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Functional capacity, exercise tolerance, muscle strength, hand grip, and quality of life in patients with COVID-19. A cross-sectional study

MAHA ALSHAMMARI[1,2], ALSAYED SHANB[1], MOHAMMED ALSUBAIEI[1], MOHAMMAD AHSAN[1], BELAL SHANB[3]

[1]Department of Physical Therapy, College of Applied Medical Sciences, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia; [2]Department of Physical Therapy and Rehabilitation, Aljouf Cardiac Center at King Abdulaziz Specialist Hospital, Aljouf Health Cluster, Ministry of Health, Sakaka Aljouf, Saudi Arabia; [3]Department of Cardiology, Faculty of Medicine, University of Helwan, Giza, Egypt

ABSTRACT

Background and aim: The COVID-19 pandemic has posed significant challenges to global health, affecting millions of individuals worldwide. This study aims to investigate the effects of moderate-severity COVID-19 on functional capacity, exercise tolerance, isometric muscle strength, hand grip strength, and quality of life.
Methods: Ninety-six participants (48 with COVID-19, 48 without COVID-19) were recruited in this cross-sectional study. The effects on functional capacity, exercise tolerance, isometric muscle power, handgrip, and quality of life were measured. The Mann-Whitney test was used to assess significant differences between the COVID-19 and matched groups. The Spearman correlation was used to determine the relationships among outcome measures.
Results: The mean values of functional capacity, isometric muscle power, hand grip, and quality of life were significantly reduced in patients with moderate COVID-19 compared with their matched counterparts ($p < 0.05$), except for exercise tolerance ($p > 0.05$). Positive relationships were detected between exercise tolerance, hand grip strength, and knee extensors; and between distance in the 6-minute walk test and exercise tolerance, hand grip strength, and knee extensors ($p <0.001$).

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Correspondence: Mohammad Ahsan, Ph.D. / Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia / E-mail: mahsan@iau.eud.sa
ORCID: 0000-0003-0232-3658

Conclusions: Moderate-severity COVID-19 patients exhibit impairments in functional capacity, exercise tolerance, isometric muscle strength, hand grip strength, and quality of life. Exercise tolerance correlated positively with the 6-minute walk test, hand grip strength, and knee extensor strength. (www.actabiomedica.it)

Key words: COVID-19, pandemic, hand grip, muscle strength, quality of life

Introduction

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, has had profound, multifaceted impacts worldwide. Originating in late 2019, the virus rapidly spread, resulting in widespread health, economic, and social challenges (1). The COVID-19 pandemic has resulted in over 290,000 deaths globally. Social distancing, self-isolation, and travel restrictions have reduced the workforce across all sectors, leading to widespread job losses. Schools have closed, and demand for commodities and manufactured products has decreased. In contrast, demand for medical supplies and food has increased significantly due to panic-buying (2). The challenge of COVID-19 includes the frequent occurrence of pandemics, the escalation of antimicrobial resistance, and the need to mitigate and adapt to climate change (3). The COVID-19 pandemic has not only led to acute health challenges but also raised concerns about the long-term effects on individuals' functional abilities, particularly in those who experienced moderate illness (4). Fatigue, muscle weakness, physical inactivity, and a reduced quality of life are among the persistent symptoms; therefore, understanding these functional outcomes is essential for providing appropriate care and supporting those recovering from the virus (5). Infected patients with SARS-CoV are associated with impairments in physical functions and fitness in comparison with matched controls. Also, 63% & 67% of those patients demonstrated significant reductions in functional status and quality of life, respectively (6). In addition, the isometric strength of the biceps brachii, quadriceps, hand grip (7,8), and dynamic leg extensor muscles (9). The one-minute sit-to-stand test was significantly limited in 33.3% of patients with COVID-19, reflecting impairments in physical fitness, exercise tolerance, and lower extremity function. In addition, reductions in short physical performance battery scores, a poor Barthel index, and impaired performance in activities of daily living were observed (10). Unfortunately, a persistence of physical and psychological symptoms was detected in 55% of patients in the eighth month after recovery from COVID-19. In comparison, 22.5% still experience limitations in daily activities to varying degrees (11). Impairments in the 6-minute walk test, hand grip strength, and quadriceps strength affect more than 20% of patients as outcome measures at the third-month follow-up (12). In contrast, significant improvements were achieved in the twelfth month of follow-up. Physical activities and exercise tolerance still be impaired in patients with COVID-19 after the time of discharge (7,13), also as a result of dyspnea and fatigue the distance of the two-minute walk test was less than 100 meters (14), existing a high proportion of impairments in physical activities at the third month, a reduction in the average time of spent distance of walking (15) and impairments in the quality of life (16) were detected up to sixth-months post-infection particularly in elderly male patients and those needed for mechanical ventilation during intensive care unit (ICU) and hospital stays (6). Pulmonary function, exercise capacity, and physical activity are negatively affected in COVID-19 patients, regardless of infection severity (17). Like coronavirus infection (SARS-CoV), COVID-19 is expected to induce impairments for two years, which may also occur in survivors. Particularly those patients who experienced severe COVID-19 symptoms; therefore, similar impairments are expected to affect the survivors of COVID-19 (18,19).

