Effect of water exercise on the respiratory function and functional capacity of patients with COPD: a randomized controlled trial

Efeito do exercício aquático na função respiratória e capacidade funcional de pacientes com DPOC: um ensaio clínico randomizado

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Abstract

Introduction: Chronic obstructive pulmonary disease (COPD) not only restricts airflow but also induces systemic manifestations in individuals with the disease. **Objective:** To evaluate the effect of a water-based aerobic exercise program on respiratory muscle strength, thoracic mobility, dyspnea, and functional capacity in patients with COPD. **Methods:** We conducted a blind randomized controlled trial with 22 patients with COPD, dividing them into a control group (CG) and a training group (TG). The TG participated in 24 sessions of a water aerobic exercise program, while the CG only participated in the evaluations. Maximal respiratory pressure (MRP), dyspnea, and functional capacity were measured. **Results:** When comparing the MRP values (cmH_2O) in the pre- and post-training conditions, the results revealed a significant improvement in the TG [maximal inspiratory pressure (MIP): 74.8 ± 15.3 vs. 83.9 ± 17.2; maximal expiratory pressure (MEP): 141.5 ± 30.7 vs. 157.6 ± 32.9], whereas no difference was observed for the CG (MIP: 55.5 ± 21.8 vs. 54.4 ± 18.4; MEP: 116.2 ± 40.3 vs. 109.3 ± 38.9). Regarding thoracic mobility in the pre- and post-training conditions, no significant difference was found for the CG, whilst for the TG there was a significant increase at the axillary level (cm) (5.9 ± 1.8 vs. 7.7 ± 1.1). With respect to functional capacity, there was a significant increase in walking distance during the six-minute walking test only in the TG when comparing pre- and post-training conditions (462.1 ± 62.9 vs. 538.5 ± 63.7). Lastly, the dyspnea results demonstrated that after the training period there was a major reduction in the scores of Medical Research Council (3.1 ± 0.8 vs. 1.9 ± 0.7) and Borg CR-10 scales (5.2 ± 0.8 vs. 3.7 ± 0.3) only for the TG. **Conclusion:** The water aerobic exercise training promoted beneficial changes in respiratory muscle strength, thoracic mobility, functional capacity and dyspnea among patients with COPD.

Keywords: COPD. Hydrotherapy. Muscle strength. Physical therapy. Respiratory function tests.

Resumo

Introdução: *A doença pulmonar obstrutiva crônica (DPOC) não apenas restringe o fluxo aéreo, mas também induz manifestações sistêmicas em indivíduos com a doença.* ***Objetivo:*** *Avaliar o efeito de um programa de exercícios aeróbicos aquáticos na força muscular respiratória (FMR), mobilidade torácica, dispneia e capacidade funcional em pacientes com DPOC.* ***Métodos:*** *Realizou-se um ensaio clínico randomizado cego com 22 pacientes com DPOC, divi-dindo-os em grupo controle (GC) e grupo treinamento (GT). O GT participou de 24 sessões de um programa de exercícios aeróbicos aquáticos, enquanto o GC participou somente das avaliações. Foram medidas a pressão respiratória máxima, (PRM) dispneia e capacidade funcional.* ***Resultados:*** *Ao comparar os valores da PRM (cmH_2O) nas condições pré e pós-treinamento, os resultados revelaram melhora significativa no GT [pressão inspiratória máxima (PImáx): 74,8 ± 15,3 vs. 83,9 ± 17,2; pressão expiratória máxima (PEmáx): 141,5 ± 30,7 vs. 157,6 ± 32,9], enquanto não observou-se diferença para o GC (PImáx: 55,5 ± 21,8; vs. 54,4 ± 18,4; PEmáx: 116,2 ± 40,3 vs. 109,3 ± 38,9). Em relação à mobilidade torácica nas condições pré e pós-treinamento, não foi encontrada diferença significativa para o GC, enquanto para o GT houve um aumento significante no nível axilar (cm) (5,9 ± 1,8 vs. 7,7 ± 1,1). Com relação à capacidade funcional, houve aumento significativo da distância percorrida durante o teste de caminhada de 6 minutos apenas no GT quando comparadas as condições pré e pós-treinamento (462,1 ± 62,9 vs. 538,5 ± 63,7). Por fim, os resultados da dispneia demonstraram que após o período de treinamento houve uma redução importante nas pontuações do* Medical Research Council *(3,1 ± 0,8 vs. 1,9 ± 0,7) e nas escalas Borg CR-10 (5,2 ± 0,8 vs. 3,7 ± 0,3) apenas para o GT.* ***Conclusão:*** *O treinamento físico aquático promoveu alterações benéficas na força muscular respiratória, mobilidade torácica, capacidade funcional e dispneia em pacientes com DPOC.*

