Original Article

Journals BAHIANA
SCHOOL OF MEDICINE AND PUBLIC HEALTH

# Correlation of maximum voluntary ventilation to the strength and resistance of young respiratory muscles

# Correlação da ventilação voluntária máxima com a força e resistência dos músculos respiratórios em jovens

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**ABSTRACT | INTRODUCTION:** Maximum voluntary ventilation is one of the widespread tests for assessing respiratory muscle strength, even without being validated for this purpose. Controversies are still found in the literature regarding the interpretation and applicability of the use of MVV in clinical practice. **OBJECTIVE:** To verify the correlation between maximum voluntary ventilation and respiratory muscle strength and endurance in healthy youngsters. **MATERIALS AND METHODS:** Observational cross-sectional study conducted at the Clinic. Individuals> 18 years of age, of both sexes and healthy were included. Participants had their respiratory muscle strength assessment using a manovacuometer, in which Pimax and Pmax were obtained. The resistance was evaluated through the constant load test by Power Breathe, using 60% of the Pimáx. Maximum voluntary ventilation was performed by a spirometer. Pearson's correlation test was applied to correlate the variables Pimax, Pmax and VVM. The study was approved by the ethics committee, CAAE 10849519.9.0000.5544. **RESULTS:** 27 participants were evaluated, of which 59.3% were male and 55.6% were active. The maximum voluntary ventilation with Pimax and Pmax, presented respectively p = 0.04 and 0.02 and r = 0.53 and 0.57. **CONCLUSION:** The maximum voluntary ventilation test has a moderate correlation with respiratory muscle strength and has no correlation with the constant load test.

**KEYWORDS:** Respiratory muscles. Maximum voluntary ventilation. Healthy volunteers.

**RESUMO | INTRODUÇÃO:** A ventilação voluntária máxima é um dos testes difundidos para avaliação da resistência da musculatura respiratória, mesmo sem ser validado para este fim. Na literatura ainda são encontradas controvérsias quanto a interpretação e aplicabilidade do uso da VVM na prática clínica. **OBJETIVO:** Verificar a correlação entre a ventilação voluntária máxima e a força e resistência dos músculos respiratórios em jovens hígidos. **MATERIAIS E MÉTODOS:** Estudo observacional de corte transversal realizado na Clínica. Foram incluídos indivíduos > 18 anos, de ambos os sexos e hígidos. Os participantes tiveram sua avaliação da força muscular respiratória através do manovacuômetro, no qual se obteve a Pimáx e Pemáx. A resistência foi avaliada através do teste de carga constante pelo Power Breathe, utilizando 60% da Pimáx. A ventilação voluntária máxima foi realizada pelo espirômetro. Para a correlação das variáveis Pimáx, Pemáx e VVM foi aplicado o teste de correlação de Pearson. O estudo foi aprovado pelo comitê de ética, CAAE 10849519.9.0000.5544. **RESULTADOS:** Foram avaliados 27 participantes, em que 59,3% eram do sexo masculino e 55,6% ativos. A ventilação voluntária máxima com a Pimáx e Pemáx, apresentaram respectivamente p = 0,04 e 0,02 e r = 0,53 e 0,57. **CONCLUSÃO:** O teste de ventilação voluntária máxima possui uma correlação moderada com a força muscular respiratória, e não obtém correlação com o teste de carga constante.

**PALAVRAS-CHAVE:** Músculos respiratórios. Ventilação voluntária máxima. Voluntários saudáveis.

Submitted 04/21/2020, Accepted 05/14/2020, Published 05/28/2020
J. Physiother. Res., Salvador, 2020 May;10(2):240-247
Doi: 10.17267/2238-2704rpf.v10i2.2886 | ISSN: 2238-2704
Designated editor: Katia Sá

*How to cite this article:* Oliveira FTO, Guimarães J, Ribeiro JR, Oliveira IAA, Costa FAS, Almeida CN et al. Correlation of maximum voluntary ventilation to the strength and resistance of young respiratory muscles. J Physiother Res. 2020;10(2):240-247. doi: 10.17267/2238-2704rpf.v10i2.2886

## Introduction

The evaluation of the performance of the respiratory musculature and the respiratory system involves tests to evaluate both the strength, the resistance of the respiratory muscles, as well as the pulmonary function. These measures guide therapeutic strategies in cardiopulmonary rehabilitation programs and in the high performance environment[1,2].

