Eight Weeks of Pilates Training Improves Respiratory Measures in People With a History of COVID-19: A Preliminary Study

Behnam Bagherzadeh-Rahmani, MD,[†] Negin Kordi, MD,[‡] Amir Hossein Haghighi, PhD,[†] Cain C.T. Clark, PhD,[§] Luca Brazzi, PhD,[||¶] Emanuele Marzetti, PhD,[#] and Paulo Gentil, PhD[***]

Background: Coronavirus disease 2019 (COVID-19) can result in prolonged and severe damage to the lungs and quality of life (QoL). This study was designed to investigate the effects of 8-week Pilates and Aqua-Pilates training on pulmonary function and QoL in patients with COVID-19.

Hypothesis: Pilates and Aqua-Pilates training promotes similar changes on pulmonary function and QoL in people with a history of COVID-19.

Study Design: Randomized controlled trial.

Level of Evidence: Level 3.

Methods: A total of 45 participants (24 men and 21 women) with a history of COVID-19 were assigned randomly to 3 groups: Pilates training (standard Pilates), Aqua-Pilates training (Pilates in water), and Control. The training protocol was performed for 8 weeks (3 sessions per week). Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and the ratio of FEV1 to the FVC (FEV1/FVC) indices were measured by a spirometer. The 26-item questionnaire World Health Organization Quality of Life (WHOQOL) BREF was used to assess QoL. Data were analyzed using paired-sample *t* test and analysis of covariance with an alpha level <0.05

Results: The mean age of the participants was 49.9 ± 6.4 years. After 8 weeks of Pilates and Aqua-Pilates training, there were significant increases in FVC (21.4% for Pilates and 22.1% for Aqua-Pilates, $P < 0.05$), FEV1 (32.3% for Pilates and 34.7% for Aqua-Pilates, $P < 0.05$), and FEV1/FVC% (9% for Pilates and 10.3% for Aqua-Pilates, $P < 0.05$) for the experimental groups, but not for control. Changes for Pilates and Acqua-Pilates were significantly higher than for control. The QoL scores were significantly different within and between the experimental groups, with greater improvements in the Aqua Pilates group than in the Pilates group.

Conclusion: An 8-week Pilates or Aqua-Pilates training can improve pulmonary function as much as 34%, depending on the parameter, and QoL in people with a history of COVID-19. Aqua-Pilates training appears to be preferable to standard Pilates.

Clinical Relevance: The findings provide important insights into how healthcare professionals can prescribe exercise for COVID-19 survivors.

Keywords: COVID-19; pulmonary function; respiratory rehabilitation; pilates; aqua-pilates; quality of life; resistance training

From [†]Department of Exercise Physiology, Faculty of Sport Sciences, Hakim Sabzevari University, Sabzevar, Iran, [‡]Department of Exercise Physiology, Faculty of Sport Sciences, Razi University, Kermanshah, Iran, [§]Faculty of Health and Life Sciences, Coventry University, Coventry, UK, [||]Anestesia e Rianimaizone 1U, Department of Anesthesia, Intensive Care and Emergency, 'Città della Salute e della Scienza' Hospital, Turin, Italy, [¶]Department of Surgical Sciences, University of Turin, Turin, Italy, [#]Department of Geriatrics and Internal Medicine, Fondazione Policlinico Universitario "Agostino Gemelli" IRCCS, Università Cattolica del Sacro Cuore, Rome, Italy, and **College of Physical Education and Dance, Federal University of Goiás, Goiania, Brazil

*Address correspondence to Paulo Gentil, PhD, College of Physical Education and Dance, Federal University of Goiás, Avenida Esperança s/n, Campus Samambaia - CEP: 74.690-900, Goiânia, Goiás, Brazil (email: paulogentil@hotmail.com).

The authors report no potential conflicts of interest in the development and publication of this article.

DOI: 10.1177/19417381221124601

The infection caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), commonly referred to as coronavirus disease 2019 (COVID-19), has spread rapidly worldwide, resulting in its classification as a global epidemic.[10,21,35] It shows a wide spectrum of severity, from asymptomatic to fatal, depending mostly on host-related factors (eg, age, sex, comorbidities). Severe forms of COVID-19 are typically characterized by extensive alveolar damage and progressive respiratory failure,[4,19] possibly induced by endothelium vascular damage,[24] and characterized by signs such as hypoxemia and noncardiogenic pulmonary edema inducing pulmonary compliance reduction.[14] Respiratory problems caused by this disease can substantially impact daily living activities and quality of life (QoL),[34] as well as physical and mental function.[7] In COVID-19 survivors, respiratory rehabilitation may improve respiratory function, functional ability, and QoL.[15,23] In this context, Pilates may be especially appealing as it can improve core stability, flexibility, muscle strength, muscle control, and breathing.[2,21,26,29] During Pilates training, several muscle groups are engaged, including muscles involved in breathing (especially in the function of exhalation), and these contractions continue during the inhalation and the exhalation stage,[12] which can yield improvements in pulmonary function.[9]