Strength of the peripheral muscle, physical performance, physical activities, mood, and sleep quality were measured at the twelfth week post-COVID-19 infection. Significant reductions in muscle strength and physical activity were observed (13). They suggested that non-severe COVID-19 survivors might be overlooked during the pandemic; thus, comprehensive assessment and proper management approaches should be considered for these patients. Severe cases of COVID-19 have received considerable attention and attracted the interest of various specialists, while those with moderate-severity COVID-19 (who exhibit a wide range of symptoms) may also suffer from functional impairments, warranting further investigation (13,15). The existing literature primarily focuses on acute respiratory symptoms and immediate clinical outcomes, often overlooking long-term functional impairments that may persist after recovery. While some studies have assessed individual components, such as muscle strength or quality of life, separately, there is a lack of integrated research evaluating these factors collectively in the context of post-COVID-19 rehabilitation. Understanding how these variables influence functional capacity and overall well-being in a post-COVID-19 population could provide critical insights for developing targeted rehabilitation strategies. This study aims to fill these gaps by investigating the effects of moderate-severity COVID-19 on functional capacity, exercise tolerance, isometric muscle power, hand grip strength, and quality of life, by comparing patients with COVID-19 to matched participants and examining correlations among these outcome measures. By adopting a cross-sectional approach, the research will address the current limitations in the literature and contribute to a more nuanced understanding of the long-term consequences of COVID-19 on physical health and quality of life.

Methods

Study design: A comparative cross-sectional study.

Ethical consideration: The procedure for this study was approved by the Institutional Review Board of Imam Abdulrahman bin Faisal University, Dammam, Saudi Arabia, with IRB number (IRB-PGS-2021-03-427). Also, by the Research Ethics Committee at Qurayyat Health Affairs, Ministry of Health, Project no: 083, Saudi Arabia. This study was conducted in accordance with the Declaration of Helsinki at the outpatient clinic of the Physical Therapy Department at King Abdulaziz Specialist Hospital in Sakaka, Al-Jouf. Before participating, all participants signed a consent form, and they were informed that the collected data would be submitted for publication.

Sample size calculation: The sample size was calculated using an online tool (http://www.stat.ubc.ca/~rollin/stats/ssize/n2a.html). It was based on the results of the 6-minute walk test for the functional capacity variable of COVID-19 patients and normal controls ($\mu1 = 550$, $\mu2 = 623$, sigma/SD = 110, in the previous study) (20). The significance level is 0.05, with a power of 0.90.

Subjects: A total of 96 participants were recruited, including 48 with COVID-19 and 48 matched controls, from the Department of Pulmonology and the outpatient clinic of the Physical Therapy at King Abdulaziz Specialist Hospital in Sakaka, Aljouf.

a. ***COVID-19 group:*** Forty-eight male and female patients, confirmed to have moderate COVID-19 infection at least 3 months after recovery, were examined after undergoing physical inspection and review of reports by specialists.
b. ***Matched Group:*** Forty-eight male and female participants, matched for the control group, were not infected with COVID-19, as their polymerase chain reaction (PCR) tests were negative.

