria, 306 articles were excluded after reviewing their titles, abstracts, and full texts. Ultimately, 11 articles were deemed eligible for the study. The literature screening process is shown in Fig. 1.

3.2. Study characteristics

A total of 11 articles were included in the statistical analysis of this study, and the characteristics of these articles are presented in Table 1. All articles were published after 2020 and involved randomized controlled trials. The total sample size was 579, including 151 acute-phase patients and 428 recovery-phase patients. Regarding the intervention methods for physical activity, 7 studies [23–29] utilized remote guidance, while 4 [30–33] studies employed face-to-face interventions. The intervention duration varied from 1 to 12 weeks. All studies reported the impact of physical activity on the exercise capacity of COVID-19 patients, with an additional 4 studies also examining the effects on pulmonary function.

3.3. Risk of bias in the included articles

Two researchers independently evaluated the risk of bias in the included articles. A weighted Cohen's kappa coefficient consistency test was conducted, and the results exceeded 0.75, indicating a good level of agreement between the evaluators. After consultation with a third researcher, the final Quality Evaluation Table for Inclusion of Articles (Table 2) was determined. The 11 articles included in this study have varying degrees of bias (Fig. 2).

Attention: A: Random sequence generation; B: Random sequence generation; C: Blinding of participants and personnel; D: Blinding of outcome assessment; E: Incomplete outcome data; F: Selective reporting; G: Other bias; +: yes; -: no; ? : unclear.

Table 2
Quality evaluation table for inclusion of articles.

Studies	Evaluating Indicator							Total
	A	B	C	D	E	F	G	
Li J, 2022	+	+	+	?	+	+	+	6
Jimeno-Almazán A, 2022	+	?	?	?	+	+	+	4
Do Amaral V T, 2022	+	?	+	?	?	+	+	4
Liu K, 2020	+	?	?	?	+	+	+	4
Rodriguez-Blanco C, 2021	+	+	+	+	+	+	+	7
Gonzalez-Gerez J J, 2021	+	+	+	+	+	+	+	7
Llurda-Almuzara L, 2022	+	+	+	?	+	+	+	6
Corna S, 2022	+	?	?	?	+	+	+	4
C Rodriguez-Blanco, 2022	+	+	+	+	+	+	+	7
Rutkowski S, 2022	+	?	?	?	+	+	+	4
Pehlivan E , 2022	+	+	?	?	+	+	+	5

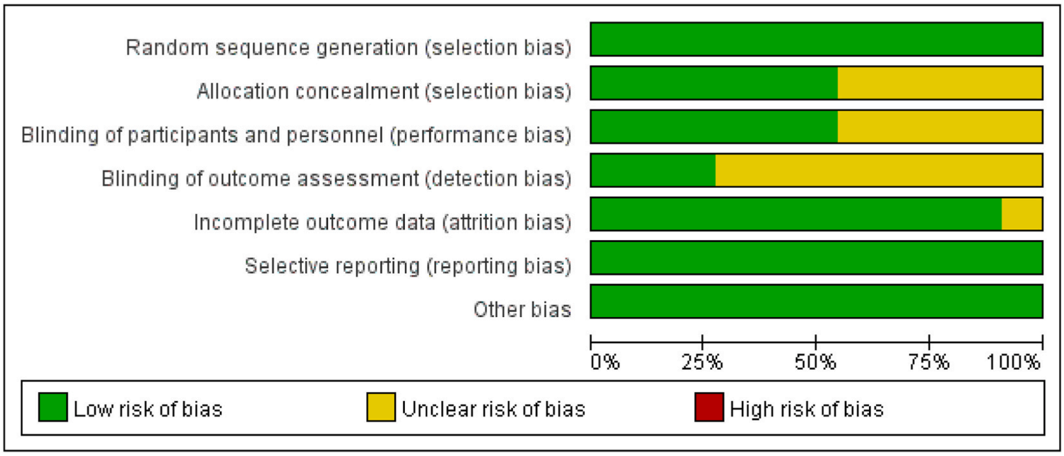

Fig. 2. Bias project risk expressed as a percentage of all included studies.