Pilates training is effective in improving lung and respiratory function by emphasizing the muscles involved in breathing.[9] A water-based extension of Pilates, termed Aqua-Pilates, has also been shown to improve balance, muscle strength, and flexibility. Given the widespread diffusion of COVID-19 and the high prevalence of respiratory system damage and physical inactivity, viable treatment and management exercise regimens must be discerned. Pilates may be useful in this regard; however, no research has yet examined the effects of Pilates training in people with a history of COVID-19 or compared the effects of Aqua-Pilates and Pilates on respiratory function and QoL. Other possible advantages of Pilates are the lower risk of contamination due to individual use of equipment and distancing and the lower respiratory stress.[3,16] The present study investigated the effects of 8-weeks Pilates and Aqua-Pilates training on pulmonary function and QoL in people with a history of COVID-19.

METHODS

Participants

According to an a priori sample analysis using GPower 3.1.9.2 (University of Kiel, Germany), a sample of 42 participants would be necessary to detect an effect size of 0.5 considering a statistical power of 0.8. Based on this, 48 participants were recruited to account for attrition. Subsequently, 1 subject in the Pilates group and 1 subject in the Aqua-Pilates group were unable to complete the study, while 1 subject in the control group withdrew from the study. Therefore, the sample consisted of 45 participants (24 men and 21 women) with a history of COVID-19, with a mean age of 49.9 years. Candidates were invited to participate in the study by direct approach at Imam Khomeini hospital, Mazandaran province, Amol City, Iran, which was a government allocated facility for COVID-19 patients. Inclusion criteria were as follows: (1) having a history of COVID-19 disease; (2) having a minimum standard in pulmonary function measurements in the pretest (FEV1 ≥ 70%); (3) at least 1 month post discharge; (4) no smoking; and (5) no regular exercise. Exclusion criteria were as follows: (1) recurrence of the disease; (2) muscle injuries; (3) inability to perform exercise; and (4) lack of regular participation in the exercise program.

Participants did not have lung problems before being infected by SARS-CoV-2. All participants experienced at least 50% of pulmonary involvement and were hospitalized in the intensive care unit of the hospital for at least 3 days and received noninvasive respiratory assistance. After hospital discharge, patients reported to experience shortness of breath and fatigue during daily activities.

Study Design

This study was a quasi-experimental and applied study, with pretest and posttest measurements. Objectives and research methods, including the method of performing Pilates training, the duration of each exercise session, and the length of the research, were explained to the participants. Demographic characteristics and pulmonary function were recorded before group randomization. Participants were divided randomly into 3 groups (n = 15): Pilates training, Aqua-Pilates training (Pilates in water), and control. Participants in the control group did not engage in any prescribed exercise during the study. The training protocol was performed for 8 weeks (3 sessions per week). Aqua-Pilates movements were performed in a pool with a depth of 120 to 140 cm based on participant height. A Pilates instructor and a lifeguard with a valid certificate from the Lifeguard and Diving Federation were also present in the pool during the training sessions; 2 certified Pilates instructors and 2 assistants conducted and supervised all training sessions. Supervisors had been trained previously, and reviewed training programs and discussed the procedures before sessions to reliably administer interventions between sessions and groups. Due to the principles of overload during the research, the training was performed gradually in 3 levels: beginner, intermediate, and advanced. Pilates training in the experimental groups, in the 1st, 2nd, and 3rd weeks, started at the beginner level, then at the intermediate level in the 4th, 5th, and 6th weeks, and, finally, up to the advanced level in the 7th and 8th weeks. The Pilates movements were performed with repetitions ranging from 5 to 10, with deep Pilates breathing and according to the desired rate of perceived exertion (RPE) intensity (according to the Borg CR10 Scale) for the subjects in the training sessions. The rest time between each movement was 1 minute, while in each training session, 10 to 15 minutes were allocated for warm-up, 40 minutes for the main exercise, and 5 to 10 minutes for cool-down. The training protocol was designed purposely similar in both land and water environments. The Pilates movements used during the training sessions are listed in Table 1.