Inclusion criteria: Male and female adult patients who were diagnosed with moderate severity of COVID-19 infection, who were recruited at least three months after recovery. Recovery is defined as being free from fever and respiratory symptoms for at least 3 days, followed by two negative PCR tests 24 hours apart, or if PCR was not available, resolution of the clinical manifestations for 3 days. At least 10 days have passed since the first symptom appeared (21). The demographic data of participants in both groups were matched.

Exclusion criteria: All participants who cannot walk, patients with unstable cardiovascular or respiratory diseases, neurological disorders, mental illness, critically ill patients with intubation, smokers, those with acute infections, liver and renal failure, individuals who have recently had surgeries, and anyone with other medical conditions that contradict the current study were excluded (22,23).

Assessment equipment & outcome measures

Stadio-cum-weighing scale was used to measure height, weight, and body mass index.

An electronic sphygmomanometer was used to measure blood pressure (Beurer BM 26).

A Pulse Oximeter was used to measure oxygen saturation and control heart rate during the 6MWT assessment for every participant. It is a valid and reliable device (24).

The Six-Minute Walk Test (6 MWT) is a simple, non-invasive test. It measures the functional capacity level (25). The validity and reliability of the 6MWT have been established to estimate submaximal exercise performance, mobility, and physical endurance in older adults (26–28) and post-COVID-19 patients (22,29).

The one-minute sit-to-stand test is a valid and reliable measure of exercise tolerance (2,30).

World Health Organization Quality of Life Questionnaire (WHO QoL-BREF) Arabic version. It has been a valid and reliable measure of quality of life during the last two weeks. It consists of four domains: physical health, psychological status, social relationships, and environment. Each domain score is graded on a scale of 1 to 5 points. The domain scores are calculated by taking the mean and multiplying it by 4. Then, the scores are transformed to a 0-10 scale (31).

A handheld dynamometer (MicroFET®2; www.hogganscientific.com) was used to measure isometric muscle strength of the right and left wrist extensors, right and left elbow flexors (32), and right and left knee extensors (7,33).

A Jamar hydraulic handheld dynamometer was used to objectively measure isometric hand-grip strength (34) according to the procedure of a previous study (35,36).

Procedure: The medical records of every participant were reviewed to assess their past medical history, comorbidities, COVID-19-related complications, COVID-19 severity, and whether they had been admitted to the intensive care unit. The degree of severity of the infection was classified according to the WHO clinical progression scale (37). The scale classifies the severity of COVID-19 infection into five categories: 1-uninfected with a zero score, 2- a mild disease with a score ranging from 1-3, 3- a moderate disease with a score ranging from 4-5, 4- a severe disease with a score ranging from 6-9, and 5- dead with a score of 10. All participants signed a consent form before participating in the subsequent assessment procedure.

Oxygen saturation and heart rate

A pulse oximeter was attached to the index and wrist of the non-dominant hand for each patient, while in a relaxed seated position, to monitor oxygen saturation and control heart rate during the 6MWT assessment (24).

Dyspnea severity was monitored in each patient during the 6 MWT using the Modified Borg Dyspnea Scale (38). Function capacity was measured (6MWT) by asking every participant to walk independently at his or her usual walking speed on a flat, non-slippery surface in a 30-meter-long corridor for 6 minutes as fast as possible without oxygen support; he or she can stop and take a rest if needed. The time was counted using a stopwatch, and the distance was recorded in meters. The quality of life was evaluated by asking each participant to take a 20–30-minute rest, during which they were given a quality-of-life questionnaire to read and accurately respond to all questions with the most suitable answers.

