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Physical Activity and Post-COVID-19 Syndrome in Older Adults: A Systematic Review

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ABSTRACT

Background: Physical activity (PA) may play a significant role in managing post-Coronavirus Disease (COVID)-19 syndrome, a significant public health concern among older adults. This study aimed to systematically review the evidence on post-COVID-19 symptoms, signs, risk factors, and the effects of PA programs in managing post-COVID-19 syndrome among older adults. **Method:** This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendation. The systematic search was conducted in August 2022 using Scopus and MEDLINE (via PubMed) databases. **Results:** There were 51 documents screened, among which 10 (7 observational and 3 experimental studies) met the selection criteria. The reported post-COVID-19 symptoms and signs associated with physical health included dyspnea, fatigue, diarrhea, and sarcopenia, abnormal lung function, cardiac pathology, immunological changes, reduced physical performance, respectively, while those associated with mental health included depression, poor concentration and memory, and anxiety. Patients with higher body mass indexes were more likely to experience more symptoms. Older patients had greater difficulties in performing daily activities and mobility. A multidisciplinary-based PA program is suggested to be feasible and effective in improving fatigue, ability to walk, balance, and cognitive function. For patients with sarcopenia, a low-intensity aerobic training exercise appears to improve muscle strength, kinesiophobia, and quality of life. **Conclusion:** Various post-COVID-19 symptoms have been reported along with their risk factors, and PA programs are potentially used for managing these symptoms. More research, however, is recommended to explore the PA program for specific post-COVID-19 symptoms.

Key words: Aged, Exercise, Health, Post-Acute COVID-19 Syndrome, Risk Factors

INTRODUCTION

Coronavirus disease (COVID)-19 is still a continuing public health threat worldwide, as indicated by the continuously growing cases. By early 2023, more than 650 million cumulative cases of COVID-19 were confirmed, with a more than 1% fatality rate (Bailly et al., 2022). The public health burden is also associated with more than 10% of patients who experience persistent symptoms past the acute stage of this Severe Acute Respiratory Syndrome Corona Virus 2 (SARS-CoV-2) infection (Ahmadi Hekmatikar et al., 2022). While several timeframes are used to define post-COVID symptoms, the most commonly accepted definition is continuing symptoms lasting more than 12 weeks since the start of the acute COVID-19 stage (Ahmadi Hekmatikar et al., 2022). The most common persistent symptoms include fatigue, dyspnea, chest and joint discomfort, palpitations, myalgia, cough, problems with smell and taste, headache, cognitive and mental impairments, as well as gastrointestinal and cardiovascular problems (Yong, 2021). These long-lasting symptoms of COVID-19 are often debilitating, thus emphasizing the need for long-term support for patients with COVID-19 symptoms.

Limited studies have discussed the possible pathophysiology of post-COVID-19. A study suggests that the potential underlying cause of the post-COVID-19 syndrome is the immune dysregulation caused by SARS-CoV-2 infection (Nalbandian et al., 2021). It subsequently leads to excessive cytokine production that induces inflammation and an increase in the coagulation state (Nalbandian et al., 2021). The immune dysregulation results in persistent symptoms that are possibly driven by long-term pathological inflammation and tissue damage (Yong, 2021). It also suggested that there are involvements of direct SAR-CoV-2 toxicity, endothelial or microvascular injury, and angiotensin-converting enzyme-2 maladaptation in the post-COVID-19 pathophysiology (Nalbandian et al., 2021). While the pathophysiologi-

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cal mechanisms of post-COVID-19 are still unfolding, these complex mechanisms possibly contributed to the myriad clinical manifestations of post-COVID-19 syndromes.

Up to the present time, there are several post-COVID-19 syndrome classifications. The first classification categorizes the post-COVID-19 syndrome into three types: (1) remaining symptoms that continue post-acute infection, (2) persistent dysfunction of organs occurring after initial recovery, and (3) different symptoms occurring after being initially symptomless (Amenta et al., 2020). Clinicians also classify post-COVID-19 into five types according to the type, duration, and onset of symptoms, as well as period of inactivity (Ahmadi Hekmatikar et al., 2022). These various classifications suggest numerous clinical manifestations of post-COVID-19 that need to be anticipated.

