Original Article

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Comparison of Fatigue Levels, Muscle Strength, Balance, and Exercise Performance of Young Adults with a History of Mild COVID-19 and Healthy Adults

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Abstract

Aim: The coronavirus disease-2019 (COVID-19) infection directly impacts fatigue and exercise performance. More studies have focused on these problems and were conducted with hospitalized patients and/or adult and geriatric populations. The aim of this study was to explore the effects of mild COVID-19 on fatigue, muscle strength, balance, and exercise performance, specifically in young adults.

Methods: This research was designed as a case-control study, and tests were conducted between January 2022 and June 2022. The study included 60 participants aged 18-28, consisting of individuals who had a mild COVID-19 diagnosis within the past year (study group, n=30) and tested negative during the study, as well as a control group of individuals who had no COVID-19 diagnosis or symptoms within the past year (control group, n=30). The participants' fatigue levels (Chalder Fatigue Scale), lower (Biodex Isokinetic-Dynamometer) and upper (Jamar-Handgrip Dynamometer) extremity muscle strength, balance (Y-Balance Test), and exercise performance (Queen's College Step Test) were evaluated using various standardized tests.

Results: Measurements showed that individuals with COVID-19 had an increase in fatigue scores (p=0.02). It was determined that fatigue was particularly prominent in women. Due to this difference that arose according to gender, it was observed that fatigue scores in those who had experienced COVID-19 were negatively correlated with muscle strength measurements.

Conclusion: This study showed that symptoms of fatigue persisted in younger individuals, especially women, even after the COVID-19 infection. We think the next research should focus on COVID-19 symptoms, surveillance, and therapy in different age groups.

Keywords: COVID-19, fatigue, dyspnea, muscle weakness

Introduction

Coronavirus disease-2019 (COVID-19) has caused a pandemic because of its rapid transmission (1). The virus severely affects various human tissues, including the lungs and heart, leading to serious and even fatal health issues (2). It has been reported that there is a rapid onset of fatigue, loss of strength and endurance, and a decrease in aerobic and lung capacity due to multisystemic effects following the COVID-19 illness (3). Immobility resulting from hospitalizations and long periods of staying at home due to pandemic conditions also contributes to these effects (4).

In a study on the severe acute respiratory syndrome (SARS) outbreak, patients were followed for fatigue at 3, 6, and 12 months after hospital discharge. Findings showed persistent fatigue during recovery: 64% at three months, 54% at six months, and 60% at 12 months (5). Another study related to COVID-19 reported that persistent fatigue affected a significant group of patients (13-33%) after 16-20 weeks of symptom onset (6). During early recovery, patients with severe COVID-19 showed reduced functional capacity, as evidenced by shorter 6-min walking distances compared with those with milder disease. This suggests weaker exercise capacity in severely affected patients (7). In addition, a systematic review highlighted that 41% of patients experienced a decline in aerobic capacity during the 3-month period following the disease (8). It has not been proven that COVID-19 directly affects muscle weakness and atrophy. However, it has been noted that both symptoms are commonly observed (9).

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Studies related to COVID-19 have evaluated exercise capacity, functional capacity, muscle strength, and fatigue (10-12). They focused mainly on individuals who had to be hospitalized or required intensive care and oxygen therapy. Research on the effects of COVID-19 on young populations who experienced the disease while standing and without known respiratory distress is limited. However, given the potential long-term effects of the disease on physical performance, muscle strength, balance, and fatigue, it is important to compare these outcomes between individuals who have and those who have not experienced COVID-19 (13,14). This will help to better understand the impact of the disease on young populations and inform strategies for prevention and treatment. In this context, the aim of the study was to compare fatigue, muscle strength, balance, and physical performance between young individuals who have and have not experienced COVID-19.

Methods

Compliance with Ethical Standards

Participants were informed about the study, and written consent was obtained. The study was conducted in accordance with the Declaration of Helsinki. Ethical permission for this study was obtained from the Ethics Committee of Marmara University, Faculty of Health Sciences for Non-Interventional Clinical Studies (date: 27.01.2022, approval no: 16).

Study Design and Participants

The study population consisted of young individuals aged 18-28 who had mild COVID-19 in the past year without any history of immobilization or hospitalization and known respiratory distress, as well as young individuals who had never been diagnosed with COVID-19. Individuals with neuromusculoskeletal problems, regular physical activity, and a history of orthopedic, rheumatologic, systemic diseases, and psychological problems in the past six months were excluded from the study. Volunteers were divided into two groups: the study group (n=30), consisting of individuals who had been diagnosed with COVID-19 in the past year, and the control group (n=30), consisting of individuals who had never been diagnosed with COVID-19 (Figure 1).

Applied Tests and Assessments

The Chalder Fatigue Scale (CFS), Y Balance Test (YBT), Queen's College Step Test (QCST), Jamar Handgrip Dynamometer (JHD), and Biodex System 3 Pro isokinetic dynamometer were used for the evaluations. The content of the tests applied in the study was explained to the volunteers at the beginning of the tests. After the necessary directions were given, the relevant tests were applied. After each completed test application, 15-minute rest periods were allowed. The order of the tests was conducted in the same way for each participant.

