Original Research

Effect of Functional Electrical Stimulation on Muscle Mass, Fatigue, and Quality of Life in Older Patients With COVID-19: A Randomized Clinical Trial Study

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Abstract

Objective: This study aimed to evaluate the effects of functional electrical stimulation (FES) on muscle strength, fatigue, muscle mass, and quality of life (QoL) in older patients with COVID-19.

Methods: Older patients with COVID-19 were randomly divided into the following 2 groups: real FES (intervention group, n = 20) and sham FES (control group, n = 20). These patients received FES concurrent with the voluntary contraction of muscles for 10 consecutive sessions. Ultrasound imaging, pressure biofeedback, Chalder fatigue scale, and QoL were utilized to measure muscle mass, muscle strength, chronic fatigue, and QoL, respectively. Evaluations were performed at the beginning, immediately, and 1 month after the end of intervention.

Results: All variables showed statistically significant improvement immediately and 1 month after the intervention in the real FES group ($P < .05$). However, the tibialis anterior muscle mass and fatigue significantly improved immediately after the intervention in the sham FES group. However, the tibialis anterior and rectus femoris muscles strength and rectus femoris muscle mass were not significantly changed immediately and 1 month after the intervention ($P > .05$). There were significant differences in muscle mass, physical fatigue, muscle strength, and QoL between groups with more efficacy of real FES ($P < .05$).

Conclusion: For this sample of patients, FES improved fatigue, muscle strength, muscle mass, and QoL in older adults with COVID-19. (J Manipulative Physiol Ther 2023;46;65-75)

Key Indexing Terms: *COVID-19; Electric Stimulation; Quadriceps Muscle; Anterior Tibial Muscle; Ultrasonography*

Introduction

Coronavirus disease 2019 (COVID-19) has involved millions of people worldwide since 2019.[1] So far, most COVID-19–related treatments have focused on controlling acute symptoms and recovery.[2] However, many recovered patients face persistent physical, cognitive, and psychological symptoms with the advancement of research.[2] Muscle fatigue is one of the most persistent and debilitating symptoms.[2-4] Most patients experience persistent symptoms for at least 2 months after leaving the hospital, which is more pronounced in older people.[5] Patients with COVID-19 report fatigue as one of the most persistent and debilitating symptoms (64%).[2-4] Post–COVID-19 fatigue is associated with decreasing physical and mental performance following changes in central, psychological, and peripheral disease factors.[2] As a result of this virus, patients with COVID-19 may experience muscle fatigue and physical fatigue, as well as myalgia, muscle wasting, and decreased muscle strength.[2,6,7] Eventually, independence and quality of life (QoL) are reduced in patients with COVID-19,[6] which imposes irreversible financial and social effects on society.[7]

Electrical neuromuscular stimulation has significant effects on increasing strength and muscle mass, retraining muscles, preventing muscle weakness, and controlling

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muscle and physical fatigue as one of the practical and promising techniques.[5,8] Functional electrical stimulation (FES) causes involuntary muscle contractions by stimulating the motor nerves,[5,8] which is usually easily tolerated without any side effects.[5,8] Mild exercise therapy concurrent with FES has been shown to be helpful in patients with muscle weakness post−COVID-19.[9] Improvement in muscle strength, muscle mass, and functionality of septic patients with critical COVID-19 following FES has also been evaluated.[10] As well, benefits of using FES on muscle weakness and function in patients with COVID-19 admitted to the intensive care unit have been described.[5] Some limited studies and case reports have shown that FES can reduce fatigue and maintain muscle strength in patients with COVID-19 during acute periods and hospitalization.[5,8-10] However, we are aware of no studies that have examined the effect of FES on fatigue, muscle mass, and muscle strength in older patients with COVID-19 after hospitalization and during recovery.

Most older patients with COVID-19 experience fatigue and muscle weakness for over 2 months after discharge, substantially affecting their QoL.[8] On the other hand, routine exercise therapy has not been advised for improving muscle strength or increasing muscle mass[10,11] because of muscle fatigue and wasting in patients with COVID-19 after discharge.[10,11] Therefore, FES, as an additional rehabilitation strategy, could possibly help patients with COVID-19 after discharge by improving muscle strength and controlling muscle fatigue.[8,10] Therefore, the purpose of this study was to evaluate the effects of FES intervention on muscle strength, fatigue, muscle mass, and QoL in older patients with COVID-19 after discharge. The research hypotheses were the following: (1) FES can improve muscle mass, fatigue, and QoL in older patients with COVID-19, and (2) there is no significant effect following sham FES in improving muscle mass, fatigue, and QoL in older patients with COVID-19.

Methods

Design and Ethics

This study was a parallel double-blinded, randomized controlled trial and was approved by the Human Ethics Committee at Semnan University of Medical Sciences, Semnan, Iran. The study was registered in the Iranian Registry of Clinical Trials (www.irct.ir; IR.SEMUMS.REC.1400.153). The current study was performed during the second half of 2021 in the Neuromuscular Rehabilitation Research Center. A consent form was signed by all participants before participating in the study.