Palavras-chave: *DPOC. Hidroterapia. Força muscular. Fisioterapia. Testes de função respiratória.*

Introduction

Chronic obstructive pulmonary disease (COPD) not only restricts airflow but also induces systemic manifestations in individuals with the disease, including malnutrition, physical deconditioning, systemic inflammation, and structural and functional changes in respiratory and locomotor muscles.[1,2]

Bronchial obstruction causes damage to respiratory mechanics, and together with decreased respiratory muscle strength, the pathophysiological changes resulting from COPD can also affect the thoracic mobility of these patients. The diaphragm, the main inspiratory muscle, is altered in the presence of the disease, leading to an increase in the number of type I fibers and a decrease in sarcomere length. Given that the inspiratory muscles have a reduced capacity to generate strength and resistance, these structural changes appear as adaptive effects in an attempt to partially recover the functional capacity of patients with COPD.[3] In addition to respiratory changes, the locomotor system of these individuals is also impaired due to systemic manifestations, contributing to both physical deconditioning and reduced functional capacity.[2]

Considering the manifestations caused by COPD, pulmonary rehabilitation aims to reduce symptoms, especially dyspnea, improve functional loss, and increase physical and social activities, preserving functional independence as much as possible and consequently promoting improved quality of life.[4] In this context, hydrotherapy appears to be a viable alternative to traditional methods of rehabilitation,[5,6] since exercises are generally easy to perform due to the physical properties of water.[7] It is well known that aerobic physical exercise is regarded as the keystone of rehabilitation and must be started regardless of the stage of the disease, since it promotes beneficial adaptations to the organism.[1]

Due to pathological changes in the lungs, patients with COPD have increased functional residual capacity and residual volume, which increase the work of breathing and dyspnea.[8] For this reason, hydrostatic pressure, one of the physical principles of water, becomes very important as it facilitates expiration and decreases the residual volume, thus reducing air trapping and the sensation of dyspnea during immersion in water, in addition to assisting in the practice of physical exercises.[8,9]

Based on the physiological effects of aerobic physical exercise and those provided by the aquatic environment, the hypothesis of this study was that water aerobic exercise can promote beneficial changes in respiratory variables, dyspnea, and functional capacity in patients with COPD. Therefore, this study aimed to evaluate the effects of a water-based aerobic exercise program on respiratory muscle strength, thoracic mobility, dyspnea, and functional capacity in patients with COPD.

Methods

This study was a blinded randomized controlled trial approved by the Research Ethics Committee of the Methodist University of Piracicaba (13/11). All the participants signed an informed consent form. Of the 60 male patients screened, 38 were excluded because they did not meet the inclusion criteria, did not agree to participate, or had problems hindering their regular participation in the exercise sessions. The remaining 22 patients who met the inclusion criteria were randomly distributed into training group (TG, n = 11) and control (CG, n = 11).

Randomization was performed by a blinded researcher using a numerical table generated by GraphPad StatMate 2.0. Nonetheless, during the study, there was a sample loss of three patients in each group who were included in the intention-to-treat analysis, as shown in the flowchart of study participation (Figure 1).

