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Physical activity levels respiratory and peripheral muscle strength and pulmonary function in young post-COVID-19 patients

A cross-sectional study

Musa Güneş · Metehan Yana · Meral Boşnak Güçlü

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Summary

Objective Coronavirus disease 2019 (COVID-19) causes permanent problems, even mild severity. The long-term consequences of COVID-19 are still unknown. This study aimed to investigate physical activity levels, respiratory and peripheral muscle strength, and pulmonary function in the long term in young adult COVID-19 patients who recovered from mild disease.

Methods This cross-sectional study was carried out at least 6 months after the COVID-19 diagnosis, 54 patients with COVID-19 (median age: 20 years) and 46 controls (median age: 21 years) were compared. Functional status (post-COVID-19 functional status scale), respiratory (maximum inspiratory and expiratory pressures (MIP, MEP)) and peripheral muscle strength (dynamometer), pulmonary function (Spirometry), dyspnea and fatigue (modified Borg scale), and physical activity levels (International Physical Activity Questionnaire) were evaluated. ClinicalTrial number: NCT05381714.

Results Patients with COVID-19 measured and percent predicted MIP and MEP were statistically decreased compared with the controls ($p<0.05$). Shoulder abductors muscle strength ($p<0.001$) and the number of individuals with low physical activity levels were significantly higher in patients compared with controls ($p=0.048$). Pulmonary function, quadriceps muscle strength, exertional dyspnea, and fatigue scores were similar in groups ($p>0.05$).

Conclusion Respiratory and peripheral muscle strength and physical activity levels are adversely affected in patients with COVID-19, even though the patients were mildly affected in the long term. Also, symptoms such as dyspnea and fatigue may persist. Therefore, these parameters should be evaluated in the long term, even in young adults who are mildly affected by COVID-19.

Keywords COVID-19 · Respiratory muscles · Pulmonary symptoms · Physical activity · Dyspnea.

M. Güneş, PT, MsC (✉) · M. Yana, PT, PhD
Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Karabuk University, Karabuk, Turkey
musagunes@karabuk.edu.tr

M. Yana, PT, PhD
metehanyana@karabuk.edu.tr

M. B. Güçlü, PT, PhD
Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Gazi University, Ankara, Turkey
meralbosnak@gazi.edu.tr

M. Güneş, PT, MsC
Iron Steel Campus, Faculty of Health Sciences, Karabuk University, City Centre/Karabük, Turkey

Introduction

The coronavirus disease 2019 (COVID-19) is a highly contagious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. It is a multisystem disease and presents various symptoms, such as fever, dry cough, fatigue, sore throat, loss of taste or smell, dyspnea, nasal congestion, chest pain, muscle or joint pain, headache, and nausea [2, 3].

COVID-19 mainly affects the respiratory system. Due to the damage to the lungs of individuals, respiratory functions are affected [4]. Respiratory functions may gradually deteriorate, which has not been clearly investigated yet. Therefore, long-term lung damage caused by COVID-19 infection is of great concern [1, 4]. Long-term COVID-19, also called post-COVID-19, is defined as signs and symptoms that develop after an infection compatible with COVID-19 and continue for more than 12 weeks [3]. Overall, the most common symptoms of long-term pulmonary effects of COVID-19 disease are fatigue, dyspnea, and/or cough. The prevalence of these symptoms and the severity of the exposure vary according to the severity of the acute disease and admission to the intensive care units [5]. While about 20% of patients with COVID-19 develop severe and critical diseases, most show mild to moderate disease with a favorable prognosis [6, 7]. Unfortunately, patients encounter various permanent symptoms, even if the disease is mild [8].