To anticipate the post-COVID-19 syndrome, primary and secondary prevention are required. Information on the characteristics of patients with an increased risk of experiencing and having serious post-COVID-19 syndromes is thus needed. A study suggests that the factors that increase the risk may include being female, age older than 70 years, having specific conditions during the acute stage (i.e., having more than five symptoms, dyspnea, increased D-Dimer, C-reactive protein, and leucocyte counts), and patients with a history of mental illness (Yong, 2021). Older age is also reported to be more vulnerable to COVID-19 and post-COVID syndrome, which is attributed to physiological decline and a higher risk of comorbidities (Larson et al., 2021). Older age, therefore, is one of the groups of patients that require more support to prevent and manage post-COVID-19 syndrome.

Several therapies for post-COVID-19 syndrome have been suggested, including pharmacological approaches and physical activity, including exercise (Ahmadi Hekmatikar et al., 2022). Physical activity modulates the immune system to optimize individuals' immunity. Studies suggest that regular physical activity increases the antipathogenic activities of immunity components, thus, increasing the defense mechanism against bacterial and viral infection, including SARs-COV infection (Da Silveira et al., 2021). As such, physical activity remains an important key factor in preventing and managing acute and chronic COVID-19 (Bailly et al., 2022). Physical activity might also prevent the risk of COVID-19 complications and sequelae and improve patients' quality of life. Regular physical activity reduces systemic inflammations (Arovah & Kushartanti, 2020), improves metabolic profiles (Arovah & Heesch, 2021; Arovah & Kushartanti, 2019) and glycaemic control (Ferreira et al., 2021), which optimizes the immune system (Zheng et al., 2015), thus playing important roles in preventing and managing COVID-19 and post-COVID-19 symptoms.

Physical activity is also of utmost importance in preventing and managing post-COVID-19 in old age. The current recommendation for older adults calls for at least 150 minutes to 300 minutes of aerobic physical activity at moderate intensity or at least 75 minutes to 150 minutes of physical activity at vigorous intensity per week. Physical activity at this level is required to maintain optimal immune function (Oliveira et al., 2021). In the elderly population, the metabolic and inflammatory disorders linked with physical inactivity are associated with severe COVID-19 manifestations (Ahmadi Hekmatikar et al., 2022). The inflammation and oxidative stress during COVID-19 in old age increase the risk of hypercatabolism, resulting in an increased risk of muscle atrophy after hospital discharge and eventually reduces their physical fitness, health, and quality of life (Ahmadi Hekmatikar et al., 2022; Pierce et al., 2022). In this context, physical activity is expected to stimulate muscle cells' morphological adaptations that could offset the detrimental effects of COVID-19 on muscle tissue (Ahmadi Hekmatikar et al., 2022). Providing physical activity guidelines to those with COVID-19 or post-COVID-19 syndrome, thus, is a primary concern in health care since it serves as the main rehabilitation means for restoring patients' functional capacity, particularly those who survived hospitalizations (Bailly et al., 2022). However, although emerging evidence has highlighted the roles of physical activity in managing post-COVID-19 and has illustrated the prevalence as well as manifestations of post-COVID-19 in the clinical setting along with the characteristics of those with an increased risk of post-COVID-19, there are existing gaps in the literature that provided the summary of the evidence, particularly among older adults. Moreover, although the systematic reviews of the COVID-19 diagnosis (Bastos et al., 2020; Böger et al., 2021), treatment (Kokkotis et al., 2022; Musa et al., 2020), and prognosis (Dissanayake et al., 2022; Wynants et al., 2020) and impacts are available in the literature, lacking is a summary of the literature that systematically review the impact of post-COVID-19 in older adults and the effect of PA on post-COVID-19 syndromes. Therefore, this study was conducted to summarize the most prevalent symptoms of post-COVID-19 and the risk factors of post-COVID-19 and to highlight evidence of the roles of physical activity in managing post-COVID-19 in older adults.

METHODS

Protocol and Registration

This systematic review conforms to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The study is registered with Open Science Framework (OSF): https://osf.io/qzav6/.

Literature Sources and Search

A systematic search was performed in August 2022 to capture studies written in English and found in Pubmed and Scopus databases from inception to the date of search. Two of the authors (TR, NIA) conducted the search, removed duplicates, and screened the articles. The search strategy used is summarized in Table 1.