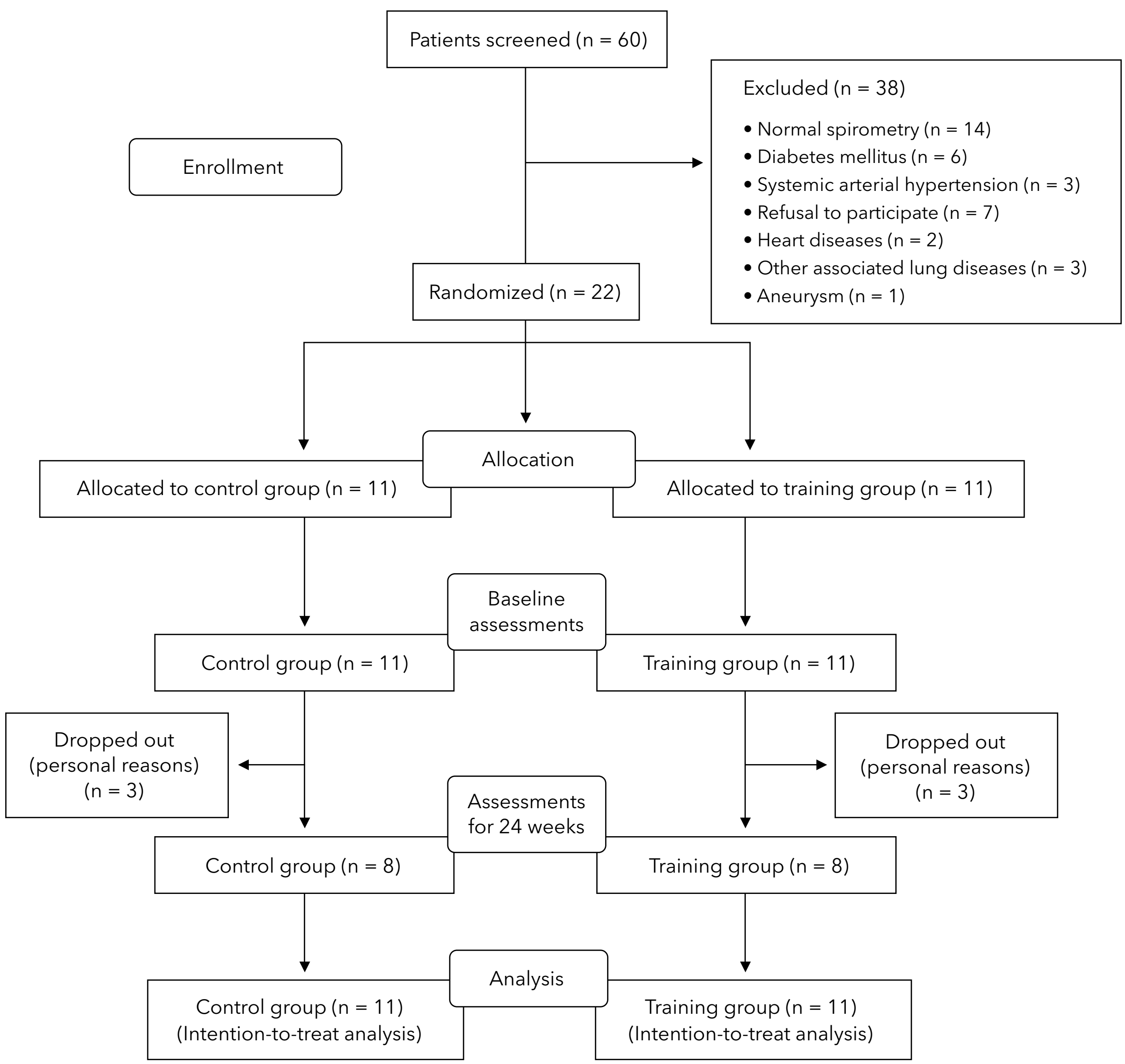

Figure 1 - Flow diagram of the study participants.

All participants took part in the assessments; however, only TG underwent a water aerobic exercise training (WAET) protocol. After the study period, the CG were invited to participate in the same WAET protocol for the same training period.

The characteristics of the study groups are presented in the Results section. The inclusion criteria were diagnosis of COPD; clinical stability; low level of physical activity, according to the International Physical Activity Questionnaire (IPAQ); absence of exacerbation in the last three months; and non-participation in physical training programs in the last six months. The exclusion criteria were diagnosis of diabetes mellitus, endocrine disorders, chronic renal failure, liver diseases, other lung diseases or associated inflammatory diseases, and heart disease; individuals that made use of drugs that could impair physical performance; patients with musculoskeletal and neuromuscular alterations that could make the execution of experimental protocols unfeasible; and patients with dermatological disorders, hypersensitivity to the products used for treating swimming pool water and hydrophobia. Initially, the patients underwent clinical and physical therapy evaluations, which were carried out in an acclimatized room so that the temperature and relative humidity varied between 22 and 25 °C and 40 to 60%, respectively.