Participants

A total of 60 patients with COVID-19 were recruited after discharge from the hospital and screened by an infectious disease specialist based on the inclusion and exclusion criteria. Then, 40 participants were randomly assigned into 2 groups by a computerized random number generator, including real FES (intervention group, n = 20) and sham FES (control group, n = 20). Finally, all 40 participants with a mean age of 68.28 ± 6.52 years completed the study. This sample size was calculated using Cohen's table (based on the effect size determined on the first 20 patients) to detect the effect of FES with 95% confidence and statistical power of 80%. The rectus femoris (RF) and tibialis anterior (TA) muscles are key muscles involved in standing and walking, and in the current study, FES was applied to these 2 muscles.[8] The inclusion criteria included the following: (1) older adults with COVID-19 discharged from the hospital, (2) going 2 weeks after the onset of the disease (the patient is in the subacute phase),[8] (3) being older than 60 years, (4) having weakness in the RF and TA muscles (the score of ≤3 in manual muscle test),[8] (5) having normal alertness, orientation, and responsiveness to a verbal stimulus,[8] and (6) willingness to participate in the study.

Exclusion criteria were as follows: (1) known or suspected malignancy in the lower limbs[8]; (2) body mass index more than 35 (kg/m^2)[8]; (3) unstable conditions, such as deep vein thrombosis and rhabdomyolysis[8]; (4) implanted cardiac pacemaker or defibrillator;[8] (5) amputation or inability to transfer independently from bed to chair before hospital admission[8]; (6) skin burning, anesthesia, or hyperesthesia after using FES[12]; and (7) patients with Alzheimer disease, degenerative disease, or polyneuropathy.[12] Figure 1 shows the flowchart of the eligibility assessment throughout the study.

Ultrasound Measurement for Assessing the Muscle Mass

A diagnostic ultrasound (US) imaging unit (HS-2100 V; Japan) set in B-mode with a 7.5 MHz linear head transducer was used to assess the RF and TA muscle mass. Real-time US imaging is a reliable and valid technique for determining muscle mass.[8,13] The US transducer was located on the RF muscle (halfway between the anterior superior iliac spine line and the upper edge of the patella) of the dominant lower limb with minimal pressure to evaluate the RF muscle mass. At the same time, the patient slept supine (Fig 2A).[8] The distance between the superficial and deep aponeurosis of the RF muscle was measured by the US curser (Fig 2B).[8] The US evaluated the TA muscle mass of the dominant lower limb in the supine crook-lying position[14] while the knees were bent 90° and the ankles relaxed.[14] In this condition, the transducer of the US was placed vertically with minimal pressure in the upper one-third of the distance between the knee and the external malleolus (Fig 2C).[14] The distance between the superficial and deep aponeurosis of the TA muscle was measured by the US curser (Fig 2D).[14] At least 3 US images were recorded from each condition to increase the US measurement accuracy. The RF and TA muscle masses