Exercise tolerance

After adequate rest, each participant was asked to repeat the sit-to-stand test as fast as possible for 1 minute, supporting their hands on their hips at the waist, and the number of repetitions was recorded. One research assistant measured isometric muscle strength. The data collection process was blinded because patients were not shown their readings during

muscle strength measurements. All patients received the same instructions to exert maximum force using the target muscle during the testing maneuver. Scores of the isometric muscle strength of the dominant side (right side) were included in the analysis.

a. ***Wrist extensors:*** From a sitting position, the handheld dynamometer was placed distal to the wrist joint on the dorsal surface of the hand with the elbow flexed at 90 degrees. Each participant was instructed to extend their wrist against the dynamometer as far as possible. This trial was repeated three times, with a 15-second rest between trials (39), and the average was recorded for analysis (32).
b. ***Elbow flexors:*** Every patient was asked to assume a supine position with shoulders in a neutral position and adducted by 40 degrees. The elbow was flexed at 90 degrees, and the handheld dynamometer was placed proximally to the styloid on the inner surface of the forearm. Each participant was asked to flex the elbow against the dynamometer as much as possible. This trial was repeated three times with adequate rest between trials. (39), the average was recorded for analysis (32).
c. ***Knee extensors:*** Every participant was asked to sit upright with their knee flexed approximately 90 degrees. The hip and trunk were kept stable, and the handheld dynamometer was positioned at the distal tibial region of each participant. Participants were instructed to extend their knee against the dynamometer as far as possible. This trial was repeated 3 times with adequate rest between trials (39). The average was recorded for analysis (7,33).
d. ***Hand grip strength:*** Each participant was instructed to sit upright in a chair with hips and knees flexed at 90°, shoulders adducted, elbows flexed at 90°, forearms in a neutral position between supination and pronation, and wrists in a neutral position. Participants were asked to exert maximum force by squeezing the dynamometer handle with their dominant hand for 3-5 seconds. This procedure was performed three times for each patient, with adequate rest between trials, and the final value was calculated as the mean of the three results (34,39).

Statistical analysis: The collected data were analyzed using SPSS (version 25) and tested for normality using the Shapiro-Wilk test. Descriptive statistics were calculated for demographic characteristics. The Chi-square test was used for categorical variables, and the independent t-test was used for continuous variables. The Mann-Whitney U test was used to determine significant differences between the two groups for variables that are not normally distributed. The Spearman correlation coefficient was used to assess relationships among outcome measures. Statistical significance was set at $P < 0.05$, with a 95% confidence interval.

Results

The mean values of anthropometric data, including age, body mass index, blood pressure, and comorbidities, show no significant differences between patients with COVID-19 and matched participants (p-values> 0.05), except for a significant difference in oxygen saturation (p-value < 0.05) (Table 1). The mean values of time of recruited COVID-19 patients after recovery time in months were (8±3.34).

The results of the Minney Whitney test show significant differences in the mean values of the 6MWT, hand grip strength, and elbow flexors, wrist & knee extensors, and quality of life (p-value < 0.05). In contrast, non-significant differences were detected in mean values of the exercise tolerance between two groups (p-value > 0.05), (Figures 1 and 2) and (Table 2).

The results of Spearman correlation in the matched group show positive correlations between sit-to-stand (exercise tolerance) and distance of the 6 MWT (functional capacity) (0.794, < 0.001), strength of the Rt & Lt hand grip (0.407, 0.004 &0.363, 0.011), isometric strength of the Rt & Lt knee (0.477, 0.001& 0.474,0.001), isometric strength of the Rt wrist extensors (0.333, 0.021), and quality of life (0.301, 0.038& 0.320,0.027). Positive correlations were detected between the distance of the 6MWT (functional capacity) and strength of the Rt & Lt hand grip (0.344, 0.017&

Table 1. Demographic data of patients with COVID-19 and matched participants.