Most long-term follow-up studies investigated for COVID-19 included hospitalized patients [9–11]. It has been reported that patients discharged from the hospital have at least one of the symptoms of sleep disturbance, depression, and respiratory dysfunction even 6 months after COVID-19 disease [12]. The prevalence of persistent dyspnea is 8–43% at 4–8 weeks and 14% at 12 weeks [13]; however, recent studies suggest that patients with mild COVID-19 also have long-term symptoms but the profile and timeline are uncertain [8, 14–16]. A study observed that the frequency of persistent symptoms such as dyspnea, cough, chest pain, headache, and especially fatigue varied between 10% and 35% in patients 3 months after mild COVID-19 infection [17].

Most infected young individuals experience mild disease, which does not require hospitalization [18]. The most common symptoms described in young people are exertional dyspnea and physical deconditioning. Therefore, young individuals with mild disease seem to be at risk of developing persistent fatigue and dyspnea [19], which may lead to functional limitation [20]. Previously, it was reported that COVID-19 also causes respiratory muscle weakness in the long term [11]; however, few numbers of studies have investigated respiratory muscle strength in mild post-COVID-19. It has been reported that young individuals with mild or asymptomatic COVID-19 may experience respiratory muscle weakness [21]. In addition, mild to moderate COVID-19 patients may exhibit extrapulmonary manifestations such as peripheral muscle weakness and deteriorated physical activity levels in the mid-term [22]; however, long-term evidence for post-COVID-19 young individuals is insufficient.

Studies have generally focused on severe or hospitalized COVID-19 patients; however, there is insufficient evidence regarding pulmonary and extrapulmonary manifestations in post-COVID-19 patients recovering from mild illness in the long term. Therefore, this study aimed to compare long-term functional status, respiratory and peripheral muscle strength, physical activity, and pulmonary function in young individuals with mild COVID-19 with healthy individuals.

Methods

Participants

Between January and June 2022, 54 post-COVID-19 patients and 46 healthy controls who were students of Karabük University were included. All students with post-COVID-19 were screened and invited to participate in the study, students who met the inclusion criteria and volunteered were included in the study. Information posters about the survey were hung on many notice boards at the university for healthy participants. According to the criteria for clinical severity of confirmed COVID-19 pneumonia, mild disease severity was defined as mild clinical symptoms and no imaging findings of pneumonia and outpatients [17, 23].

Inclusion criteria for the patients were as follows: diagnosed with COVID-19, with a positive polymerase chain reaction (PCR) test, at least 6 months ago, aged between 18 and 25 years, non-hospitalization due to COVID-19, non-smoker/for ex-smokers with 10 pack-years or less of smoking, and not continuing any regular physical activity program. Exclusion criteria for the patients were: received inpatient or intensive care treatment due to COVID-19, having any acute infection, previous pulmonary resection or cardiac surgery, having lung or heart comorbidities such as asthma, chronic obstructive pulmonary disease (COPD) and heart failure, uncontrolled hypertension, history of malignancy, neurological disease (e.g., Alzheimer, multiple sclerosis, Parkinson), and rheumatologic diseases. Inclusion criteria for healthy individuals were: willingness to participate in the study, 18–25 years of age without any known and diagnosed chronic diseases, who declared no known history of COVID-19 infection and with a negative PCR test, while those with body mass index (BMI) $< 18.5\,kg/m^2$ or $\geq 30.0\,kg/m^2$, current smokers, and ex-smokers (≥ 10 pack-years) were excluded.

The study was approved by the Ethics Committee of the University (2021/668) and performed in accordance with the Declaration of Helsinki. Written informed consent to participate in the study was obtained from all patients and controls. Retrospectively submitted to ClinicalTrial number: NCT05381714.

Study design

A cross-sectional study was performed. A physiotherapist tested all patients and controls. Demographic and clinical characteristics were recorded. Post-COVID-19 functional status, respiratory and peripheral muscle strength, pulmonary function, physical activity level, dyspnea, and fatigue perception were evaluated and compared with age and gender-matched healthy controls who volunteered to participate in the study. The patients and controls were evaluated over 2 consecutive days. Post-COVID-19 functional status, dyspnea, fatigue, pulmonary function, and respiratory muscle strength measurements were performed on the first day; peripheral muscle strength and physical activity levels measurements were performed on the second day. The sociodemographic characteristics of individuals were recorded. The BMI (body weight(kg))/(height(m^2)) of individuals was calculated. The BMI values of the participants were classified into four categories according to WHO classification: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≥30.0 kg/m^2) [24].

