ORIGINAL RESEARCH

EFFECTS OF AN AQUATIC VERSUS NON-AQUATIC RESPIRATORY EXERCISE PROGRAM ON THE RESPIRATORY MUSCLE STRENGTH IN HEALTHY AGED PERSONS

Maiza Ritomy Ide, Marize Angélica Vicentini Belini, and Fátima Aparecida Caromano

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Aging of the worldwide population is a concern of most governmental entities, spanning practically all areas of prevention and rehabilitation. Aging leads to physiological alterations that result in adverse social and financial effects. There is a trend to emphasize prevention, which is less expensive and socially more desirable than therapeutic intervention.

PURPOSE: To assess the effect of a program of aquatic versus non-aquatic respiratory exercises on respiratory muscle strength in healthy aged persons.

METHODS: The respiratory muscle strength was measured in 81 subjects between 60 and 65 years, 59 of which completed the program. Subjects were randomized into 3 groups. $G_{aquatic}$ undertook a program of respiratory exercise in an aquatic environment. $G_{non\text{-}aquatic}$ undertook the same program in a non-aquatic environment. $G_{control}$ acted as the negative control. Programs were applied three times a week for 10 consecutive weeks. Subsequently, subjects were reevaluated, and results compared to each individual's pre-treatment own result and between the groups. The data were statistically analyzed using the paired *t* test and the Sign test. Comparisons between the groups were performed through parametric and nonparametric variance. A comparison of $G_{aquatic}$ and $G_{non\text{-}aquatic}$ versus $G_{control}$ was performed using the Dunnett test.

RESULTS: A significant improvement in the inspiratory muscle strength in the $G_{aquatic}$ group compared to the $G_{control}$, group was found, suggesting beneficial effects mediated by the aquatic exercise. The expiratory muscles did not show significant alterations.

CONCLUSION: Aquatic respiratory exercise improves the inspiratory muscle strength of healthy aged persons. However, neither aquatic nor non-aquatic respiratory exercise influences the expiratory muscle strength.

KEYWORDS: **Respiratory muscle strength. Respiratory exercise. Respiratory strength. Aged. Prevention.**

Population aging has been ooccurring for many years in developed countries. From the 1980s, this phenomenon has become practically worldwide, including Brazil.[1]

The aging process causes many physiological alterations that are almost always discrete and gradual.[2] The respiratory system undergoes many physiological modifications during aging. A reduction in the pulmonary elasticity and fusion between sternum and rib cartilages occurs. There is an increase in the thoracic kyphosis of the spine, which leads to biomechanical damage of the respiratory muscles.[3] All these changes culminate in the reduction of respiratory muscle strength and of practically every spirometric parameter.

Pulmonary volumes and dynamics can be altered by many lung illnesses. In the absence of such alterations, inspiratory and expiratory maximal pressures (IP_{max} and EP_{max}) specifically indicate the respiratory muscle strength.[4]

Any weakness of the expiratory muscles harms the effectiveness of the cough,[5,6] interfering with clearance and predisposing to the retention of secretions and development of pulmonary infections.[7] Atelectasis and pneumonia are

From the *Universidade Estadual do Oeste do Paraná* – Cascavel/PR and the Faculty of Medicine, University of São Paulo – São Paulo/SP, Brazil.
E-mail: maizaide@hotmail.com
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caused mainly by the reduction in the ability to eliminate secretions, being also one of the most common causes of postoperative complications.[6] Fatigue in the diaphragm as well as in the parasternal and external intercostals is a clinical problem because it results in respiratory failure. It can lead to dyspnea, exercise capacity limitation, a need for mechanical ventilatory support, and difficulties in speach emission.[5,7-10]

Respiratory exercise is a physical therapeutic resource. It uses trunk and upper limb movements associated with respiratory incursions. Although much used, respiratory exercise is not supported by studies that adequately justify its use. More research is needed to prove its real effect.

The lack of studies is particularly evident regarding preventive aquatic respiratory exercise programs for the elderly. A comparison between exercise performed in aquatic and non-aquatic environments would provide evidence regarding the relative efficacy of each environment. The aquatic environment presents many advantages when compared to the non-aquatic environment, including thermal effects, in which water continuously removes heat from the body, and mechanical effects, particularly those due to hydrostatic pressure and buoyancy that induce the respiratory system to work under constant resistance. Despite the increase in number of studies and therapeutic successes related to aquatic exercise, studies involving the healthy aged population are rare.