Spirometry

Pulmonary function tests were performed according to the American Thoracic Society guidelines[10] using a spirometer (EasyoneTM; NDD Medizintechnik AG, Zurich, Switzerland). The system was calibrated before each test, according to the manufacturer's instructions. From the spirometric tests, it was possible to obtain absolute and percentage values for forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and FEV_1/FVC ratio. To characterize the population, we used equations to predict reference values based on the equations for healthy subjects developed by Pereira et al.[11]

Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP)

The maximal respiratory pressures were measured using an analog manovacuometer (GER-AR, São Paulo, Brazil) in an operating range of ± 300 cmH_2O, adapted for maximal inspiratory and expiratory pressures.

All measurements were taken by the same researcher and performed under homogeneous verbal commands, with the subjects seated and their nostrils occluded using a nasal clamp to prevent air leakage. MIP was measured during the effort initiated by the residual volume, while MEP was assessed from total lung capacity.

Each subject was asked to perform at least three technically satisfactory maximal inspiratory and expiratory efforts, that is, without perioral air leakage, and sustain them for at least one second and with values close to each other (≤ 10%). In this study, only the greatest value was considered.[12,13] The prediction equations for the reference values of MIP and MEP used herein were those proposed by Neder et al.[12]

Thoracic cirtometry

To assess thoracic mobility, chest circumference was measured at the axillary and xiphoid levels in the maximal expiratory and inspiratory phases using a measuring tape in centimeters, with the subject in the orthostatic posture and with a bare chest. For the aforementioned levels, the reference points were the anterior axillary line and the xiphoid process. The standard procedure for these measurements was to keep the zero-point of the tape fixed to the midline of the body and aligned horizontally with the reference points, whereas the other end of the tape was kept loose to allow displacement. The tape was positioned firmly against the skin without force, such that the soft tissue contours remained unchanged. The patients were asked to perform maximal inspiratory effort, followed by maximal expiratory effort. Two measurements were recorded at each level, one at the end of maximal inspiration and the other at the end of maximal expiration. The patients were asked to temporarily suspend breathing (apnea) after inspirations and expirations of at least two seconds to allow data collection. To guarantee reliability, measurements were performed three times at each level. The respiratory coefficients at the three levels were calculated as the difference between inspiration and expiration measurements. The mean of the measurements was used for the analysis.[14,15]

Six-minute walk test (6MWT)

Functional capacity was assessed using the 6MWT, in which patients were asked to wear appropriate clothing. Two tests were performed with a 30-minute interval between them by two physical therapists,[16] with the test of longer distance traveled used for data analysis. The 6MWT was conducted in the afternoon in a covered, airy, light, and silent corridor with a regular, non-slippery floor. Two cones were used to delimitating the 30-meter circuit, with markings at each meter.

The patients rested for 10 min before the test and received instructions on how to proceed during the test and were advised to interrupt it in the case of any respiratory distress, chest pain, severe muscle pain, or sickness. All of them were monitored during the test, and to avoid influencing their walking speed, the therapist stayed behind them. The patients were then instructed to walk as fast as possible for six minutes. During the walk, they received incentives from the examiner through verbal stimuli every minute, with phrases recommended by the American Thoracic Society.[17] The distance traveled in meters was recorded at the end of the test. Blood pressure, heart rate, respiratory frequency, peripheral oxygen saturation (SpO_2), and subjective perception exertion values for dyspnea and lower limbs according to the Borg scale were recorded at the beginning and end of the 6MWT. In the case of desaturation (SpO_2 < 90%), the researcher was allowed to interrupt the test, offer supplemental oxygen, or start another test.[18] To interpret and compare the results, they were expressed as absolute values.