Eligibility Criteria and Study Selection

Studies were included in this systematic review if: (1) involving older adults as the targeted population; (2) defining the post-COVID-19 COVID-19 as long-term consequences

occurring in those with a history of possible or SARS-CoV-2 infection that has been confirmed, with symptoms that persist for a minimum of two months within three months of onset in which an alternative diagnosis cannot explain; and (3) being published as an article. The exclusion criteria included (1) short commentaries or letters written in non-IMRAD (Introduction, Method, Results, and Discussion) format, (2) focused on COVID-19 instead of Post COVID-19, (4) published as literature reviews, (5) the full text is unavailable.

Figure 1 illustrates the flow of the searching and screening process based on the PRISMA recommendation. The references resulting from the search strategy were imported into reference manager software (i.e., EndNote XX). All duplicates were removed automatically and manually, then screened in three stages (i.e., based on title, abstract, and full text). Two reviewers (TR and NIA) screened the titles, abstract and full text independently. A discussion with the 3rd and 4th authors (KRP and BWK) were conducted to resolve any discrepancies.

Table 1. Search strategy

Database	Keywords
Scopus	(Title-Abs-Key (sport*) OR Title-Abs-Key ("physical activity") OR Title-Abs-Key (exercise) AND Title-Abs-Key ("post covid*") OR Title-Abs-Key ("long covid*") AND Title-Abs-Key ("older adults") OR Title-Abs-Key (elderly) OR Title-Abs-Key (aging))
Pubmed	((((sports[Title/Abstract]) OR ("physical activity"[Title/Abstract])) OR (exercise[Title/Abstract])) AND ((("post covid"[Title/Abstract]) OR ("long covid"[Title/Abstract]))) AND ((("older adults"[Title/Abstract]) OR (aging[Title/Abstract])) OR (elderly[Title/Abstract]))

Data Collection Process

The data collection process was carried out by two researchers (TR and NIA) independently. Any discrepancies between them were resolved with a discussion with the 3rd and 4th authors (KRP and BWK). The data extraction for each study included: (1) the last name of the author and the publication year, (2) the study design, (3) the study aim, (4) the participants' characteristics, (5) the assessment methods, and (6) results. Data extraction was completed using the table in Microsoft Word (Microsoft Corporation, Redmond, WA, USA).

Methodological Quality of Individual Studies (Quality Assessment)

The quality assessments were then conducted using tools developed by the United States National Heart, Lung, and Blood Institute (NHLBI) in 2013 for the studies that were included in this systematic review to evaluate the risks of bias potential of the studies.

RESULTS

Studies Selection and Quality Assessments

In total, 51 documents met the search criteria, among which 10 articles met the selection criteria, as depicted in Figure 1. The selected studies were published between 2021 and 2022. The selected studies are categorized into studies on post-COVID-19 symptoms' prevalence and risk factors resulting from observation studies (n=7) and intervention studies on physical activity programs for managing post-COVID-19 syndrome (n=3). The assessments of the quality of these studies are available from the authors, upon request. The as-