3.4. Meta-analysis results

3.4.1. Exercise capacity

3.4.1.1. 6MWT. The present study included a total of 7 articles in the literature, reporting the intervention effects of physical activity on the 6MWT scores of COVID-19 patients. A random effects model was used to conduct a meta-analysis, and the results showed a weighted mean difference (WMD) of 69.19 (95%CI = 39.38, 98.99), with a heterogeneity of $I^2 = 57\%$ ($p = 0.03$) (Fig. 3). The results showed that the physical activity intervention in the experimental group was more effective in improving the 6MWT scores of COVID-19 patients than the control group treated with conventional methods ($p < 0.001$).

3.4.1.2. 30STST. A total of 4 articles in the literature were included in the study, reporting the effects of physical activity intervention on the 30STST scores of COVID-19 patients. A fixed effects model was used to conduct a meta-analysis to combine the effect sizes, and the results showed a statistically significant difference in the intervention effects of physical activity and conventional interventions on the 30STST scores ($p < 0.001$), [WMD = 2.98(95%CI = 1.91, 4.04), $I^2 = 0\%$($p = 0.56$)] (Fig. 4). The results showed that the effect of physical activity in improving the 30STST scores was superior to that of conventional treatment methods.

3.4.1.3. GS. The present study included a total of 4 articles in the literature, reporting the effects of physical activity intervention on the GS scores of COVID-19 patients. A fixed effects model was used to conduct a meta-analysis, and the results showed [WMD = 2.35 (95%CI = −0.49, 5.20), $I^2 = 0\%$ ($p = 0.80$)] (Fig. 5). The results showed that there was no statistically significant difference in the effects of physical activity and conventional treatment methods in improving the GS scores of COVID-19 patients ($p = 0.11$).

3.4.1.4. TUG. The present study included a total of 3 articles in the literature, reporting the effects of physical activity intervention on the TUG scores of COVID-19 patients. A fixed effects model was used to conduct a meta-analysis, and the results showed [WMD = −1.16 (95%CI = −1.98, −0.34), $I^2 = 4\%$ ($p = 0.35$)] (Fig. 6). The results showed that the effect of physical activity in improving the TUG scores of COVID-19 patients was superior to that of conventional treatment methods ($p = 0.005$).

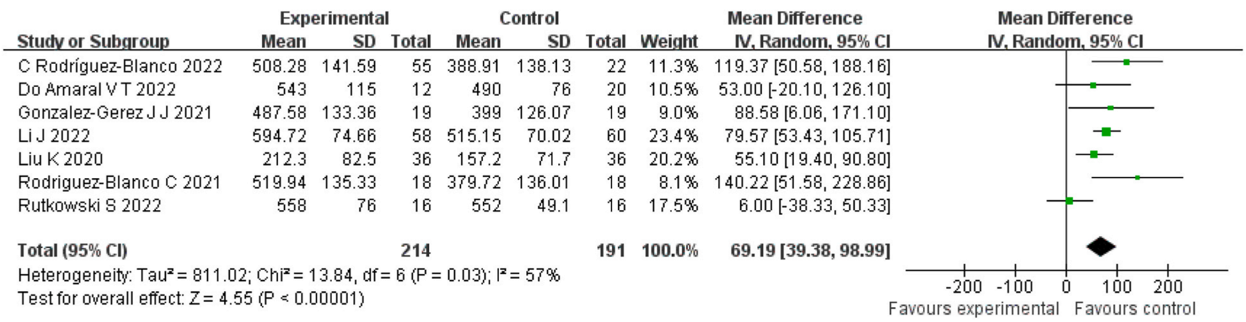

Fig. 3. Forest plot of 6MWT of experimental and control groups.