Variables		Groups	Mean ± SD	CI at 95% Lower (upper)	p-value
Age		*COVID-19 participants*	47.15 ± 9.32	-1461(5.451)	0.213†[a]
		Matched participants	44.64 ± 10.21	-1.451 (6.462)	
BMI		*COVID-19 participants*	27.93 ± 4.49	-2.498 (1.744)	0.725† [a]
		Matched participants	28.31 ± 5.88	-2.500 (1.746)	
HR		*COVID-19 participants*	78.29 ± 10.78	-6.738 (2.863)	0.425 [a]
		Matched participants	80.23 ±12.82	-6.740 2.865	
SBP		*COVID-19 participants*	109.48 ±11.03	-7.088 (1.746)	0.233† [a]
		Matched participants.	112.15 ±10.77	-7.087 (1.746)	
DBP		*COVID-19 participants*	72.69 ±12.79	-6.150 (4.234)	0.715† [a]
		Matched participants	73.65 ±12.83	-6.150 (4.234)	
SPO2		*COVID-19 participants*	97.29 ±1.05	-1.310 (-0.606)	.000 [a] *
		Matched participants	98.25 ± 0.64	-1.311 (-0.605)	
Comorbidities With 2 n (%) with 3&4 n (%)		*COVID-19 participants*	33(69%) & 25(31%)		0.567†[b]
		Matched participants	21(44%) & 27(56%)		
Sex	***Male n (%) & Female n (%)***	*COVID-19 participants*	17(35%) & 31(65%)		0.830†[b]
		Matched participants	16(33%) &32(67%)		

a: Independent t-test was used to compare continuous variables, b: Chi-square test was used to compare categorical variables *. Significant differences (p-value < 0.05). †: Non-significant differences (p-value > 0.05). *Abbreviations:* BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; SPO2: Oxygen saturation. HR: Heart rate: CI: confidence interval at 95%.

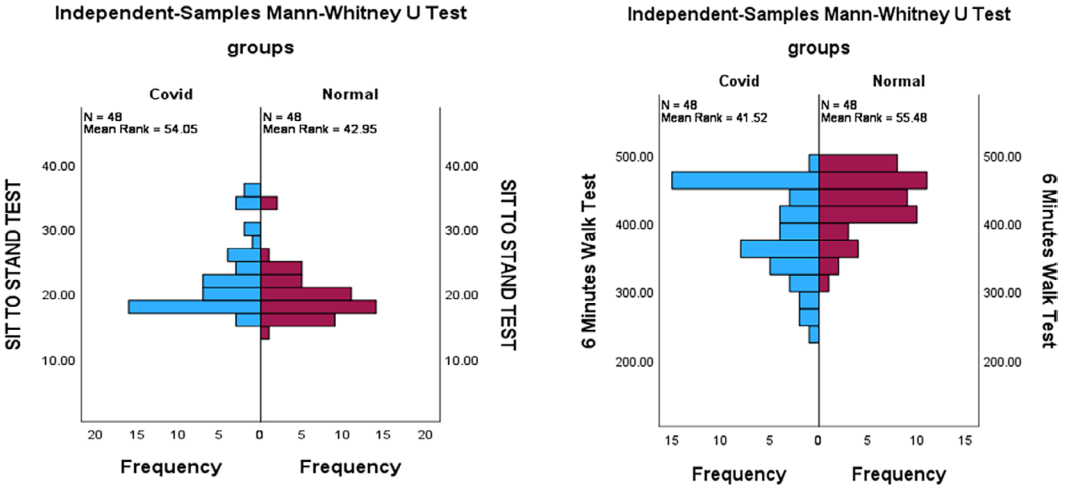

Figure 1. Comparison of mean values of the Sit to Stand test, 6MWT of patients with COVID-19, and matched participants.

