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ORIGINAL RESEARCH

Assessment of respiratory muscle strength in adult choir singers and non-singers

Avaliação da força muscular respiratória em adultos cantores de coral e não cantores

Evaluación de la fuerza muscular respiratoria en adultos cantantes de coro y no cantantes

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ABSTRACT | A good musical performance requires singers to have high respiratory system skills since the respiratory muscles produce an increase and decrease in the rib cage during singing. Our research aimed to verify and compare the respiratory muscle strength of adult choir singers and non-singers. This is a cross-sectional study consisting of individuals between 18 and 45 years of age, of both sexes, sedentary and non-smokers, distributed between two groups: choir singers (GC; n=23) and non-singers (GNC; n=23). Both groups were evaluated for inspiratory (maximal inspiratory pressure – MIP) and expiratory (maximal expiratory pressure – MEP) muscle strength through a manovacuometer. Individuals in the GC showed higher values of MIP (p=0.049) and MEP (p <0.001) when compared to the GNC. Moreover, MIP values were identified as having a moderate magnitude of effect and power (d=0.56; power=0.59), whereas MEP values had a moderate magnitude of effect and high power (d=0.77; power=0.82). This difference in MIP and MEP measurements between GNC and GC was also observed regarding values of the predicted percentages (p<0.05). From the analyzes performed, one can conclude that adult choir singers have greater inspiratory and expiratory muscle strength when compared to non-singers.

Keywords | Maximum Respiratory Pressures; Singing; Breathing; Physical Therapy.

RESUMO | Um bom desempenho musical exige dos cantores alta habilidade do sistema respiratório, uma vez que, durante o canto, a musculatura respiratória produz o aumento e diminuição da caixa torácica. O objetivo deste estudo foi verificar e comparar a força muscular respiratória de indivíduos adultos cantores de coral e não cantores. Trata-se de uma pesquisa transversal, composta por indivíduos com idade entre 18 a 45 anos, de ambos os sexos, sedentários e não tabagistas, distribuídos entre dois grupos: indivíduos cantores de coral (GC; n=23) e indivíduos não cantores (GNC; n=23). Os grupos foram avaliados quanto à força muscular inspiratória (pressão inspiratória máxima – PImáx.) e expiratória (pressão expiratória máxima – PEmáx.) por meio da manovacuometria. Indivíduos do GC apresentaram valores maiores da PImáx. (p=0,049) e PEmáx. (p<0,001) quando comparados ao GNC. Além disso, identificou-se que os valores da PImáx. têm magnitude de efeito e poder moderados (d=0,56; poder=0,59), e os valores da PEmáx. magnitude de efeito moderado e poder elevado (d=0,77; poder=0,82). Essa diferença das medidas de PImáx. e PEmáx. entre GNC e GC foi também observada ao se considerar os valores dos percentuais dos preditos (p<0,05). A partir das análises realizadas, conclui-se que cantores adultos de coral apresentam maior força muscular inspiratória e expiratória quando comparados a não cantores.

Descritores | Pressões Respiratórias Máximas; Canto; Respiração; Fisioterapia.

RESUMEN | Para un buen desempeño musical, los cantantes necesitan tener una alta capacidad pulmonar, ya que los músculos respiratorios durante el canto producen un aumento y disminución de la caja torácica. El objetivo

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de este estudio fue verificar y comparar la fuerza muscular respiratoria entre individuos adultos cantantes de coro y no cantantes. Este es un estudio transversal, en el que participó individuos con edades comprendidas entre 18 y 45 años, de ambos los sexos, sedentarios y no fumadores, que fueron distribuidos en dos grupos: cantantes de coro (GC; n=23) y no cantantes (CNG; n=23). Los grupos se sometieron a evaluación de la fuerza muscular inspiratoria (presión inspiratoria máxima, PImáx.) y espiratoria (presión espiratoria máxima, PEmáx.) mediante manovacuometría. Los individuos del GC presentaron valores más altos de PImáx. (p=0,049) y de PEmáx. (p<0,001) que los de GNC. Además, se identificó que los valores de PImáx. tienen magnitud del efecto y potencia moderados (d=0,56; potencia=0,59), y los valores de PEmáx, magnitud de efecto moderado y alta potencia (d=0,77; potencia=0,82). Esta diferencia en las mediciones de PImáx. y PEmáx. entre GNC y GC también se observó al considerar los valores de los porcentajes de los predichos (p<0,05). De los análisis realizados se concluye que los adultos cantantes de coro tienen mayor fuerza muscular inspiratoria y espiratoria que los no cantantes.