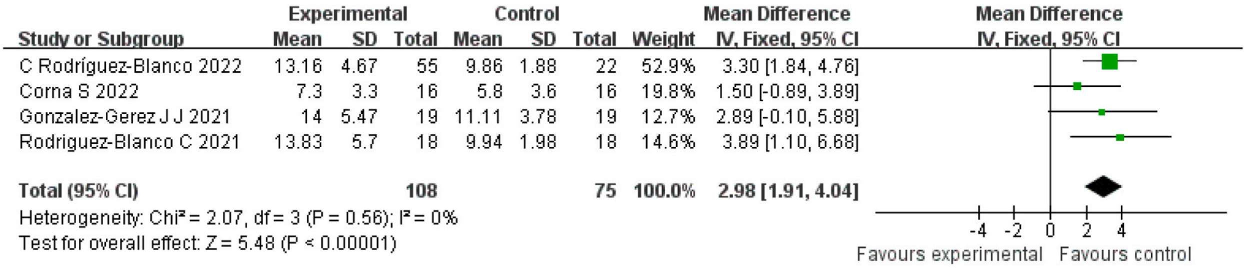

Fig. 4. Forest plot of 30STST of experimental and control groups.

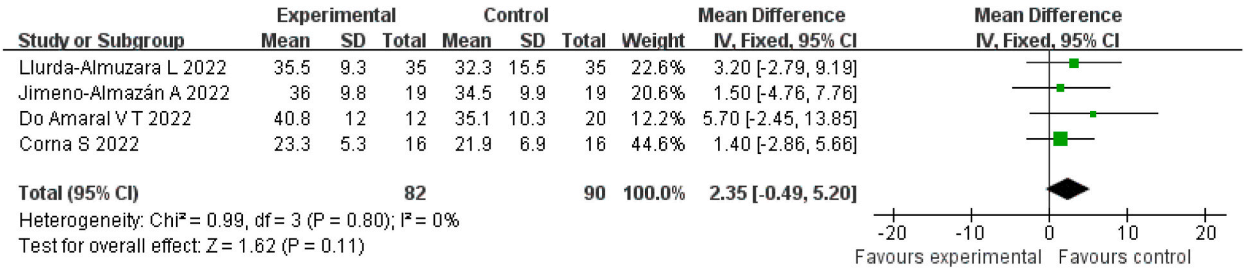

Fig. 5. Forest plot of GS of experimental and control groups.

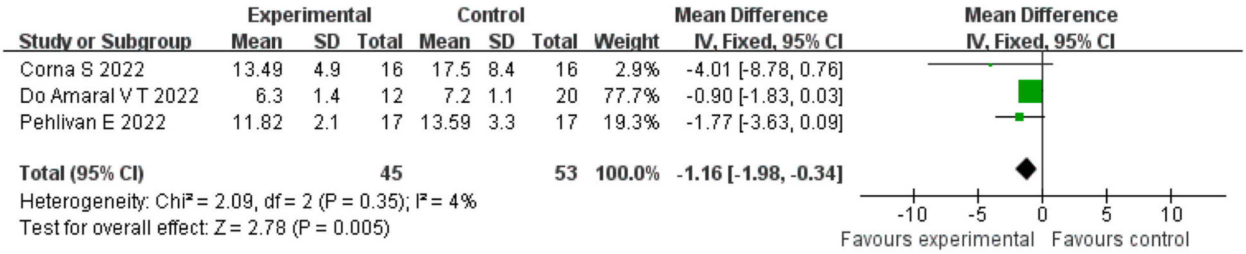

Fig. 6. Forest plot of TUG of experimental and control groups.

3.4.2. Pulmonary function

The indicators reflecting pulmonary function in the literature included in this study are mainly Forced Vital Capacity (FVC) and Forced Expiratory Volume in the first second (FEV-1). A fixed effects model was used to conduct a meta-analysis. The data showed that the combined effect size of physical activity and conventional treatment methods on FVC and FEV-1 intervention was WMD = 0.14 (95%CI = 0.08, 0.21), $I^2 = 0\%$ (p = 0.45) and WMD = 0.08 (95%CI = 0.02, 0.15), $I^2 = 52\%$ (p = 0.10), respectively (Fig. 7). The results indicated that there was a statistically significant difference in the effect of physical activity and conventional treatment methods on improving pulmonary function in COVID-19 patients ($p < 0.001$), and physical activity was more effective than conventional treatment methods in promoting the recovery of pulmonary function.

3.4.3. Reporting bias

The publication bias of studies on the 6MWT was assessed using the Egger's test, and the results showed p = 0.632. This indicates that there is no significant publication bias among the included studies.

