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MAXIMAL RESPIRATORY PRESSURES: ACTUAL AND PREDICTED VALUES IN HEALTHY SUBJECTS

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ABSTRACT

Objective: To compare actual values for maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) found in a sample of healthy individuals from the State of Minas Gerais (Brazil) with the values predicted from the equations put forward by Neder et al.[3]. Method: Using an analog manovacuometer, 100 healthy subjects (54 women and 46 men aged 20-80 years old) were studied. Statistical analysis was performed using parametric or non-parametric tests, depending on the distribution of the variables, and $p< 0.05$ was considered to be significant. Results: For MIP in women, the mean of the actual values was significantly lower than the mean of the predicted values (68.24 ± 29.48 vs. 86.53 ± 8.76; $p= 0.000$) and there was a moderate and significant correlation ($r= 0.557$; $p< 0.000$). For MIP in men, no significant difference was observed between the actual and predicted values (104.67 ± 42.66 vs. 116.78 ± 14.02; $p= 0.055$) and there was a low and non-significant correlation ($r= 0.236$; $p= 0.115$). For MEP in women, there was no significant difference between the actual and predicted values (80.37 ± 33.32 vs. 85.88 ± 10.90; $p= 0.164$) and there was a low and non-significant correlation ($r= 0.149$; $p= 0.283$). For MEP in men, the mean of the actual values was significantly higher than the mean of the predicted values (142.28 ± 43.89 vs. 126.30 ± 14.19; $p= 0.017$) and there was a low and non-significant correlation ($r= 0.159$; $p= 0.290$). Conclusion: Considering that concordance between actual and predicted values requires the lack of difference and the existence of correlation between them, the equations proposed by Neder et al.[3] were not successful in predicting MIP and MEP values in the population studied.

Key words: maximal respiratory pressures; respiratory muscles; predictive equations; lung.

RESUMO

Pressões Respiratórias Máximas: Valores Encontrados e Preditos em Indivíduos Saudáveis

Objetivo: Comparar os valores encontrados de pressões respiratórias máximas (pressão inspiratória máxima-PImáx e pressão expiratória máxima-PEmáx) em uma amostra de indivíduos saudáveis de Minas Gerais com valores preditos pelas equações propostas por Neder et al.[3]. Métodos: Por meio de um manovacuômetro analógico, foram estudados 100 indivíduos saudáveis (54 mulheres, 46 homens), com idade entre 20-80 anos, recrutados no estado de Minas Gerais - Brasil. A análise estatística foi realizada com testes paramétricos ou não-paramétricos, dependendo da distribuição das variáveis, considerando significativo $p< 0,05$. Resultados: PImáx em mulheres: a média dos valores encontrados foi significativamente menor que a média dos preditos (68,24 ± 29,48 x 86,53 ± 8,76; $p= 0,000$) e houve correlação de moderada magnitude e significativa ($r= 0,557$; $p< 0,000$); PImáx em homens: não houve diferença significativa entre os valores encontrados e preditos (104,67 ± 42,66 x 116,78 ± 14,02; $p= 0,055$) e houve correlação de baixa magnitude e não significativa ($r= 0,236$; $p= 0,115$); PEmáx em mulheres: não houve diferença significativa entre os valores encontrados e preditos (80,37 ± 33,32 x 85,88 ± 10,90; $p= 0,164$) e houve correlação de baixa magnitude e não significativa ($r= 0,149$; $p= 0,283$); PEmáx em homens: a média dos valores encontrados foi significativamente maior que a média dos preditos (142,28 ± 43,89 x 126,30 ± 14,19; $p= 0,017$) e houve correlação não significativa de baixa magnitude ($r= 0,159$; $p= 0,290$). Conclusão: Considerando que para haver concordância entre os valores encontrados e preditos é preciso não haver diferença e haver correlação entre os valores, as equações propostas por Neder et al.[3] não foram capazes de predizer os valores de PImáx e PEmáx na população estudada.

Palavras-chave: pressões respiratórias máximas; músculos respiratórios; equações preditivas; pulmão.

INTRODUCTION

Respiratory muscle strength can be directly evaluated by means of static measurements such as Maximal Respiratory Pressures[1-3] or inferred from a dynamic maneuver such as Maximal Voluntary Ventilation[3].