Medical Research Council (MRC) scale

The MRC assesses the degree of functional disability caused by dyspnea. The patients were asked to choose the item that corresponds to how much dyspnea limits their daily life activity by attributing a value between 1 and 5 to describe their subjective degree of dyspnea, where 1 indicates shortness of breath only during intense exercise, 2 corresponds to shortness of breath when walking quickly or walking up a slight hill, 3 indicates when they walk slower than other people of the same age because of shortness of breath or have to stop for breath even when walking slowly, 4 corresponds to some stops for breath after walking less than 100 m or after a few minutes, and 5 indicates that they feel so much shortness of breath that they no longer leave the house or feel shortness of breath while getting dressed.[19]

Water aerobic exercise protocol

The training was carried out following the water aerobic exercise protocol for approximately 60 minutes, on alternate days, three times a week for eight weeks, totaling 24 sessions.[20,21] Before therapy, blood pressure, heart rate, respiratory frequency, SpO_2, Borg dyspnea, and lower limbs were measured and recorded. The sessions were performed individually, and every 10 minutes of therapy, heart rate, SpO_2 and perceived exertion for dyspnea and lower limbs were monitored using a Polar® heart rate monitor model FT1 (Polar Electro Co. Ltd. Kempele, Oulu, Finland), a pulse oximeter model ONYX 9500 (Nonin®), and the Borg CR-10 scale, respectively.

The physical training program was performed in a pool with water temperature of approximately 32 °C and depth from 1.20 to 1.30 meters (all exercises were performed with the chest submerged). This procedure consisted of the following steps: 1) warm-up, in which stretching exercises and dynamic aerobics were performed for 5-10 min; 2) water physical conditioning, which consisted of aerobic exercise training for the trunk, upper limbs, and lower limbs. During the training period, the load was adjusted progressively. Individualized training intensity progression was prescribed according to the symptoms reported by the patient. The intensity was prescribed and monitored based on the Borg scale using scores ranging between 4 and 6 with the purpose of maintaining the intensity of the exercise between moderate and high.[22-24] Aerobic training was performed in intervals.[25] The duration of the aerobic training started with eight sessions of 20 minutes, progressing to eight sessions of 30 minutes, and ending with eight sessions of 40 minutes;[20,21] 3) finally, cool-down involved stretching, breathing, and relaxation exercises with an approximate duration of 10 minutes.

The types of water exercise training followed a previously described protocol (Table 1).[26] During all sessions, the patients were instructed to perform pursed-lip breathing. During the physical training protocol, supplemental oxygen was used in three patients with SpO_2 levels below 90%.[18]

Statistical analysis

The sample size was calculated using GraphPad StatMate 2.0, with a significance level of 5% and a power test of 80% based on the standard deviations of maximal respiratory pressures from a pilot study conducted by the responsible researcher, who suggested nine subjects per group. All analyses were conducted using multiple imputations to determine missing values.

Table 1 - Description of the exercise protocol used

Exercise	Deascription
Warmup	Walking forward, sideways, and backward
Conditioning	Shoulder adduction and abduction; shoulder horizontal adduction and abduction; shoulder circumduction; pressure in water (shoulder flexion-extension); throw ball; brachial triceps; water – pool (flexion-extension of elbow and wrist); twist (trunk rotation); push-ups; jumping jacks (hip adduction and abduction); mule kick (hip extension and knee flexion); cancan kick (hip flexion and knee extension); sports balance (hip flexion-extension; stationary running; short-step running, long-step running; bicycle; squats; kicking (hip flexion-extension); hip circumduction; jumping and kicking; skiing (hip flexion-extension) ; jumping on the trampoline; saltitos (triple-flexion of the lower limbs) and getting on and off the step
Cool down	Stretching upper limbs, trunk, and lower limbs

Note: Protocol adapted from Kim et al;[26] exercise performed using pursed-lips breathing.

The Shapiro-Wilk test was used to verify the distribution of the data. Unpaired t-tests and chi-squared tests were used to compare the characteristics of both groups. A mixed-model ANOVA was applied to test intra- (pre- vs. post-WAET) and inter- (TG vs. CG) differences between groups using SPSS version 16.0. The possible influence of training was tested using an effect size to compare the training and control groups and by applying Cohen's d pooled variance. This analysis was carried out on the "effect size generator" application version 2.3 (Swinburne University of Technology, Center for Neuropsychology, Melbourne, Australia). The results were interpreted according to the values proposed by Cohen,[27,28] with values below 0.3 considered a small effect, between 0.4 and 0.7, a medium effect, and above 0.8, a large effect. The significance level was set at 5%.

Results

Table 2 lists the values referring to the characteristics of the groups studied. No significant differences were observed between the two groups.

The results for MRP, thoracic mobility, walking distance, and dyspnea based on the MRC scale and the Borg rating of perceived exertion scales at the end of the 6MWT are presented in Table 3.