Although most exercise efforts are generally directed towards prevention, studies related to respiratory exercises almost always concern people with chronic respiratory illness, undergoing intensive therapy, or confined to home. Few have been the studies about the healthy aged population. A majority of the studies use inspiratory incentive devices or other devices that cause resistance to air flow to improve strength and/or endurance of the respiratory muscles—particularly the inspiratory ones.

Thus, a preventive approach, possibly of low cost, that improves respiratory muscle strength could be of great value. An efficient respiratory system can prevent or optimize recovery from the common respiratory ailments in the elderly population.

The effects of a program of aquatic vs. non-aquatic exercises on respiratory muscle strength in healthy age persons were measured and a comparison of $G_{aquatic}$ and $G_{non-aquatic}$ vs. $G_{control}$ was performed.

METHODS

Sample and randomization

Eighty-one subjects between 60 and 65 years were initially selected, and 59 completed the study (average age: 62.2 years). Calculation of the required sample size was contemplated a 90% statistic power to detect a 40% difference in the intervention group. An a of 5% and confidence interval of 95% was established. For the calculation, the equation of Pocock[11] was used.

Subjects were sequentially entered into the study. Initial screening of volunteer candidates regarded the inclusion and exclusion criteria. To be included, subjects would have to be socially active but should not be practicing any kind of physical activity more than once per week. They must not have been non-smokers over the last 10 years, and must not present respiratory, muscular, cardiac, or neurologic problems, nor have any other chronic illness that could prevent them from performing the activities. Subjects who had significant water phobia or skin disease were excluded. Time availability, access to transport, acceptance of the routine of training (foreseeing a maximum of 20% abseteeism), intention to complete the training, and the signing of the informed consent form were also considered.

Subjects were randomized into 3 groups, by drawing numbers from an envelope. The first group ($G_{aquatic}$, n = 19) underwent a program of aquatic respiratory exercises. The second one ($G_{non-aquatic}$, n = 19) participated in the same program, but out of the water. The third gourp ($G_{control}$, n = 21) did not undergo an exercise program, acting as the control.

During the execution of the program, 22 subjects dropped out of the study (6 for too many no-shows, 6 for undisclosed reasons, 8 because of lack of time and/or transportation, 1 due to death immediately prior to initiating the program, and 1 who integrated another program of physical activity while participating of this study). The resulting group sizes at the concluding evaluation were 19, 19, and 21, for $G_{aquatic,}$ $G_{non-aquatic,}$ $G_{control,}$ respectively.

Procedures

The strength of the expiratory and inspiratory muscles was determined by the evaluation of the IP_{max} and EP_{max}. These were measured using a manovacuometer (Gerar Co), with a scale varying from 0 to +150 mm H_2O (for measurements of EP_{max}) and 0 to -150 mm H_2O (for measurements of IP_{max}). Subjects were positioned seated, erect, without leaning against the chair, with their feet on the floor. A nasal clip was placed and measurements of IP_{max} and EP_{max}, were taken after a normal expiration and inspiration, respectively.[12]

The participant was instructed to secure the buccal connector of the device, by pressing it against the lips. The maneuvers were repeated 3 times, with an interval of 2 minutes between each one. The best 1 of the 3 measurements was used for the study. The subjects were verbally stimulated to encourage them to produce the best possible effort for 3 seconds of the execution of these maneuvers was preceded by a detailed explanation of the technique, followed by demonstrations, and by trial attempts offered to each subject.

The weight and height of the subjects were measured for the calculation of the body mass index. Such measurements were taken to control possibly significant extremes of body weight. Such extremes could affect respiratory function and hinder accurate determination of the effects of the exercise on the subjects.[10] After the completion of the exercise program, subjects would be excluded from the study if their body mass index had altered by more than 5%,. There were no exclusions for this reason.

At the end of the program, the subjects were reevaluated in exactly the same way. Individual results were compared for each subject before and after the program. Average group results were compared between the groups. The final evaluation was applied with a minimum of 24-hour and maximal interval of 5 days after ending the exercise program. At the end of the study, subjects were informed of their results.

The respiratory exercise programs were developed with identical objectives, but were adjusted to the aquatic or non-aquatic environments. They were applied for 10 consecutive weeks, 3 times per week, with sessions of 1 hour each. The activities are described in Table 1. Each exercise was performed for approximately 6 to 7 minutes.