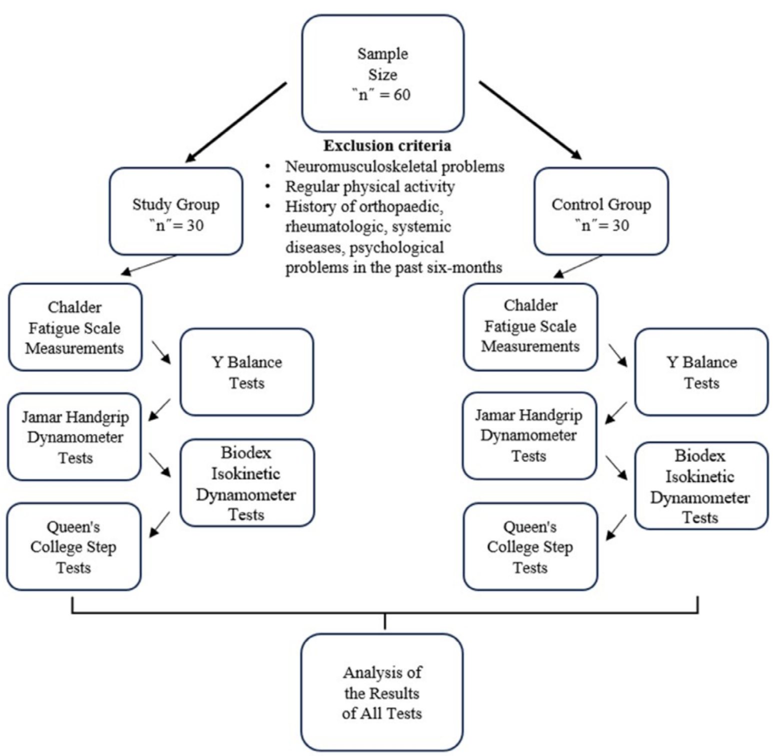

Figure 1. Flow diagram of the study

Chalder Fatigue Scale

The CFS measures fatigue levels over the past month using 11 questions. Seven questions focused on physical fatigue and four on mental fatigue. Scores for each question range from 0 to 3, and a higher total score indicates greater fatigue (15).

"Y" Balance Test

The YBT, validated by Plisky et al. (16), was used to measure dynamic balance. Participants tested barefoot and reached in three directions: anterior (A), posteromedial (PM), and posterolateral (PL). Reach distances on surface tapes were measured from specific points on the foot. Participants kept their hands on their iliac crests and their heels on the surface while reaching. Before the official test, they practiced six times in each direction for both legs. Tests were repeated if balance was lost or if other specific criteria were not met (16).

Jamar Handgrip Dynamometer

The JHD was used to measure grip strength as an objective assessment of overall body strength and upper extremity performance. Participants were seated with their elbows flexed at 90 degrees and their wrists in a neutral position. Grip strength was measured for both hands through three repetitions, and the dominant hand was noted. The average of the three repetitions was recorded as the final measurement (17).

Biodex Isokinetic Dynamometer

The Biodex System 4 ProTM device was used to assess the maximum isokinetic torque production of the quadriceps femoris and hamstring muscle groups. Tests were conducted at speeds of 180 s1, 120 s1, 90 s1, and 60 s1 in the isokinetic concentric mode, which is known for its statistically significant test-retest reliability. Maximum voluntary contractions lasting up to 3 s were performed, with 1-min rest periods between assessments. The maximum torque force parameters were used for the evaluation (18).

Queen's College Step Test

Queen's College Step Test is a method used to determine cardiorespiratory fitness in terms of VO_{2max} (19). The test was conducted according to the manual and was performed using a 41.3 cm (16.25 inches) high step. Participants were asked to step onto the platform for three minutes, maintaining a rhythmic pace of 22 steps per minute for females and 24 steps per minute for males. At the end of the 3 min, their heart rate was measured by taking their pulse at the carotid artery during the 15-s recovery period between the 5th and 20th s. The heart rate was then used to estimate VO_{2max}.

Estimated VO_{2max} calculation using QCST (20):

For men: VO_{2max}=111.33 - [0.42 × pulse/min]

For women: VO_{2max}=65.81- [0.1847 × pulse/min]

Flow chart of the study (CFS: Chalder Fatigue Scale, YBT: Y Balance Test, JHD: Jamar Handgrip Dynamometer, QCST: Queen's Collage Step Test) (Figure 2).

Sample Size

When the statistical significance level was determined as p≤0.05 and the test power was determined as 90%, a minimum of 40 participants were required for the study when t-tests and Wilcoxon-Mann-Whitney U tests were applied to the two-group means. This analysis was performed using G Power 3.1.9.7. To account for the risk of participants discontinuing the study because of secondary issues or dropping out, 60 volunteers were included in the study.

Statistical Analysis

Statistical Package for Social Sciences (SPSS) Windows v22.0 (SPSS Inc., IBM Corp., Armonk, New York) was used for all statistical analyses. The mean and standard deviation were used for quantitative results, and percentage (%) values were used for qualitative results. The normal distribution of data was assessed by the one-sample Kolmogorov-Smirnov test and by examining histograms. Independent samples t-tests were used to determine the differences between group parameters, and Pearson correlation analysis was used to evaluate the relationship between parameters. The level of statistical significance was set at p≤0.05.