Table 1. Pilates training program in experimental groups[a]

Parts of the Training Program		
Warm-up[b]	**The Main Program[c]**	**Cool-down[d]**
(1) Pilate standing (2) Pilates breathing (3) Walking on one's toes (4) Scapular stabilization-elevation and depression (5) Scapular protraction and retraction (6) Spinal rotation (7) Spinal articulation from prone (8) Spinal articulation from supine	(1) The hundred (2) Leg circles (3) Foot swing (4) Rolling like a ball (5) Single-leg stretch (6) Tree pose (7) Spine stretch (8) Open-leg rocker (9) Spine twist (10) Corkscrew (11) Jump standing (12) Leg kick-back (13) One leg adduction and abduction (14) Neck pull (15) Side kick (16) Teaser (17) Swimming (18) Kicks	(1) Stretching the neck, triceps, deltoid (2) Chest expansion back stretch (3) One leg, double leg and upper leg stretching (4) Mermaid (5) Relaxation (6) Breathing

[a]The number of repetitions each movement: 5 to 10 repetitions. The rest time between each movement: 1 minute.
[b]Intensity and duration of training in the warm-up section: rate of perceived exertion (RPE) 7 to 9 in 10 to 15 minutes.
[c]Intensity and duration of training in the main program section: RPE 14 to 16 in 40 minutes.
[d]Intensity and duration of training in the cool-down section: RPE 7 to 9 in 5 to 10 minutes.

Assessments

At 24 h before the beginning of the training protocol, the most common important spirometric indicators were measured according to health protocols and prerequisites of the spirometry test, using a medical-grade spirometer (MIR; New Spirolab model). Respiratory maneuvers were performed as standard, and the required sitting position was explained to the subjects. Subsequently, a clip was used to occlude the nose and participants took 3 normal inhalations and exhalations to measure forced vital capacity (FVC), followed by a full inhalation and maximal exhalation. To measure forced expiratory volume in 1 second (FEV1), after 3 normal inhalations and exhalations, participants took a full inhalation, followed by a deep exhalation that lasted more than 6 seconds, and finally a deep inhalation. After performing each test 3 times, the best result of each participant was recorded, and the ratio of FEV1 to FVC (FEV1/FVC) was calculated (20). All measurements were performed at a temperature of 24 ± 2°C and a humidity of 49% to 51%. The 26-item questionnaire World Health Organization Quality of Life BREF was used to assess QoL, including 5 dimensions of general health, physical health, mental health, environmental health, and social function. A score was obtained for each dimension, which was converted to a standard score between 0 and 100 using a standardized formula, where a higher score indicated higher QoL. All measurements were repeated in the same position after 8 weeks of research and 48 hours after the last training session.

Health Protocol

All stages of the study were performed in compliance with all health protocols and the "social distancing plan" in the country. In the experimental groups, the training protocol was performed while observing a social distance of 150 cm. Participants were advised to wear a mask for commuting. Before entering the training sessions, participants were disinfected with the Sanocid-Plus solution, and their body temperature was measured with a digital thermometer (Rosmax model HA500). For spirometry testing, disposable Turbines with Cardboard Mouthpiece (MIR; FlowMir) were used for each participant. After each measurement, the tools and work environment were completely disinfected.

Study Termination

If we observed fever above 37.5°C, any reported feeling of weakness, discomfort, shortness of breath (dyspnea), and excess RPE, participants were not permitted to continue engaging in the study.

Table 2. Demographic characteristics of the groups[a]

Characteristics	Pilates Training	Aqua-Pilates Training	Control
Age, years	49.5 ± 7.1	50.4 ± 6.6	50 ± 5.9
Weight, kg	72.7 ± 12.6	75.8 ± 16.3	74.7 ± 12.8
Height, m	1.69 ± 0.08	1.72 ± 0.07	1.70 ± 0.09
BMI, kg/m^2	25.5 ± 2.4	25.6 ± 3.5	25.8 ± 3.1

[a]Data are shown as mean ± SD; 8 men and 7 women in each group. BMI, body mass index.

Ethical Considerations

The ethics committee of Hakim Sabzevari University approved the study protocol with the ethics code IR.HSU.REC.1399.016. The participants, with the condition of volitional unconditional withdrawal from the research, signed a written consent.