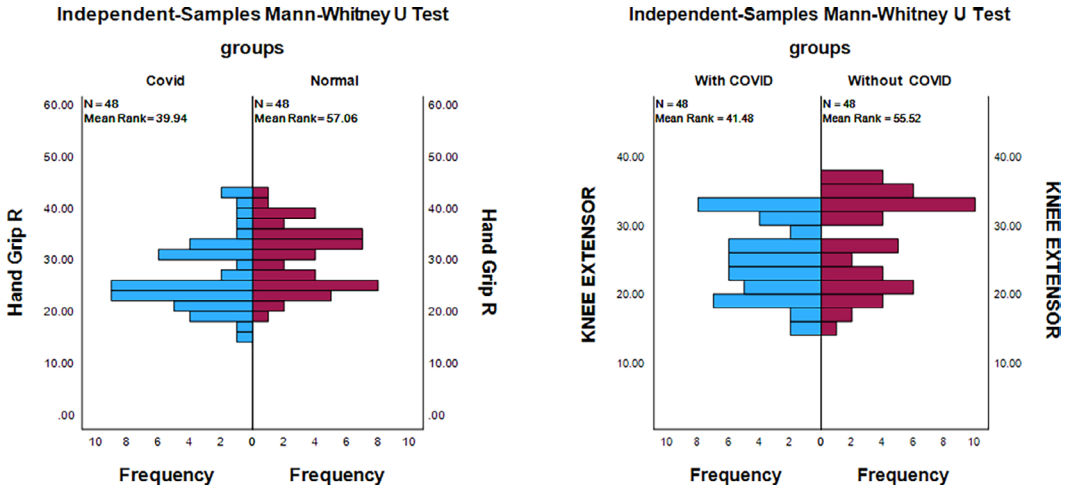

Figure 2. Comparison of mean values of strength of the hand grip and knee extensors of patients with COVID-19 and matched participants.

Table 2. Functional measures between patients with COVID-19 and matched participants.

Variables	Groups	Mean ± SD	Mean Rank	CI at 95% Lower (upper)	p-value
Sit-to-stand test	*COVID-19 participants*	24.98±5.72	54.05	- 4.233(0.608)	0.163†
	Matched participants	26.79±6.21	42.95	- 4.232(0.608)	
6 MWT	*COVID-19 participants*	390.60±70.8	41.52	- 60.406(-13.177)	0.014*
	Matched participants	427.39±43.7	55.48	- 60.469(-13.114)	
Hand grip	*COVID-19 participants*	25.96±6.49	39.94	- 6.304(-1.237)	0.003*
	Matched participants	27.33±5.99	57.06	- 6.304(-1.238)	
Knee extensors	*COVID-19 participants*	24.29 ±5.28	41.48	-5.477(-0.606)	0.013*
	Matched participants	29.73±6.66	55.52	-5.479(-0.604)	
Wrist extensors	*COVID-19 participants*	10.02±2.33	32.18	- 4.221(-2.186)	<0.001*
	Matched participants	13.13±2.21	64.82	- 4.122 -2.181	
Elbow flexors	*COVID-19 participants*	14.58±2.53	37.25	- 4.88(-1.911)	<0.001*
	Matched participants	17.98±4.52	59.75	- 4.85(-1.906)	
Physical Health	*COVID-19 participants*	71.00±9.84	37.06	- 15.708 - 5.916	<0.001*
	Matched participants	81.81±13.96	59.94	- 15.716 - 5.909	
Mental Health	*COVID-19 participants*	72.17±12.56	39.98	- 13.922 - 3.244	0.003*
	Matched participants	80.75±13.76	57.02	- 13.923 - 3.243	
Social Health	*COVID-19 participants*	72.27±8.42	42.44	- 9.633 1.008	0.032*
	Matched participants	76.58±16.54	54.56	- 9.657 1.032	
Environmental Health	*COVID-19 participants*	71.27±8.06	35.80	- 15.049 - 5.075	<0.001*
	Matched participants	81.33±15.42	61.20	- 15.071 - 5.054	

The Mann-Whitney U test was used to compare COVID-19 cases with matched participants for non-normally distributed variables. *. Significant differences (p-value < 0.05). †: Non-significant differences (p-value > 0.05). *Abbreviations:* 6MWT: Six Minute Walk Test. CI: confidence interval at 95%.

0.358,0.013), isometric strength of the Rt & Lt knee (0.511, <0.001&0.344, <0.001) and quality of life (0.334, 0.02& 0.365,0.04), in addition positive correlations between strength of the Rt hand grip and isometric strength of the Rt & Lt knee (0.571, <0.001&0.592<0.001). While the results of the sit-to-stand (exercise tolerance) of patients with COVID-19 show positive correlations with 6 MWT (functional capacity) (0.626, < 0.001), strength of the Rt & Lt hand grip strength(0.484, < 0.001&0.440, 0.002), strength of the Rt & Lt knee isometric (0.791, < 0.001& 0.786, < 0.001), Also the distance of the 6MWT (functional capacity) was positively correlated with isometric strength of the Rt & Lt knee (0.488, <0.001&0.497, <0.001), in addition positive correlations between strength of the Rt hand grip and isometric strength of the Rt & Lt knee (0.603, < 0.001&0.522< 0.001).