Outcome measures

Post-COVID-19 functional status

The functional status of individuals after COVID-19 was evaluated using the post-COVID-19 functional status scale (PCFS) [20]. According to the functional status limitation of the PCFS scale: grade 0 (no functional limitations), grade 1 (negligible functional limitations), grade 2 (slight functional limitations), grade 3 (moderate functional limitations), grade 4 (severe functional limitations), and grade 5 (death) [20]. Turkish validity and reliability were performed [25], and its internal consistency coefficient (Cronbach α) was 0.82.

Dyspnea and fatigue

The modified Borg scale was used to assess shortness of breath and fatigue. The scale is subjective and scores 0–10 for breathlessness and fatigue at rest and/or during activity. The lowest 0 points are "not at all" and the highest 10 points are "very severe" denoting shortness of breath and fatigue [26].

Pulmonary function tests

Pulmonary function was evaluated using a spirometer (Pony FX, Cosmed, Rome, Italy) according to the American Thoracic Society (ATS) and European Respiratory Society (ERS) criteria in a sitting position with the nose closed [27, 28]. Dynamic lung volumes, including forced expiratory volume in 1s (FEV_1), forced vital capacity (FVC), forced expiratory volume in 1s/ forced vital capacity (FEV_1/FVC), peak expiratory flow (PEF), and forced expiratory flow at 25–75% ($FEF_{25–75\%}$) were measured and expressed as percentages of predicted values [27]. The best of the three technically acceptable maneuvers with 95% agreement was selected for statistical analysis. The reduction in predicted FEV_1/FVC and FVC was classified as obstructive and restrictive lung function abnormality, respectively [29].

Respiratory muscle strength

Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were assessed using a portable mouth pressure device (Pony FX, Cosmed, Rome, Italy) based on the guidelines set by the ATS and the ERS [30]. The MIP was measured at residual volume, whereas MEP was at total lung capacity. The measurements were performed seated, and the subjects wore a nose clip. The mouthpiece was pressed tightly against the patients' lips during the measurements to prevent air leakage. The highest values of at least seven measurements were selected for analysis. Values were expressed as cmH_2O. Reference equations were used [31]. If maximum pressures were <80% of predicted, it was classified as having respiratory muscle weakness [1].

Peripheral muscle strength

Quadriceps femoris and shoulder abductors isometric muscle strength was evaluated using a hand-held dynamometer (JTECH Power Track Commander, Baltimore, MA, USA). Measurements were done with the patient in an upright sitting position with hip and knees flexed at 90°, hands resting on the lap, and feet in the air. Measurements were repeated three times; the best values in Newtons (N) were recorded and expressed as percentages of predicted [32].

Physical activity

The International Physical Activity Questionnaire-Short Form (IPAQ) scale evaluates the physical activity level during the last week. The activity-specific MET values are multiplied by the day and minute to obtain a score of MET min/week. In the evaluation of activities, each activity is taken as a criterion for 10 min at a time. Activity-specific MET values are 3.3 METs for walking, 4 METs for moderate intensity physical activity, and 8 METs for vigorous intensity physical activity. The total MET minutes/week score is calculated by summing the MET min/week values from these three different physical activity levels [33]. Physical activity levels are classified as low (<600 MET min/week), moderate (600–3000 MET min/week), and high (>3000 MET min/week) [34].

Statistical analysis

All statistical analyses were performed using the SPSS 21.0 statistical package (SPSS, Chicago, IL, USA). Based on the inspiratory muscle strength results from the pilot study, we estimated that a sample size of at least 54 individuals in each group would have 80% power for an α value of 0.05 and an effect size d = 0.55.