Statistical Analysis

SPSS 26.0 was used for all statistical analyses. Normality was assessed through the Kolmogorov-Smirnov test and Levene's test was used to assess equality of variance. Next, paired-samples *t* tests were used to compare the pretest and posttest results within groups, and analysis of covariance (ANCOVA), with Bonferroni-adjusted post hoc tests, was used to compare results between groups. To compare the posttest results, we used the pretest values as covariate variables. Pearson product moment correlation coefficient was used to calculate the association between variables. Statistical significance was accepted at $P < 0.05$.

RESULTS

Normality of the data was checked using Kolmogorov-Smirnov's test ($P > 0.05$), and the equality of error variance was assessed and confirmed using Levene's test of error variance ($P > 0.05$). One subject in the Pilates group and 1 subject in the Aqua-Pilates group were unable to complete the study, while 1 subject in the control group withdrew from the study. Hence, 45 subjects (49.9 ± 6.4 years) completed the 8-week programme. The demographic characteristics of the subjects are shown in Table 2.

The results of the paired-samples *t* test to compare the within-group differences showed that there were significant differences in pulmonary function indices and dimensions of QoL, but only in the experimental groups, and these results were significantly higher in the posttest than in the pretest (Table 3).

Changes in FVC were 1.9% ($P > 0.05$), 21.4% ($P < 0.05$) and 22.1% ($P < 0.05$) for control, Pilates, and Aqua-Pilates groups, respectively. FEV1 changed 3% ($P > 0.05$), 32.3% ($P < 0.05$), and 34.7% ($P < 0.05$); and FEV1/FVC% changed 1.1% ($P > 0.05$), 9% ($P < 0.05$), and 10.3% ($P < 0.05$) for control, Pilates, and Aqua-Pilates groups, respectively. The results of the ANCOVA to compare the differences between groups showed that there were significant differences in FVC, FEV1, and FEV1/FVC (%) indices in the experimental groups compared with the control group. Differences between Aqua-Pilates and Pilates groups were not statistically significant (Figure 1). The QoL scores showed significant differences between the experimental groups and the control group, and these differences were significantly higher in the Aqua-Pilates group than in the Pilates group (Table 3).

There were significant correlations between changes in FVC and changes in general QoL (0.32, $P = 0.03$), as well as in physical (0.51, $P < 0.01$), social (0.369, $P = 0.01$), environmental (0.577, $P < 0.01$), and mental domains (0.653, $P < 0.01$). Changes in FEV1 were significantly correlated with changes in general QoL (0.423, $P < 0.01$) and physical (0.554, $P < 0.01$), social (0.427, $P < 0.01$), environmental (0.646, $P < 0.01$), and mental domains (0.685, $P < 0.01$). Changes in FEV1FVC were significantly correlated with changes in general QoL (0.597, $P < 0.01$), physical (0.567, $P < 0.01$), social (0.509, $P < 0.01$), environmental (0.717, $P < 0.01$), and mental domains (0.64, $P < 0.01$).

DISCUSSION

Our findings indicate that 8-week Pilates training, in both aquatic and land environments, significantly improved pulmonary function and QoL, compared with a control group ($P < 0.05$). Moreover, Aqua-Pilates training yielded greater responses than the Pilates training ($P < 0.01$). Due to the lack of similar research on sports activity in people with a history of COVID-19, direct comparisons are difficult. However, specific to the application of Pilates, Giacomini et al[17] found that 8 weeks of Pilates training improved maximum expiratory volume, ventilation, and transverse abdominal muscle thickness in 16 physically inactive women. Liu et al[22] examined the effects of respiratory training on respiratory function, QoL, and psychological function, reporting positive effects following the intervention.

Indeed, Pilates is regarded as a type of resistance training in which resistance is applied in the form of body weight, and the

Table 3. Comparison of lung function and quality of life before and after the study (mean ± SD)[a]