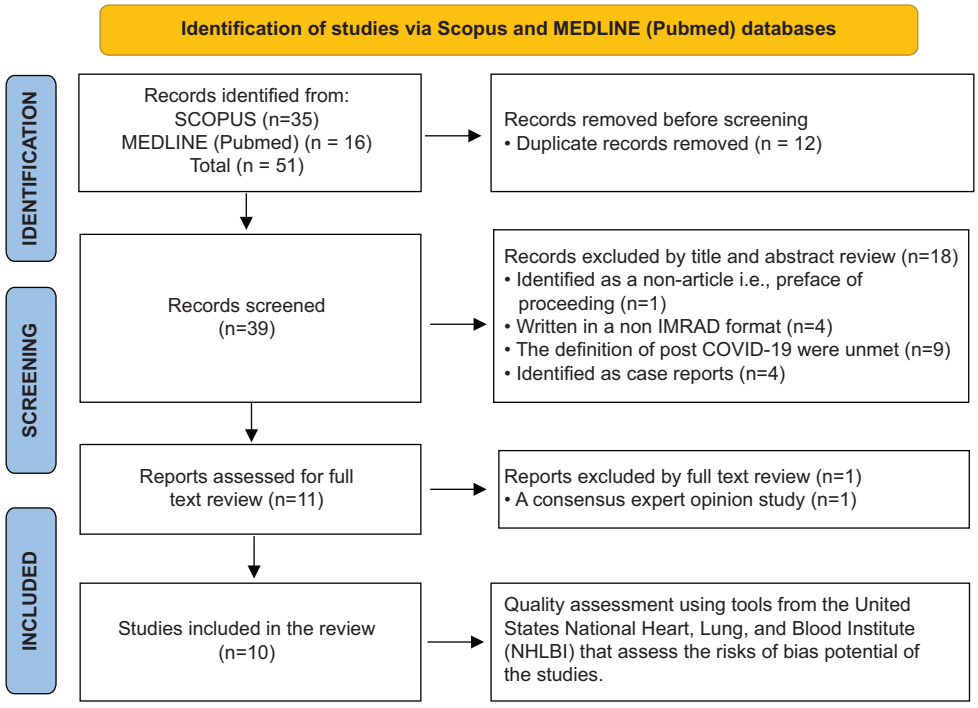

Figure 1. Flow diagram of the study screening process

sessments indicate that all studies were rated fair to good, indicating low to fair risks of bias potential.

Observation Studies on Post-COVID-19 Symptoms, Prevalence, and Risk Factors

The search strategy resulted in seven observational studies focusing on prevalence, symptoms, risk factors, and correlations of post-COVID-19 symptoms (see Table 2). Five were observational cross-sectional studies, while 2 were case-control studies comparing patients with the post-COVID-19 syndrome with those who did not have a COVID-19 diagnosis.

Physical symptoms

Among the reported symptoms associated with physical health included dyspnea (61%), fatigue (54%) (Holdsworth et al., 2022), persistent COVID-like symptoms of 20%, diarrhea of 13% (Islam et al., 2021), and sarcopenia (19.5%) (Martone et al., 2022). A small proportion of patients experience abnormal lung function and pathology, pulmonary thromboembolic, and cardiac pathology (Holdsworth et al., 2022). Another study highlighted the persistent immunological changes among patients with post-COVID-19 symptoms compared to the control (Townsend et al., 2021)

Mental health symptoms

A significant percentage of depression that was moderate to severe (48%) was reported (Islam et al., 2021). Depression was correlated with conditions such as having a low family income, poor health s, sleep difficulties, physical inactivity, hypertension, asthma/respiratory difficulties, worry about contracting COVID-19 again, and ongoing COVID-19 symptoms (Islam et al., 2021). Similarly, cognitive deficits were also reported in individuals with persistent symptoms of lethargy, such as reduced concentration, reduced memory, low mood, and anxiety (Holdsworth et al., 2022).

Physical performances and quality of life

Reductions in physical performance and the overall quality of life were also reported. Post-COVID-19 patients had substantial exertional dyspnea, lower health-related quality of life, and a decrease in functional status (Lam et al., 2021). They were also more likely to experience worse physical health, worse physical endurance, poorer functional status, and difficulties in performing physical activities, as well as experiencing generalized muscle weakness compared to those without the post-COVID-19 diagnosis (Rogers-Brown et al., 2021). Difficulties in recovering from pre-COVID-19 physical performance were reported by 67% of post-COVID-19 patients 24 weeks after the onset of COVID-19 (Holdsworth et al., 2022). Another study reported that their study participants did not return to their previous functional baseline after 3-4 months from the acute infection (Lam et al., 2021).

Prevalences, risk factors and correlations of post-COVID-19 symptoms

The prevalences of post-COVID-19 syndromes reported in our inclusion studies were varied, ranging from 20% to 69%. These studies also reported several participants' characteristics associated with post-COVID-19 symptoms, including the decline in participants' physical performance. As expected, older patients had greater mobility difficulties and daily activities than younger patients (Mińko et al., 2022). Younger participants, however, were associated with lower exercise tolerance function and reduced health-related quality of life (Lam et al., 2021). More frequent post-COVID-19 symptoms are also associated with sarcopenia. Patients with longer hospital stays, inactivity, and lower serum albumin levels were more likely to have sarcopenia. (Martone et al., 2022). Those with greater body mass index were also more likely to have more symptoms such as dyspnea, chronic fatigue, mobility problems, and daily activities (Mińko et al., 2022). Interestingly, patients who received care after COVID-19 were more likely were men, younger in age, employed, and insured. (Rogers-Brown et al., 2021).