3.4.4. GRADE evidence grading

The results of the GRADE evidence grading indicate that the 30STST and FVC provide high-quality evidence. The 6MWT, TUG, GS, and FEV-1 provide moderate-quality evidence (Fig. 8).

4. Discussion

In recent years, the sudden outbreak of the novel coronavirus has swept across the world, causing serious harm to human health and life. WHO has pointed out that some individuals will experience varying degrees of after-effects after being diagnosed with COVID-19, with common symptoms including fatigue, shortness of breath, and cognitive dysfunction, among others. This phenomenon is known as "long-COVID". As the global number of COVID-19 infections continues to expand, an increasing number of people are struggling

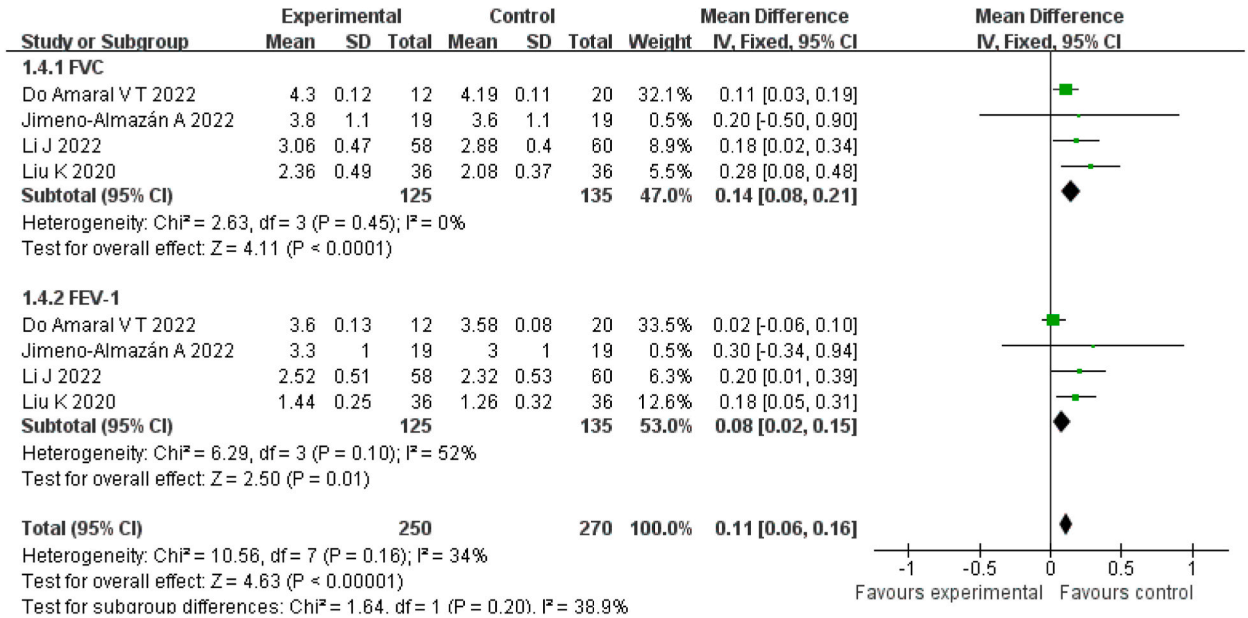

Fig. 7. Forest plot of PFTs of experimental and control groups.

Author(s):
Question: Physical Activity compared to Conventional Treatment for Physical Function in COVID-19 Patients
Setting:
Bibliography:

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Physical Activity	Conventional Treatment	Relative (95% CI)	Absolute (95% CI)		
6MWT												
7	randomised trials	not serious	serious[a]	not serious	not serious	none	214	191	-	MD **69.19 higher** (39.38 higher to 98.99 higher)	⊕⊕⊕◯ Moderate	CRITICAL
TUG												
3	randomised trials	not serious	not serious	not serious	serious[b]	none	45	53	-	MD **1.16 lower** (1.98 lower to 0.34 lower)	⊕⊕⊕◯ Moderate	CRITICAL
30STST												
4	randomised trials	not serious	not serious	not serious	not serious	none	108	75	-	MD **2.98 higher** (1.91 higher to 4.04 higher)	⊕⊕⊕⊕ High	CRITICAL
GS												
4	randomised trials	not serious	not serious	not serious	serious[b]	none	82	90	-	MD **2.35 higher** (0.49 lower to 5.2 higher)	⊕⊕⊕◯ Moderate	CRITICAL
FVC												
4	randomised trials	not serious	not serious	not serious	not serious	none	125	135	-	MD **0.14 higher** (0.08 higher to 0.21 higher)	⊕⊕⊕⊕ High	CRITICAL
FEV-1												
4	randomised trials	not serious	serious[a]	not serious	not serious	none	125	135	-	MD **0.08 higher** (0.02 higher to 0.15 higher)	⊕⊕⊕◯ Moderate	CRITICAL

CI: confidence interval; **MD:** mean difference

Explanations

a. High heterogeneity
b. Insufficient sample size

Fig. 8. The GRADE evidence grading for the physical functioning outcome measures of physical activity interventions in COVID-19 patients.

with "long COVID", which cannot be ignored in terms of both individual health and the burden on public health. Although vaccination is an effective measure in the current efforts to prevent and control the spread of the COVID-19 pandemic, protect vulnerable populations, and reduce the incidence of severe cases and fatalities, it is equally important not to overlook the role of non-pharmaceutical interventions while promoting vaccination.

Physical activity, as a way to promote human health, has been widely recognized by society. It is not only considered a part of a healthy lifestyle but also commonly used as a tool for the adjunct treatment of certain diseases. Moreover, it has gradually become one of the main determinants of health [34]. Research has shown that physical activity has a good effect on promoting the recovery of respiratory tract infections [35]. However, reports about exercise after COVID-19 infection leading to sudden death have raised concerns about physical activity during the recovery period of COVID-19 [18]. According to reports, the risk of myocarditis in COVID-19 patients is 16 times higher than that in non-infected individuals [36], and there is a certain correlation between COVID-19 infection and myocarditis [37]. Although regular physical activity is a good way to improve cardiovascular health, intense physical activity in COVID-19 patients with related cardiac complications can increase the risk of adverse consequences by putting a tremendous strain on the heart [17]. It remains debatable whether physical activity can effectively promote the recovery of COVID-19 patients, given the specific nature of this disease.

Therefore, this article quantitatively evaluates the effect of physical activity intervention on the improvement of physical function in COVID-19 patients. Based on the existing literature, the results indicate that physical activity has positive effects on promoting the recovery of pulmonary function and exercise capacity in COVID-19 patients during both the acute and recovery phases.

4.1. Exercise capacity

Exercise capacity can comprehensively reflect the level of the human nervous, respiratory, and cardiovascular systems, and is an important indicator for objectively reflecting the level of human physical function. Good exercise capacity can meet the needs of daily activities and is the foundation for maintaining a high quality of life. However, the infection of COVID-19 causes significant damage to patients' physical activity and inconvenience in daily life. On one hand, the pathogenesis of COVID-19 infection is related to excessive immune response and delayed antiviral response, which leads to an over-inflammatory state in the body [38]. On the other hand, the sharp decrease in physical activity due to infection or isolation can further reduce the function of patients' skeletal muscles [11]. This may explain the reason for the sharp decline in patients' exercise capacity after the acute infection period.

This study quantitatively analyzed multiple indicators related to exercise capacity, and the results showed that physical activity had a positive effect on improving the 6MWT, 30STST, GS, and TUG scores in COVID-19 patients. The TUG test and the 6MWT are commonly used as reliable, cost-effective, safe, and time-efficient methods for assessing overall functional mobility [39,40]. The 30STST is widely applied as an effective and reliable tool for assessing lower limb muscle performance in physical activity capacity rehabilitation [41]. Additionally, an increase in physical activity levels is generally associated with improvements in GS [42].