Data normality was analyzed using visual (histograms, probability plots) and analytical methods (Kolmogorov-Smirnov test). Demographic and clini-

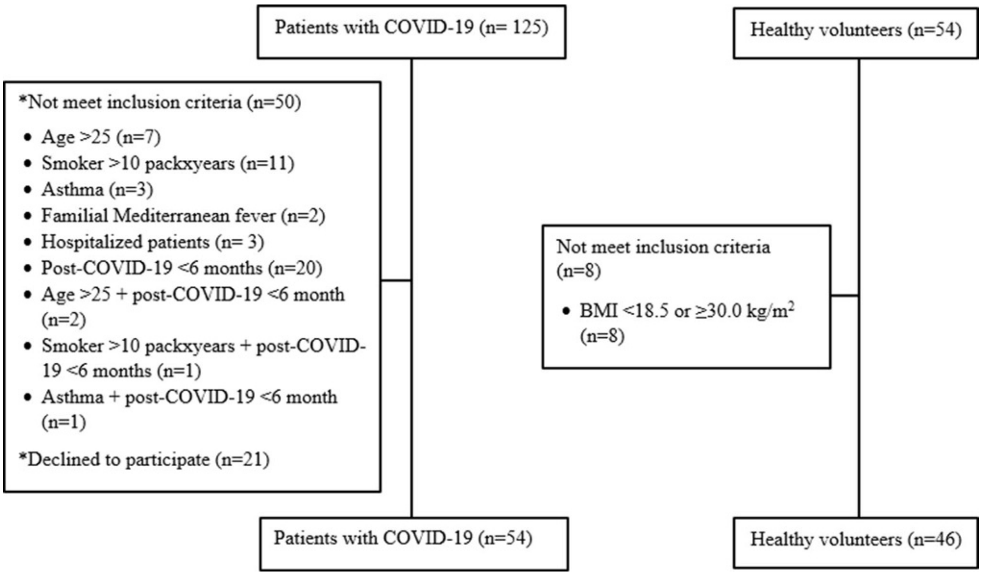

Fig. 1 STROBE flow diagram of the patients with post-COVID-19 and healthy controls

cal characteristics of the two groups were compared to normally distributed variables using Student's t-test, undistributed variables using Mann–Whitney U test, and nominal data using a χ^2-test. Descriptive analyses were expressed as mean ± standard deviation ($X \pm SD$), and 95% confidence interval (95% CI) for normally distributed variables; median, interquartile range$_{25–75\%}$ ($IQR_{25–75\%}$) for normally undistributed variables, as well as a percentage (%), frequency (n) for categorical variables. The level of significance was set to $p \leq 0.05$.

Results

A total of 125 patients with post-COVID-19 and 54 healthy controls were screened, 71 patients and 8 healthy controls were excluded from the study, the reasons for which were noted that 54 patients and 46 healthy individuals were included and compared (Fig. 1). Demographic characteristics were similar in the groups ($p > 0.05$, Table 1).

The median PCFS score of the patients was 1 (0–2). There was no functional limitation in 22 (40.7%) patients, negligible in 18 (33.3%) patients, mild in 12 (22.2%) patients, and moderate in 2 (3.7%) patients after recovery from COVID-19 and 3 (5.7%) patients had mild resting dyspnea. The exertional dyspnea, cough, and fatigue sensations were significantly higher in patients ($p < 0.05$). There was no statistically significant difference in exertional dyspnea and fatigue scores between the groups according to the modified Borg dyspnea scale ($p > 0.05$, Table 1). Exertional dyspnea was mild in 15 (27.4%), moderate in 9 (16.7%), and severe in 3 (5.5%) patients.