Intervention Studies on Physical Activities Programs for Managing the Post-COVID-19 Syndrome

Three studies met the search criteria, focusing on physical activity programs in managing post-COVID-19 symptoms (see Table 3). Two studies were one group pre-post design, while one study was an RCT design. One of the non-RCT studies was a feasibility study on patients in a deprived community. The study reported that 8 of the 10 participants completed the multidisciplinary-based physical activity program, thus indicating the quite high acceptability of this intervention (Fowler-davis et al., 2021). The other non-RCT study was conducted on post-COVID-19 patients treated with a physical activity program to improve their functional status (Udina et al., 2021). They reported improvement in the Short Physical Performance Battery (SPBB), Barthel Index, walk ability, single leg stance, and clinical status and cognitive indicators post-treatment, with younger patients experiencing greater improvement in SPPB and gait speed (Udina et al., 2021). The RCT study reported that aerobic training exercises at low intensity improved kinesiophobia, quality of life, and muscle strength in post-COVID-19 patients with sarcopenia than in high-intensity aerobic training (Nambi et al., 2022).

DISCUSSION

This systematic review aimed to synthesize existing findings from studies exploring post-COVID-19 symptoms, risk factors, and the roles of PA interventions in managing post-COVID-19 syndrome among older adults. The overall findings of this systematic review indicate several physical and mental health problems and reduced activity performance linked to the post-COVID-19 syndrome among older adults. The intervention studies that were included in this systematic review also suggest the feasibility and effectiveness of

Table 2. Observation studies on post-COVID-19 symptoms, prevalence, and risk factors

No	Author (year)	Design	Aim	Participants	Assessments	Results
1.	Holdsworth et al. (2022)	Observation Cross-sectional	Identify physical and neurocognitive deficits in post-COVID-19 patients at 24th weeks after onset	N=205 84% men Age 39 (IQR=30–47)	• Post-COVID-19 symptoms • Performance status by WHO • Cardiopulmonary exercise assessment • Pulmonary function and angiogram • High-resolution computerized tomography chest (HRCT) • Cardiac magnetic resonance imaging (MRI) • Cognitive assessment	• 69% reported more than three persistent symptoms, fatigue (54%), dyspnea (61%), cognitive issues (47%), anxiety (17%), and depression (24%). • AT week 24th, 67% of performances did not reach the pre-COVID level. • 30% experienced abnormal pulmonary function, • HRCT was required in fewer than 50% of patients, in which pathology was found in 25% of these cases. • Low rate of pathologies in lung thromboembolic. • Cognitive declines were reported in those with persistent symptoms of fatigue, which included low concentration, memory, and mood, as well as anxiety
2.	Islam et al. (2021)	Observation Cross-sectional	Analyze the effects of treatment, ongoing symptoms, and depression in post-COVID-19 patients.	N=1002 60% men Age,mean=35, SD=14; age range=18–81	• Socio-demographics and lifestyle.Post-COVID-19 signs and symptoms • Medication covers both over-the-counter medicines and prescriptions by doctors • Depression was assessed using the Patient Health Questionnaire	• 20% of patients reported ongoing COVID-like symptoms, diarrhea (12.7%), and fatigue (11.5%). • 48% of patients experienced moderate to severe depression. • Depression is associated with a low family income, insufficient health status, problems in sleep, physical inactivity, asthma/respiratory issues, hypertension, worry about experiencing COVID-19 re-infection, and ongoing symptoms of COVID-19.
3.	Lam et al. (2021)	Observation Cross-sectional	Describe the characteristics of patients with post-COVID-19	N=165 Age, Mean=51, SD=16 Low exercise tolerance N=59 (36%) Age, Mean= 40, SD=15 Normal exercise tolerance N=106 (64%) Age, Mean= 54, SD=14	• Quality of life • Functional status • Pulmonary function • Neurologic, musculoskeletal, and fatigue symptom	• Post-COVID-19 patients had substantial dyspnea, a decline in health-related quality of life, and low functional status. • They did not experience lung function or neurological, musculoskeletal, and fatigue symptoms. • Those with lower exercise tolerance function were younger and had a substantially lower health-related quality of life. • They did not return to their previous functional baseline after 3-4 months from acute infection

(*Contd...*)

Table 2. (*Continued*)