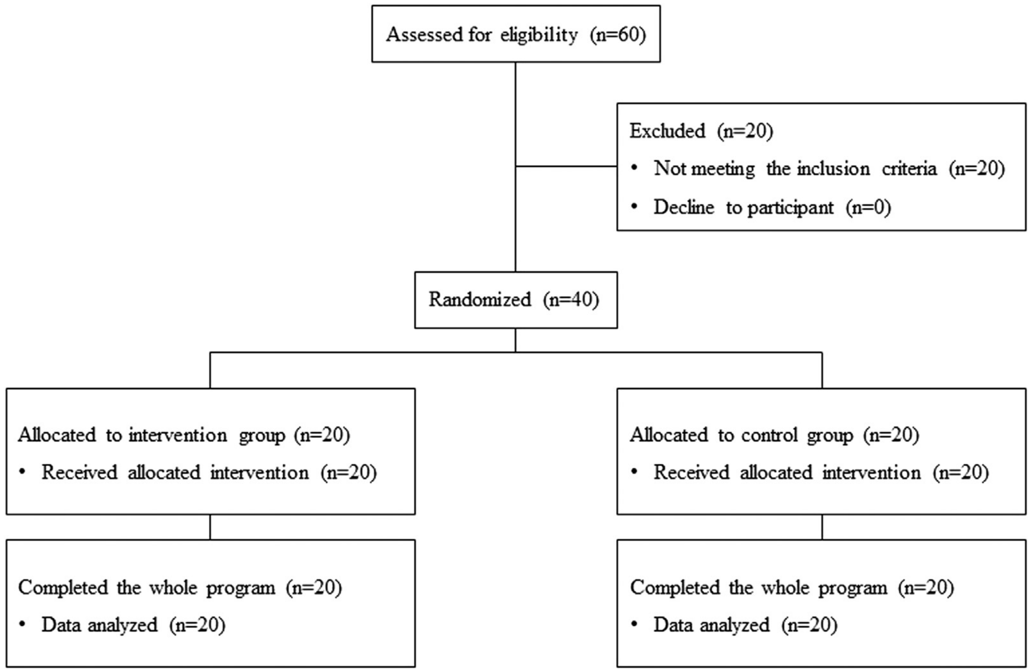

Fig 1. *Flow diagram of participant's eligibility assessment.*

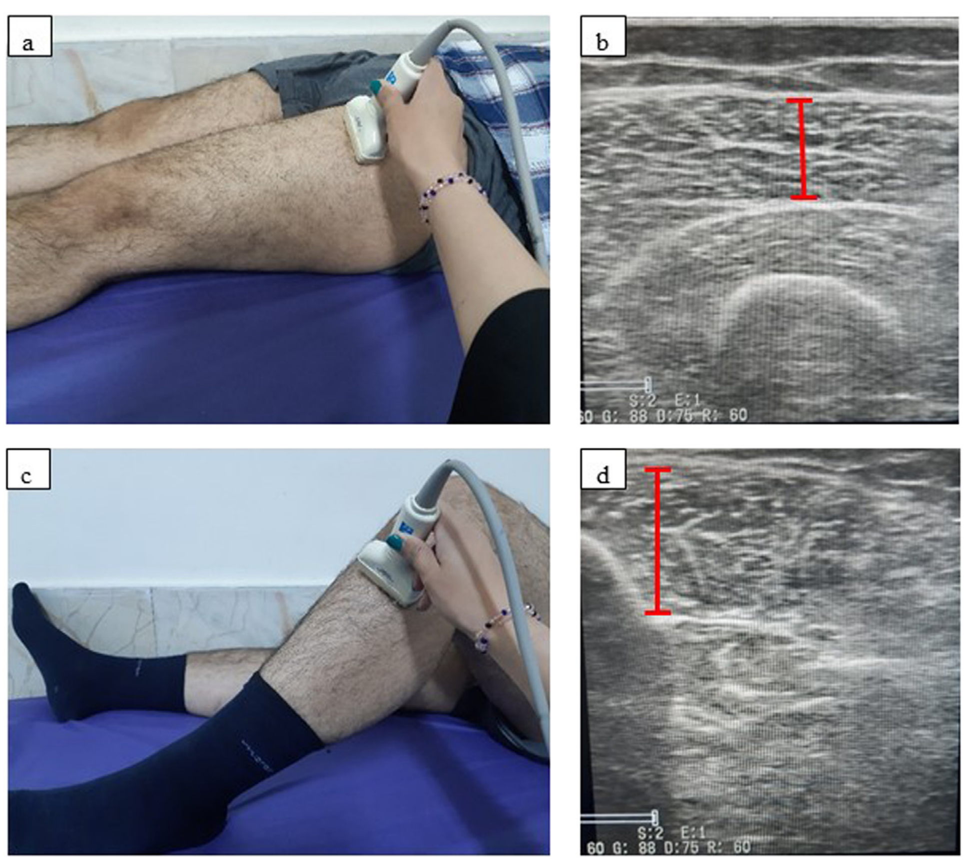

Fig 2. *Position of the participants for measuring the RF muscle mass (A), ultrasound measurement of the RF muscle thickness (B), position of the participants for measuring the TA muscle mass (C), and ultrasound measurement of the TA muscle thickness (D). RF*, rectus femoris; *TA*, tibialis anterior.

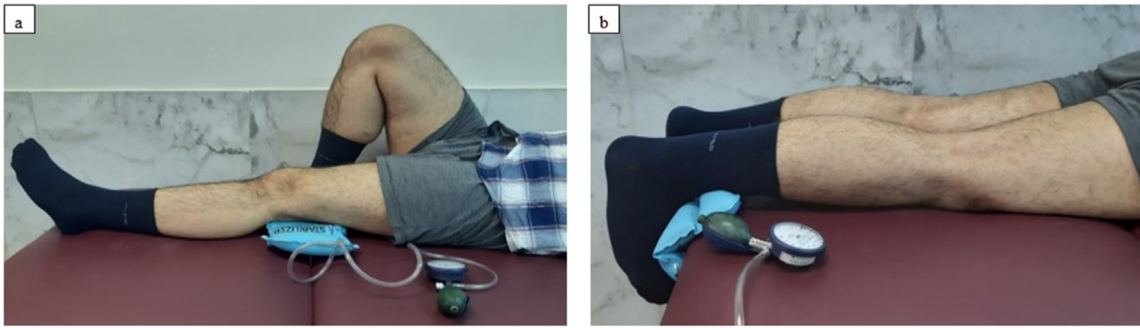

Fig 3. *The assessment of RF muscle strength in the supine position (A), and the assessment of TA muscle strength in the prone position (B) with a biofeedback pressure device. RF*, rectus femoris; *TA*, tibialis anterior.

were assessed at the beginning of the first session (T_0), after the end of the intervention (T_1), and 1 month after the end of the intervention (T_2). An expert physiotherapist performed all measurements.

