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Original Article

Association between respiratory muscle strength and reduction of arterial blood pressure levels after aerobic training in hypertensive subjects

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Abstract. [Purpose] The purpose of present study was associate the increase of respiratory muscle strength with blood pressure levels in hypertensive subjects who underwent an aerobic exercise program. [Subjects and Methods] 90 hypertensive subjects were divided in two groups: intervention and control. All participants had an interview with a physiotherapist and were evaluated by 6-minute walk test, maximal inspiratory pressure, maximal expiratory pressure, heart rate, systolic blood pressure and diastolic blood pressure, before and after the 8 weeks. In the intervention group, the subjects underwent aerobic exercise program, 2 times a week for 8 weeks [Results] After the program, the levels of blood pressure were significantly reduced and the distance walked in the 6-minute walk test and the respiratory muscle strength were increased, compared to pre intervention and control group values. However, there was no correlation between the results provided by 6-minute walk test, maximal inspiratory pressure and maximal expiratory pressure with systolic arterial blood pressure levels. Nonetheless, the distance walked correlated with respiratory muscle strength values, in the intervention group. [Conclusion] The present study demonstrated that the aerobic training was effective in reducing the arterial blood pressure in hypertensive subjects associated with an improvement of physical conditioning and respiratory muscle strength.
Key words: Hypertension, Aerobic exercise, Respiratory muscle strength

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INTRODUCTION

Systemic hypertension (SH) is considered an important risk factor for coronary heart disease and ischemic as well as hemorrhagic stroke[1)]. In accord to World Health organization, the SH cause 7.5 million deaths, about 12.8% of the total of all deaths[2)]. Studies have demonstrated an association between body weight, diet composition, dietary fat, physical inactivity and high blood pressure levels. Among these risk factors, sedentary lifestyle control have gained importance in the last years. Physical activity has been considered an important lifestyle modification that may aid in the prevention of hypertension[3)]. Several studies have found that aerobic training reduced both systolic blood pressure (SBP) and diastolic blood pressure (DBP)[4, 5)]. Furthermore, physical exercise have been a strategy to reduce the medicine consumption and doses used in hypertensive subjects[6)].

In addition to the importance of physical activity in the control of hypertension, same variables, such as heart rate (HR) at rest and distance walked in the 6 minute walk test (6MWT) have been used as marker of physical conditioning. A lower HR at rest was found after aerobic training with consequent reduction of blood pressure in hypertensive subjects[7)]. Moreover, these

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effects may be associated with a better performance in the 6MWT[8]. However, during the physiotherapy assessment, same factors can interfere with the HR and 6MWT values, such as the use of beta blockers drugs, hypotireoidism, and orthopedic problems. Thus, the evaluation of respiratory muscle strength may be a tool to investigation of physical conditioning gain and of influence of this conditioning on the blood pressure levels in hypertensive subjects.

Respiratory muscle strength is a marker related to the evolution of several pathologies, mainly of pulmonary origins[9, 10]. Respiratory muscle strength is assessed by maximal inspiratory pressure (MIP), which evaluates the inspiratory muscle strength, and maximum expiratory pressure (MEP), which evaluates the strength of the expiratory muscles. MIP and MEP represent the highest pressure that can be generated during maximum inspiration and expiration, respectively, against a closed airway[11]. A study evaluating male and female swimmers found that MIP and MEP can be used as a marker of an athlete's performance[12]. These authors demonstrated that MIP and MEP values after the physical training were higher that baseline values.

Furthermore, Roceto et al.[13] demonstrated that an aerobic exercise program once a week for 12 weeks increased the maximum respiratory pressure in patients with obstructive pulmonary disease. Additionally, a higher levels of respiratory muscle strength were associated with a slower rate of mobility decline in older persons[14], and some of these elderly were hypertensive.

Despite studies that have demonstrated that the aerobic training promotes reduction in blood pressure in hypertensive subjects and consequently improves physical conditioning[15], no study has associated these effects with an increase in respiratory muscle strength. Thus, the present study aimed to associate the increase of MIP and MEP with the blood pressure levels in hypertensive subjects that performed an aerobic training program.