Table 1 - Program of respiratory exercise applied to water and land groups.

Initial warm-up - walk in circles with sporadic changes of direction.
Active/resisted exercise of horizontal adduction-abduction of shoulder joint.
Active/resisted exercise of flexion-extension of the shoulder joint.
Active/resisted exercise of anterior flexion associated with trunk rotation.
Active/resisted exercise of trunk lateral flexion.
Active/resisted exercise of trunk lateral rotation.
Active exercise in closed kinetic chain for upper limbs.
Active exercise of raising the upper limbs above the head.
Final relaxation—deep inspiration and expiration, without the accompaniment of other movements.

Exercises were performed with gradual increases in intensity in accordance with the ability of each subject. They followed a logical sequence of warm-up, conditioning, strengthening, and cool-down routines. Deep inspirations and expirations were requested during all the exercises. The inspirations were requested for the times when the movement involved an increase of the rib cage size, as, for example, during abduction or flexion of the shoulder joint. Verbal incentives were provided during the performance of all the activities. The exercises were performed as a group activity but with individual attention to each participant. Both groups used resources for best exercise motivation, such as bars, bells, balls, arcs, and batons.

Participants in the $G_{aquatic}$ group were guided to always keep their shoulders covered by water. To prevent problems, subjects were observed and encouraged to report any adverse symptoms as soon as they were felt. Participants in the $G_{control}$ went to the place of the program once per week. Subjects performed activities different from exercises, such as attending lectures on general subjects and participating in enjoyable activities. This was intended to produce equivalent attitudes in the two active groups and in $G_{control}$, since the active groups might have benefited from the change of scenery and by the social conviviality experienced during the exercise program. Such factors could have influenced and/or caused the effects produced by the exercises to be overestimated.

All the procedures were performed with the help of trained researchers of the physical therapy clinics and of the laboratories of the involved universities. For the aquatic program, a warm swimming pool at 32 ± 2ºC was used, with the dimensions of 11.8 x 7.75 m and 1.05 m of depth. The $G_{control}$ used a room with dimensions of 7 x 11.5 m.

Statistical Analysis

The variables IP_{max} and EP_{max} were analyzed before and after treatment, the difference before and after treatment being calculated. The difference was analyzed through the Student *t* test for paired samples to determine whether the average difference was significantly different from 0. To confirm the results found by the parametric test, a nonparametric Sign test was also applied. When there was average difference between at least one of the groups, the Dunnett test was used to compare the $G_{aquatic}$ and $G_{non\text{-}aquatic}$ versus $G_{control}$. A level of significance of 5% was adopted.

Regarding the validity of the tests applied in all the comparisons, assumption of normality of the differences was not violated in any instance. The tests used to verify normality were those of Shapiro-Wilk, Kolmogorov-Smirnov, Cramer-von Mises and Anderson-Darling. Calculations were carried out using SAS software, version 8.2. As an alternative to the paired *t* test, the Sign test and test of the designated orders (Wilcoxon Signed Ranks test) were applied. Results of both nonparametric tests were in accordance with the conclusions produced by the paired *t* test.

RESULTS

Data relating to the IP_{max} and EP_{max} of the subjects are shown in Figures 1 and 2.

Using the paired *t* test, the IP_{max} and EP_{max} of each individual before and after intervention in each group were compared. Data are presented in Table 2. There was no significant difference in the IP_{max} before vs. after treatment within either of the two treatment groups. However, for unknown reasons, the IP_{max} of the $G_{control}$ experienced a statistically significant reduction ($P < .01$).

For the IP_{max}, the averages of the differences (before vs. after) were not equal between the groups ($P < .03$). The average differences between the $G_{aquatic}$ and $G_{control}$ were different ($P < .02$) (Dunnett test).

The same test did not detect significant difference between the averages of $G_{non-aquatic}$ and $G_{control}$ ($P > .27$).

Also using variance analysis, it was not possible to reject the null hypothesis for the average differences between the groups for EP_{max} ($P > .99$).

The nonparametric variance analysis (Kruskal-Wallis test) did not contradict the conclusions obtained by the analysis of parametric variance, for both IP_{max} and EP_{max}.