Measures	Groups	Pre	Post	Between-Group Changes		Within-Group Changes	
				F	*P*	T	*P*
General health	Pilates training	35.83 ± 15.57	56.66 ± 11.44*	20.44	<0.01	–5.00	<0.01***
	Aqua training	34.16 ± 16.68	69.16 ± 13.25*,**			–6.91	<0.01***
	Control	36.66 ± 17.96	41.66 ± 15.43			–1.70	0.11
Physical health	Pilates training	31.90 ± 4.76	54.04 ± 16.07*	17.71	<0.01	–5.52	<0.01***
	Aqua training	31.19 ± 8.48	68.33 ± 12.28*,**			–9.35	<0.01***
	Control	34.52 ± 8.92	38.57 ± 14.79			–1.23	0.24
Mental health	Pilates training	41.11 ± 9.43	57.22 ± 13.03*	32.34	<0.01	–4.18	<0.01***
	Aqua training	37.22 ± 6.58	66.94 ± 9.51*,**			–8.68	<0.01***
	Control	40.27 ± 8.28	37.22 ± 8.40			1.97	0.07
Environmental health	Pilates training	40.62 ± 11.14	57.70 ± 5.64*	72.21	<0.01	–6.85	<0.01***
	Aqua training	35.20 ± 8.22	67.91 ± 7.03*,**			–10.37	<0.01***
	Control	40.20 ± 8.58	40.83 ± 6.83			–0.37	0.72
Social function	Pilates training	36.11 ± 15.32	50.55 ± 16.20	8.68	<0.01	–3.02	<0.01***
	Aqua training	32.77 ± 11.12	66.66 ± 14.77#*			–7.42	<0.01***
	Control	37.77 ± 9.89	43.88 ± 16.80			–1.24	0.23

[a]Between-group changes: * Compared with the control group, $P<0.05$; **Compared with the Pilates group, $P<0.05$. Within-group changes: ***Compared with the pretest within each group, $P<0.05$.

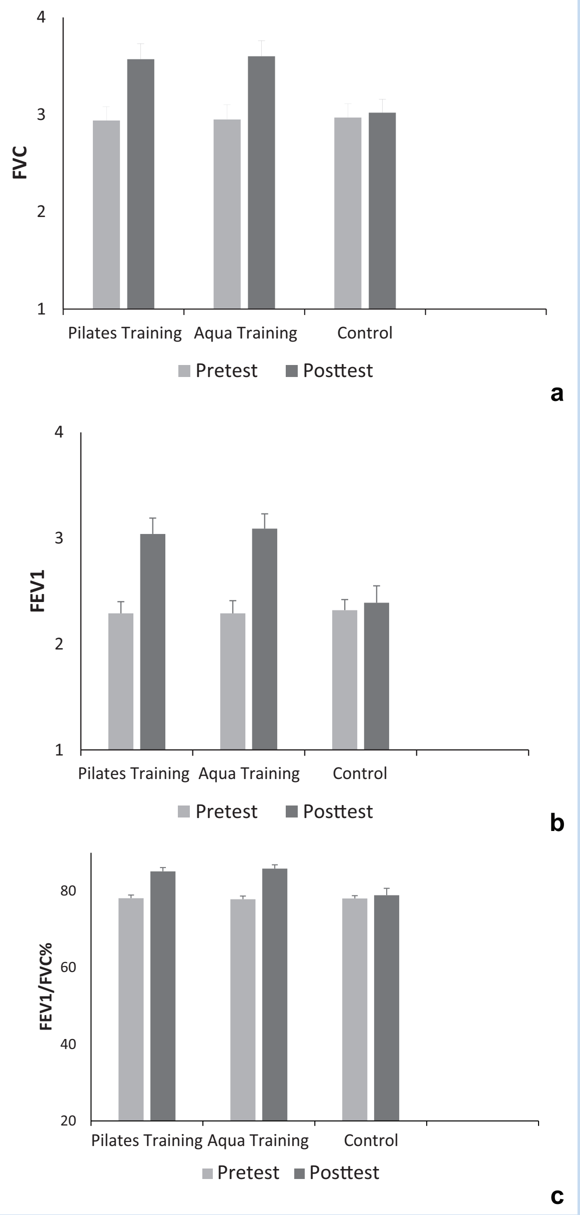

Figure 1. (a) FVC, (b) FEV1, and (c) FEV1/FVC% from pre- to post-intervention period. FEV1, forced expiratory volume in 1 second; FVC, forced vital capacity.

principle of overload is in the form of increasing the level of training and repetitions. According to the physiological principles of Pilates training, skeletal muscles can be strongly affected by training.[9]