SUBJECTS AND METHODS

Ninety-six subjects with SH diagnosis, referred by cardiologists for cardiac rehabilitation program of the UNIFAL, between the dates of March 2014 to November 2015. Initially were 96 subjects evaluated, the 6 were excluded for abandoning the training program. The participants were of both sexes (43 females and 27 males, intervention group; 17 females and 3 males, control group) with a mean age 59.65 ± 13.21 (intervention group) and 56.10 ± 8.75 (control group) years. They were divided in two groups: intervention group, composed by exercised subjects (n=70) and the control group, composed by non-exercised subjects (n=20). Among the subjects studied, all had arterial hypertension controlled by medicine, in the intervention group 30% were diabetic, 14% had had heart surgery, 37% reported sleep disorders, 60% lung disease and, in the control group, 45% were diabetic, 0.2% had had heart surgery, 65% reported sleep disorders and 41.42% lung disease. Furthermore, in the intervention group, 47.1% of participants were classified as obese, 32.9% were classified as overweight, 14.3% classified as having a healthy weight and 5.7% underweight; in the control, 60.0% of participants were classified as obese, 35.0% were classified as overweight and 5.0% were classified as having a healthy weight. The inclusion criteria were the following: sedentary participants and have no history of psychiatry or psychological disorders or abnormalities, aged≥30 years with chronic mild-to-moderate and stable (>1 year duration) hypertension. Subjects excluded from the study included those with grade III or IV heart failure, recent acute myocardial infarction, unstable angina, acute pericarditis, pulmonary hypertension or severe untreated blood, ventricular tachycardia at rest, acute infections, III or IV peripheral arterial obstruction, and uncontrolled diabetes. This was a controlled clinical study that evaluated the comparison between body mass, (BMI), 6MWT, SBP, DBP, MIP and MEP inter and intra-groups and the correlation between MIP, MEP, 6MWT with the SBP and DBP levels and the correlation between 6MWT with MIP and MEP values intra-groups, before and after 8 weeks. The study was performed in the physiotherapy clinic at the Federal University of Alfenas (UNIFAL), Brazil. Written informed consent was obtained from all volunteers before participation, and the study was approved by Ethics Committee of the UNIFAL.

Firstly, all subjects had an interview with a physiotherapist. The interview concentrated on the time of hypertension onset, symptoms, life quality, pharmacotherapy, physical activity, and work. In addition, an anthropometric measurement was performed, which measured the subjects' physical characteristics (weight [kg] and height[m]) and body composition (body mass index [BMI] (kg/m^2).

Furthermore, we did the measurements of MIP and MEP for the evaluation of respiratory muscle strength. MIP and MEP were measured with respiratory pressure meter at the beginning and at the end of the eight-weeks. The measurement is non-invasive, is well tolerated by patients, and is recommended by The American Thoracic Society and The European Respiratory Society as a test of respiratory muscle strength[16]. In addition, 6MWT was used to evaluate the cardiovascular and physical conditioning gain[17]. All participants tolerated the 6MWT without any adverse effects. HR, arterial blood pressure, Borg's rate of perceived exertion (RPE), and arterial oxygen saturation (Sa02) were measured at rest continuously every 2 minutes during walking and after the test[17].

In the training program, the patients underwent to aerobic exercise on a treadmill (Movement RT250- Manaus, AM, Brazil) 2 times a week for 8 weeks. Exercise sessions started with a 10-minute warm-up period (stretching and slow walking) followed by 30 minutes of aerobic activity on a treadmill and ended with an appropriate cooling-off period of 10 minutes. Patients exercised at 60 to 70% HR, calculated according to the Karvonen formula, which was measured continuously with a portable HR monitor (Polar RS200, Woodbury, NY, USA). Blood pressure was monitored periodically during each workout