No	Author (year)	Design	Aim	Participants	Assessments	Results
4.	Martone et al. (2022)	Observation Cross-sectional	Define the prevalence of sarcopenia among post-COVID-19 patients and related risk variables in post-COVID-19 patients.	N=541 51% women Age, mean=53, SD=15, range=18-86 years	• Multidisciplinary clinical assessment • Muscle strength testing • Physical performance evaluations	• The sarcopenia prevalence was 19.5% • The cases were more frequent in patients with longer hospitalization periods, physical inactivity, and low level of albumin serum. • Sarcopenic patients had more frequent ongoing symptoms, which included dyspnoea, fatigue, and joint pain.
5.	Mińko et al. (2022)	Observation Cross-sectional	Evaluate factors influencing the type and severity of post-COVID-19 symptoms.	N=932 84% Women Age, Mean =41, SD= 12	• COVID-19 Yorkshire Rehab Screen (C19-YRS) questionnaire.	• Older patients had greater difficulties in mobility and in performing daily activities • Patients with higher BMI had more symptoms (i.e., dyspnea, chronic fatigue, problems with mobility, and in performing daily activities
6.	Rogers-Brown et al. (2021)	Observation Case-Control	Compare patient-reported health measures between post–COVID-19 patients and control (patients with a current or previous neoplasm diagnosis that required rehabilitation)	Cases N=1,295 57% women 40% >60 year Control, N=2,395 75% women 55%>60 years.	• Self-reported health measures and a 6-minute walking test • Clinical evaluations for health and physical endurance	• Post–COVID-19 patients had higher odds of reporting (1) worse physical health and difficulty with physical activities, (2) worse physical endurance measured than control patients, (3) poorer physical health and functional status than control and (3) experiencing fatigue and generalized muscle weakness • Most Patients were male, younger in age, employed, and had insurance
7.	Townsend et al. (2021)	Observation Case-Control	Determine whether ongoing inflammation and immune cell dysregulation were evident in post-COVID-19 Investigate risk factors of persistent immune dysregulation	Cases N=111 63% women Age, Mean=46, SD=15 Control N=40 55% women Age, Mean=48, SD=15	• Symptoms • Exercise tolerance and fatigue were evaluated as cardinal features of post-COVID-19, which was assessed using the Chalder Fatigue Scale and 6-minute-walk test (69% of participants) • Immunophenotyping at acute COVID-19 and in the post-COVID-19 period.	• Of all patients, 64% stated they did not feel fully recovered, and 55% qualified as fatigued, according to the case description. • 475m was the average distance traveled (IQR 415 – 540). • The average score for maximum weariness was 3. (IQR 2–5). • At a median of 68 days after the commencement of COVID-19, it was discovered that intermediate monocytes and CD8+ T cells and a decrease in CD8+ T cells and naive CD4+ with activated CD8+ T cells were expanding. • At 101 days, patients older than 60 showed decreased CD4+ and CD8+ naive T cells and increased CD4+ T cells that had been activated. • In this cohort, poor health, exhaustion, and decreased exercise tolerance were frequent, but neither immune cells nor circulating cytokines pro-inflammatory were related to these symptoms.

Table 3. Intervention studies on physical activities programs for managing post-COVID-19

No	Author (year)	Design	Aim	Participants	Intervention	Outcomes	Results
1.	Fowler-Davis et al. (2021)	One group pre and post design (feasibility study)	Develop an intervention for adults with post-COVID-19 who reside in underprivileged community areas.	N=10 75% women Age= 38 -73	Techniques spanning multiple disciplines, including functional rehabilitation, structural advice, and sport and exercise medicineDuration=4 months	Acceptability (participation and completion)	• 80% completed the intervention • Participants' needs during the program were linked to general deconditioning, fatigue, anxiety, and depression.
2.	Nambi et al. (2022)	Randomized control trial	Compare clinical and psychological effects of concurrent exercise at low and high intensities in Post COVID-19 older aged men with sarcopenia.	N=68 100% of men with sarcopenia Age=60–80	One session every day, 4 days per week, for 30 minutes eachDuration=8 weeks. Allocation Group undergoing low-intensity aerobic exercise (n = 38) Group undergoing high-intensity aerobic exercise (n = 38)	Muscle mass and strength Kinesiophobia Quality of life Measurement: Baseline, 4th week, 8th week 6th-month follow-up.	• In the sixth month, the group that engaged in low-intensity aerobic exercise saw greater improvements in kinesiophobia, hand grip, and quality of life than the group that engaged in high-intensity aerobic exercise. • No difference was found in muscle mass
3.	Udina et al. (2021)	One group pre-post design	Analyze the effect of multi-modality exercise on physical performance for post-COVID-19 symptoms.	N=33 58% women Age, mean=66, SD=13	A daily 30-minute multi-component therapeutic exercise program that included balance, endurance, and resistance trainingDuration=10 days	Short Physical Performance Battery (SPBB) Barthel Index Walk ability Leg stance balance single Clinical status Cognitive indicators	• All outcomes improved significantly • SPPB and gait speed were improved more in younger individuals.