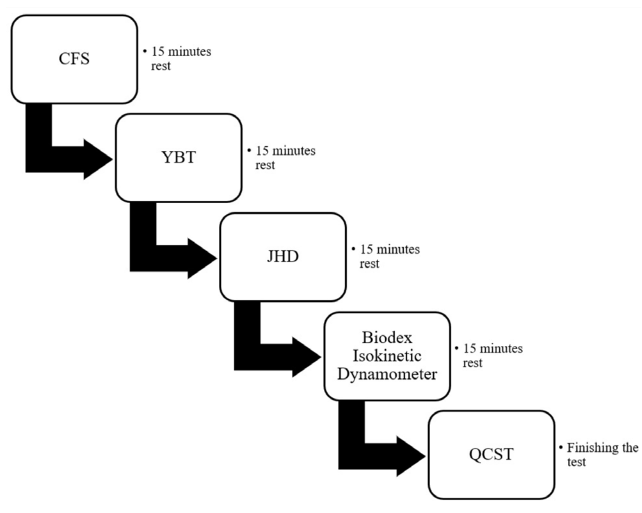

Figure 2. Flow chart of the study
CFS: Chalder Fatigue Scale, YBT: Y Balance Test, JHD: Jamar Handgrip Dynamometer, QCST: Queen's Collage Step Test

Results

Our study included 60 volunteers, including a study group with a history of COVID-19 (n=30) and a control group without (n=30). The demographic characteristics of both groups were statistically similar in the comparisons (Table 1).

In assessing fatigue via the CFS, the study group exhibited a significantly higher mean CFS score of 16±4 compared with 13.7±3.4 in the control group. This difference was statistically significant with a p value of 0.02 (Figure 3), indicating that post-COVID-19 individuals exhibited increased levels of fatigue.

Physical performance metrics such as balance (YBT), grip strength (JHD), and knee muscle strength showed no significant differences between the two groups (all p>0.05, Table 2).

The physical performance measurements, balance (YBT), grip strength (JHD), and knee muscle strength showed no significant difference between the two groups (all p>0.05, Table 2).

Cardiovascular measures were assessed using the QCST. Heart rate and estimated VO_{2max} were found to be similar between the groups (p=0.6 for heart rate and p=0.58 for VO_{2max}, Table 2).

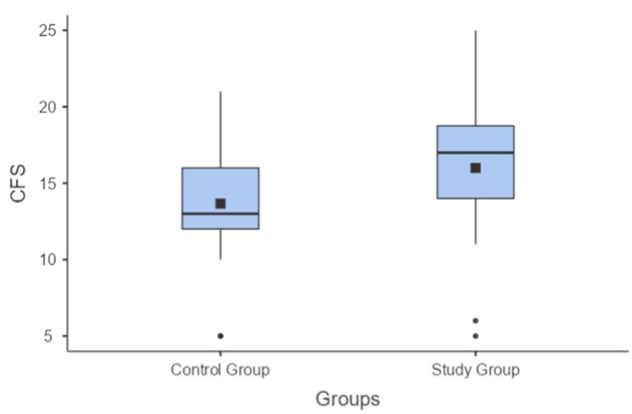

Figure 3. Graph of chalder fatigue scale means (p=0.02)
CFS: Chalder Fatigue Scale

After the gender-specific analysis, while male participants' results were similar, the CFS scores of females with COVID-19 histories were higher (p<0.05).

Correlation Analysis

In the study group, moderate correlations were found between gender and balance tests (p<0.05), as well as between gender and fatigue scores (r=-0.503, p=0.005). Negative correlations were observed between CFS scores and knee muscle strength measurements, specifically at 60° knee extension (r=-0.487, p<0.05), 90° knee extension (r=-0.478, p<0.05), and others. Additionally, a moderate negative correlation was found between CFS scores and JHD measurements for both the right hand (r=-0.424, p=0.019) and the left hand (r=-0.438, p=0.016).

Heart rate metrics from the QCST were negatively correlated with knee angular torque measurements at various angles in the study group, with coefficients ranging from r=-0.472 to r=-0.571 (all p<0.05). Moreover, strong positive correlations were identified between estimated VO_{2max} and knee flexion-extension angular torque measurements, with r-values up to 0.783 (all p<0.05, Study group correlation analyzes in Table 3, Control group correlation analyzes in Table 4).

Discussion

In this study, we aimed to compare exercise performance, muscle strength, balance, and fatigue levels between young individuals with mild COVID-19 in the past year and those without COVID-19. Our results showed that individuals who had COVID-19 in the past year had increased fatigue compared with those who did not, but there were no significant changes in muscle strength, balance, or exercise performance.