Table 2 - Characteristics of the groups studied

Variable	CG (n = 11)	TG (n = 11)
Age (years)	66.3 ± 10.2	65.5 ± 6.3
Body mass (kg)	74.3 ± 18.7	66.3 ± 10.5
Height (m)	1.6 ± 0.04	1.6 ± 0.1
BMI (kg/m²)	26.6 ± 5.8	23.7 ± 2.8
Smoking time (years)	35.6 ± 13.0	41.1 ± 12.7
IPAQ	IA	IA
GOLD I/II/III/IV (n)	3/3/3/2	3/4/2/2
Spirometry		
FVC (L)	2.1 ± 0.7	2.5 ± 1.0
FVC (%)	56.8 ± 14.4	64.0 ± 17.2
FEV_1 (L)	1.3 ± 0.9	1.4 ± 0.9
FEV_1 (%)	46.0 ± 26.5	44.6 ± 23.2
FVC/FEV_1	0.6 ± 0.2	0.5 ± 0.2
FEV_1/FVC (%)	73.3 ± 27.5	66.1 ± 21.6
MVV	49.1 ± 29.5	45.8 ± 27.2
MVV (%)	46.0 ± 26.2	44.2 ± 27.1
CF classification (n)		
Very low	6	5
Low	2	2
Regular	2	2
Good	1	2
Excellent	0	0
Superior	0	0

Note: CG = control group; TG = training group; BMI = body mass index; IPAQ = International Physical Activity Questionnaire; IA = insufficiently active; GOLD = Global Initiative for Chronic Obstructive Lung Disease; FVC = forced vital capacity; FEV_1 = forced expiratory volume in one second; MVV = maximum voluntary ventilation; CF = cardiorespiratory fitness. Values are expressed as mean and standard deviation.

After the experimental protocol period, there was a significant increase in both MIP and MEP in the TG compared to pre-training values, whereas the CG showed no difference between the two conditions. A comparison between the groups in the post-training condition revealed that the TG had higher MIP and MEP values than the CG. Regarding thoracic mobility, it was observed that after the training protocol, the TG showed superior values to those obtained in the pre-training condition at the axillary level, but with no difference at the xiphoid level. However, no differences between the levels were observed in the CG. By comparing the groups, the TG obtained higher values of thoracic mobility at the axillary level after the training period than the CG. With respect to the 6MWT, there was no major difference in walking distance between the pre- and post-training conditions for the CG, whereas a significant increase was observed in the TG. The TG showed increased walking distance after the training protocol compared to the CG.

Regarding dyspnea according to the MRC scale, no considerable difference was observed in the CG when comparing both conditions, whereas the TG experienced a significant decrease. A comparison between the groups indicated that the TG had lower post-training values than the CG. Regarding the Borg CR-10 scale, there was no significant difference between the pre- and post-training periods in the CG, whereas a remarkable decrease was observed in the TG after the training period. By comparing both groups, the TG presented lower values in the post-training condition than the CG.

The effect size results are presented in Table 4. The effect size for the CG was small for all variables, whereas for the TG, it was medium for MIP, MEP, and axillary symmetry, and large for walking distance in the 6MWT and dyspnea using both MRC and Borg CR-10 scales.

Table 3 - Values of maximal respiratory pressures, cirtometry, walking distance during the six-minute walk test and dyspnea in the pre- and post-training conditions for the control (CG) and training (TG) groups