PA programs when they are organized as a multidisciplinary approach. To be noted, however, that while we used the term 'older adults' and its synonyms in our search strategy, only one selected study exclusively studied older adults (Nambi et al., 2022). The average of participants' age in most studies fell into middle age, which involved a wider age range from middle age to older adults. Therefore, the term 'older adults' in this systematic review covers these age ranges.

This current systematic review indicated that the most reported symptoms and signs associated with physical health included dyspnea (Holdsworth et al., 2022), fatigue (Holdsworth et al., 2022), diarrhea (Islam et al., 2021), sarcopenia (Martone et al., 2022), and abnormal lung function (Holdsworth et al., 2022), cardiac pathology (Holdsworth et al., 2022), immunological alterations (Townsend et al., 2021), reduced physical performance (Lam et al., 2021; Rogers-Brown et al., 2021; Townsend et al., 2021), respectively; while the reported symptoms associated with mental health included depression, poor concentration and memory, and anxiety (Holdsworth et al., 2022). These findings confirm the vast array of post-COVID-19 clinical manifestations stated in previous studies and thus signified the importance of screening and managing physical and mental health symptoms in older patients with post-COVID-19 syndrome (Ahmadi Hekmatikar et al., 2022; Amenta et al., 2020).

The systematic review also suggests some risk factors for the likelihood of post-COVID-19 syndrome. Older patients with higher body mass indexes were more likely to have more post-COVID-19 symptoms. The findings align with previous studies' findings indicating that obesity is related to more severe and frequent COVID-19 symptoms since it generates alterations in immune responses associated with poor viral responses (Albashir, 2020; Alberca et al., 2021; Yu et al., 2021). In addition, older patients also had greater difficulties in mobility and in performing daily activities (Mińko et al., 2022). This is similar to the findings from previous studies, which indicated the increased risk of older adults experiencing physical performance declines (De Smet et al., 2020; Sun et al., 2020).

A study performing a 6 minutes walking test (MWT) on post-COVID-19 older patients suggested that those with reduced exercise tolerance were likely to be younger in age,

while those who were lighter had normal exercise tolerance function (Lam et al., 2021). The findings were unexpected as there were also no differences between the two groups in the proportion of the acute COVID-19 phase that required hospitalization and ICU admission in both groups, as well as the rates of diabetes, musculoskeletal disease, chronic obstructive pulmonary disease, coronary artery disease, peripheral vascular disease, congestive heart failure, and mental health disorders between groups. However, those with lower exertional tolerance had less dexamethasone exposure, thus increasing the prospect of acute steroid treatment that may lessen long-term COVID-19 problems (Lam et al., 2021). Further studies that employ regression analyses for controlling for covariates, therefore, are required to conclude whether age or the use of steroids independently influences the risk of post-COVID development. Moreover, another study utilizing a 6MWT test demonstrated that post–COVID-19 older patients experienced fatigue, lower ability to be physically active, and lower physical functioning when compared to those in the control group with no previous diagnosis of COVID-19 (Rogers-Brown et al., 2021). To be noted that the control group of that study consisted of those with previous neoplasm diagnoses. Thus, it was expected that the difference between the case and control group would be larger compared if the control groups consisted of normal individuals. Since it was difficult to return to pre-COVID-19 physical performance months after the commencement of the acute infection, the deficits in physical performance were linked to declines in quality of life (Lam et al., 2021). The overall findings highlight the value of the 6-MWT as a tool for identifying people who are fatigue intolerant and dyspneic despite having normal lung function. Furthermore, those with reduced exercise tolerance may also need support for accelerating recovery and physical performance to the pre-COVID-19 condition.