The measurement of maximal static respiratory pressure is a relatively simple, rapid and non-invasive test which consists of two measures. Maximal inspiratory pressure (MIP) is an index of inspiratory muscle strength, and maximal expiratory pressure (MEP) is an index of expiratory muscle strength. MIP and MEP are respectively the greatest pressure that can be generated during maximal inspiration and expiration against a blocked airway[3-5]. Both can be measured by a manovacuometer, a classic instrument used to gauge the respiratory muscle strength at the mouth. MIP and MEP values depend not only on the strength of the respiratory muscles, but also on the pulmonary volume in which the measurements are collected as well as on the corresponding value of the elastic retraction pressure of the respiratory system. However, the measurement of maximal respiratory pressures also depends on the individual's understanding of the maneuvers to be performed and their willingness to cooperate and perform truly maximal respiratory efforts[5].

MIP and MEP can be used to quantify respiratory muscle strength in healthy individuals of all ages, in patients with several types of disorders, as well as to evaluate the response to respiratory muscular training[5-10].

In 1969, Black and Hyatt[7] described the method used to evaluate respiratory muscle strength. These authors carried out a study involving 120 healthy individuals of both genders, aged 20 to 86, and determined the values for maximal respiratory pressure and reference equations for the healthy population, taking into account gender and age. After this first study, various authors evaluated MIP and MEP among healthy individuals from different age groups, in different parts of the world, and published their findings as reference values[7,11,12] or predictive equations[3,7,8,13-15] for the calculation of maximal respiratory pressures.

According to the revised literature, Camelo Jr et al[11] were the first to describe MIP and MEP values for a sample of the Brazilian population in Ribeirão Preto, in the state of São Paulo, in 1985. They evaluated 60 healthy individuals of both genders, aged 20 to 49. In 1999, Neder et al.[3] evaluated 100 healthy individuals of both genders, aged 20 to 80, in the state of São Paulo. By means of multiple regression analysis, these authors were the first to develop dependent predictive equations for gender and age for MIP and MEP based on a sample of the Brazilian population.

We have found no published studies on the applicability of predictive equations in a wide-range age group sample of individuals from the state of Minas Gerais. Thus, the object of this study was to compare the maximal respiratory pressure values found among healthy individuals from Minas Gerais with those predicted by the equations put forward by Neder et al.[3].

MATERIALS AND METHODS

One hundred and three individuals (47 males and 56 females) were recruited in the cities of Belo Horizonte, Itabira, and Sete Lagoas. The criteria for inclusion were: individuals aged 20 to 80[3]; body mass index ranging from 18 to 29.9 (kg/m^2)[16], no present[3,17] or past history of smoking[5,17]; no evident thoracic deformities (*pectus carinatum* or *pectus escavatum*)[5]; no reports of neuromuscular, respiratory or cardiac pathologies[3,5,17]; no fever (in the past three weeks)[3,5,17], influenza and/or a cold during the week prior to the treatment[5]; no use of oral corticoids[14], central nervous system depressants, barbiturates[14], or muscle relaxants[13,14]; no performance of strenuous physical activity in the previous 12 hours and no ingestion of a full meal in a period shorter than three hours prior to the testing procedures[3,17]. The criteria for exclusion were: inability to understanding and/or perform the procedures.

The procedures of this study were approved by the Institution's Committee for Ethics in Research (Approval ETIC 502/04) and all individuals signed a written informed consent. The individuals were recruited according to their age group (20-29, 30-39, 40-49, 50-59, 60-69, 70-80) and gender, with a stratification in subgroups, totaling 12 strata, similarly to the study carried out by Neder et al.[3]. The individuals underwent an initial evaluation and were then measured for maximal respiratory pressures.

There was an interview consisting of standardized questions related to lifestyle habits and previous and/or current illnesses, based on the guidelines for pulmonary function tests[5].

Next, the short form of the International Physical Activity Questionnaire – IPAC (version 8) was applied,[18] with the aim of classifying each participant's level of physical activity. This questionnaire was validated for the Brazilian population by Matsudo et al.[18] in 2001. The individuals were classified into sedentary, insufficiently active, active, and very active groups as to the type, duration and frequency of their physical activity.

Weight was measured using a portable scale, and height was measured with a manual tape measure. Both were verified by means of a calibrated scale (Filizola Ind. Ltda, SP, Brazil). Based on these data, the body mass index was calculated through the formula [BMI = weight (kg) / height^2 (m)][16].