Assessment of Muscle Strength

A biofeedback pressure device was used to evaluate the muscle strength of the dominant lower limb. The participants were placed in a position supine to assess the RF muscle strength. The cuff of the device was placed below the patient's knee, and the patients were asked to contract the RF muscle with a maximal isometric contraction and press the knee to the bed immediately after the verbal command of the physiotherapist (Fig 3A). A pressure biofeedback device was placed between the patient's ankle and the end edge of the bed, allowing the cuff to measure the strength of the TA muscle. The patients were requested to take their ankles to the dorsiflexion during the verbal command of the physiotherapist while applying maximum pressure to the cuff of the device (Fig 3B). The device's pressure was set to 40 mmHg before maneuvering, and muscle strength was measured in millimeters of mercury.[15] Three records were taken from each condition of tests to increase the measurement accuracy.

Assessment of Walking Speed as a Functional Task

Patients were asked to walk a straight distance of 4 m to assess their daily function.[8] The time to complete this distance was taken with a chronometer and calculated the walking speed.[8] Walking speed was recorded at the beginning of the first session (T_0), after the end of the intervention (T_1), and 1 month after the end of the intervention (T_2). An expert physiotherapist performed all measurements.

Assessment of the QoL

The 26-item version of the World Health Organization Quality-of-Life scale was used in this study,[16,17] comprising 5 domains, including physical health, psychological health, social relationship, environment, and general health.[16] Each item is rated on a 5-point Likert scale (higher scores denote higher QoL).[16] The scores were transformed to a 0 to 100 scale after computing.[16] Quality of life was recorded at the beginning of the first session (T_0), after the end of the intervention (T_1), and 1 month after the end of the intervention (T_2).

Assessment of Fatigue (Physical and Mental)

The participants' fatigue was assessed by the Persian translation of the Chalder fatigue scale with 14 questions. This self-rating scale is reliable and valid for measuring fatigue.[18] The principal components analysis supported the notion of a 2-factor physical solution measured by items 1 to 8, and mental fatigue was measured by items 9 to 14. Each of the 14 items included a 4-point scale range in the least symptomatic to maximum symptomologies, such as "better than usual," "no worse than usual," "worse than usual," and "much worse than usual". The answers to "better than usual" were on the left of the response scale with a score of 0. The responses to "much worse than usual" were located on the correct scale.[18,19] This questionnaire was completed at the beginning of the first session (T_0), after the end of the intervention (T_1), and 1 month after the end of the intervention (T_2).

Therapeutic Interventions in Each Group

Two physiotherapists were involved in this study to supervise the interventions in both groups and assess the outcomes. The assessor who evaluated the outcomes was blind to the group assignment, and the participants were also blind to the intervention of the other group. All participants of both groups received their interventions for 10 consecutive sessions. Intervention group members received actual FES concurrent with voluntary muscle contractions, whereas control group members received only sham FES. The current study used the 30-minute FES (710 P plus, Iran) for RF and TA muscles during 10 consecutive sessions.[5]

The FES was administered to patients seated on a chair with voluntary contractions of RF muscle. A pair of electrodes (10 × 5 cm) was used on the RF muscle so that 1 electrode was placed 5 cm below the inguinal area, and the other was 5 cm above the patella.[8] The excitation protocol used symmetric 2-phase rectangular pulses with a frequency of 50 Hz (250 μs pulse duration).[8] Stimulation (on) time was 6 seconds, and relaxation (off) time was 12 seconds, which provoked the muscle with a total of 90 contractions per day.[8] The stimulation intensity was adjusted daily to create a visible contraction in each muscle and simultaneously stimulate the muscle.[8] The maximum stimulation intensity was recorded for each session as an indicator of the FES dose.[8]

The FES and voluntary contraction of the TA muscle were combined with stimulating the TA muscle in the intervention group. One electrode was placed on the motor point of the muscle, and the other immediately below the muscle bulk.[5] Functional electrical stimulation was applied for 30 minutes with a diversion pulse of 250 μs, a frequency of 50Hz, on-time stimulation of 6 seconds, and off-time stimulation of 12 seconds.[5,20]

In the control group receiving the sham treatment, FES was used for only the first 20 seconds for providing the sham FES condition. Then, the stimulation intensity was decreased to 0 during the remaining intervention.

Patients were instructed to follow a regular and mild aerobic exercise program every 10 sessions of intervention. Home-based exercise training is composed of warm-up (5 minutes) and aerobic exercise (outdoor walking, cycle ergometer, and stair climbing or step; 3 sets of 20 repetitions with the maximum tolerated load).[21] Exercise intensity and duration increased progressively based on patients' capability.