Research indicates that both 2-week and 12-week combined resistance training and aerobic training can improve the TUG performance of COVID-19 patients to some extent. A controlled trial study indicated that 2 weeks of physical activity significantly improved the 6MWT scores and led to varying degrees of improvement in the quality of life of post-recovery COVID-19 patients [43]. Another similar trial further supported these results, showing significant improvement in the exercise capacity of 33 discharged COVID-19 patients and significant relief of their depression and anxiety states, leading to a significant improvement in their quality of life, through 4 weeks of Liu Zi Jue Qigong exercise [44]. Studies have shown that the benefits of physical activity may be achieved by enhancing the body's antiviral infection ability [45], creating an anti-inflammatory environment, and reducing inflammatory responses by inducing a series of physiological adaptive changes such as biological rhythms, hormone secretion, and immune regulation [46]. Meanwhile, regular and routine physical activity can have a beneficial effect on systems such as bone and muscle and enhance cardiovascular function through pathways such as increased mitochondrial production [47]. These findings provide scientific evidence for the improvement of post-COVID-19 patient's physical health through physical activity.

4.2. Pulmonary function

Pulmonary function is typically regarded as an essential indicator of respiratory system function and one of the important factors influencing normal human activities. This study conducted a systematic review of indicators related to pulmonary function and found that physical activity has a significant promoting effect on improving FVC and FEV-1 in patients with COVID-19.

Respiratory muscle weakness is believed to be a possible cause of the decline in pulmonary function in COVID-19 patients [48], as lung disease is often associated with muscle mass and function loss [49,50]. In an observation of 57 hospitalized COVID-19 patients, it was found that more than half of the patients experienced a decrease in respiratory muscle strength during the early recovery period [51]. Chronic symptoms following COVID-19 infection are frequently accompanied by respiratory muscle weakness. This can lead to an imbalance in the ventilatory demand of the body and trigger various physiological mechanisms, ultimately resulting in respiratory dysfunction [52]. A prospective study examined the changes in respiratory function among unvaccinated athletes following COVID-19 infection. The results showed that maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) decreased by 13% and 8%, respectively, after COVID-19 infection. FEV-1 decreased by 2%, and FVC decreased by 5%. Although MEP and FEV-1 quickly returned to normal in the subsequent days, MIP and FVC still exhibited abnormalities 52 days after COVID-19 infection [53]. Similar studies have also confirmed the presence of pulmonary function abnormalities in COVID-19 patients during a prolonged period following the acute infection phase [54–56]. Therefore, it can be inferred that the impact of COVID-19 infection on pulmonary function in the human body may persist in the long term.

Research have shown a certain correlation between low muscle strength and lack of physical activity in patients with respiratory diseases [57]. Therefore, physical activity is often recommended as a non-pharmacological adjunctive therapy during the rehabilitation period of respiratory diseases [58], with the key goal of improving muscle function to enhance respiratory muscle performance, pulmonary capacity, and exercise ventilation [59].

Research has shown that a 5-week aerobic exercise program combined with respiratory exercises not only effectively improves the cardiorespiratory health and quality of life of COVID-19 patients after discharge, but also increases their exercise endurance levels [60]. Results from a controlled trial not included in this study's meta-analysis showed that pulmonary function in COVID-19 patients during the recovery phase improved significantly after 2 weeks of physical activity intervention [43]. Research indicates that respiratory exercises can improve specific respiratory parameters in moderate to severe COVID-19 patients, and even short-term training is effective [61]. Another single-center retrospective study showed that interval training combined with resistance training can increase the maximum oxygen uptake of COVID-19 patients in the recovery period by 18% and reduce exercise-induced hyperventilation by 10% [62].

Research has shown that physical activity during hospitalization for acute respiratory illnesses can have beneficial effects on physical health and functional recovery, with good tolerance and a low probability of adverse events [63]. Both resistance training and aerobic exercise have been found to significantly improve pulmonary function capacity [64]. Therefore, physical activity may be a preferred non-pharmacological approach to promoting the recovery of pulmonary function in COVID-19 patients.

4.3. Exercise is medicine

As a health-promoting activity, "Exercise is Medicine" plays an important role in addressing current global public health issues. It is advocated as a means of preventing, treating, and improving the negative effects of certain acute and chronic diseases on the body [65]. Exercise is considered to have significant and irreplaceable benefits in preventing COVID-19 infection and improving post-COVID symptoms [15], and both short-term and long-term physical activity have a positive impact on promoting the physical function of patients [23,24,29].