Groups' measured and percent predicted FEV_1, FVC, FEV_1/FVC, PEF, and $FEF_{25–75\%}$ were similar ($p > 0.05$, Table 2), 15 (27.8%) patients had a restrictive type, and 7 (12.9%) patients had obstructive; 9 (19.5%) controls had restrictive, and 8 (17.4%) controls had obstructive pulmonary function abnormalities.

Measured and predicted MIP and MEP values were significantly lower in the patients compared with the controls ($p < 0.05$, Table 2), 27 (50%) patients' and 16 (34.8%) controls' MIP; 36 (66.7%) patients' and 21 (45.6%) controls' MEP were below 80% of predicted values. According to the MIP value, the study power is $(1-\beta) = 80.9\%$.

While shoulder abductors muscle strength was significantly lower in the patient group than in controls ($p < 0.05$), no statistically significant differences were observed in quadriceps femoris muscle strength between groups ($p > 0.05$, Table 3). Quadriceps femoris muscle strength was less than 80% of predicted values in all patients (%100) and 44 (95.6%) healthy individuals. All individuals' shoulder abduction muscle strength in the groups was stronger than 80% of predicted values.

The median weekly IPAQ MET scores and IPAQ daily sitting duration of the groups were similar ($p > 0.05$, Table 3); however, the number of individuals with low physical activity levels was significantly higher in patients compared with controls ($p = 0.048$).

Discussion

The present study indicated that young individuals with mild COVID-19 with preserved lung function have long-term muscle weakness, respiratory and (50% and 66.7% inspiratory and expiratory, respectively) lower extremity muscle weakness, decreased physical activity level, increased cough and perception of dyspnea and fatigue. Also, individuals who survived the disease mildly after COVID-19 had functional limitations even in the long term. The upper extremity muscle strength of patients was in normal ranges but weaker than healthy controls.

Table 1 Comparison of demographic characteristics, dyspnea, and fatigue of patients with COVID-19 and healthy controls

Characteristics	Patients ($n = 54$)	Controls ($n = 46$)	p
	Mean ± SD Median ($IQR_{25–75\%}$)	Mean ± SD Median ($IQR_{25–75\%}$)	
Age, years	20 (20–21.25)	21 (20–21.25)	0.378
Female; male, n/%	45/83.3%;9/16.7%	37/80.4%;9/19.6%	0.707
Weight, kg	60 (54–65.25)	58 (53.50–68.50)	0.964
Height, cm	164.5 (160–170.25)	168 (160–173)	0.497
BMI, (kg/m²)	21.48 (19.65–23.51)	20.80 (19.57–23.08)	0.693
BMI (kg/m²)			0.060
Underweight	7 (13%)	0 (0%)	
Normal	38 (70.4%)	38 (82.6%)	
Overweight	8 (14.8%)	8 (17.4%)	
Obese	1 (1.9%)	0 (0%)	
Smoking (current; ex-smoker; non-smoker), n/%	0/0%;7/13%;47/87%	0/0%;7/15.2%;39/84.8%	0.746
Smoking, pack-years	6.57 ± 2.57	6.00 ± 2.38	0.674
Time from symptom onset to follow-up, months	11 (7–12)	–	–
Cough, n/%	11 (20.4%)	1 (2.2%)	*0.005**
Dyspnea (exertional) n/%	27 (50%)	8 (17.4%)	*0.001**
M. Borg dyspnea scale (0–10)	2 (2–3)	2 (1.25–3)	0.742
Fatigue n/%	43 (79.6%)	24 (52.2%)	*0.004**
M. Borg dyspnea scale (0–10)	2 (1–3)	2.50 (2–3)	0.109

BMI body mass index, *SD* standard deviation, *IQR* interquartile range
*$p < 0.05$

Many pathologies, such as chronic inflammation, epithelial destruction, endothelial damage, and hyaline membrane formation, affect the lungs in the long term after COVID-19. It is thought that the long-term consequences of these pathologies will result in a decrease in respiratory muscle strength and a worsening of lung functions [2, 13].