Statistical Analysis

Data were analyzed with SPSS software, version 22 (IBM Corp., Armonk, New York). The normality of data distribution was evaluated for the tested variables by Kolmogorov-Smirnov test. An independent *t* test was used to assess baseline values between groups. Furthermore, the general linear mixed model repeated measure analysis of variance was performed to evaluate the main effects of the intervention and time (before, immediately, and 1 month after the intervention) and their interaction on muscle mass, muscle strength, walking speed, QoL, and fatigue. The paired and

Table 1. *Baseline Characteristics of the Study Participants*

Variable	Intervention Group, Real FES (n = 20)	Control Group, Sham FES (n = 20)	*P* Value
Age (y)	69.7 ± 7.87	66.85 ± 4.59	.17
BMI	.27 ± .04	.25 ± .02	.13
RF muscle mass	16.64 ± 4.75	15.77 ± 2.31	.46
TA muscle mass	20.64 ± 3.69	21.39 ± 2.82	.47
RF muscle strength	74.73 ± 8.02	71.89 ± 7.96	.25
TA muscle strength	97.25 ± 28.46	98.08 ± 11.64	.90
Walking speed	5.84 ± 1.60	5.27 ± 1.46	.24
General health	56.25 ± 17.90	56.87 ± 17.43	.91
Physical health	47.49 ± 16.22	48.89 ± 15.07	.78
Psychological health	54.99 ± 13.69	55.41 ± 10.65	.91
Social relationship	64.38 ± 13.42	71.66 ± 14.90	.11
Environmental health	53.22 ± 15.23	53.43 ± 10.72	.96
Physical fatigue	17.55 ± 4.55	16.35 ± 6.07	.48
Mental fatigue	7.90 ± 3.09	7.75 ± 3.72	.89

BMI, body mass index; *FES*, functional electrical stimulation; *RF*, rectus femoris; *TA*, tibialis anterior.

independent *t* tests assessed the differences within and between groups. The type I error (α) was set at .05.

Results

Table 1 indicates no significant differences between the groups in baseline variables of age, body mass index, muscle mass (RF and TA muscles), muscle strength (RF and TA muscles), walking speed, QoL, and fatigue (physical and mental) ($P > .05$).

Table 2 shows the results of the general linear mixed model repeated measure analysis of variance analysis on muscle mass (RF and TA muscles), muscle strength (RF and TA muscles), walking speed, QoL, and fatigue (physical and mental). The findings indicated that the main effect of the group was significant for RF muscle mass ($P = .042$), RF muscle strength ($P = .005$), walking speed ($P = .004$), general health ($P = .018$), psychological health ($P = .029$), environmental health ($P = .04$), and physical fatigue ($P = .029$). In addition, the main effect of "Time" was significant for all variables ($P < .001$) except for social relationships ($P = .37$). The group x time interaction effects were also significant for all variables ($P < .001$), except for mental fatigue ($P = .064$) and social relationships ($P = .18$) (Table 2).

Post hoc within-group analyses with Bonferroni correction significantly improved RF and TA muscle mass and

Table 2. *ANOVA Analysis on Muscle Mass (RF and TA muscles), Muscle Strength (RF and TA muscles), Walking Speed, QoL, and Fatigue*

Variable	Effect		Degree of Freedom	F	*P* Value
RF muscle mass	Main	Group	1	4.45	.04[a]
		Time	2	21.87	<.001[a]
	Interaction	Group x time	2	17.86	<.001[a]
TA muscle mass	Main	Group	1	.75	.39
		Time	2	34.15	<.001[a]
	Interaction	Group x time	2	22.41	<.001[a]
RF walking strength	Main	Group	1	8.78	.005[a]
		Time	2	13.77	<.001[a]
	Interaction	Group x time	2	8.16	.002[a]
TA walking strength	Main	Group	1	2.52	.12
		Time	2	20.51	<.001[a]
	Interaction	Group x time	2	15.28	.001[a]
Walking speed	Main	Group	1	9.44	.004[a]
		Time	2	40.71	<.001[a]
	Interaction	Group x time	2	72.18	<.001[a]
General health	Main	Group	1	6.08	.018[a]
		Time	2	32.06	<.001[a]
	Interaction	Group x time	2	12.58	<.001[a]
Physical health	Main	Group	1	3.98	.053
		Time	2	50.10	<.001[a]
	Interaction	Group x time	2	12.94	<.001[a]

(*continued*)

Table 2. (*Continued*)

Variable	Effect		Degree of Freedom	F	*P* Value
Psychological health	Main	Group	1	5.19	.029[a]
		Time	2	29.19	<.001[a]
	Interaction	Group x time	2	10.46	<.001[a]
Environmental health	Main	Group	1	4.54	.04[a]
		Time	2	17.93	<.001[a]
	Interaction	Group x time	2	11.18	.001[a]
Physical fatigue	Main	Group	1	5.17	.029[a]
		Time	2	62.92	<.001[a]
	Interaction	Group x time	2	19.42	<.001[a]
Mental fatigue	Main	Group	1	.75	.392
		Time	2	27.23	<.001[a]
	Interaction	Group x time	2	2.85	.064