Palabras clave | Presiones Respiratorias Máximas; Canto; Respiración; Fisioterapia.

INTRODUCTION

The sound of the human voice is generated from the moment air enters the lungs and, when it exits, it promotes the vibration of vocal cords, being an essential tool for human communication[1]. Thoracic and abdominal cavity musculatures are responsible for producing the force necessary to direct the air to the lower airways and then mobilize it to the larynx, where the vocal cords are located[2].

According to Le Huche and Allali[3], the voice can be considered a sounded exhalation produced by the action of expiratory muscles to expel air. During singing, exhalation is also an active process, however, it takes longer than in speech[4]. In addition, breathing will vary according to the requirements of the musical performance[4], involving strong and rapid inspirations, followed by prolonged and regulated exhalation[5]. In this sense, each type of singing demands a specific form of respiratory support, as it changes according to the demands imposed by music to obtain the best vocal emission[1].

Choral singing consists of a group of singers who perform pieces in unison or in various voices, with or without instrumental accompaniment. The choir can be composed of male and female voices, which are grouped according to their vocal classification[6,7]. In singing, the function of the respiratory musculature is to increase and decrease the rib cage; thus, the strength of the respiratory musculature is a primary factor in the performance of choir singers[8].

Adequate breathing in singing should be deep and with the use of inspiratory and expiratory muscles in order to provide sufficient support for sustaining the notes[1,9]. Through respiratory awareness, adaptations and constant improvement in the ways of exercising singing, such as the relaxation of muscle tension and appropriate respiratory control, one can observe a reduction in body stiffness and an increased lung capacity[10,11]. In this context, previous studies report that adult and elderly choir singers have greater vital and inspiratory capacity when compared to non-singers, thus suggesting that the habit of singing is probably equivalent to the effect of physical training on lung function, due to the frequent use of respiratory muscles[12,13].

Additionally, Bonilha et al.[5] demonstrated that one singing class was able to reduce the volume of expiratory reserve in patients with Chronic Obstructive Pulmonary Disease (COPD), thus indicating that singing could promote small reductions in dynamic pulmonary hyperinflation. In addition, in the same study, there was an improvement in expiratory muscle strength after singing training, which, according to the authors, could be related to the fact that the practice of singing requires sustained contractions of expiratory muscles to generate extended musical sounds.

Similarly, in the study by Rosa et al.[13], the benefit of singing was demonstrated in the expiratory muscle strength of elderly choir singers, being an indication that the activity of choral singing can be beneficial for respiratory muscle strength. Thus, it has been found that lung volumes and capacities in the adult and elderly population can be influenced by choral singing. In a complementary way, in the elderly and in COPD patients, the beneficial effect of singing also seems to be present in respiratory muscle strength. However, considering that elderly individuals have reduced respiratory muscle strength[8], the effects of singing on this variable can be different between the elderly and adults. In this context,

the impacts of choral singing on the respiratory muscle strength of healthy adult individuals are still unknown. Therefore, this work aims to verify and compare the respiratory muscle strength of adult choir singers and non-singers.

METHODOLOGY

Study design

This is a cross-sectional study, developed at the Centro Universitário Metodista Izabela Hendrix (CEUNIH), Belo Horizonte (MG). This study was conducted in accordance with Resolution No. 466/2012 of the National Health Council, Brazil. All participants signed the Informed Consent Form prior to research.

Sampling

This study consisted of a convenience sample, consisting of adults, of both sexes, allocated in two groups: singers group (GC=23) and non-singers group (GNC=23). Singers were recruited from a gospel music choir at a religious institution and non-singers were recruited from the same religious institution and CEUNIH. For recruitment, the pairing of groups regarding sex, age and body mass index (BMI) was taken into account. The period of sampling and data collection ranged from October to December 2019.

Participants met the following inclusion criteria: age between 18 and 45 years; not being a smoker and having no smoking history; not performing physical activity for at least 30 minutes, at least three times a week[14]; do not present cardiac, metabolic or respiratory diseases and do not present contraindications for the tests proposed, as published in the literature[15]. In addition to these criteria, singers should regularly attend choir rehearsals (once a week) and do not engage in other singing activities or wind instruments. Finally, the participants of the non-singers group could not perform any type of singing. Participants who expressed difficulty in understanding and carrying out the proposed evaluations would be excluded.