Studies on the effects of COVID-19 on muscle strength and exercise performance have often focused on cases that require hospitalization or intensive care unit stays (21,22). The systemic effects of the disease, the intense and severe cytokine storm, and the adverse effects of steroid treatments administered in response, as well as complications in the musculoskeletal system, are

Table 1. Socio-demographic characteristics of individuals

Demographic headlines	Control group Mean ± SD	Study group Mean ± SD	p-value
Average age (years)	22.46±1.5	23±1.1	0.12[a]
Height (cm)	167.93±9.57	169±9.22	0.47[a]
Body weight (kg)	62.6 ±10.49	64.36±13.78	0.58[a]
Female/Male (n)	18/12	17/13	0.79[a]
Cigarette (use/not use)	19/11	18/12	0.79[a]
Dominant side (right/left)	27/3	29/1	0.31[a]

[a] Independent samples t-tests were applied, SD: Standard deviation

Table 2. Balance, grip strength, knee muscle strength and exercise performance test results of the groups

Test Methods and Parameters	Study Group	Control Group	p-value
	Mean ± SD	Mean ± SD	
Y Balance Test Reach Direction			
Right Anterior (cm)	70.17±7.15	70.73±10.58	0.81[a]
Right Posterolateral (cm)	96.41±12.85	96.1±12.81	0.93[a]
Right Posteromedial (cm)	87.98±14.06	90.3±11.06	0.49[a]
Left Anterior (cm)	69.78±7.25	72.3±9.87	0.26[a]
Left Posterolateral (cm)	94.1±13.99	98.65±13.05	0.2[a]
Left Posteromedial (cm)	89.6±13.45	91.3±12.08	0.6[a]
Jamar Hand-Grip Dynamometer Related Limb			
Right Hand (kg)	30.38±11.39	30.09±9.54	0.92[a]
Left Hand (kg)	27.3±10.21	28.29±9.13	0.69[a]
Biodex Isokinetic System Measurement Angles			
Extension 60° (Nm)	74.84±35.51	77.51±35.49	0.77[a]
Flexion 60° (Nm)	107.54±40.48	105.72±47.93	0.87[a]
Extension 90° (Nm)	70.02±31.44	71.86±28.28	0.81[a]
Flexion 90° (Nm)	94.8±34.8	92.59±37.86	0.82[a]
Extension 120° (Nm)	64.2±27.89	66.46±24.53	0.74[a]
Flexion 120° (Nm)	84.29±30.68	80.08±30.70	0.6[a]
Extension 180° (Nm)	57.25±25.36	60.26±20.16	0.61[a]
Flexion 180° (Nm)	69.93±29.65	68.17±24.97	0.81[a]
Queen's Collage Step Test Parameters			
Heart Rate Per Minute (Beats/Minute)	163.47±12.32	165.3±14.73	0.6[a]
Estimated VO_{2max}	38.71±5.77	37.86±6.25	0.58[a]

[a] Independent samples t-tests were applied, SD: Standard deviation, cm: Centimetre, kg: Kilogram, Nm: Newton Meter, Tests Applied: Y Balance Test - Jamar Hand-Grip Dynamometer - Biodex Isokinetic Dynamometer System - Queen's Collage Step Test

Table 3. Study group correlation analyzes of gender, fatigue, exercise performance, and balance measurements with knee flexion-extension angular torque measurements

Study Group (Isokinetic Dynamometer Measurement Angles)		Gender	Chalder	QCST		YBT					
				HR	VO_{2Max}	Right Leg Anterior	Right Leg PL	Right Leg PM	Left Leg Anterior	Left Leg PL	Left Leg PM
60° Knee Extension	r	0.721**	-0.487**	-0.539**	0.783**	NS	0.500**	0.521**	NS	0.579**	0.519**
	p	0.000	0.006	0.002	0.000		0.005	0.003		0.001	0.003
60° Knee Flexion	r	0.541**	-0.411*	-0.571**	0.689**	0.407*	0.558**	0.475**	NS	0.546**	0.508**
	p	0.002	0.024	0.001	0.000	0.025	0.001	0.008		0.002	0.004
90° Knee Extension	r	0.779**	-0.478**	-0.486**	0.787**	0.361*	0.501**	0.522**	NS	0.561**	0.545**
	p	0.000	0.008	0.007	0.000	0.050	0.005	0.003		0.001	0.002
90° Knee Flexion	r	0.622**	NS	-0.519**	0.702**	0.484**	0.553**	0.493**	NS	0.536**	0.536**
	p	0.000		0.003	0.000	0.007	0.002	0.006		0.002	0.002
120° Knee Extension	r	0.743**	-0.478**	-0.504**	0.779**	NS	0.542**	0.528**	NS	0.597**	0.569**
	p	0.000	0.008	0.005	0.000		0.002	0.003		0.001	0.001
120° Knee Flexion	r	0.627**	-0.369*	-0.566**	0.741**	0.426*	0.563**	0.491**	NS	0.568**	0.545**
	p	0.000	0.045	0.001	0.000	0.019	0.001	0.006		0.001	0.002
180° Knee Extension	r	0.726**	-0.482**	-0.472**	0.740**	NS	0.561**	0.545**	NS	0.605**	0.574**
	p	0.000	0.007	0.008	0.000		0.001	0.002		0.000	0.001
180° Knee Flexion	r	0.639**	-0.387*	-0.466**	0.680**	0.456*	0.632**	0.530**	NS	0.593**	0.598**
	p	0.000	0.035	0.009	0.000	0.011	0.000	0.003		0.001	0.000