Among these assessments we have spirometry, which is an accurate and validated test for assessing lung function and diagnosing ventilatory disorders. For the assessment of respiratory muscle strength, the gold standard is the manovacuometry, described since 1999, with the first Neder[3] equation for the prediction value of the Brazilian population, which supports the respiratory assessment in clinical practice until today. It is an equipment with easy access, cost-benefit, precision in relation to the determination of the values of inspiratory pressure (Pimax) and maximum expiratory pressure (Pemax)[4-6].

Maximum Voluntary Ventilation (MVV) is one of the widespread tests in the clinical setting, to assess respiratory muscle resistance, even without being validated for this function. In this measurement, the capacity of the respiratory muscles to mobilize the largest volume of air between 10 and 15 seconds in a maximum voluntary ventilatory effort is evaluated[1,6].

The literature is still controversial regarding the interpretation and applicability of the use of MVV in clinical practice. A study carried out in patients with myotonic muscular dystrophy, who analyzed MVV as a predictor for progression of ventilatory dysfunction. His hypothesis was that MVV is the first parameter of lung function that showed a reduction in the analyzed population. They confirmed the theory, however the voluntary maximum ventilation test still lacks specificity as to its actual assessment of respiratory muscles[7].

In addition, during 12 seconds of breathing with no load, there may not be adequate stress on the respiratory muscles, so the information is limited, and the specificity of the test has not yet been elucidated. Thus, the objective of this study was to verify the correlation between maximum voluntary ventilation and the strength and resistance of respiratory muscles in healthy young people.

## Materials and methods

This is an observational cross-sectional study, which was carried out at the Clinic. Volunteers were recruited in the second half of 2019, using the Snowball method[8]. The study was approved by the ethics committee according to the following CAAE 10849519.9.0000.5544. Individuals who agreed to participate in the collection signed the informed consent form (ICF), according to resolution 466/12. This methodology was guided by STROBE[9].

Individuals over 18 years old, both sexes, healthy, active and sedentary were included. Excluding those who had a ventilatory disorder on a spirometric test (ventilatory restriction or obstruction), history of asthma, smoking and lack of understanding to perform the tests. Participants were instructed not to drink alcohol in the past 24 hours, not to exercise on the day of the exam and to avoid tight clothing that could potentially affect their dynamics during the test[2].

An evaluation form created by the research team was carried out at the first moment, to collect sociodemographic data, practitioner of physical activity and clinical respiratory history, and the results of respiratory tests.

### Assessment of respiratory muscle strength

Respiratory muscle strength was assessed using the Ventbras® analog sport manometer with an operating range of ± 150 cmH2O, which is to obtain the maximum inspiratory pressure (Pimax) and maximum expiratory pressure (Pemax). The rubber tube nozzle with an internal diameter of 32 mm was coupled to a piece of plastic that has a diameter of approximately two mm of leakage, which allowed a small amount of air to escape to prevent any action from the facial muscles. Participants were instructed to remain in a seated position to perform the respiratory movements on the equipment, with the nasal passages occluded by a clip and the lips sealed around the mouthpiece so that no air escapes. The equipment was calibrated and tested to guarantee the reliability of the collected data[3].

Pimax values were obtained by inhaling from the residual volume, repeating at least three times with an interval of one minute between repetitions. The same was true for obtaining Pemax, which occurred through an expiration from total lung capacity. In the Pimax maneuver, the participant kept the mouthpiece in the oral cavity during inhalation and in Pemax during exhalation. The value adopted was the highest in three repetitions for each maneuver, without exceeding 10% of the second highest value, if a fourth maneuver occurred. Manovacuometry was performed by a single evaluator, with standardized verbal instructions, always in the afternoon and in the same place[3].