Previous studies suggested that the lungs are the most affected organs by COVID-19 with different pathophysiological events.[8,25,31] Problems such as restrictive ventilation disorders, compromised diffusion capability, and residual impaired lung function are common and could decrease QoL among survivors of COVID-19.[37] Moreover, respiratory capacity and function may be reduced for months in COVID-19 survivors, making pulmonary rehabilitation highly recommended.[5,8] Respiratory muscles play an essential role in all aspects of daily living, in such a way that higher ability and respiratory capacity are associated with better QoL.[20] The correlation found between respiratory markers and QoL confirms these suggestions. A prominent issue in respiratory diseases is a decrease in respiratory vital capacity and inefficiency of the respiratory system.[20] The vital capacity, or the maximum amount of air exhaled after intense inhalation, is used as an indicator of lung function and provides useful information about the strength of respiratory muscles and lung function.[11] Lung lesions following active treatment protocols may affect the patient's respiratory function[30]; however, our study showed that pulmonary function improved significantly after 8 weeks of Pilates training. The focus on using the respiratory muscles, abdominal muscles, and intercostal muscles may contribute to its beneficial effects.[22] In general, it has been reported that exercise ameliorates respiratory problems by improving diaphragm muscle function, possibly by inducing favorable adaptation in cellular bioenergetics and stress response.[32] Pilates training can elicit improvements in ventilation, can prevent the accumulation of secretions and atelectasis, increases strength and coordination of respiratory muscles, and reduces bronchospasm and inflammation of the airways.[17] Adaptation to this training reduces the pressure on the respiratory muscles and increases the efficiency of these muscles, reduces resistance to inhaling and exhaling, and improves the signs and symptoms of respiratory diseases such as wheezing, sputum, shortness of breath, and cough.[18] The present study showed that the improvement in pulmonary function was greater in the Aqua-Pilates group than in the Pilates group. This result may be due to the water resistance with which the participants had to perform breathing movements. Indeed, Ozcan et al[27] showed that water training improves respiratory muscle strength and FVC to a greater extent than land training, due to viscosity and water resistance.

We also showed that 8 weeks of Aqua-Pilates or Pilates training improved QoL, and these improvements were greater in the Aqua-Pilates group than in the Pilates group. These results are concordant with some previous works. Yohannes et al[36] showed that 147 patients with coronary artery disease who performed 6 weeks of continuous physical activity, improved their QoL and reduced depression. Furthermore, Gandolfi et al[13], who examined the effects of Pilates training on QoL and bone regeneration in older women, highlighted that the Pilates group had greater improvements in all components of QoL (physical, vitality, and emotional) compared with the control group. Kovach et al[33] investigated the effects of 6 months of Pilates and fitness training in water in older participants and reported that training, both on land and in water, improved various dimensions of QoL. Indeed, the improvement in the psychological dimension of QoL in people with a history of COVID-19 in this study may be due to increases in self-confidence, self-efficacy, and independence. Moreover, Pilates training improves the physical dimension of QoL by increasing mobility, ameliorating the weaknesses caused by inactivity, and increasing strength.[28]

It is conceivable that the significant improvements in the QoL of people in the active groups were related to the positive effects of Pilates training on reducing depression and improving mental health, which, in turn, may be related to the role of serotonin. Imbalance in serotonin levels may affect social and psychological functions related to QoL. Indeed, it is well known that participation in physical activity can positively influence serotonin.[38] In a study by Hassan and Amin, 12 weeks of Pilates training in women with depression increased blood serotonin concentration, decreased depression, improved social relationships, and improved social function.[1] These findings are consistent with the present study.

Similarly, Eyigor et al[10] found that sports activity improved physical function and increased muscle strength and QoL in older women. It has been proposed that sports and physical activity improve the dimensions of QoL by improving cardiovascular endurance, strengthening muscles, balance, coordination, relaxation, stress, anxiety, mood, general health, mental health, and cognitive function.[6] The Bonferroni-adjusted post hoc test results showed that the QoL dimensions were statistically significantly different between the Pilates and Aqua-Pilates groups, with higher results for the latter.

Moreover, our results show that improvements in all respiratory parameters were significantly correlated with all general QoL and all domains, suggesting that the increased vital capacity is an important aspect for COVID-19 survivors.

However, despite the novelty of this work, there are major limitations that need to be considered. We did not control diet during the training protocol, physical level activity, normal daily activities or oxygen saturation, which can affect individual responses. Another important limitation is the absence of objective measurements of function, such as muscle strength and cardiorespiratory capacity.

CONCLUSION

Eight weeks of Pilates or Aqua-Pilates training can improve pulmonary function and QoL in people with a history of COVID-19. Moreover, Aqua-Pilates training appears to be preferable to standard Pilates. Thus, according to these results, Pilates training could be used or explored as a strategy to foster recovery in patients with postacute COVID-19.

ORCID ID

Paulo Gentil https://orcid.org/0000-0003-2459-4977

DATA ACCESSIBILITY STATEMENT

Data are available under reasonable request.