Table 1. Comparison of intragroup and intergroup variables

Variables	Intervention group (n=70)			Control group (n=20)			Intergroup	
	Pre-intervention $\bar{x} \pm \sigma$ CI (95%)	Post-intervention $\bar{x} \pm \sigma$ CI (95%)	D Power	Pre-intervention $\bar{x} \pm \sigma$ CI (95%)	Post-intervention $\bar{x} \pm \sigma$ CI (95%)	D Power	Pre D Power	Post D Power
Age (years)		59.6 ± 13.2			56.1 ± 8.7^{a}		0.3	
		53.4–65.8			52.0–60.1		0.4	
Height (cm)		159.9 ± 9.9			158.6 ± 9.2^{b}		0.1	
		155.2–164.5			154.2–162.9		0.08	
Body Mass (kg)	84.5 ± 15.1	84.1 ± 15.0^{c}	0.02	79.5 ± 12.1^{e}	79.6 ± 11.9^{ce}	0.005	0.1	0.1
	77.4–91.5	77.1–91.1	0.05	73.8–85.2	74.0–85.1	0.05	0.3	0.3
BMI (kg/m^2)	32.4 ± 7.0	32.0 ± 7.1 ^{c}	0.06	31.7 ± 4.8^{e}	31.7 ± 4.91^{ce}	0.004	0.06	0.02
	29.2–35.7	28.6–35.3	0.09	29.4–33.9	29.4–34.0	0.05	0.09	0.05
6MWT (m)	373.4 ± 96.4	537.0 ± 81.1^{c***}	1.8	420.7 ± 85.7^{e}	412.2 ± 83.9^{ce*}	0.1	0.2	0.6
	328.2–418.5	499.0–575.0	1.0$^{\#}$	380.6–460.8	372.9–451.5	0.1	0.5	0.9$^{\#}$
SBP (mmHg)	131.2 ± 13.1	121.0 ± 10.2^{c***}	0.8	133.5 ± 11.8^{e}	136.5 ± 11.8^{ce***}	0.2	0.07	0.6
	125.0–137.4	116.2–125.7	1.0$^{\#}$	127.9–139.0	130.5–142.0	0.6	0.1	0.9$^{\#}$
DBP (mmHg)	83.0 ± 15.5	73.5 ± 8.7^{d***}	0.7	85.5 ± 9.9^{e}	86.0 ± 12.7^{ce***}	0.08	0.1	0.6
	75.7–90.2	69.4–77.5	0.9$^{\#}$	80.8–90.1	80.0–91.9	0.1	0.1	0.9$^{\#}$
MIP (mmH_2O)	−94.3 ± 27.4	−106.2 ± 20.9^{d***}	0.4	−95.0 ± 23.7^{e}	−95.5 ± 24.8^{de}	0.02	0.01	0.2
	−82.0–107.7	−96.4–116.0	0.9$^{\#}$	−83.8–106.1	−83.8–107.1	0.05	0.05	0.5
MEP (mmH_2O)	100.7 ± 20.5	109.6 ± 17.4^{d***}	0.4	94.0 ± 22.4^{e}	90.4 ± 21.1^{de}	0.1	0.1	0.4
	91.0–110.3	101.4–117.8	0.9$^{\#}$	83.5–104.5	80.5–100.2	0.3	0.2	0.9$^{\#}$

^{a}independente t test; ^{b}Mann-Whitney test; ^{c}paired t test; ^{d}Wilcoxon test; ^{e}ANOVA One Way test; *p<0.05, ***p<0.001, $^{\#}$Power>80%; D: effect size; BMI: body mass index; 6MWT: Six-Minute Walk Test; SBP: systolic blood pressure; DBP: diastolic blood pressure; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; $\bar{x} \pm \sigma$: Mean ± Standard deviation; CI: confidence interval

to ensure that it was within safe limits (SBP<220 mmHg, DBP<110 mmHg). The workload was adjusted to maintain the target HR and blood pressure within the prescribed limits throughout the exercise session. Patients were also subjectively rated on RPE. Arterial blood pressure, HR, and RPE were measured before, during (every 10 minutes), and after the training program.