The intervention studies included in this systematic review suggest the feasibility of a multidisciplinary-based PA program (Fowler-davis et al., 2021). Improvements in physical performance, reduced fatigue, ability to walk, balance, and recovery of clinical functional and cognitive function after an exercise program was also suggested. (Udina et al., 2021). Exercises using low-intensity aerobic training have been found to be more successful than exercises involving high-intensity aerobic training in improving kinesiophobia, muscle strength, and quality of life in older patients with sarcopenia who underwent COVID-19. More studies are required to explore the most appropriate exercise programming for older patients with post-COVID-19 syndrome who demonstrate specific symptoms.

This systematic review has summarized the findings on clinical manifestation and risk factors of post-COVID-19 and the preliminary evidence on the feasibility and effectiveness of PA programs in managing post-COVID-19 syndrome by following the PRISMA guideline. This systematic review is, however, also subject to some limitations. First, this systematic review did not extend to the quantitative meta-analysis due to the heterogeneity of the selected studies. Second, also due to the heterogeneity of our results, the recommended PA intervention for the targeted population, older post-COVID-19 patients, could not yet be drawn. However, studies included in this systematic review indicate that a multidiscipline-based PA program combining resistance, endurance, and balance training, which is performed regularly at a lower intensity and for a long period (i.e., six months), appears to provide more benefit to alleviate the post-COVID-19 syndrome in older adults. It complements the recommendation for younger people in a similar situation, suggesting that they are recommended to exercise 2 to 3 times per week at moderate for 150 to 300 min per week or high-intensity exercise for 75 minutes (Yang et al., 2022). Third, although the search strategy in this systematic review focused on older adults, which are usually defined as individuals older than 60 years (Mathers et al., 2015), the population in the included studies also covers middle age. The findings from this study, thus, need to be interpreted accordingly. Fourth, there were only two databases (i.e., Scopus and PubMed) that we used for literature searching, thus excluding relevant literature outside the repositories. Pubmed, however, was the optimal database for biomedical electronic research (Al Ryalat et al., 2019; Falagas et al., 2008). Additionally, Pubmed provides the best update frequency and has early articles online. Scopus, as a multidisciplinary database (Al Ryalat et al., 2019), on the other hand, has the advantage of having approximately 20% more coverage than Web of Science, which is also a multidisciplinary database. These two databases also have an advantage over Google Scholar, as Google Scholar is not curated and is often considered inadequate (Falagas et al., 2008). It is expected, therefore, that Scopus and PubMed are representatives of biomedical research. In light of the limitations of this current study, further exploration of the most effective PA programming for older post-COVID-19 patients, using stringent age criteria and covering larger databases, is recommended in future research.

CONCLUSION

This systematic review summarizes the symptoms and signs associated with physical health, including dyspnea, fatigue, diarrhea, sarcopenia, and abnormal lung function, cardiac pathology, immunological changes, reduced physical performance respectively. While the reported symptoms associated with mental health included depression, poor concentration and memory, and anxiety, those with higher body mass indexes were more likely to have more symptoms, and older patients had greater difficulties in mobility and in performing daily activities. The intervention studies suggest the feasibility and the effectiveness of the PA program, which are multidisciplinary and based on improving fatigue, ability to walk, balance, and cognitive function. For patients with sarcopenia, the quality of life, kinesiophobia, and muscle strength appears to be improved more by low-intensity aerobic training than by high-intensity aerobic training. Although older adults have reported a variety of post-COVID-19 symptoms related to their physical and mental health, as well as its risk factors, patients recovering from COVID-19 may still continue to experience poor health, and as a result, they could

benefit from additional support to enhance their physical functioning. To avoid and manage the possible impacts of long-term post-COVID-19 infection, the healthcare system and provider should be ready to identify and fulfill the ongoing requirements of this group of patients. Finally, further research is recommended to explore the most appropriate PA program for these patients.

AUTHOR CONTRIBUTIONS

Conceptualization: TR, WK, NIA. Data curation: NIA. Formal analysis: TR, NIA. Methodology: TR, WK, NIA. Project administration: TR. Visualization: NIA, KRP. Writing - review & editing: TR, WK, NIA, KRP.

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