Pearson Correlation Analysis Applied, *: p≤0.05, **: p≤0.01, Isokinetic Dynamometer Measurement Angles: Biodex Isokinetic System Measurement Angles, QCST: Queen's Collage Step Test, YBT: Y Balance Test, HR: Heart rate, PL: Posterolateral, PM: Posteromedial, NS: Not significant

Table 4. Control group correlation analyzes of gender, exercise performance, and balance measurements with knee flexion-extension angular torque measurements												
Control Group (Isokinetic Dynamometer Measurement Angles)	**Gender**		**Chalder**	**QCST**		**YBT**						
				HR	**VO_{2Max}**	**Right Leg Anterior**	**Right Leg PL**	**Right Leg PM**	**Left Leg Anterior**	**Left Leg PL**	**Left Leg PM**
60° Knee Extension	r	0.681**	**NS**	-0.379*	0.631**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
	p	0.000		0.039	0.000						
60° Knee Flexion	r	0.641**	**NS**	**NS**	0.418*	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
	p	0.000			0.022						
90° Knee Extension	r	0.683**	**NS**	-0.415*	0.685**	0.412*	**NS**	**NS**	**NS**	**NS**	**NS**
	p	0.000		0.023	0.000	0.023					
90° Knee Flexion	r	0.686**	**NS**	**NS**	0.457*	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
	p	0.000			0.011						
120° Knee Extension	r	0.732**	**NS**	-0.381*	0.683**	0.439*	**NS**	**NS**	**NS**	0.378*	**NS**
	p	0.000		0.038	0.000	0.015				0.039	
120° Knee Flexion	r	0.678**	**NS**	**NS**	0.494**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
	p	0.000			0.006						
180° Knee Extension	r	0.747**	**NS**	**NS**	0.613**	0.365*	**NS**	**NS**	**NS**	0.389*	**NS**
	p	0.000			0.000	0.047				0.033	
180° Knee Flexion	r	0.667**	**NS**	**NS**	0.416*	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
	p	0.000			0.022						

Pearson Correlation Analysis Applied, *: p≤0.05, **: p≤0.01, Isokinetic Dynamometer Measurement Angles: Biodex Isokinetic System Measurement Angles, QCST: Queen's Collage Step Test, YBT: Y Balance Test, HR: Heart rate, PL: Posterolateral, PM: Posteromedial, NS: Not significant

considered the main causes of losses in muscle strength and exercise performance in this group (23). Additionally, statistically significant decreases in muscle strength and exercise performance after COVID-19 have been reported in cases followed up on the ward (21).

Our study was conducted with the participation of young individuals (aged 18-28) who had mild COVID-19 and did not require hospitalization. Our measurements showed no significant differences between the two groups, except for fatigue scores. This finding is consistent with the literature results for young individuals in the mild COVID-19 category and may explain why no significant changes were observed in our study.

Fatigue is influenced by many factors, such as age, gender, disease status, and mental conditions. It also impairs the quality of life and reduces functionality (12). Due to these effects, fatigue is an important factor that affects life throughout the lifespan. Fatigue, which is also one of the most common symptoms of COVID-19 infection, is seen as the most persistent and performance-reducing symptom among COVID-19 symptoms. In a systematic review and meta-analysis study, it was reported that fatigue developed in 99.1% of cases, especially in patients with post-COVID-19 syndrome lasting 12 weeks or longer (24). The exact cause of the fatigue observed because of the COVID-19 infection is not yet fully understood. However, it is thought to be caused by factors such as inflammation, mitochondrial dysfunction, autonomic nervous system anomalies, poor nutritional conditions, respiratory complications, obesity, and physical inactivity, according to some estimates (25,26).

In our study, it was found that there was a difference in fatigue between individuals who had COVID-19 and those who did not, based on the results of CFS (p=0.02). This result is consistent with those of previous studies (24). However, statistical analysis between the study and control groups showed no difference in fatigue scores between men who had COVID-19 and those who did not (p=0.748), whereas a difference was observed in women (p=0.001). This result is consistent with the research conducted by Rudroff et al. (27). Rudroff et al. (27) stated that the exact reason for higher fatigue scores in women is unknown. However, they concluded that anxiety, depression, and sex hormones may be causative factors. None of our participants had any known psychological problems. The effect of the menstrual cycle and hormonal factors on fatigue is emphasized in the literature (28). Because we did not inquire about participants' ovarian hormone concentrations and menstrual phase parameters, as well as their depression and anxiety scores, and we could not perform a correlation analysis on this topic, we cannot make a clear interpretation. However, the use of CFS in our evaluation, which is mainly used to assess physical fatigue and whose exclusion criteria include psychogenic problems, strengthens the claim that our fatigue measurements are not related to psychological conditions and that our results are reliable.

Previous studies have emphasized muscle strength loss and balance loss due to physical inactivity and inflammation encountered during the COVID-19 process (29,30). However, some studies have reported that rapid recovery of muscle strength occurs in young individuals (31). The similarity of the strength and balance measurements between the groups in our study may be related to the rapid recovery process of the young population. While the literature shows cases where this difference occurs due to prolonged post-COVID-19 syndrome, the mild COVID-19 status of our cases, the age factor, and the normal course of the recovery process can be associated with obtaining results independent of prolonged COVID-19 (32).