### Assessment of lung function and maximum voluntary ventilation

The American Thoracic Society (ATS) protocol was used to assess pulmonary function and MVV and the FlowMax Pro Spirometer® was used[2]. The participant followed the instructions to remain in the sitting position, with the nasal route occluded and the lips sealed around the mouthpiece to avoid any air leakage during the test. During the assessment, the participant was instructed to perform a maximum inhalation, followed by a maximum exhalation for at least six seconds. To perform the MVV, the individual was instructed to perform the rapid and forced inspiration and expiration maneuver for 12 seconds. The measurement was repeated twice after a recovery period of at least five minutes, it was considered as it obtained the best performance[1,2]. The participant was informed about the adverse effects (dizziness, cough and fainting) that the VVM technique could bring and if the person felt any of these symptoms, the test was interrupted.

### Assessment of resistance of inspiratory muscles

To assess the resistance of the respiratory muscles, the adapted constant load test was used. The original test is proposed with a load of 70% of Pimáx, however a pilot test was initially carried out, in which it was verified that some volunteers remained at least one minute, so we used the test with a load of 60% previously tested by Ozalp and collaborators[10].

The linear load resistor was used by the POWERBreath® Classic equipment. Initially, the participant warmed up the inspiratory muscles with 30 repetitions at an intensity of 30% of the MIP, followed by a two-minute rest. After this phase, the test started with 60% of Pimax, the volunteer was encouraged to remain breathing under this load if possible. The test was interrupted when the volunteer was no longer able to overcome the resistance imposed by the device[9]. The outcome variable of the test was the time of tolerance of the volunteer breathing under this load, called time limit (Tlim). The respiratory rate was controlled by the researcher through verbal command, encouraging the volunteer to take an inspiration every five seconds[10].

### Statistical analysis

For the analysis of the data, the software Statistical Package for Social Sciences (SPSS) version 14.0 for Windows platform was used. To verify the normality of the numerical variables, descriptive statistics were performed. The variables of symmetrical distribution (age, mass, height, BMI, weekly number of physical activity, Pimáx, Pemáx, FVC, FEV1, PEF and MVV) were presented as mean and standard deviation and asymmetric (time limit) as median and interquartile range. Student's t test was performed for independent samples and Mann-Whitney for the timeout variable. We applied the Pearson correlation coefficient for the association of the variables Pimax, Pemax and MVV.

## Results

The sample consisted of 27 participants, with a higher frequency of males, 59.3% and active individuals, 55.6%. The mean age was 23.4 ± 5.9 years and the BMI 23.6 ± 3.0 kg / m2. The characteristics of the population are shown in Table 1.

**Table 1.** Sociodemographic and anthropometric data of 27 healthy participants. 2019.

| Variables | n | % |
|---|---|---|
| **Gender** | | |
| Male | 16 | 59.3 |
| Female | 11 | 40.7 |
| **Physical activity** | | |
| Active | 15 | 55.6 |
| Sedentary | 12 | 44.4 |
| | **average** | **SD** |
| Age (years) | 23.4 | ± 5.9 |
| Mass (kg) | 68.3 | ±12.2 |
| Height (cm) | 169.6 | ±7.4 |
| BMI (kg/m$^2$) | 23.6 | ±3.0 |

Data expressed as frequency and mean ± standard deviation. SD = standard deviation. BMI = body mass index. Kg = kilogram. Cm = centimeters. Kg / m2 = kilogram per square meter.

All the variables presented, the male gender presented higher average values when compared to the female. Except, in the FEV1 / FVC ratio, % FEV1 and %FVC in which women had the respective means 87.0 ± 5.7, 97.8 ± 5.9, 97.8 ± 5.9 greater than that of men, with no significant p, Table 2.