ANOVA, analysis of variance; *QoL*, quality of life; *RF*, rectus femoris; *TA*, tibialis anterior.
[a] Significant differences.

strength, walking speed, general, physical, psychological, and environmental health, as well as physical and mental fatigue in the intervention group, immediately and 1-month follow-up after the intervention ($P < .01$; Table 3). However, the TA muscle mass and mental fatigue were significantly improved immediately after sham FES intervention in the control group ($P < .01$). In addition, walking speed, general, physical, and psychological health, as well as physical and mental fatigue, were significantly better in the 1-month follow-up ($P < .01$; Table 3). At the same time, the other variables were not significant changes immediately, and 1-month follow-up after the intervention ($P > .05$; Table 3).

Moreover, the post hoc between-group analysis indicated significant differences between the intervention and control groups in the RF muscle mass, RF and TA muscle strength, walking speed, general, physical, psychological, and environmental health, as well as physical fatigue immediately and at 1-month follow-up after the intervention ($P < .01$; Figs 4 and 5; Table 4). There were no side effects, such as burning under the electrodes, for each intervention and control group.

Discussion

In this study, we found that those receiving real FES significantly improved RF and TA muscle mass, RF and TA muscle strength, walking speed, general, physical, psychological, and environmental health, as well as physical and mental fatigue immediately and 1-month follow-up after the intervention. However, the TA muscle mass and mental fatigue significantly improved immediately after sham FES intervention in the control group. In addition, significant effects of the intervention on walking speed, general health, physical health, psychological health, and physical and mental fatigue were observed during only a 1-month follow-up in the control group. Moreover, the other variables were not significantly changed immediately and after 1-month follow-up after the sham FES intervention in the control group.

In comparison to other studies, a randomized controlled trial conducted by Minetto et al (2021) showed the positive effects of FES on improving muscle function.[8] This study evaluated physical performance, fatigue, muscle strength, RF muscle thickness, and walking performance. The results supported the effectiveness of electrical stimulation in improving the physical and muscle function of patients with COVID-19.[8] Burgess et al (2021) assessed the effect of neuromuscular electrical stimulation on the recovery of patients with COVID-19 and concluded that electrical stimulation could reduce muscle atrophy in hospitalized patients as an effective intervention for rehabilitating patients with COVID-19.[5] The current study also revealed that FES significantly improved lower limb muscle performance, QoL, and fatigue, immediately and 1-month after the intervention. Kyeongyoon et al (2018) investigated the

Table 3. *The Results of Paired t Test on Muscle Mass (RF and TA muscles), Muscle Strength (RF and TA muscles), Walking Speed, QoL, and Fatigue in Different Assessment Times Within the Groups*

			Intervention Group, Real FES			Control Group, Sham FES		
Variable	Time Assessment		Mean Difference	SD	*P* Value	Mean Difference	SD	*P* Value
RF muscle mass	T0	T1	−2.41	1.91	<.001[a]	−.10	.30	.12
		T2	−2.49	2.40	<.001[a]	−.13	.35	.11
TA muscle mass	T0	T1	−2.59	1.75	<.001[a]	−.26	.50	.03[a]
		T2	−2.63	1.84	<.001[a]	−.24	.67	.14
RF muscle strength	T0	T1	−9.48	6.50	<.001[a]	.45	5.26	.70
		T2	−9.48	11.07	.002[a]	−2.46	6.25	.11
TA muscle strength	T0	T1	−20.10	12.83	<.001[a]	−1.16	3.82	.18
		T2	−21.06	16.26	<.001[a]	−1.48	4.10	.14
Walking speed	T0	T1	−1.09	.54	<.001[a]	−.04	.34	.57
		T2	−1.17	.51	<.001[a]	.35	.32	<.001[a]
General health	T0	T1	−19.62	16.47	<.001[a]	−2.50	8.73	.21
		T2	−24.37	19.49	<.001[a]	−6.75	11.05	.01[a]
Physical health	T0	T1	−15.99	12.45	<.001[a]	−2.71	7.63	.12
		T2	−22.04	13.41	<.001[a]	−8.34	7.98	<.001[a]
Psychological health	T0	T1	−13.09	11.03	<.001[a]	.36	5.76	.78
		T2	−16.52	11.64	<.001[a]	−6.73	9.72	<.001[a]
Environmental health	T0	T1	−13.67	12.70	<.001[a]	−.76	11.10	.76
		T2	−14.91	12.04	<.001[a]	−2.95	7.69	.12
Physical fatigue	T0	T1	8.25	5.44	<.001[a]	.95	2.89	.15
		T2	10.45	5.70	<.001[a]	3.94	2.92	<.001[a]
Mental fatigue	T0	T1	2.50	2.35	<.001[a]	1.00	1.48	<.001[a]
		T2	2.90	2.55	<.001[a]	1.75	2.14	<.001[a]

FES, functional electrical stimulation; *QoL*, quality of life; *RF*, rectus femoris; *T0*, before intervention; *T1*, after the end of the intervention; *T2*, 1 month after the end of the intervention; *TA*, tibialis anterior.