Experimental procedures

All experimental procedures were performed on the same day. The anthropometric assessment consisted of measuring body weight and height, and BMI calculation. To measure the weight, a portable digital scale (MainStays) was used. To measure height, an inelastic measuring tape (Easy Read, Cateb, São Paulo/Brazil) was used. BMI was determined by calculating body weight divided by square height (kg/m^2)[16].

The assessment of inspiratory and expiratory muscle strength was defined by measuring the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP), respectively, using the manovacuometer, model MRN -300/+ 300 cmH_2O (Murenas Produtos para Saúde Ltda., Brazil). For this analysis, the volunteers were seated and their nose was occluded with a nose clip. MIP was measured from residual volume and MEP from total lung capacity. The maneuvers were repeated up to a maximum of five times, with the collection of three acceptable maneuvers. Maximum respiratory efforts should be sustained for at least two seconds, with measures without air leaks being considered acceptable, which obtained a variation ≤10% of the highest value found. Between each of the MIP and MEP measurements, an interval of one minute was established for the volunteer to recover[15].

The measurements were performed by an examiner previously trained on the technique who, before the collection, taught and demonstrated the procedures to be tested, in addition to having used a vigorous and standardized verbal command during the test. For analysis of results, the gross values and the values of the predicted percentage were considered, the latter being calculated from equations specific for the Brazilian population[15].

Statistical analysis

Data were analyzed using the statistical program GraphPad Prism 5.0 (GraphPad Software, Inc., USA) and are presented as mean ± standard deviation. We verified data normality using the Shapiro-Wilk test. The comparison of results between groups and between sexes was performed using the independent t-test (parametric data) or the Mann-Whitney test (non-parametric data).

The magnitude of effect (d), statistical power, and sample calculation were examined by the GPower 3.1 program. According to Cohen[17], values of $d \leq 0.49$ were considered as a small effect, 0.5-0.79 as a moderate effect, and ≥0.8 as a high effect. By the sample size calculation performed, which was based on the study by Rosa et al.[13], the need for at least seven subjects per group was identified.

In addition, the level of statistical significance of p≤0.05 was considered.

RESULTS

Fifty-one individuals were recruited for the study, five of whom were excluded because they had difficulty performing the maneuver, totaling 23 individuals in the GNC and 23 individuals in the GC. The demographic and anthropometric data of these individuals are shown in Table 1. One may observe the groups were homogeneous in relation to age, sex, height, weight, and BMI (p>0.05). Individuals' mean singing time was 9.17 ± 5.5 years.

Table 1. Demographic and anthropometric characteristics of the participants

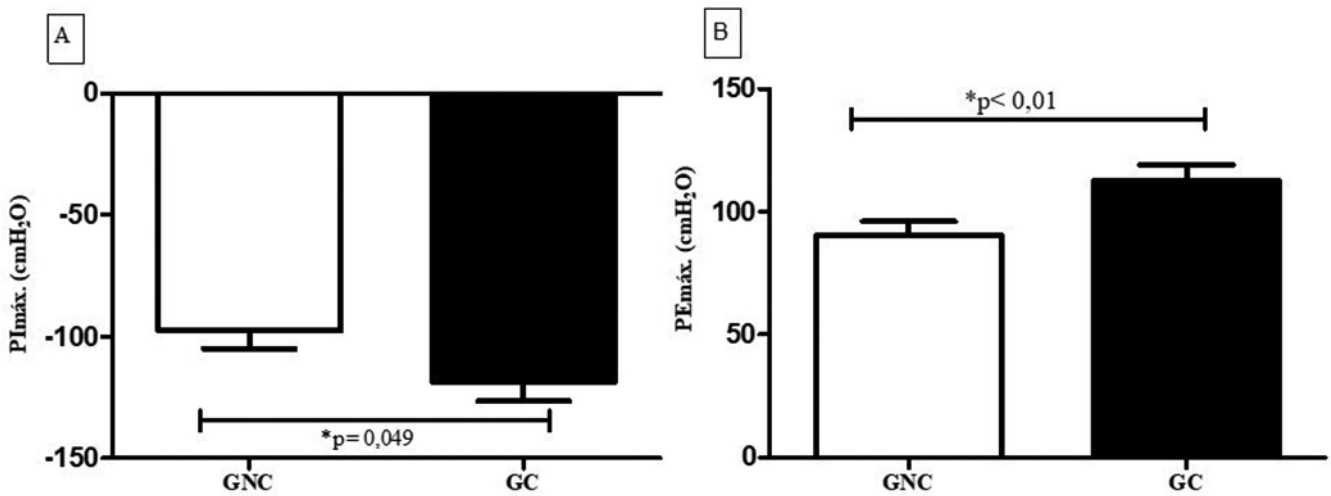
Characteristics	GNC (n=23)	GC (n=23)	P
Sex (M/F)	11/12	11/12	---
Age (years)	26.00 ± 4.00	25.00 ± 5.00	0.416[b]
Height (m)	1.69 ± 0.1	1.7 ± 0.1	0.524[a]
Weight (kg)	67.88 ± 17.24	72.17 ± 13.48	0.227[a]
BMI (kg/m^2)	23.62 ± 4.43	24.95 ± 4.02	0.292[b]