**Table 2.** Spirometry and manovacuometry data between male and female groups in healthy participants. 2019

| Variables | | Mean | SD | p |
|---|---|---|---|---|
| **FVC** | Mean | 4.5 | ± 0.5 | **<0.001** |
| | Female | 3.5 | ± 0.3 | |
| **% FVC** | Mean | 96.6 | ± 8.1 | 0.69 |
| | Female | 97.8 | ± 5.9 | |
| **$FEV_1$** | Mean | 3.9 | ± 0.4 | **<0.001** |
| | Female | 3.0 | ± 0.3 | |
| **% da $FEV_1$** | Mean | 96.6 | ± 8.1 | 0.69 |
| | Female | 97.8 | ± 5.9 | |
| **$FEV_1$/ FVC** | Mean | 86.4 | ± 4.5 | 0.77 |
| | Female | 87.0 | ± 5.7 | |
| **PEF** | Mean | 8.5 | ± 1.5 | **<0.001** |
| | Female | 6.0 | ± 1.4 | |
| **MVV (L)** | Mean | 132.9 | ± 28.4 | **0.03** |
| | Female | 100.5 | ± 18.8 | |
| **Predicted MVV (L)** | Mean | 164.7 | ± 18.7 | **<0.001** |
| | Female | 131.8 | ± 13.5 | |
| **Pimax ($cmH_2O$)** | Mean | 112.8 | ± 24.9 | 0.20 |
| | Female | 99.5 | ± 27.8 | |
| **Pimax ($cmH_2O$) predicted** | Mean | 136.5 | ± 4.7 | **<0.001** |
| | Female | 99.7 | ± 0.8 | |
| **Pmax ($cmH_2O$)** | Mean | 97.0 | ± 27.8 | **0.02** |
| | Female | 73.6 | ± 17.0 | |
| **Pmax ($cmH_2O$) predicted** | Mean | 146.3 | ± 4.7 | **<0.001** |
| | Female | 104,5 | ± 1.2 | |
| | | **Median** | **I.Q** | |
| **Tlim (seconds)** | Mean | 170.0 | (434.5 – 74.5) | 0.40 |
| | Female | 213.0 | (276 – 74.5) | |

**SD = standard deviation. I.Q: Interquartile range. Pimax: maximum inspiratory pressure. Pmax: maximum expiratory pressure. FVC: forced vital capacity. MVV: maximum voluntary ventilation. FEV1: forced expiratory volume in the first second. M: Male. F: Female. The Student t test was used for independent samples and the Mann Whitney test was used for the Tlim variable.**

Despite the practitioners of physical exercise, FVC, MVV, Pimax and Pemax obtained an average of 4.2 ± 0.7, 130.3 ± 28.3, 121.2 ± 20.7 and 98.3 ± 23,5 respectively. The values were higher when compared to the sedentary ones, presenting statistical significance. Consequently, when analyzing the percentage of FEV1 and the predictions of VVM, the sedentary ones expressed respectively the means 97.9 ± 7.2 and 151.6 ± 23.0. Likewise, in the FEV1 / FVC ratio, sedentary people brought an average of 89.0 ± 5.1 higher than that of the assets. Regarding the time limit, assets had an average higher than 244.4 ± 300.3, but there was no significance, Table 3.