MIP and MEP measurements were taken with a manovacuometer with an operational interval of ± 300

cmH_2O (GeRar®, São Paulo, Brazil). The manovacuometer was connected to a plastic trachea measuring 16 centimeters in length by 2.4 centimeters in internal diameter. One end of the trachea was connected to a hard plastic mouthpiece. The device was calibrated before the beginning of the study according to recommendations by INMETRO (National Institute of Metrology, Standardization and Industrial Quality), by means of a gradual application of pressure and vacuum until the limit set by the manufacturer was reached. It should be noted that a more reliable method could have been used, such as water or mercury column calibration. However, after data collection, the equipment was sent out once again for calibration, which was deemed unnecessary according to technicians. Before each test, the pointer was checked to see if it marked zero and, if necessary, the pointer screw was adjusted.

In 1994, Hamnegard et al.[19] evaluated maximal respiratory pressures in healthy individuals and respiratory illness patients. The authors compared the measurements taken with a portable manometer with those obtained with a pressure transducer, considered the gold standard, and did not find significant differences, which attests to the precision and reproducibility of the portable manometer. In 1999, McConnell et al.[1] showed that the coefficient of variation was 10.2% and 12.8% for MIP and MEP respectively in healthy senior citizens, which shows an acceptable reproducibility.

In this study, the values found for MIP and MEP were compared to those predicted by the equations of Neder et al.[3] given below:

MIP - Women: y= -0.49 (age) + 110.4; standard error of the estimate = 9.1

- Men: y= -0.80 (age) + 155.3; standard error of the estimate = 17.3

MEP - Women: y= -0.61 (age) + 115.6; standard error of the estimate = 11.2

- Men: y= -0.81 (age) + 165.3; standard error of the estimate = 15.6

For each parameter, the inferior and superior normality thresholds were obtained by subtracting or adding respectively the product from the value predicted by the equation (1.645 x standard error of the estimate)[5].

Maximal respiratory pressure measurements were taken with the individuals in a seated position, wearing a nose clip and keeping a mouthpiece held firmly between the lips. Firstly, two learning maneuvers were performed[3]. The evaluation was considered complete when the individual was able to produce three acceptable measurements, out of which at least two were reproducible[5]. The last value found could not be greater than the others[3,5]. The maneuvers considered acceptable were those which did not present air leakage and which sustained pressure for at least one second[3], and the measurements considered reproducible were those with a variation less than or equal to 10% of the greatest value[3,5]. There was a 1-minute interval between the measurements, and the greatest value among the reproducible maneuvers was selected for analysis[3,5].

For MIP measurement, the individuals exhaled into the mouthpiece until residual volume and then generated a maximal inspiratory effort against a blocked airway[3,5]. For MEP, the individuals inhaled through the mouthpiece until they reached their total lung capacity and then generated a maximal expiratory effort against a blocked airway[3,5]. During the last measurement, the individuals held their lower facial muscles with their hands in order to avoid leakage and the accumulation of air in the lateral part of the oral cavity[3].

The procedure was carried out by three testers. To minimize possible interferences in the heterogeneity of the samples, we analyzed inter-tester reliability for MIP and MEP by studying the data of five volunteers, following the recommendations of the statistical advisors. For this analysis, two complementary tests were used: the testers' coefficient of variation of the means, and the intraclass correlation coefficient (ICC)[20].

The coefficient of variation was used to test the hypothesis of equality of the mean responses among testers. A coefficient of variation lower than 0.25 was considered suitable. The coefficient observed was 0.032 and 0.037 for MIP and MEP, respectively, which shows that the testers obtained very similar results.

The ICC was used to evaluate the correspondence among the measurements taken by the several testers. The observed ICC was 0.89 for MIP and 0.83 for MEP, which indicates a strong agreement among them, as an ICC equal to or greater than 0.80[20] reveals a strong tester agreement.

Statistical analysis

The data were expressed as mean ± standard deviation. The Kolmogorov-Smirnov normality test was used to check data distribution. In order to compare the mean values for maximal respiratory pressure obtained in this study with the values predicted by means of the equations proposed by Neder et al.[3], we used the paired Student t-test when distribution was normal, and the Wilcoxon test when distribution was different from normal. To verify the association between these values, the Pearson correlation coefficient or Spearman correlation coefficient was used, depending on the type of distribution of the variable[20].

A p value less than 0.05 was considered statistically significant.