Variable	Control group (n = 11)		Training group (n = 11)	
	Pre-training	Post-training	Pre-training	Post-training
Maximal inspiratory pressure (cmH_2O)	55.5 ± 21.8 (43.6 - 67.3)	54.4 ± 18.4 (43.2 - 65.7)	74.8 ± 15.3 (62.9 - 86.6)	83.9 ± 17.2*# (72.6 - 95.1)
Maximal expiratory pressure (cmH_2O)	116.2 ± 40.3 (93.6 - 138.7)	109.3 ± 38.9 (86.6 - 132.0)	141.5 ± 30.7 (118.9 - 164.1)	157.6 ± 32.9*# (134.9 - 180.3)
Axillary cirtometry (cm)	4.9 ± 1.0 (4.0 - 5.9)	5.6 ± 1.1 (4.6 - 6.5)	5.9 ± 1.8 (4.0 - 7.7)	7.7± 1.1*# (6.6 - 8.9)
Xiphoid cirtometry (cm)	4.0 ± 1.6 (2.6 - 5.4)	3.7 ± 1.1 (2.7 - 4.8)	4.8 ± 1.5 (3.3 - 6.5)	4.9 ± 1.6 (3.3 - 6.6)
Walking distance (m)	430.3 ± 86.0 (382.9 - 477.7)	422.3 ± 89.4 (373.5 - 471.2)	462.1 ± 62.9 (414.7 - 509.5)	538.5 ± 63.7*# (489.6 - 587.3)
Medical Research Council dyspnea	3.5 ± 0.7 (3.0 - 4.0)	3.2 ± 0.5 (2.8 - 3.6)	3.1 ± 0.8 (2.6 - 3.6)	1.9 ± 0.7*# (1.4 - 2.3)
Borg dyspnea	6.8 ± 1.3 (6.0 - 7.5)	6.3 ± 0.7 (5.9 - 6.7)	5.2 ± 0.8 (4.5 - 5.9)	3.7 ± 0.3*# (3.3 - 4.1)

Note: Values are expressed as mean, standard deviation and confidence interval. *p< 0,05: pre- vs. post-training for TG; #p < 0,05: CG vs. TG.

Table 4 - Effect size for the variables studied in the pre- and post-training conditions for the control (CG) and training (TG) groups

Variable	Pre- and post-training for CG		Pre- and post-training for TG	
	Effect size	Classification	Effect size	Classification
Maximal inspiratory pressure (cmH_2O)	0.04	Small	0.55	Medium
Maximal expiratory pressure (cmH_2O)	0.15	Small	0.50	Medium
Axillary cirtometry (cm)	0.00	Small	0.70	Medium
Xiphoid cirtometry (cm)	0.00	Small	0.00	Small
Walking distance during the 6-min walk test (m)	0.09	Small	1.20	Large
Medical Research Council dyspnea	0.00	Small	1.41	Large
Borg dyspnea	0.00	Small	0.80	Large

Discussion

The present study showed that the proposed water aerobic training program produced significant changes in respiratory muscle strength, thoracic mobility, dyspnea, and functional capacity of patients with COPD.

The findings presented herein are relevant because dyspnea is a common complaint of patients with COPD and is associated with severe limitation of functional capacity and practice of physical activities, with the reduction in walking distance during the 6MWT being related to mortality and reduced quality of life in this population.[29,30]

The values of MRP increased in the TG and had a medium effect size, while in the CG they remained unchanged, suggesting that the ventilatory muscles were sufficiently overloaded during training and were subject to functional and structural adaptations.[31] As already reported,[32,33] during the practice of physical exercises, expiratory muscles are recruited in patients with COPD. According to O'Donnell et al.,[31] the strength of the expiratory muscles increases in parallel with that of the inspiratory muscles. Although expiratory muscles use a smaller fraction of their maximum capacity to produce strength than inspiratory muscles, the results suggest that repetitive expiratory muscle activity during exercise can increase muscle strength after training. Ramirez-Sarmiento et al.[34] proposed specific training for the inspiratory muscles and found an increase in the number of type I fibers and the size of type II fibers in the external intercostal muscles.

The improved respiratory muscle strength observed after water aerobic training may also be related to the physiological effects induced by body immersion in water. Hydrostatic pressure promotes compression of the rib cage and abdomen, consequently causing cranial displacement of the diaphragm, increased intrathoracic pressure, and altered respiratory rhythm, with a subsequent 65% increase in breathing work.[35]

Regarding cirtometry, it has been used to measure thoracic mobility and detect possible adaptations after rehabilitation programs.[36] In the present investigation, after the training period the results revealed an increase in the thoracic mobility in the axillary region, with a medium effect size for the TG.