[a] Significant differences.

effects of 20-minute FES along with in-bed cycling on the RF muscle strength and muscle mass of the left leg in mechanically ventilated patients, while in-bed cycling alone was used in the right leg.[22] The cross-sectional area thigh circumferences RF was assessed with ultrasonography, and muscle strength was measured by the Medical Research Council scale.[22] The results indicated that no significant RF muscle strength and muscle mass changes between 2 interventions and 1-session FES could induce the training effects.[22] However, this study investigated the temporary impact of FES and training on RF muscle strength and muscle mass.[22] In contrast, the current study's findings indicated that 10 sessions of FES significantly improved RF and TA muscle mass and strength immediately and 1-month follow-up after the intervention in older patients with COVID-19.

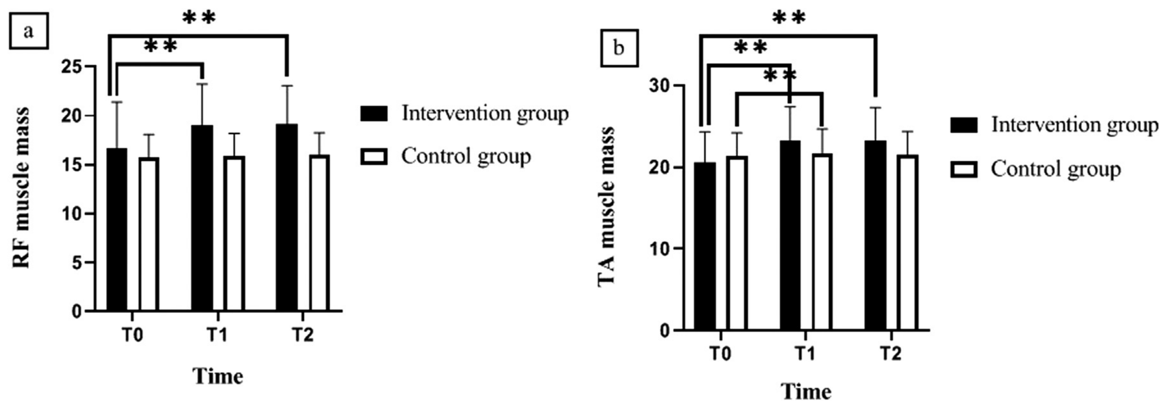

Fig 4. *The comparison of RF muscle mass (A), the TA muscle mass before (T_0), after the end of the intervention (T_1), and 1 month after the end of the intervention (T_2) between intervention and control groups (B). RF*, rectus femoris; *TA*, tibialis anterior.

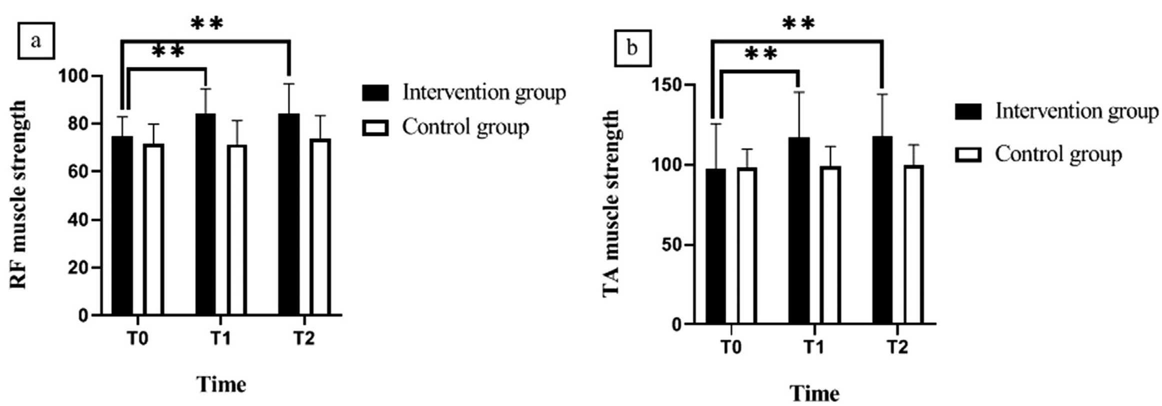

Fig 5. *The comparison of RF muscle strength (A), and the TA muscle strength before (T_0), after the end of the intervention (T_1), and 1 month after the end of the intervention (T_2) between intervention and control groups (B). RF*, rectus femoris; *TA*, tibialis anterior.