REFERENCES

1. Abdel-Hamid Hassan E, Ahmed Amin M. Pilates exercises influence on the serotonin hormone, some physical variables and the depression degree in battered women. *World J Sport Sci*. 2011;5(2):89-100.
2. Aladro-Gonzalvo AR, Machado-Díaz M, Moncada-Jiménez J, Hernández-Elizondo J, Araya-Vargas G. The effect of Pilates exercises on body composition: a systematic review. *J Bodyw Mov Ther*. 2012;16(1):109-114. doi:10.1016/J.JBMT.2011.06.001
3. Blocken B, van Druenen T, van Hooff T, Verstappen PA, Marchal T, Marr LC. Can indoor sports centers be allowed to re-open during the COVID-19 pandemic based on a certificate of equivalence? *Build Environ*. 2020;180:107022. doi:10.1016/J.BUILDENV.2020.107022
4. Chan JFW, Yuan S, Kok KH, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. *Lancet*. 2020;395(10223):514-523. doi:10.1016/S0140-6736(20)30154-9
5. Chen H, Shi H, Liu X, Sun T, Wu J, Liu Z. Effect of pulmonary rehabilitation for patients with post-COVID-19: a systematic review and meta-analysis. *Front Med (Lausanne)*. 2022;9:837420. doi:10.3389/FMED.2022.837420
6. Chodzko-Zajko W, Schwingel A, Chae Hee Park, Park CH. Successful aging: the role of physical activity. *Am J Lifestyle Med*. 2008;3(1):20-28. doi:10.1177/1559827608325456
7. Dalhoff K. Ambulant erworbene Pneumonie bei Erwachsenen. *C (Berl)*. 2017;14(11):46-54. doi:10.1007/S11298-017-5989-Y
8. Doerschug KC, Schmidt GA. Pulmonary aspects of COVID-19. *Annu Rev Med*. 2022;73:81-93. doi:10.1146/ANNUREV-MED-042220-014817
9. Endleman I, Critchley DJ. Transversus abdominis and obliquus internus activity during pilates exercises: measurement with ultrasound scanning. *Arch Phys Med Rehabil*. 2008;89(11):2205-2212. doi:10.1016/J.APMR.2008.04.025
10. Eyigor S, Karapolat H, Durmaz B. Effects of a group-based exercise program on the physical performance, muscle strength and quality of life in older women. *Arch Gerontol Geriatr*. 2007;45(3):259-271. doi:10.1016/J.ARCHGER.2006.12.001
11. Fisher LR, Cawley MID, Holgate ST. Relation between chest expansion, pulmonary function, and exercise tolerance in patients with ankylosing spondylitis. *Ann Rheum Dis*. 1990;49(11):921-925. doi:10.1136/ARD.49.11.921
12. Franco CB, Ribeiro AF, Morcillo AM, Zambon MP, Almeida MB, Rozov T. Effects of Pilates mat exercises on muscle strength and onpulmonary function in patients with cystic fibrosis. *J Bras Pneumol*. 2014;40(5):521. doi:10.1590/S1806-37132014000500008
13. Gandolfi NRS, Corrente JE, De Vitta A, Gollino L, Mazeto GMF da S. The influence of the Pilates method on quality of life and bone remodelling in older women: a controlled study. *Qual Life Res*. 2020;29(2):381-389. doi:10.1007/S11136-019-02293-8
14. Gattinoni L, Marini JJ, Pesenti A, Quintel M, Mancebo J, Brochard L. The "baby lung" became an adult. *Intensive Care Med*. 2016;42(5):663-673. doi:10.1007/S00134-015-4200-8
15. Gentil P, de Lira CAB, Coswig V, et al. Practical recommendations relevant to the use of resistance training for COVID-19 survivors. *Front Physiol*. 2021;12:637590. doi:10.3389/FPHYS.2021.637590
16. Gentil P, de Lira CAB, Souza D, et al. Resistance training safety during and after the SARS-CoV-2 outbreak: practical recommendations. *Biomed Res Int*. 2020;2020:3292916. doi:10.1155/2020/3292916
17. Giacomini MB, da Silva AMV, Weber LM, Monteiro MB. The Pilates method increases respiratory muscle strength and performance as well as abdominal muscle thickness. *J Bodyw Mov Ther*. 2016;20(2):258-264. doi:10.1016/J.JBMT.2015.11.003
18. Ten Hacken NHT. Physical inactivity and obesity: relation to asthma and chronic obstructive pulmonary disease? *Proc Am Thorac Soc*. 2009;6(8):663-667. doi:10.1513/PATS.200907-070DP
19. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020;395(10223):497-506. doi:10.1016/S0140-6736(20)30183-5
20. Kendall F, McCreary EK, Provance PG, Rodgers M, Romani W. *Muscles: Testing and Function, with Posture and Pain*. 5th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2010.
21. Küçükçakir N, Altan L, Korkmaz N. Effects of Pilates exercises on pain, functional status and quality of life in women with postmenopausal osteoporosis. *J Bodyw Mov Ther*. 2013;17(2):204-211. doi:10.1016/J.JBMT.2012.07.003