Soares et al. (23) showed that skeletal muscle atrophy can develop because of COVID-19 infection. In the study conducted by de Andrade-Junior et al. (22) on 32 patients, it was observed that individuals who had severe COVID-19 with an average age of 64.1 years had 30% atrophy in their rectus femoris cross-sectional areas. In this regard, when our study was reviewed again, it was determined that the individuals included in the study had a mild COVID-19 infection, so there was no exposure to the adverse effects of medication or long-term inactivity. Therefore, we anticipate that any potential muscle atrophy did not develop, or if it did, it was not at a level that would affect muscle strength. In addition, due to the age range of the participants in the sample being composed of young individuals, we anticipate that any potential atrophy would regenerate rapidly and not be reflected in the tests conducted. This view is supported by the study by Muehlbauer et al. (30), which showed that muscle atrophy is rapidly eliminated in young individuals. In our study, a moderate negative correlation was observed between fatigue score, JHD measurements, and Biodex angular torque measurements in the correlation analysis conducted among the study group. This is thought to be due to the significant difference between the fatigue scores of women (mean: 17.52±2.83) and men (mean: 13.36±4.61) in the study group ($p=0.005$). This difference may be related to gender.

Coronavirus disease-2019 has also been shown to have neurological effects. These effects include hyposmia, anosmia, myalgia, headache, confusion, delirium, dizziness, encephalopathy, stroke, epilepsy, Guillain-Barré syndrome, Miller-Fischer syndrome, and acute myelitis. Many of these diseases adversely affect the balance. Adverse effects on balance are important factors for mobility, functionality, and quality of life. Studies have reported that balance is negatively affected in COVID-19 patients compared with healthy individuals (33). In a study by de Sousa et al. (34), conducted on post-acute COVID-19 patients who were not hospitalized and had an average age of 35, it was stated that the balance of COVID-19 patients was negatively affected compared with the control group, and their quality of life was also adversely affected. In addition, they found that changes in balance values were correlated with physical capacity, hand grip strength, and mental health evaluation parameters (34). In a functional balance assessment study conducted by Guzik et al. (35) on young individuals with an average age of 22 years who had a moderate level of COVID-19, balance was negatively affected. However, in contrast to this information, Ychowska et al. (36) reported no significant difference in stabilometric measurements between individuals who had mild COVID-19 within two-four weeks and those who did not (average age 40 and 38.9, respectively). In addition, they noted that balance impairment increased in COVID-19 patients who had respiratory complaints compared with those without respiratory involvement (36).

In the correlation analysis performed within our study groups, it was determined that the balance scores of individuals with COVID-19 were associated with gender. No relationship was found among individuals without COVID-19. Plisky et al. (16) reported a difference in YBT scores based on gender in their study on healthy individuals, with higher scores in males. In our study, the high YBT scores in both groups of males were associated with anatomical differences compared with females. Shamsi et al. (37) predicted that gender is an important variable for YBT (38), and their study results support our view. Regarding COVID-19, our study found no loss of balance performance, which is similar to Ychowska et al.'s (36) studies.

Lewis et al. (38) highlighted the effect of heart rate variability during exercise on physical work capacity, stating that decreases in heart rate were inversely proportional to increases in muscle strength. The negative correlation between heart rate measurements during QCST, angular torque measurements, and JHD measurements obtained from the Biodex device in the study group is consistent with the findings of Lewis et al. (38). Additionally, the young age of the participants is consistent with the level of results obtained. In the control group, there were differences in angular torque and grip strength measurements by gender. The difference between our groups can be attributed to the COVID-19 infection, which can cause a loss in heart performance that may not cause complaints in daily life but may become apparent during submaximal exercise testing. This idea is supported by Wu et al.'s (39) study, where they found similar heart rate values after a 6-minute walk test in COVID-19 patients with and without cardiac damage. They interpreted this result as cardiac fibrosis developing in COVID-19 patients who developed cardiac damage; however, because the fibrosis was in the early stages, there was no difference between the two groups.

The correlation between the estimated VO_{2max} measurements obtained from QCST and the isokinetic angular torque measurements obtained from Biodex agrees with the expected results. Lovell et al. (40) demonstrated that as lower extremity muscle strength increased, VO_{2max} measurements also increased. The negative correlation between estimated VO_{2max} measurements and fatigue scores in the study group was attributed to the lower fatigue scores of male participants in the study group. This is because male participants had higher muscle strength than females, and a negative correlation between fatigue scores and VO_{2max} measurements was expected because of the higher fatigue scores in female participants.

Study Limitations

This study has some limitations that should be considered. The difficulty of implementing the QCST and the requirement for continuous step cadence with a metronome may have negatively affected the participants' adaptation to the test. However, this test was chosen because of its ease of use, practical estimation of VO_{2max}, and minimal equipment requirements. For balance assessment, the decision not to use a computerized system may be attributed to the ease of using YBT in different clinical conditions and its frequent preference. In addition, limited access and the high cost of computerized systems played an effective role in our choice to use the YBT. Despite these limitations, our research has strengths. The researchers who administered the tests and evaluated the results during the study were different. In addition, the tests used in the assessments were selected in accordance with the target parameters. These tests are basic, non-invasive, cheaper, easy to understand, and suitable for every clinical situation. The sample of the study was selected from young adults, and our results contributed to the literature from this perspective.