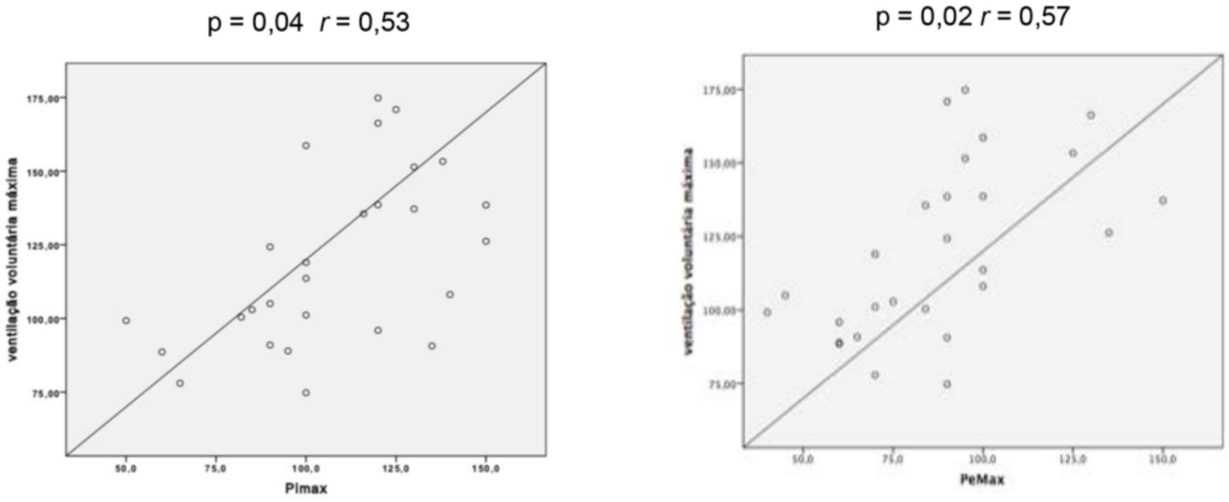
**Table 3.** Spirometric data and manovacuometry in active and sedentary individuals. 2019

| Variables | | Mean | SD | p |
|---|---|---|---|---|
| **FVC** | Active | 4.2 | ± 0.7 | **0.05** |
| | Sedentary | 4.0 | ± 0.7 | |
| **% FVC** | Active | 96.5 | ± 7.3 | 0.06 |
| | Sedentary | 97.9 | ± 7.2 | |
| **$FEV_1$** | Active | 3.6 | ± 0.6 | 0.09 |
| | Sedentary | 3.6 | ± 0.6 | |
| **% $FEV_1$** | Active | 96.5 | ± 7.3 | 0.06 |
| | Sedentary | 97.9 | ± 7.2 | |
| **$FEV_1$/ FVC** | Active | 84.8 | ± 4.1 | **0.02** |
| | Sedentary | 89.0 | ± 5.1 | |
| **PEF** | Active | 8.3 | ± 1.4 | **0.02** |
| | Sedentary | 6.5 | ± 2.0 | |
| **MVV (L)** | Active | 130.3 | ± 28.3 | **0.03** |
| | Sedentary | 106.5 | ± 26.0 | |
| **Predicted MVV (L)** | Active | 151.2 | ± 24.4 | 0.09 |
| | Sedentary | 151.6 | ± 23.0 | |
| **Pimax ($cmH_2O$)** | Active | 121.2 | ± 20.7 | **0.01** |
| | Sedentary | 90.2 | ± 23.0 | |
| **Pimax ($cmH_2O$) predicted** | Active | 123.5 | ± 18.4 | **0.05** |
| | Sedentary | 119.0 | ± 19.7 | |
| **Pmax ($cmH_2O$)** | Active | 98.3 | ± 23.5 | **0.01** |
| | Sedentary | 74.0 | ± 24.0 | |
| **Pmax ($cmH_2O$) predicted** | Active | 131.5 | ± 20.9 | **0.05** |
| | Sedentary | 126.4 | ± 22.2 | |
| | | **Median** | **I.Q** | |
| **Tlim (segundos)** | Active | 136.5 | (378.0 – 26.5) | 0.09 |
| | Sedentary | 232.0 | (271.0 – 135.0) | |

SD: standard deviation. Pimax: maximum inspiratory pressure. Pmax: maximum expiratory pressure. FVC: forced vital capacity. VVM: maximum voluntary ventilation. FEV1: forced expiratory volume in the first second. Tlim: Timeout. *Por the Tlim variable, the Mann Whitney test was used and the others performed a test for independent groups.

When verifying the correlation between MVV with Pimax and Pmax, a moderate correlation was observed, and with statistical significance showing respectively p = 0.04 and 0.02 and r = 0.53 and 0.57, Figure 1.