Table 4. *The Results of Independent t Test on Muscle Mass (RF and TA muscles), Muscle Strength (RF and TA muscles), Walking Speed, QoL, and Fatigue in Different Assessment Times Between the Groups*

Variable	Time Assessment	Intervention Group, Real FES Mean ± SD	Control Group, Sham FES Mean ± SD	Mean Difference	*P* Value
RF muscle mass	T1	19.05 ± 4.19	15.87 ± 2.332	3.17	.006[a]
	T2	19.14 ± 3.93	15.99 ± 2.27	3.14	.005[a]
TA muscle mass	T1	23.23 ± 4.17	21.65 ± 3.01	1.57	.17
	T2	23.27 ± 4.07	21.46 ± 2.89	1.80	.12
RF muscle strength	T1	84.22 ± 10.44	71.34 ± 9.95	12.87	<.001[a]
	T2	84.38 ± 12.29	73.88 ± 9.48	10.49	.006[a]
TA muscle strength	T1	116.96 ± 28.41	99.24 ± 12.25	17.71	.017[a]
	T2	117.72 ± 26.36	99.96 ± 12.50	17.76	.014[a]
Walking speed	T1	6.93 ± 1.57	5.31 ± 1.30	1.62	.001[a]
	T2	7.01 ± 1.61	4.91 ± 1.33	2.09	<.001[a]

(*continued*)

Table 4. (*Continued*)

Variable	Time Assessment	Intervention Group, Real FES Mean ± SD	Control Group, Sham FES Mean ± SD	Mean Difference	*P* Value
General health	T1	75.87 ± 13.65	59.37 ± 15.23	16.50	.001[a]
	T2	80.62 ± 15.23	63.62 ± 15.15	17.00	.001[a]
Physical health	T1	63.48 ± 10.07	51.60 ± 14.17	11.88	.004[a]
	T2	69.54 ± 9.95	57.23 ± 12.86	12.31	.002[a]
Psychological health	T1	68.08 ± 11.81	55.04 ± 10.65	13.04	.001[a]
	T2	71.52 ± 12.60	61.82 ± 8.62	9.70	.01[a]
Environmental health	T1	66.90 ± 16.53	54.19 ± 9.55	12.71	.006[a]
	T2	68.14 ± 17.33	56.07 ± 7.53	12.06	.009[a]
Physical fatigue	T1	9.30 ± 4.64	15.40 ± 5.51	−6.10	.001[a]
	T2	7.10 ± 3.64	12.39 ± 5.79	−5.28	.002a
Mental fatigue	T1	5.40 ± 2.52	6.75 ± 2.77	−1.35	.115
	T2	5.00 ± 2.53	6.00 ± 2.77	−1.00	.241

FES, functional electrical stimulation; *QoL*, quality of life; *RF*, rectus femoris; *T0*, before intervention; *T1*, after the end of the intervention; *T2*, 1 month after the end of the intervention; *TA*, tibialis anterior.

[a] Significant differences.

Limitations and Recommendations

The present study was performed with a small sample size of 40 patients. Future studies are recommended to have a larger sample size. This study did not include specific examinations to provide possible insights into the neural and muscular mechanisms underlying the effects of FES in patients. The assessment of neural and muscular activity by electromyography, electroneurography, or muscle biopsy techniques is suggested in future studies.

Conclusion

This study showed that FES significantly improved all variables of RF and TA muscle mass, RF and TA muscle strength, walking speed, QoL, as well as physical and mental fatigue immediately and 1-month follow-up after the intervention. In addition, the TA muscle mass and mental fatigue were significantly improved immediately after sham FES intervention in the control group. However, significant effects of the intervention were observed on walking speed, general, physical, and psychological health, as well as physical and mental fatigue only at the 1-month follow-up. This knowledge helps the physicians and/or therapists to plan FES interventions for improvement of muscle mass, muscle strength, fatigue, and QoL in older patients with COVID-19.

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Contributorship Information

Concept development (provided idea for the research): F.E.
Design (planned the methods to generate the results): F.E.
Supervision (oversight, organization and implementation): F.E.
Data collection/processing (experiments, organization, or reporting data): M.R.
Analysis/interpretation (analysis, evaluation, presentation of results): F.E.
Literature search (performed the literature search): M.R.
Writing (responsible for writing a substantive part of the manuscript): M.R.
Critical review (revised manuscript for intellectual content): F.E., A.G.

Practical Applications

- This study showed that functional electrical stimulation significantly improved all variables of rectus femoris and tibialis anterior muscle mass, rectus femoris and tibialis anterior muscle strength, walking speed, and quality of life.
- Physical and mental fatigue was also improved immediately and at 1-month follow-up after the intervention.
- In addition, the tibialis anterior muscle mass and mental fatigue were significantly improved immediately after sham functional electrical stimulation intervention in the control group.

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