Values presented as mean ± standard deviation. BMI: body mass index. GNC: individuals who are not choir singers; GC: choir singers; [a]: Mann-Whitney test; [b]: Independent t-test.

Figure 1 shows the results of MIP and MEP gross values for the GNC and GC. Individuals in the GC showed higher values of MIP (p=0.049) and MEP (p<0.001) when compared to the GNC. In addition to the statistical differences, we identified the MIP data had a moderate magnitude of effect and power (*d*=0.56; power=0.59), whereas MEP data had a moderate magnitude of effect and high power (*d*=0.77; power=0.82).

Similar behavior was observed in the analysis of predicted percentages of data, with significant differences being found in MIP (GNC: -84.31 ± 25.96; GC: -103.1 ± 31.36; p=0.032; *d*=0.67; power=0.72) and MEP (GNC: 90.43 ± 26.71; GC: 112.6 ± 31.7; p<0.01; *d*=0.77; power=0.82) measures between groups. In the GC, 74% of the participants reached values higher than the predicted (> 100%) of MEP and 48% reached higher values than predicted for MIP. In comparison, in the GNC 30% of the participants reached values higher than predicted for both MIP and MEP.

In a complementary way, the results were compared between the sexes. As expected, in both groups, men scored higher than women (p <0.0001, data not shown), although no significant difference was observed in BMI (CNG, p=0.249; CG, p=0.678, data not shown). Regarding the differences in muscle strength, one can notice that only the gross values of MEP of GC was higher in men compared to women, and also the gross values of MIP of the CNG was higher in men than in women. No significant differences were observed when analyzing the data of the predicted percentages (Table 2).



*p<0.05. GNC: individuals who are not choir singers. GC: choir singers; MIP: maximal inspiratory pressure; MEP: maximum expiratory pressure. Mann-Whitney's test.

Figure 1. Gross values of MIP (panel A) and MEP (panel B) of the GNC and GC

Table 2. Respiratory muscle strength data of choir singers and non-singers according to sex

Variables	GNC (n=23)		P	GC (n=23)		P
	Male (n=11)	Female (n=12)		Male (n=11)	Female (n=12)	
MIP (cmH_2O)	115.5 ± 41.8	81.11 ± 20.28	0.037[b]	130.9 ± 46.57	108.9 ± 28.04	0.301[a]
MIP (% pred)	85.64 ± 31.4	85.61 ± 20.10	0.998[b]	96.44 ± 34.42	110.8 ± 29.13	0.334[b]
MEP (cmH_2O)	96.36 ± 28.38	86.67 ± 27.39	0.450[b]	130.9 ± 35.34	100.0 ± 13.23	0.02[a]
MEP (% pred)	66.85 ± 19.58	87.78 ± 29.5	0.078[b]	90.28 ± 25.89	99.27 ± 12.23	0.352[b]

Values presented as mean ± standard deviation. GNC: individuals who are not choir singers; GC: choir singers; [a]: Mann-Whitney test; [b]: Independent t-test.

DISCUSSION

To our knowledge, this was the first study to investigate the respiratory muscle strength of adult choir singers and non-singers. It demonstrated that adult choir singers had both inspiratory and expiratory muscle strength superior to non-singers.