Descriptive data were expressed as mean and standard deviation. Data normality was verified through the Kolmogorov-Smirnov test. For comparison between the intragroup evaluations, the paired t-test and the Wilcoxon test. To comparison intergroup, was used t-test independent, Mann-Whitney and one-way ANOVA. In the correlation between the data we used the Spearman correlation test. A Significance level of 5% was adopted. Furthermore, was adopted the power>80% to determine the sample since. Statistical analyses were performed using SPSS for Windows version 20.0 (SPSS, Chicago, IL, USA).

RESULTS

Table 1 shows the comparison of intragroup and intergroup variables. We can verify that there were no statistical difference of participants' main anthropometric characteristics, such as age, height, body weight and BMI, before and after 8 weeks.

Although no significant differences occurred in the anthropometric characteristics assessed, participants walked a greater distance (373.43 ± 96.44 m × 537.07 ± 81.15 m, p<0.001) in the 6MWT after the aerobic training program, indicating an improvement in the physical conditioning (Table 1). Furthermore, after the aerobic training program, the levels of SBP and DBP were significantly reduced, respectively (131.25 ± 13.16 mmHg × 120.00 ± 10.20 mmHg, p<0.001 and 83.00 ± 15.59 mmHg × 73.50 ± 8.75 mmHg, p<0.001), in the intervention group (Table 1). Table 1 also shows that after the aerobic training program, respiratory muscle strength was significantly increased, represented by MIP (−94.30 ± 27.48 cmH_2O × −106.25 ± 20.95 cmH_2O, p<0.001) and MEP (100.70 ± 20.51 cmH_2O ×109.65 ± 17.45 cmH_2O, p<0.001), respectively.

However, there was no correlation of the results provided by MIP, MEP and 6MWT with SBP and DBP levels, after the aerobic training program (Table 2). Nonetheless, there was a correlation between the distance walked in the 6MWT with the MIP and MEP values (6MWT and MIP, p<0.01; 6MWT and MEP, p<0.02) (Table 2).

Table 2. Correlation between respiratory pressure with blood arterial pressure and six-minute walk test for both groups

Variables		Intervention group (n=70)				Control group (n=20)			
		Systolic blood pressure		Diastolic blood pressure		Systolic blood pressure		Diastolic blood pressure	
		Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Maximum inspiratory pressure	Pre-intervention	−0.007 (r)		0.09 (r)		0.1 (r)		0.4 (r)	
	Post-intervention		0.02 (r)		−0.007 (r)		−0.05 (r)		−0.3 (r)
Maximum expiratory pressure	Pre-intervention	−0.08 (r)		0.05 (r)		0.1 (r)		0.4 (r)	
	Post-intervention		0.09 (r)		0.2 (r)		0.07 (r)		−0.06 (r)
Six-minute walk test	Pre-intervention	0.08 (r)		0.03 (r)		−0.3 (r)		−0.4 (r)	
	Post-intervention		0.1 (r)		0.1 (r)		−0.08 (r)		−0.1 (r)
		Maximum inspiratory pressure		Maximum expiratory pressure		Maximum inspiratory pressure		Maximum expiratory pressure	
		Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Six-minute walk test	Pre-intervention	−0.2 (r)		0.2 (r)**		−0.2 (r)		0.2 (r)	
	Post-intervention		−0.3 (r)**		0.3 (r)**		−0.2 (r)		0.5 (r)**

Spearman test. **p<0.01.

DISCUSSION

Physical activity has been recognized in the literature as a method of preventing hypertension. Over the years, it has been found that for optimal BP, pharmacological drugs alone are not sufficient for preventing hypertension and, the physical activity is a crucial aspect of treatment as well. Thus, the American College of Sports Medicine recommends that hypertensive people start a regular exercise program with moderate intensity[18].

In the present study, we found that aerobic exercise 2 times a week for 8 weeks was efficient in promoting a reduction in arterial blood pressure levels in hypertensive patients. Another study found similar results using the same training period[19], reinforcing the hypothesis that 8 weeks of aerobic exercise are efficient in reducing arterial blood pressure.