Conclusion

The study focuses on the impact of COVID-19 on young adults, especially women, emphasizing that fatigue is a significant issue even in mild cases that do not require hospitalization. While muscle strength, exercise performance, and balance were generally unaffected in this group, fatigue symptoms were notably higher in the first year post-diagnosis than in those without COVID-19. The study also found some correlation between fatigue and other physical parameters, suggesting that the issue is complex. The data on the fatigue of COVID-19-related events are limited; therefore, these outcomes may be valuable for future research. The researchers believe that the mild disease history and young age of the participants could be factors in these outcomes. We think the next research should focus on COVID symptoms, surveillance, and therapy in different age groups.

Ethics

Ethics Committee Approval: Ethical permission for this study was obtained from the Ethics Committee of Marmara University Faculty of Health Sciences for Non-Interventional Clinical Studies (date: 27.01.2022, approval no: 16).

Informed Consent: Participants were informed about the study, and written consent was obtained.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: T.K., B.S., Concept: B.S., A.Y.O., Design: A.Y.O., Data Collection or Processing: T.K., B.S., Analysis or Interpretation: T.K., B.S., A.Y.O., Literature Search: T.K., B.S., A.Y.O., Writing: T.K., A.Y.O.

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References

1. Khan WH, Hashmi Z, Goel A, et al. COVID-19 Pandemic and Vaccines Update on Challenges and Resolutions. Front Cell Infect Microbiol 2021;11:690621.
2. Kornowski R, Witberg G. Acute myocarditis caused by COVID-19 disease and following COVID-19 vaccination. Open Heart 2022;9:e001957.
3. Besnier F, Bérubé B, Malo J, et al. Cardiopulmonary Rehabilitation in Long-COVID-19 Patients with Persistent Breathlessness and Fatigue: The COVID-Rehab Study. Int J Environ Res Public Health 2022;19:4133.
4. Pfefferbaum B, Van Horn RL. Physical Activity and Sedentary Behavior in Children During the COVID-19 Pandemic: Implications for Mental Health. Curr Psychiatry Rep 2022;24:493-501.
5. Islam MF, Cotler J, Jason LA. Post-viral fatigue and COVID-19: lessons from past epidemics. Fatigue: Biomedicine, Health & Behavior 2020;8:61-9.
6. Michelen M, Manoharan L, Elkheir N, et al. Characterising long COVID: a living systematic review. BMJ Glob Health 2021;6:e005427.
7. Huang Y, Tan C, Wu J, et al. Impact of coronavirus disease 2019 on pulmonary function in early convalescence phase. Respir Res 2020;21:163.