There are several muscles whose functions are related to the breathing process. External intercostal muscles and diaphragm are responsible for inspiration, whereas the internal intercostal muscles participate in expiration, which can also be aided by the contraction of the abdominal muscles (straight, transverse and oblique)[18], leading to a forced and deeper exhalation, similar to what happens during singing[19].

Despite recruiting the same inspiratory and expiratory muscles, speaking basically requires 60% of the vital capacity, whereas for singing the activation of this musculature is on average 70% to 100%, resulting in a much greater demand on the respiratory muscles[20]. During singing, sound production is emitted through active exhalation; however, for exhalation to occur efficiently and sustainably, adequate inspiration is necessary. Therefore, singing requires an appropriate inspiratory and expiratory support[21].

According to this study results, individuals in the singers group showed higher values of respiratory muscle strength both in the analysis of crude values and in values of the predicted percentage. Therefore, it is believed that the best inspiratory and expiratory muscle strength in choir singers can be justified by the demands of singing, such as repeated muscle activations with variations in intensity, height, sustain time, and projection of the musical phrase[1].

Electromyographic studies support such hypothesis, reporting increased respiratory muscle activity during singing. In this context, Ramli, Hamzaid and Engkasan[22] investigated in adults, using mechanomyography (MMG) and electromyography (EMG), the activity of the sternocleidomastoid (ECM) as an accessory respiratory muscle during inspiration. It was observed that ECM activity during singing was significantly different from breathing at rest. Another study also demonstrated, in adults and through EMG, that there is an increase in the activity of the upper trapezius, intercostal and lateral oblique muscles in the expiratory phase of the singing[23].

Our results corroborate the findings of the study carried out by Rosa et al.[13], in which it was possible to verify that healthy sedentary elderly choir singers obtained better results of expiratory muscle strength when compared to non-singers. Unlike the study by Rosa et al.[13], this study demonstrated that, in addition to expiratory muscle strength, adult choristers presented inspiratory muscle strength superior to that of non-singing individuals. It is believed that these divergent findings are related to the age differences between the study subjects and that the benefits of singing over inspiratory muscle strength can happen mainly in adulthood, at which time the strength of this musculature is still preserved.

This hypothesis can be confirmed with the findings of the study by Bonilha et al.[5], which proved the effect of singing on respiratory muscle strength in elderly people with COPD, who are known to have inspiratory muscle weakness[24]. This study demonstrated that elderly people with COPD who underwent a training program with singing lessons showed an improvement in expiratory muscle strength when compared to control patients, who performed only manual activities[5]. Thus, in the elderly population, singing seems to promote an increase in expiratory muscle strength only.

In addition, in this study, it was observed that in the analysis of the raw data, male singers revealed expiratory muscle strength superior to women, and male non-singers had inspiratory muscle strength superior to women.

However, this is an expected finding, since men are known to have greater stature, greater airway size, larger chest cavity and greater lung volume[25]. Thus, the data from this study do not allow for confirming whether there is a difference in muscle strength between the sexes, since the values of the predicted percentage (which takes into account sex and age) were not significantly different in inspiratory and expiratory muscle strength measurements in both groups.

This study has some limitations that should be noted. There was no medical assessment or analysis of respiratory capacities to confirm the exclusion of respiratory disorders, the participants only declared that they did not present and/or were unaware of the presence of respiratory diseases. In addition, the level of physical activity of the participants was not assessed by direct measures, such as questionnaires. Only the questioning about the pattern of weekly physical activity and the performance of sports activities was carried out, following criteria that characterized individuals as sedentary or physically inactive. Another issue is the lack of blinding by the evaluator in relation to the individuals in each group. However, to reduce the influence of the evaluator in the measurements, he was previously trained with the technique, in order to always maintain the same verbal command during the measurements. Finally, we did not analyze whether the respiratory muscles in the group of singers had greater electromyographic activity.

It is noteworthy that the analyzes carried out in this study showed moderate to high statistical power, demonstrating the benefits of singing in the respiratory muscle strength of adults. Thus, it is believed that singing initiated in adulthood may be an alternative therapy to promote the maintenance or improvement of respiratory muscle strength. To elucidate this issue, we suggest the performance of experimental studies to assess the strength and electromyographic activity of respiratory muscles after the implementation of a structured singing program.

CONCLUSION

From the analyzes carried out in this study, one can observe that adult choir singers had greater respiratory muscle strength, both inspiratory and expiratory, when compared with adult non-singers.

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