Despite the control of hypertension, in our study, the aerobic training did not produce changes in body weight and BMI, mainly reduction as demonstrated in similar studies. A reduction of body weight and BMI and blood pressure was found in women with postmenopausal hypertension after 8 weeks of low-impact aerobic training[20]. However, this training was 3 times a week. An explanation for the lack of reduction of BW in this study could be the frequency of exercise (2 times a week), but Martin et al.[21] using a protocol of a 30-minute aerobic training program held 4 times a week for 10 weeks, also found no differences in the weight of participants after the training. Thus, we suggest that despite the fact that the participants received information in relation to the importance of a balanced diet, they lacked the accompaniment of a nutritionist to assess them with greater efficiency. Moreover, participants reported not having made any special diet during the study. In addition, education on how to modify lifestyle and gain more self-control over one's eating has demonstrated a reduction in the weight and BMI of obese adults[22]. Thus, we suggest that to physical exercise be effective in controlling body weight, it must be associated with a food education, especially with the accompaniment of a specialist.

Although the present found no improvement in terms of weight lost and BMI after the aerobic training program, it was demonstrated by the 6MWT that after the training, participants could walk a greater distance, suggesting a gain in physical and cardiovascular conditioning through the exercise protocol used. The 6MWT is commonly used to assess the fitness level of healthy adults and of older adults with disabilities and pathologies, such as stroke, chronic obstructive pulmonary disease, pulmonary arterial hypertension, pulmonary fibrosis, and heart failure[23–25]. However studies are rare evaluating the 6MWT in hypertensive subjects. The 6MWT is highly reproducible and is a strong marker of prognosis of several treatments. However, orthopedic problems, medicines, labyrinthitis, etc. can influence the response to the test. Despite the present study suggest that aerobic exercise program produced an increase in the 6MWT, we not found a correlation this finding with the reductions of SBP and DBP levels. A large number of patients were taking medications to SH control and this may have influenced on this correlation. However, the increase of distance walked in the 6MWT was correlated with the improvement of MIP and MEP after aerobic training. We suggesting that the physical and cardiovascular conditioning gain produced by aerobic exercise program increased the respiratory muscle strength of hypertensive subjects. Thus, the measurement of MIP and MEP can be an important tool to evaluated physical conditioning gain. Although the improvement of MIP and MEP produced by aerobic exercise program not correlated with the SBP and DBP levels, future studies using a larger number of patients will find this correlation.

Most studies have shown that physical activity can reduce high levels of arterial blood pressure in hypertensive subjects[3], but these studies have not associated this effect with MIP and MEP values. In addition, a study demonstrated that swimmers present a greater respiratory muscle strength compared a non-swimmers[26], indicating that aerobic conditioning promotes an increase in respiratory muscle strength. Another study, evaluating the elderly, demonstrated that respiratory muscle strength is associated with mobility decline[14]. In addition, our study showed for the first time this correlation with hypertensive subjects.

Watson et al.[27] found that the reduction in respiratory muscle strength, by MIP and MEP, in patients with heart failure is related to poor cardiac output. Nevertheless, this muscle weakness was not limited by exercise capacity in these patients. However, MIP and MEP were found to be reduced, with a consequent reduction in the handgrip force of patients with congestive heart failure[28].

In some of these pathologies previously described, the authors suggest that decreased MEP and MIP is related with generalized skeletal muscle weakness in pulmonary hypertension, possibly related to decreased systemic oxygen transport, leading to a variety of consequences. These include muscle atrophy, a relative increase in the easily fatigable type-IIb fibers, decreased oxidative enzymes and mitochondria, abnormal intracellular calcium profiles, and decreased phosphocreatine-all of which have been previously reported in heart failure[29]. In addition, all of these consequences are related to a sedentary lifestyle and consequently with arterial blood hypertension.

Thus, the present study suggests that the MIP and MEP values are associated with arterial blood pressure levels since a reduction of respiratory muscle strength was associated with high arterial blood pressure. Furthermore, we demonstrated that an aerobic exercise training program of 8 weeks was efficient in promoting a gain in cardiovascular and physical conditioning and an increase of respiratory muscle strength with a consequent reduction in arterial blood pressure in hypertensive subjects.

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