**Figure 1.** Correlation between Pimax, Pmax and MVV variables in healthy participants. Pearson's correlation. 2019




## Discussion

This research is pioneering with the proposal to test the correlation between the constant load test, the strength of the respiratory muscles and the maximum voluntary ventilation in healthy volunteers. From the analysis of the data, we identified that, maximum voluntary ventilation has a better correlation with the strength of the respiratory muscles than the resistance under a constant load.

The gold standard method for assessing respiratory muscle resistance is maximal isocapnic voluntary hyperpnea. In this method, the volunteer is encouraged to maintain minute volume rates in a closed system that allows to maintain balanced values of carbon dioxide pressure (PCO2)[1,6]. However, this test requires a high-cost device, therefore, it is not very accessible in Brazilian clinical practice. Therefore, MVV is used to infer the resistance and capacity of the ventilatory muscles.

However, from the analysis of the results, it is suggested that the MVV is influenced more by the strength of the respiratory muscles than by the resistance, given that a short-term measure and without the imposition of external load does not constitute a measure of resistance of the muscles respiratory. However, it is not possible to affirm this theory in this study. Since the gold standard test was not performed to assess resistance.

It is important to highlight that in the sample studied, in accordance with the literature[13], there is a high variation in the time limit tolerated by the volunteers breathing under a load of 60% of Pimax. Thus, we highlight the hypothesis that this test is not the most sensitive to identify the low resistance of the respiratory muscles. In this study, we observed that two volunteers interrupted the test due to TMJ pain and one due to difficulty swallowing saliva. These findings were also found by a group of researchers from Brazil, who studied patients with COPD[13]. However, it is necessary to investigate these symptoms, in the researches that apply this method of respiratory assessment.

It is essential to reveal that there was a moderate correlation between the strength of the inspiratory and expiratory muscles with MVV in healthy young people. This finding can be explained by the fact that when performing the test, the individual is instructed to mobilize a large amount of air in a short period of time[1,6]. In this way, not only resistance fibers are recruited, but mainly fibers from the type II14, making MVV a test more associated with muscle power than endurance.

In relation to sex and the variables of lung function and respiratory muscle strength, the male gender had higher averages, when compared to women. These findings are attributed to greater muscle mass, greater number of alveoli and lower resistance of the male airways[15]. The increase in the resistive load in women is explained by the geometric difference of the airways between genders, resulting in greater oxygen consumption of the muscles in women[14,15].

When comparing active individuals with sedentary ones, it was proven that the active individuals had higher MVV and muscle strength. In another study, Oliveira et al.,16 did not corroborate the results regarding respiratory muscle strength. This discrepancy can be explained by the sample size applied in the current study, in addition to the predominance of males, with higher averages when associated with women.

The limitations come from the resistance assessment method, as the gold standard test was not used. Thus, the constant load test should be interpreted with caution.

## Conclusion

The maximum voluntary ventilation test has a moderate correlation with respiratory muscle strength and has no correlation with the constant load test. In addition, further studies are needed to propose to analyze other respiratory muscle resistance tests that are easily accessible and useful in clinical practice.

### Acknowledgements

This project was funded by the Bahia Research Support Foundation (FAPESB), linked to the Bahiana Cardiovascular and Respiratory Physiotherapy Research Group.

### Author contributions

Oliveira FTO participated in the research supervision, conception and design, search and statistical analysis of the research data, data collection, interpretation of results, writing of the manuscript, and review of the scientific article. Santos JG participated in the conception, design, search and statistical analysis of the research data, data collection, interpretation of results, writing of the manuscript and review of the scientific article. Dias CMCC participated in the research orientation, group coordination, study design and conception, search and statistical analysis of the research data, data collection, interpretation of results, writing of the manuscript and review of the scientific article. Ribeiro JR participated in data collection, interpretation of results, presented important suggestions, and reviewed the scientific article. Costa FAS participated in the data collection and presented suggestions for the research. Oliveira IAA participated in data collection, interpretation of results, presented important suggestions and drafted the scientific article. Almeida CN participated in the data collection and presented important suggestions.

### Competing interests

No financial, legal or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

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