Table 2 - Respiratory pressures comparison after-before intervention.

	n			Average	SD
$G_{aquatic}$	19	IP_{max}	Before	92.37	36.87
			After	100.00	34.88
		EP_{max}	Before	95.79	35.79
			After	100.26	30.11
$G_{non-aquatic}$	19	IP_{max}	Before	86.05	26.70
			After	88.42	25.00
		EP_{max}	Before	80.26	25.14
			After	85.00	29.67
$G_{control}$	21	IP_{Max}	Before	100.95	30.60
			After	89.28	26.75
		EP_{max}	Before	90.95	42.59
			After	95.48	30.57

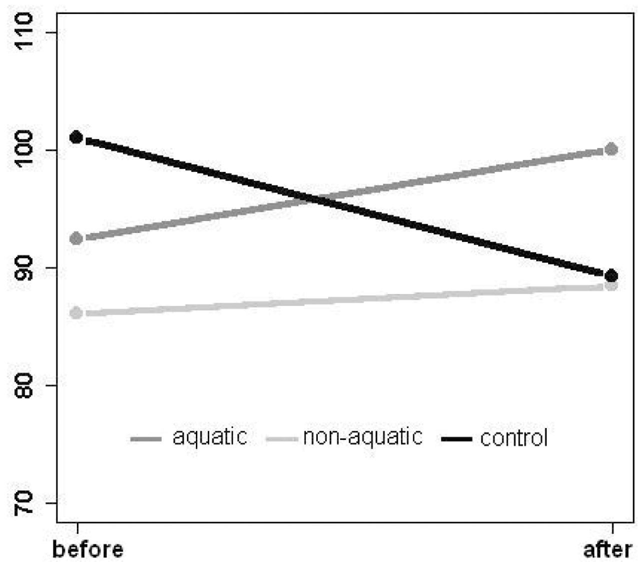

Figure 1 - IP_{max} before and after intervention. The line in boldface indicates the average trajectory.

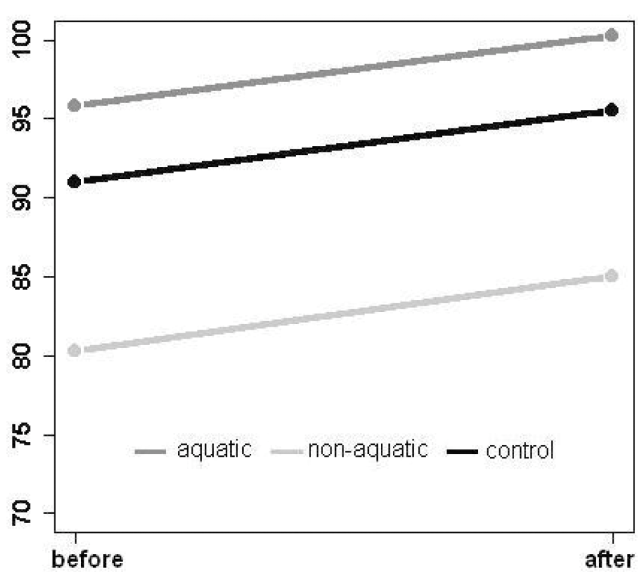

Figure 2 - EP_{max} before and after intervention. The line in boldface indicates the average trajectory.

Table 3 - Comparison of the IP_{max} and EP_{max} after-before intervention in aquatic, non-aquatic and control groups using paired *t* test.

	n		Before vs. after average difference [(1)]	95% Confidence interval	Standard error	paired *t* test	*P*
$G_{aquatic}$	19	IP_{max}	7.63	-5.80 to 21.06	6.40	1.19	.25
		EP_{max}	4.47	-9.55 to 18.50	6.68	0.67	.51
$G_{non-aquatic}$	19	IP_{max}	2.37	-7.80 to 12.54	4.84	0.49	.63
		EP_{max}	4.74	-5.50 to 14.98	4.87	0.97	.34
$G_{control}$	21	IP_{max}	-11.67	-19.72 to -3.61	3.86	-3.02	.01[(2)]
		EP_{max}	4.52	-10.29 to 19.34	7.10	0.64	.53

[(1)] Values in mmH_2O [(2)] Significant difference

DISCUSSION

Analyzing the within-group before vs. after intervention results for IP_{max}, only the $G_{control}$ presented a statistically significant alteration. There is no clear explanation for the fall in the paired values for $G_{control}$, since no change in values, or even an increase in values because of learning, was expected. The learning effect has been reported by many authors.[4,13,14]