8. Halpin SJ, McIvor C, Whyatt G, et al. Postdischarge symptoms and rehabilitation needs in survivors of COVID-19 infection: A cross-sectional evaluation. J Med Virol 2021;93:1013-22.
9. De Giorgio MR, Di Noia S, Morciano C, Conte D. The impact of SARS-CoV-2 on skeletal muscles. Acta Myol 2020;39:307-12.
10. Durstenfeld MS, Sun K, Tahir P, et al. Use of Cardiopulmonary Exercise Testing to Evaluate Long COVID-19 Symptoms in Adults: A Systematic Review and Meta-analysis. JAMA Netw Open 2022;5:e2236057.
11. Abdallah SJ, Voduc N, Corrales-Medina VF, et al. Symptoms, Pulmonary Function, and Functional Capacity Four Months after COVID-19. Ann Am Thorac Soc 2021;18:1912-7.
12. Poole-Wright K, Guennouni I, Sterry O, Evans RA, Gaughran F, Chalder T. Fatigue outcomes following COVID-19: a systematic review and meta-analysis. BMJ Open 2023;13:e063969.
13. Paneroni M, Simonelli C, Saleri M, et al. Muscle Strength and Physical Performance in Patients Without Previous Disabilities Recovering From COVID-19 Pneumonia. Am J Phys Med Rehabil 2021;100:105-9.
14. Balakrishnan B, Hamrick L, Alam A, Thompson J. Effects of COVID-19 Acute Respiratory Distress Syndrome Intensive Care Unit Survivor Telemedicine Clinic on Patient Readmission, Pain Perception, and Self-Assessed Health Scores: Randomized, Prospective, Single-Center, Exploratory Study. JMIR Form Res 2023;7:e43759.
15. Adın RM, Ceren AN, Salcı Y, Fil Balkan A, Armutlu K, Ayhan Kuru Ç. Dimensionality, psychometric properties, and population-based norms of the Turkish version of the Chalder Fatigue Scale among adults. Health Qual Life Outcomes 2022;20:161.
16. Plisky P, Schwartkopf-Phifer K, Huebner B, Garner MB, Bullock G. Systematic Review and Meta-Analysis of the Y-Balance Test Lower Quarter: Reliability, Discriminant Validity, and Predictive Validity. Int J Sports Phys Ther 2021;16:1190-209.
17. Conforto I, Samir C, Chausse F, Goldstein A, Pereira B, Coudeyre E. Comparison of psychometric properties between the Labin, a new electronic dynamometer, and the Jamar: Preliminary results in healthy subjects. Hand Surg Rehabil 2019;38:293-7.
18. Feiring DC, Ellenbecker TS, Derscheid GL. Test-retest reliability of the biodex isokinetic dynamometer. J Orthop Sports Phys Ther 1990;11:298-300.
19. Chatterjee S, Chatterjee P, Bandyopadhyay A. Validity of Queen's College Step Test for estimation of maximum oxygen uptake in female students. Indian J Med Res 2005;121:32-5.
20. McArdle WD, Katch FI, Katch VL. Exercise physiology: energy, nutrition, and human performance. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins; 2015.
21. Perumal R, Shunmugam L, Naidoo K, et al. Long COVID: a review and proposed visualization of the complexity of long COVID. Front Immunol 2023;14:1117464.
22. de Andrade-Junior MC, de Salles ICD, de Brito CMM, et al. Skeletal muscle wasting and function impairment in intensive care patients with severe COVID-19. Front Physiol 2021;12:640973.
23. Soares MN, Eggelbusch M, Naddaf E, et al. Skeletal muscle alterations in patients with acute Covid-19 and post-acute sequelae of Covid-19. J Cachexia Sarcopenia Muscle 2022;13:11-22.
24. Ceban F, Ling S, Lui LMW, et al. Fatigue and cognitive impairment in Post-COVID-19 Syndrome: A systematic review and meta-analysis. Brain Behav Immun 2022;101:93-135.
25. Azzolino D, Passarelli PC, D'Addona A, Cesari M. Nutritional strategies for the rehabilitation of COVID-19 patients. Eur J Clin Nutr 2021;75:728-30.
26. Lacourt TE, Vichaya EG, Chiu GS, Dantzer R, Heijnen CJ. The High Costs of Low-Grade Inflammation: Persistent Fatigue as a Consequence of Reduced Cellular-Energy Availability and Non-adaptive Energy Expenditure. Front Behav Neurosci 2018;12:78.
27. Rudroff T, Workman CD, Bryant AD. Potential Factors That Contribute to Post-COVID-19 Fatigue in Women. Brain Sci 2022;12:556.
28. Kajiwara S, Akiyama N, Baba H, Ohta M. Association between COVID-19 vaccines and the menstrual cycle in young Japanese women. J Infect Chemother 2023;29:513-8.
29. Aghamohamadi N, Shahba F, Zarezadeh Mehrabadi A, et al. Age-dependent immune responses in COVID-19-mediated liver injury: focus on cytokines. Front Endocrinol (Lausanne) 2023;14:1139692.
30. Muehlbauer T, Gollhofer A, Granacher U. Associations Between Measures of Balance and Lower-Extremity Muscle Strength/Power in Healthy Individuals Across the Lifespan: A Systematic Review and Meta-Analysis. Sports Med 2015;45:1671-92.
31. Hasegawa S, Nakagawa Y, Yoshihara A, et al. Older Age, Poor Preoperative Quadriceps Muscle Strength, and Residual Pain as Risk Factors for Poor Quadriceps Muscle Strength Recovery at 1 Year After ACL Reconstruction: A TMDU MAKS Study of 402 Patients. Orthop J Sports Med 2023;11:23259671231194593.
32. Nalbandian A, Sehgal K, Gupta A, et al. Post-acute COVID-19 syndrome. Nat Med 2021;27:601-15.
33. Yılmaz O, Mutlu BÖ, Yaman H, Bayazıt D, Demirhan H, Bayazıt YA. Assessment of balance after recovery from Covid-19 disease. Auris Nasus Larynx 2022;49:291-8.
34. de Sousa KCA, Gardel DG, Lopes AJ. Postural balance and its association with functionality and quality of life in non-hospitalized patients with post-acute COVID-19 syndrome. Physiother Res Int 2022;27:e1967.
35. Guzik A, Wolan-Nieroda A, Kochman M, Perenc L, Drużbicki M. Impact of mild COVID-19 on balance function in young adults, a prospective observational study. Sci Rep 2022;12:12181.

36. Żychowska M, Jaworecka K, Mazur E, et al. COVID-19 and Postural Control-A Stabilographic Study Using Rambling-Trembling Decomposition Method. Medicina (Kaunas) 2022;58:305.

37. Shamsi M, Mirzaei M, Shahsavari S, Safari A, Saeb M. Modeling the effect of static stretching and strengthening exercise in lengthened position on balance in low back pain subject with shortened hamstring: a randomized controlled clinical trial. BMC Musculoskelet Disord 2020;21:809.

38. Lewis MJ, Kingsley M, Short AL, Simpson K. Rate of reduction of heart rate variability during exercise as an index of physical work capacity. Scand J Med Sci Sports 2007;17:696-702.

39. Wu X, Deng KQ, Li C, et al. Cardiac Involvement in Recovered Patients From COVID-19: A Preliminary 6-Month Follow-Up Study. Front Cardiovasc Med 2021;8:654405.

40. Lovell D, Cuneo R, Delphinus E, Gass G. Leg strength and the VO2 max of older men. Int J Sports Med 2011;32:271-6.