The ACSM has suggested that moderate physical activity can help enhance an individual's immune response to COVID-19 infection [66]. A cross-sectional study showed that individuals who engage in long-term, regular physical activity may have a shorter and milder duration of symptoms after being infected with the novel coronavirus [67]. Although COVID-19 infection can affect respiratory function and blood oxygen levels, severely limiting exercise and physical activity, low-intensity physical activity can still improve patients' oxygen saturation, resting heart rate, blood pressure, and other physical functions, thereby accelerating recovery [68]. Studies have indicated that a structured exercise program based on aerobic exercise and strengthening of respiratory and peripheral muscle strength can have positive effects on COVID-19 patients' daily activities, pulmonary function, respiratory muscle strength, grip strength, and other physical functions, thus improving their overall quality of life [69]. A structured exercise program is one of the methods for improving the human immune system. Evidence suggests that an exercise program consisting of resistance training and aerobic exercise can improve post-COVID-19 patients' exercise capacity and quality of life [70]. It is worth noting that the physical activities conducted in the aforementioned studies were of moderate or low intensity. Considering that high-intensity exercise may temporarily increase susceptibility to post-exercise infection [71]. Therefore, caution should be exercised, or high-intensity exercise should be avoided, for COVID-19 patients in the recovery phase. Due to the decline in physical functioning after COVID-19 infection, engaging in physical activity without proper consideration can pose certain risks for COVID-19 patients. Therefore, COVID-19 patients should undergo individual assessments and evaluations before engaging in physical activity. During physical activity, they should proceed gradually and engage in self-monitoring to avoid adverse events or conditions. As indicated by WHO, convalescent COVID-19 patients are advised to undergo a phased approach to physical activity, while monitoring their physical condition using the Rating of Perceived Exertion (RPE) scale to regulate exercise intensity. Specifically, these stages encompass: Preparation for return to exercise (RPE score of 0–1). Low-intensity activity (RPE score of 2–3). Moderate-intensity activity (RPE score of 4–5). Moderate-intensity exercises with coordination and functioning skills (RPE score of 5–7). Return to baseline exercises (RPE score of 8–10). Each phase should be sustained for a minimum of seven days before progression to the subsequent stage. This phased approach to physical activity aids convalescent COVID-19 patients in gradually adapting and recuperating their physical condition [1].

Physical activity has gradually been applied in clinical rehabilitation practices for COVID-19 patients, and most studies have indicated the necessity of physical activity intervention to promote the recovery of physical function in COVID-19 patients. However, these results can only provide limited clinical guidance, as our understanding of the disease itself, its impact on human health, and its treatment is still limited, and more long-term research is needed to evaluate and validate these findings. Moreover, standardized exercise prescriptions for physical activity in COVID-19 patients are still lacking. Therefore, future research should focus on exploring the effects of variables such as exercise intensity, duration, and combination methods that affect the effectiveness of physical activity, as well as investigating the impact on other outcome measures and different populations. This will provide specific and actionable recommendations for exercise prescriptions for different populations.

5. Limitations

This study has the following limitations: (1) the analysis is limited to published English literature with publicly available data, and unpublished and confidential literature was not included; (2) the included literature had different physical activity intervention plans, and the study participants had varying potential comorbidities and ages, which may have led to biased results.

Future research needs to have higher methodological quality, larger sample sizes, and other relevant outcome measures to better understand the role of physical activity in managing the decline in physical function caused by COVID-19 infection and other related health conditions.

6. Conclusions

Physical activity is a convenient and effective method to enhance physical functioning and improve chronic diseases. Based on the existing research evidence, this study found that physical activity has a positive effect on promoting the recovery of physical functioning in COVID-19 patients, primarily manifested in the improvement of exercise capacity and pulmonary function. Physical activity appears to help patients accelerate their journey towards physical health, which is crucial for the promotion of physical activity in the rehabilitation treatment of individuals with COVID-19. To avoid adverse events during physical activity, patients should undergo a prior assessment of their physical condition, constantly monitor their own sensations during physical activity, and adjust their strategies accordingly to ensure safety and maximize benefits.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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