Comparing the groups, only the $G_{aquatic}$ inspiratory strength improved significantly when compared to $G_{control}$., although this result could have been partially the consequence of the large unexplained decline in the IP_{max} values of the $G_{control}$. Nevertheless, it appears that the aquatic respiratory exercise strengthened inspiratory muscles. We believe that this improvement occurred because of the influence of the physical properties of water which increase the volunteers' respiratory efforts compared to exercising in air. As previously described, a subject immersed up to the xiphoid process has an increase of 60% to 65% in respiratory work. This is primarily a result of 2 factors: resistance to the thoracic expansion (produced by hydrostatic pressure) and an increase in the thoracic blood volume (produced by buoyancy and hydrostatic pressure). We believe that the resistance that was added to the larger inspiratory effort produced by deep inspiratory breaths by the subjects during all the exercises and respiratory incursions was enough to improve the respiratory muscle strength of the subjects treated. Moreover, we believe that the program exercises improved other trunk and upper limb muscles that are not directly related with the breath. They also may have influenced related—but not specific—variables of the respiratory system, such as amplitude of movement, coordination, agility, and balance, leading to beneficial alterations in global and respiratory biomechanics. However, these conclusions must be carefully analyzed, since as previously noted, the increase in the IP_{max} reached only significance with the aid of an unexplained worsening of $G_{control}$ values.

In our literature review, we found many studies in which inspiratory muscle training (IMT) to improve strength or endurance was used. However, few of them used aquatic respiratory exercise with such ends. A lone study[15] used the aquatic modality exclusively, but its results could not be directly compared with those of our study, since the sample type, variables evaluated, and conditions of treatment were different. The authors found a significant increase in the FEV_1 (forced expiratory volume in 1 second) for subjects with chronic obstructive pulmonary disease (COPD) who performed respiratory exercises in warm water (38ºC).

Although in a few studies respiratory exercise such as respiratory muscle training (RMT) was used, many studies were aimed at improving the strength and/or endurance using other resources, such as incentive devices (threshold) or circuits for isocapnic hyperpnea. They used also an incentive spirometer and other resources. The great majority of these works are dedicated to training and evaluating the inspiratory muscles[23-26]. Only 1 study using other modalities of training specific to the aged population was found.[16] However, the study did not directly evaluate the maximal respiratory pressures, but rather demonstrated improvement in the maximal sustained ventilatory capacity, maximal voluntary ventilation, tidal volume, and FEV_1 of aged persons with undergoing training using isocapnic hyperpnea. Several studies showed an improvement in the IP_{max} of subjects undergoing IMT with different resources, periods of time, apparatus, and ways of randomization.[7,9,14,17-24] Using many methodologies, other authors did not find improvement in the IP_{max}.[9,25-28] In subjects with Duchenne muscular dystrophy, the benefits of resisted IMT were found to be few and difficult distinguish from a learning effect.[13] In one analysis of 22 randomized clinical trials, the results found for IMT were very contradictory.[30]

It should be noted that almost all of the above-mentioned studies used some method of inspirational and/or expirational mechanical resistance (except the study of Kurabayashi et al., 1997), which differs from our research, making comparison of the results difficult.

Due to the scarcity of studies related to RMT with respiratory exercise, particularly when related to the aquatic exercise and involving the elderly, it is difficult to determine what truly occurred in our study with regard to changes in the IP_{max}, particularly in light of unexplained worsening in IP_{max} presented by the $G_{control}$. We believe that a repetition of the experiment or increase in intervention time could help confirm conclusions about the behavior of the IP_{max} of aged persons undertaking a respiratory exercise program.

When analyzed individually, there was no significant difference in the EP_{max} between any of the groups before vs. after the intervention. The slight increase EP_{max} in the two test groups may be a result of the effect of learning.

Other authors have also found no effect of training on the strength of expiratory muscles or EP_{max}. Halseth et al. found the structural effects difficult to study.[29] Kurabayashi et al. got similar results to this study, when they did not find improvement in expiratory parameters in subjects with COPD who underwent aquatic RMT.[15] Kurabayashi et al. reported improvement in FEV_1 and peak flow of subjects with emphysema who accomplished expiration under water.[31] They believed that the added resistance given by water resistance was similar to the pursed-lips expiration, preventing the small airway from collapsing. Additionally, they speculated that the increase of pressure on the abdominal surface probably assisted the diaphragm in the expiration and reduced the anatomical dead space.