Discussion

This study aimed to investigate the effects of COVID-19 with moderate infection severity on functional capacity, exercise tolerance, isometric muscle strength, handgrip strength, and quality of life, and to identify relationships among these factors. The findings of the current study revealed significant negative impacts of COVID-19 on various functional outcome measures. The current functional capacity (distance on the 6MWT) was significantly reduced in the COVID-19 group compared with matched controls. This finding agrees with the results of Magdy et al. who detected significant reduction in results of the 6MWT for the survivors of COVID-19 on comparison with the matched normative data (40), this reduction may be due to the extended time of hospital stay and the excessive uses of corticosteroid medication with its reflections on muscles condition (resulting in muscle wasting and myopathy) (40–42). Additionally, the results of 2021 support the current findings, attributing the restriction in functional capacity to muscle wasting, a general catabolic state resulting from severe illness, and associated inflammation (43–45). In addition, Abdallah et al. reported limitations in exercise tolerance in hospitalized and non-hospitalized survivors of COVID-19 after 3 months, which may be due to residual defects in total lung capacity, thereby explaining the persistence of breathlessness in hospitalized patients (46). Moreover, the differences in the current results between the groups may be explained by the direct impact of the disease on different body systems, although our samples include only participants with moderate severity and a recovery time of at least 3 months. Contrary to the current results, the findings of previous studies by Lerum et al. and Eksombatchai et al. indicated that 6MWT results were statistically typical (47,48). Also, Lerum et al., (2021) concluded that the ICU group did not exhibit reductions in the distance of the6MW D than the non-ICU group (47), which is negatively influenced by several factors, including sex, overweight, obesity, shorter height, and some pulmonary complications such as asthma (46). Accordingly, the reductions in the 6MWT distance may be attributed to higher BMI, the presence of comorbidities, including restrictive lung diseases, and the high proportion of female participants among survivors of COVID-19 in the current study. The current results of the one-MSTS test and isometric muscle strength of the selected upper- and lower-limb muscles show significant reductions in the COVID-19 group. Similar findings from previous studies support ours. Tanriverdi et al. reported that survivors of COVID-19 still suffer from poor physical activity and impaired strength of the hand grip and quadriceps muscle at least three months after discharge (13). Additionally, our findings are supported by those of Paneroni et al., who compared isometric muscle power of the biceps brachii and quadriceps, as well as the one-MSTS at discharge, with predicted normal values (7). They determined the weakness of the biceps and quadriceps muscles to be 86% and 73%, respectively. The authors explained that these changes may be attributed to patients' effort during hospital activities, which can alter symptom evaluations; the brief duration of the one-MSTS test, which may underestimate exercise-induced desaturation; and the failure to account for the effects of pharmacotherapy on physical performance and muscle strength. The current results show significant reductions in the strength of both the quadriceps and the handgrip, which agree with the findings of Lorent et al. They found impairments in the strength of both quadriceps and hand grip at the third month of follow-up (which improved between3 and 12 months) (12). They thought that the extended hospital stay