Table 1: Data from 100 subjects according to hometown. At the top, demographic and anthropometric data (mean ± standard deviation); at the bottom, distribution by age group.

	Belo Horizonte	**Itabira**	**Sete Lagoas**
Variables		*Men*	
Age (years)	47.47 ± 17.78	49.00 ± 18.85	48.00 ± 17.12
Weight (kg)	70.67 ± 6.68	71.70 ± 7.94	70.06 ± 8.84
Height (m)	1.70 ± 0.08	1.67 ± 0.07	1.69 ± 0.07
Body Mass Index (kg/m^2)	24.42 ± 2.33	25.71 ± 2.58	24.32 ± 2.92
		Women	
Age (years)	48.67 ± 18.08	48.17 ± 18.79	49.33 ± 17.77
Weight (kg)	60.11 ± 7.25	59.50 ± 8.77	56.21 ± 10.37
Height (m)	1.59 ± 0.06	1.57 ± 0.06	1.57 ± 0.08
Body Mass Index (kg/m^2)	23.83 ± 3.05	24.14 ± 3.15	22.59 ± 2.77
Age Groups		*Men*	
20-29 years	3	3	3
30-39 years	3	2	2
40-49 years	2	2	3
50-59 years	3	2	3
60-69 years	2	3	3
70-80 years	2	3	2
Total	15	15	16
		Women	
20-29 years	3	3	3
30-39 years	3	3	3
40-49 years	3	3	2
50-59 years	3	3	3
60-69 years	3	3	4
70-80 years	3	3	3
Total	18	18	18

RESULTS

Of the 103 individuals recruited, three were excluded (two due to inability to perform the experiments and one for reaching MEP values greater than 300 cmH_2O). One hundred individuals were studied (46 males and 54 females). Table 1 describes the demographic and anthropomorphic data of the sample, and shows the distribution according to gender, age, and hometown. According to the IPAC classification, 54% were classified as sedentary or insufficiently active, and 46% as active or very active.

Actual vs. predicted values

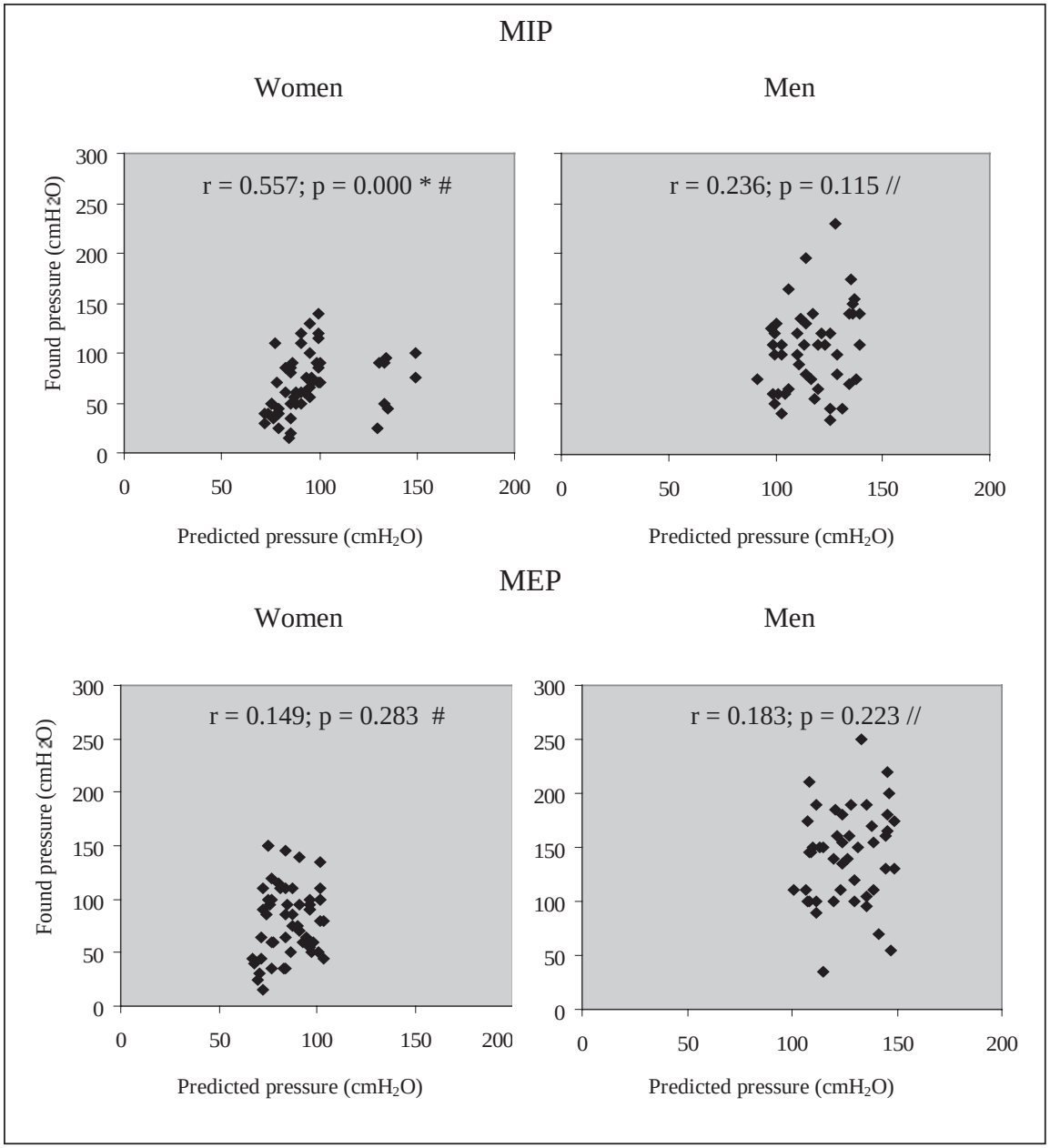
Table 2 presents actual MIP and MEP values and those predicted by the equations of Neder et al.[3]. The data were presented separately for men and women and expressed in cmH_2O. Actual MIP values for women were significantly lower than the ones predicted. When comparing MIP values for men, we found no significant difference between predicted and actual values. Comparisons between actual and predicted MEP values for the female group did not differ significantly. The actual MEP values for the male group were significantly greater than the predicted values.