Other studies concerning expiratory strength were found. Improvement in parameters related to the expiration was found in several studies[16,33] as well as directly to the EP_{max}.[7,14,22,25,32] One study[22] concerned subjects with asthma. These authors believe that the expiratory benefit occurred because of the changes in the structure of the inspiratory muscles. The therapy produced a greater thoracic-abdominal mobility and structural reorganization of all breathing. Moreover, they believe that the direct diaphragm training probably produced greater mobility of the abdominal muscles, enlisting more the muscles of the abdominal wall, which is an accessory of the breath. Three of the 5 studies that showed significant improvement in the EP_{max} involved subjects with some pathology and having initially reduced EP_{max} compared to normal parameters. Subjects in these conditions may be more easily and intensely benefited by intervention programs.

The lack of effect on EP_{max} in our study may be explained by 3 main factors. First, the forced expiratory muscles (retro abdominus, internal and external obliques, and transverse abdominus) are tonic and very powerful, and they are not exclusively used in ventilation. The strength of these muscles is not built simply by expiratory ventilation. According to Azeredo,[9] in the forced inspiration the maximal flow to be reached with each volume depends on the effort undertaken by the inspiratory muscles. However, forced expiration does not use the same mechanism. At first, the forced expiration depends on the individual's effort, but later in the expiration, greater efforts do not lead to proportionally increased flows. Effort can even cause a small reduction in flow due to dynamic compression in the aerial ways, favoring an increased energy expense for the breath and even though harming the ventilation.

Finally, the abdominal muscles and consequently the expiration of subjects who participated in the aquatic program were supported by the physical properties of water. The hydrostatic pressure tends to cause the inspired thorax to return to its initial position of rest. Moreover, this property exerts pressure on all surfaces of the immersed bodies, tending to assist the expiratory muscles in one more of their functions: containment of pelvic and abdominal contents.

An improvement in the EP_{max} would be of great clinical relevance when the integrity of the expiratory muscles are essential for some maneuvers that involve the forced expiration, as in the case of the cough. The cough also requires integrity of the inspiratory muscles, being an efficient physiological alternative for removal of secretions and preventing the onset of serious pathology.

CONCLUSIONS

The program of aquatic respiratory exercise appeared to improve the IP_{max} and, consequently, the inspiratory muscle strength of healthy aged persons. This improvement is thought to be due to the influence of the physical properties of water, since such improvement was not observed in the group that performed the same activities out of the water. The program, whether completed on land or in water, does not exert an effect on the expiratory strength of healthy aged persons.

RESUMO

IDE MR e col. Efeitos de um programa de cinesioterapia respiratória desenvolvido em dois meios diferentes – aquático e solo – na força muscular respiratória de idosos saudáveis. **CLINICS 60**(2):151-158, 2005.

O envelhecimento da população mundial é uma preocupação para grande parte das entidades governamentais. Acarreta alterações fisiológicas em todo o organismo e causa prejuízos sociais e financeiros. Observa-se uma tendência de que as atenções se voltem à prevenção, menos dispendiosa e socialmente mais viável do que qualquer intervenção terapêutica.

OBJETIVO: Analisar os efeitos e a influência do meio em um programa de cinesioterapia respiratória sobre a força muscular respiratória de idosos.

MÉTODOS: Completaram o estudo 59 sujeitos entre 60 e 65 anos, cujas pressões respiratórias máximas foram mensuradas previamente à sua randomização em três grupos. O $G_{água}$ foi submetido a um programa de cinesioterapia respiratória em ambiente aquático. O G_{solo} utilizou o mesmo programa em solo. O $G_{controle}$ funcionou como controle negativo. Os programas foram aplicados três vezes por semanas, por dez semanas consecutivas. Os sujeitos foram reavaliados e os resultados comparados com os obtidos pré intervenção e entre os grupos. A análise estatística utilizou o teste "t" de Student" para amostras pareadas. A comparação entre os grupos foi realizada através da análise de variância paramétrica e não paramétrica. O teste de *Dunnett* foi utilizado para comparação dos grupos de intervenção em relação ao $G_{controle}$.

RESULTADOS: Observou-se melhora significativa no $G_{água}$ em relação ao grupo controle. A $PE_{máx}$ não sofreu alteração, independente do meio de realização.

CONCLUSÃO: A cinesioterapia respiratória realizada em meio aquático melhora a força muscular inspiratória de idosos saudáveis. Entretanto, não influencia a força expiratória máxima.

UNITERMOS: **Fisioterapia. Idoso. Envelhecimento. Exercícios respiratórios. Hidroterapia.**

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