period and use of neuromuscular blocking agents could contribute to the results, as these were the required therapeutic interventions for COVID-19 (10,12,42,48). Our results show that quality of life (QoL) across all domains was significantly reduced among survivors of COVID-19 compared with matched controls. Previous studies support our findings. Magdy et al. compared the QoL of survivors of COVID-19 at 3 and 6 months post-infection with normative values (40) and found a significant reduction in QoL. Dorri et al. concluded that the QoL of survivors of COVID-19 was significantly reduced compared with their pre-infection status or with matched controls (16). Moreover, Taboada et al. reported a reduction in QoL among 67% of survivors compared with their status six months before the infection (6). In addition, Sar-van der Brugge et al. detected lower QoL across all domains among survivors of COVID-19, except for the bodily pain domain (49). They attributed these reductions in QoL to the isolation and social distancing, particularly in the physical functioning domains. Dorri et al. and Taboada et al. reported on the persistence of disease symptoms, advanced age, male sex, and the need for mechanical ventilation (6,16). Taboada et al. suggested that their results may be biased by self-reported pre-COVID-19 health status and by the inclusion of patients who had acute infections (6). The case of uncertainty during the pandemic, and physical impairments, resulted in panic and mental health issues to the population, which could hamper the health status and QoL for this category of patients (40,50,51). In contrast to our findings, Latronico et al. found good health-related QoL among survivors of COVID-19 when evaluated at 3-, 6-, and 12-month post-ICU discharge (8). They thought that the improvements in patient outcomes may be due to the support and referral guidance provided to specialists to cover care delivery gaps during points of care. Finally, the current results show positive correlations between the 6MWT (functional capacity) and sit-to-stand (exercise tolerance) in both groups, as well as between knee isometric strength and the 6MWT in both groups, except for handgrip in patients with COVID-19. This aligns with normal physiological changes, as functional capacity and exercise tolerance increase with quadriceps muscle strengthening. The most notable and interesting aspect is the direct proportionality to the strength of the handgrip, which is now considered the fifth vital sign, reflecting the body's overall condition. There is a lack of prior research on correlations among the included outcome measures under normal conditions, and, to the best of the authors' knowledge, this has not been explored in patients with COVID-19. These studies provide previous support for our findings. Pradon et al. concluded that the 6MWT distance may be a good indicator of lower-limb muscle strength, and that lower-limb strengthening may improve gait capacity in stroke patients (52). Hamdani & Florencia Leona concluded that there is a positive and statistically significant relationship between handgrip strength and 6-minute walking distance in patients with heart failure (53). Nunes et al. concluded that there is a strong correlation between the isokinetic dynamometer for quadriceps and the manual dynamometer for handgrip strength (54). These findings suggest that, in clinical practice, the manual dynamometer used to measure handgrip strength can also be used to assess peripheral muscle strength in patients with COPD. In contrast to the current findings, Yee et al. stated that the STS test in older adults is influenced by strength, dynamic balance, and cardiorespiratory endurance, and thus represents overall physical performance rather than mere muscle strength. Hence, they find a weak correlation between exercise tolerance (1-minute sit-to-stand test) and hand grip in older individuals (55). In patients recovering from COVID-19, one might expect decreased exercise tolerance due to respiratory issues, muscle deconditioning, and fatigue. However, the non-significant findings suggest that exercise tolerance may not be as negatively impacted as initially thought. If patients are evaluated too soon after recovery, they might still be experiencing residual effects that influence exercise tolerance. Conversely, if assessed too late, they may have had enough time to regain their tolerance levels. Subjective measures of perceived exertion may not accurately reflect actual physical abilities. Additionally, the standardized tests used may not be sufficiently sensitive to detect subtle changes in exercise tolerance in this population. Clinicians may need to shift their focus from solely improving exercise tolerance to addressing other aspects of recovery, such as strength training and psychological support, which could improve overall quality of life. The findings may support encouraging gradual resumption of physical activity after COVID-19,

as patients may not experience as much limitation in exercise tolerance as expected. This study has some limitations, as there is a lack of data on patients' health conditions before contracting COVID-19. To address this limitation, the authors included a matched control group and a small sample size. Despite these limitations, the authors believe that the results of this study help fill a significant knowledge gap regarding the consequences of COVID-19 3 months after recovery.

Conclusion

Patients with moderate-severity COVID-19 have impairments in functional capacity, exercise tolerance, isometric muscle strength, hand grip strength, and quality of life. Exercise tolerance correlated positively with the 6-minute walk test, handgrip strength, and knee extensor strength. Therefore, healthcare with multidimensional, proper training programs needs to be extended to those patients, regardless of the severity of the infection. Further studies are required to investigate the long-term complications of COVID-19 and their follow-up in patients with different disease severities, as well as the efficacy of individualized comprehensive rehabilitative training programs for these patients.

Ethical approval: Imam Abdulrahman Bin Faisal University, IRB number (IRB-PGS-2021-03-427) and Research Ethics Committee in Qurayyat Health Affairs, Ministry of Health, Project no: 083, Saudi Arabia.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interests, patent/licensing, arrangement, etc) that might pose a conflict of interest in connection with the submitted article.

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