In our study, both inspiratory (50%) and expiratory (66.7%) muscle strength were found as weakened according to the long-term results of young individuals who had mildly recovered from COVID-19. In contrast to the present study, Plaza and Sevilla [21] showed preserved respiratory muscle strength in university students who had recovered from mild COVID-19 at least 6 months later; however, they showed that the inspiratory muscle strength of individuals with COVID-19 decreased compared to healthy individuals, but the expiratory muscle strength did not change. The difference between respiratory muscle strength results may be due to the female gender dominance in this study, unlike the Plaza and Sevilla study [21] because the subgroup results showed that the respiratory muscle strength of women with COVID-19 decreased more [21]. In addition, the inclusion of individuals with asymptomatic COVID-19 in the study [21] may explain the preservation of respiratory muscle strength, as it is thought to reduce the severity and effect of the disease.

In another study, Çelik et al. [35] compared the medium-term results of respiratory muscle strength of female volleyball players with and without COVID-19. Unlike this study, the inspiratory muscle strength of both groups was within normal range, but expiratory muscle strength was decreased [35]. This difference may result from the inclusion of athletes in the study of Çelik et al. [35]. Also, players with COVID-19 had lower inspiratory and expiratory muscle strength than controls [35]. These results are consistent with our study. In addition, our study showed that respiratory muscle weakness persisted in the long term. Respiratory muscle weakness, indicated by decreased MIP and MEP as in our study, may be based on the long-term effects of various factors, such as a myopathy caused by the virus in the respiratory muscles, particularly the diaphragm. In addition, there may be a possible effect of impaired physical activity during the pandemic process, depending on the quarantine conditions [36].

It was previously stated that there are abnormalities in FEV_1, FVC, and small airways in the early phase of the COVID-19 disease [2]; however, adult follow-up studies suggest that spirometry results are normal or close to normal [11, 13, 36]. Therefore, the results are inconsistent, and the long-term effects of the COVID-19 disease on individuals still need to be determined. This study showed that the pulmonary function of young individuals with mild COVID-19 was within normal ranges, except for PEF (56%). In addition, pulmonary function was similar to healthy ones. In their study, Lund Berven et al. [18] stated that spirometry results were like healthy and within normal limits in adolescents and young people even in the early period. In another study, Çelik et al. [35] showed that the pulmonary function of young volley-

Table 2 Comparison of pulmonary function and respiratory muscle strength in patients with COVID-19 and healthy controls

	Patients (*n* = 54)	Controls (*n* = 46)		
Characteristics	Mean ± SD Median ($IQR_{25–75\%}$)	Mean ± SD Median ($IQR_{25–75\%}$)	Mean difference 95%CI	*p*
FEV_1, L	3.25 (2.82–3.63)	3.32 (2.96–3.73)	–	0.437
FEV_1, % predicted	85.94 ± 9.55	86.07 ± 8.91	–0.12 (3.79 to 3.54)	0.948
FVC, L	3.64 (3.37–4.18)	3.90 (3.47–4.34)	–	0.213
FVC, % predicted	84.87 ± 9.28	86.72 ± 9.24	–1.84 (–5.53 to 1.84)	0.323
FEV_1/FVC, %	87 (82–90.25)	84.50 (80.75–89)	–	0.158
PEF, L	5.32 (4.28–6.67)	5.68 (4.59–6.89)	–	0.529
PEF, % predicted	58.41 ± 14.75	58.46 ± 13.01	–0.049 (–5.56 to 5.46)	0.986
$FEF_{25–75\%}$, L	3.57 (3.20–4.05)	3.69 (3.07–4.29)	–	0.453
$FEF_{25–75\%}$, % predicted	79.74 ± 15.98	77.76 ± 16.80	1.98 (–4.53 to 8.49)	0.548
MIP, cmH_2O	77.54 ± 20.49	90.67 ± 25.00	–13.13 (–22.16 to –4.10)	*0.005**
MIP, % predicted	78.79 ± 18.94	91.48 ± 22.23	–12.69 (–20.86 to –4.51)	*0.003**
MEP, cmH_2O	90.63 ± 20.91	99.85 ± 23.78	–9.21 (–18.08 to –0.348)	*0.042**
MEP, % predicted	71.75 (66.69–85.22)	81.76 (74.58–90.68)	–	*0.022**