22. Liu K, Zhang W, Yang Y, Zhang J, Li Y, Chen Y. Respiratory rehabilitation in elderly patients with COVID-19: a randomized controlled study. *Complement Ther Clin Pract*. 2020;39:101166. doi:10.1016/J.CTCP.2020.101166
23. Maki N, Sakamoto H, Takata Y, et al. Effect of respiratory rehabilitation for frail older patients with musculoskeletal disorders: a randomized controlled trial. *J Rehabil Med*. 2018;50(10):908-913. doi:10.2340/16501977-2490
24. Marini JJ, Gattinoni L. Management of COVID-19 respiratory distress. *JAMA*. 2020;323(22):2329-2330. doi:10.1001/JAMA.2020.6825
25. Mo X, Jian W, Su Z, et al. Abnormal pulmonary function in COVID-19 patients at time of hospital discharge. *Eur Respir J*. 2020;55(6). doi:10.1183/13993003.01217-2020
26. de Oliveira Francisco C, de Almeida Fagundes A, Gorges B. Effects of Pilates method in elderly people: systematic review of randomized controlled trials. *J Bodyw Mov Ther*. 2015;19(3):500-508. doi:10.1016/J.JBMT.2015.03.003
27. Özcan RB, Irez GC, Ozcan S, Ceylan İ. Aqua-pilates exercises improves some physical fitness parameters of healthy young women. *Niğde Üniversitesi Beden Eğitimi Ve Spor Bilim Derg*. 2018;12(3):160-175.
28. Öztürk F. Investigation of the effects of eight weeks of Pilates and step-aerobic exercises on physical performance and self esteem scores of females. *Int J Sci Cult Sport*. 2017;5(23):76-86. doi:10.14486/INTJSCS650
29. Penelope L. Updating the principles of the Pilates method - Part 2. *J Bodyw Mov Ther*. 2002;2(6):94-101. doi:10.1054/JBMT.2002.0289
30. Rodriguez-Morales AJ, Cardona-Ospina JA, Gutiérrez-Ocampo E, et al. Clinical, laboratory and imaging features of COVID-19: a systematic review and meta-analysis. *Travel Med Infect Dis*. 2020;34:101623. doi:10.1016/J.TMAID.2020.101623
31. Shi H, Han X, Jiang N, et al. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study. *Lancet Infect Dis*. 2020;20(4):425-434. doi:10.1016/S1473-3099(20)30086-4
32. Vancini RL, Camargo-Neto L, de Lira CAB, et al. Physical activity and sociodemographic profile of Brazilian people during COVID-19 outbreak: an online and cross-sectional survey. *Int J Environ Res Public Health*. 2020;17(21):7964. doi:10.3390/IJERPH17217964
33. Vécseyné Kovách M, Kopkáné Plachy J, Bognár J, Olvasztóné Balogh Z, Barthalos I. Effects of Pilates and aqua fitness training on older adults' physical functioning and quality of life. *Biomed Hum Kinet*. 2013;5(1):22-27. doi:10.2478/BHK-2013-0005
34. World Health Organization. WHOQOL-BREF: introduction, administration, scoring and generic version of the assessment: field trial version, December 1996. https://apps.who.int/iris/handle/10665/63529. Accessed July 31, 2021.
35. Wu F, Zhao S, Yu B, et al. A new coronavirus associated with human respiratory disease in China. *Nature*. 2020;579(7798):265-269. doi:10.1038/S41586-020-2008-3
36. Yohannes AM, Doherty P, Bundy C, Yalfani A. The long-term benefits of cardiac rehabilitation on depression, anxiety, physical activity and quality of life. *J Clin Nurs*. 2010;19(19-20):2806-2813. doi:10.1111/J.1365-2702.2010.03313.X
37. You J, Zhang L, Ni-jia-Ti M yi di li, et al. Anormal pulmonary function and residual CT abnormalities in rehabilitating COVID-19 patients after discharge. *J Infect*. 2020;81(2):e150-e152. doi:10.1016/J.JINF.2020.06.003
38. Young SN. How to increase serotonin in the human brain without drugs. *J Psychiatry Neurosci*. 2007;32(6):394-399.