Paulin et al.[14] and Rodrigues et al.[37] conducted a study involving activity programs aimed at enhancing thoracoabdominal mobility in patients with COPD. While Paulin et al.[14] found increased mobility in the thoracic region, Rodrigues et al.[37] reported an increase in lower thoracic and abdominal mobility after the proposed program, evidencing a positive response to training. However, none of these programs involved water exercise. Owing to the scarcity of studies assessing the thoracic mobility of patients with COPD undergoing water physical training, we hypothesized that the improvement observed in the TG could be justified by the beneficial effects of physical exercise, as well as the physiological effects of body immersion in water. Since the hydrostatic pressure causes chest compression, there is a decrease in the expiratory reserve volume and the forced vital capacity, resulting in reduced diameters of the rib cage.[35] Such effect, repeated in the training sessions, may have favored the increase in thoracic mobility of the patients under study. Due to these changes, patients tend to use the anaerobic mechanism early, generating lactate accumulation, lower resistance to fatigue in the lower limbs, and lower tolerance to effort.[38,39]

In addition to the significant increase in MRP and axillary thoracic mobility, the water aerobic exercise training proposed herein significantly improved the functional capacity of the TG, measured through the walking distance during the 6MWT, with a large effect size. According to Puhan et al.,[40] the minimal clinically important difference is greater than 26 meters and/or 10%. In the TG, it was possible to verify that there was an increase of 76 meters between the pre- and post-training conditions, while in the CG no significant difference was observed. Some possible explanations for the enhanced functional capacity of the patients under study may be related to the action of hydrostatic pressure, which stimulates the production of mitochondrial oxidative enzymes, as well as the increased capillarization of the trained muscles.[41]

Considering that dyspnea is a frequent complaint of patients with COPD and that it can severely limit the practice of physical activities and worsen their functional capacity, the present study verified whether the proposed training program would influence this symptom. For this purpose, the MRC and Borg CR-10 scales were used. The results showed a significant decrease in the sensation of dyspnea after protocol application, with a large effect size. These findings are possibly justified by the improved coordination of the muscles participating in the proposed exercises in addition to metabolic adaptations.[42]

Hydrostatic pressure is also associated with a decreased sensation of dyspnea, as it adjusts the diaphragmatic position to a higher and mechanically efficient level, working as a load for the constriction of this muscle during inspiration (thus resulting in diaphragmatic exercise), and contributing to a reduction in dead space. Furthermore, expiration with the chest immersed in water can increase the respiratory tract pressure and prevent small airways from collapsing. As a consequence of the decrease in both residual volume and air trapping during immersion in water, the sensation of dyspnea is reduced, which facilitates physical exercises.[8,9,43,44]

In addition to hydrostatic pressure, other physical properties of water, such as viscosity, may have influenced the results obtained in this study because they refer to the magnitude of the specific internal friction during movement. Because of this viscosity, exercises in water are subject to drag and turbulence resistive effects, thus increasing the resistance to performing movements.[7,45] In addition to hydrostatic pressure and viscosity, it is also possible to add buoyancy, which promotes a reduction in hydrostatic weight, with a consequent reduction in the impact on the joints,[7,46] which possibly allows for a more effective performance of the exercises proposed in the experimental protocol.

A study evaluating the feasibility and acceptance of water as an exercise medium for patients with COPD showed that all individuals who attended the sessions rated the program as good or very good. Another important finding was the improvement in dyspnea scores during the walk test and the level of socialization of these patients.[47] Araujo et al.[48] proposed a low-intensity water aerobic training program and found positive results for respiratory variables and functional capacity in patients with COPD, which corroborates the results of the present investigation.

This study is also in agreement with the results reported by Wu et al.,[49] who investigated the beneficial effects of water-based Liuzijue exercise on respiratory musculature and peripheral skeletal muscle function in patients with COPD, and the study conducted by Felcar et al.,[45] who evaluated the effects of high-intensity water training and observed a significant improvement in peripheral, inspiratory, and expiratory muscle strength, in addition to an increase in submaximal exercise capacity.

Conclusion

The present study demonstrated that 24 sessions of water aerobic exercise training in patients with COPD promoted an increase in maximal respiratory pressure, thoracic mobility, and walking distance during the 6MWT, as well as a reduction in dyspnea indices according to the MRC and Borg scales, suggesting that this type of training may be successfully used for the rehabilitation of this population. However, once only male patients were included and only a minority were classified as GOLD stage IV, these results cannot be generalized to women or patients with severe COPD.

Authors´ contributions

All authors were responsible for the study design, data collection and article writing. DGF was responsible for the patient screening, and MAM, for the statistical analyses. All authors approved the final version.

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