FEV_1 forced expiratory volume in one second, *FVC* forced vital capacity, *PEF* peak expiratory flow, *$FEF_{25–75\%}$* forced expiratory flow from 25% to 75%, *MIP* maximal inspiratory pressure, *MEP* maximal expiratory pressure, *L* liter, *SD* standard deviation, *IQR* interquartile range
*$p < 0.05$

Table 3 Comparison of peripheral muscle strength and physical activity levels in patients with COVID-19 and healthy controls

	Patients (*n* = 54)	Controls (*n* = 46)		
Characteristics	Mean ± SD Median ($IQR_{25–75\%}$)	Mean ± SD Median ($IQR_{25–75\%}$)	Mean difference 95% CI	*p*
Quadriceps femoris (D), *N*	279 (244–322)	274.50 (250–344)	–	0.696
Quadriceps femoris (D), % predicted	58.19 (50.82–65.16)	57.30 (54.33–66.08)	–	0.559
Shoulder abductors (D), *N*	184.50 (164.75–213.25)	206 (179.50–230.75)	–	*0.013**
Shoulder abductors (D), % predicted	124.68 ± 19.71	137.13 ± 22.88	–12.45 (–20.90 to –3.99)	*0.004**
IPAQ, MET/h/week	1403.50 (584.50–2833.25)	1516 (956.50–2808)	–	0.276
IPAQ levels n/%				
Low	15 (27.8%)	4 (8.7%)	–	*0.048**
Moderate	28 (51.9%)	32 (69.6%)	–	
High	11 (20.4%)	10 (21.7%)	–	
IPAQ sitting, min/day	720 (480–780)	600 (480–720)	–	0.317

IPAQ International Physical Activity Questionnaire, *N* Newton, *SD* standard deviation, *IQR* interquartile range, *D* dominant
*$p < 0.05$

ball players with and without COVID-19 was similar in the mid-term; however, a decrease in PEF values of individuals with COVID-19 was observed, similar to our study [35]. PEF is linked to airway size, expiratory muscle strength, and lung tissue compliance [28].

Thus decreased PEF may be associated with a decrease in expiratory muscle strength, as in our study. Also, due to the iron and steel factory in the region where the study was conducted, the gas level causing air pollution is above the limits determined by WHO [37]. This situation is associated with a decrease in FEV_1, FVC, and PEF values, even in healthy individuals [38]. Therefore, PEF may also be decreased due to air pollution in the healthy group. Demonstrating long-term preservation of respiratory function in our study is important for investigating the underlying mechanism of persistent respiratory symptoms [18].

The COVID-19 virus may cause restrictive and obstructive pulmonary function abnormalities in patients by affecting the small airways [39]. This may lead to deterioration in the diffusion capacity of patients [4]. A meta-analysis study showed that patients with COVID-19 who do not have severe disease had 5–23.5% restrictive and 5.5–16.7% obstructive pulmonary function abnormalities in at least a 1-month follow-up [39]. Similarly, in the present study, post-COVID-19 young adults with mild disease were found to have restrictive and obstructive pulmonary function abnormalities in 27.8% and 12.9%, respectively. In addition to the COVID-19 virus, this situation may be caused by respiratory muscle weakness in patients, affecting ventilation [10]. In addition, physical inactivity due to COVID-19 may have led to a decrease in respiratory muscle strength [36], and the regional air pollution may have caused pulmonary function abnormalities in healthy individuals [38].

Previous studies have reported that the most common long-term pulmonary sequelae experienced by non-hospitalized COVID-19 patients are fatigue, dyspnea, and cough [16, 17]. The prevalence of these symptoms varies according to the severity of the acute illness [5]. A study found that in hospitalized and non-hospitalized COVID-19 patients, 92.9% and 93.9% reported fatigue after 3 months, and 89.3% and 87% reported dyspnea, respectively. In addition, most of the COVID-19 patients who were not hospitalized continued to have a cough (68.1%) [40]. In our study, fatigue (79.6%), exertional dyspnea (50%), and cough (20.4%) symptoms were persistent in the long term in young individuals with mild COVID-19. Compared with healthy individuals, a difference was found between dyspnea scores during activity, similar to the literature [19]. Fatigue is a symptom that causes exhaustion in individuals and is caused by various factors [2]. Healthy individuals also experienced similar levels of fatigue to those with COVID-19. As a result, healthy individuals were also evaluated during the pandemic period. Studies confirmed that inactivity caused by the pandemic and quarantine also affected healthy individuals [41]. Therefore, the underlying mechanism needs to be investigated.

It is claimed that skeletal muscle may be vulnerable to the COVID-19 virus via angiotensin-converting enzyme 2. Therefore, metabolic homeostasis is impaired, and muscle loss occurs [42]. Paneroni et al. [43] showed that most COVID-19 patients had quadriceps muscle weakness at discharge. A study showed that more than one third of adult post-COVID-19 patients had mid-term handgrip and quadriceps muscle weakness. In addition, hand grip and quadriceps muscle strength were weaker in the moderate disease group than in the mild disease group [22].

This study showed that the quadriceps femoris muscle was similarly weakened in individuals with COVID-19 and healthy controls. In addition, upper extremity muscle strength was preserved in individuals with COVID-19 and weaker than in healthy controls. The decrease in peripheral muscle strength can be explained by the mechanism described above; however, various factors may have caused a decrease in lower extremity muscle strength in almost all healthy individuals. Exposure to air pollution and during the pandemic, less exercise and physical activity [36] due to the quarantine may explain peripheral muscle weakness by causing insufficient oxygen use and transport. To avoid COVID-19 and control the spread of the disease, quarantine, and social distancing have led to restrictions on ordinary daily activities and social interaction, reducing physical activity. It has drastically changed the lifestyle of the young in particular [41].

In our study, individuals with COVID-19 were more inactive in the long term than healthy individuals. Similarly, a study showed that adults who recovered from mild to moderate COVID-19 decreased physical activity in the medium term [22]. These results showed that the decrease in physical activity after COVID-19 is a long-term problem. Various strategies to increase physical activity should be applied to improve general health and reduce the effects on pulmonary function, musculoskeletal system, cardiovascular, and psychological factors in individuals after COVID-19 [44]. Recent studies have shown that enduring physical activity and exercise training improve cardiovascular fitness, respiratory parameters, and general health in post-COVID-19 [45–47].

This study has limitations. First of all, post-COVID-19 patients were recruited from a single center. Another limitation is the lack of data on healthy controls because all controls were evaluated during a pandemic and those may all possibly be affected during a pandemic. In addition, the assessment of exercise capacity and physical activity with objective methods, such as pedometers and accelerometers would provide more detailed and accurate information.

Conclusion

The present study indicated that young individuals with mild COVID-19, with preserved lung function, have long-term muscle weakness, respiratory and lower extremity muscle weakness, and decreased physical activity and upper extremity muscle strength. In addition, persistent symptoms such as dyspnea, fatigue, and cough may cause functional limitations in individuals in the long term, even after mild disease. All these symptoms may also adversely restrict physical activity levels. Therefore, a comprehensive evaluation should be considered to identify dysfunction in patients with mild post-COVID-19. The effects of respiratory, peripheral muscle training, and physical activity counselling should be investigated in patients after mild COVID-19, even in the long term.

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Conflict of interest M. Güneş, M. Yana and M.B. Güçlü declare that they have no competing interests.

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