Figure 1 shows diagrams representing the dispersion of the MIP and MEP data, both actual values and those predicted by the equations proposed by Neder et al.[3]. The data were presented separately for men and women and

Table 2: Actual maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) values and those predicted by Neder's equations.

Maximal respiratory pressures	Actual values	Predicted values	p value
MIP (cmH2O)			
Women	68.24 ± 29.48	86.53 ± 8.76	0.000 * #
Men	104.67 ± 42.66	116.78 ± 14.02	0.055 //
MEP (cmH2O)			
Women	80.37 ± 33.32	85.88 ± 10.90	0.164 #
Men	142.28 ± 43.89	126.30 ± 14.19	0.017 * //

Data are presented as mean ± standard deviation, * refers to p< 0.05, estimated by Wilcoxon test (#) or paired t test (//).



* refers to p< 0.05, estimated by Spearman (#) or Pearson (//) correlation coefficients.

Figure 1: Correlations between actual maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) values and those predicted by Neder's equations.

expressed in cmH_2O. Both the actual and the predicted MIP values for the female group presented an association of moderate magnitude and significant with the predicted values. The actual and the predicted MIP values in the male group presented a low-magnitude, non-significant association. The analysis of the MEP values in the male and female groups presented a low-magnitude, non-significant correlation between the predicted values and the ones actually found.

In addition to that, we carried out an analysis of the percentage of the individuals who presented values within the predicted normality range, indicating the percentage of individuals who fell into the lower or upper limit, according to the equations proposed by Neder et al.[3]. The values for MIP and MEP were analyzed separately for men and women. As regards MIP values for the female group, 68.52% were below the lower limit; 22.22%, within the predicted range, and 9.26%, above the upper limit; as for the male group, 35.30% were below the lower limit; 56.00%, within the predicted range, and 8.70%, above the upper limit. Concerning MEP values in the female group, 35.19% were below the lower limit; 40.74%, within the predicted range, and 24.07%, above the upper limit; in the male group, 14.00% were below the lower limit; 43.00%, within the predicted range, and 43.00%, above the upper limit.

DISCUSSION

In this study, the actual MIP and MEP values were compared to the values predicted by the equations put forward by Neder et al.[3]. The main results observed were: 1 - The mean of the MIP values found in the female group was significantly lower than the mean of the predicted values, and these were correlated with moderate magnitude and in a significant way; most individuals presented values that lay outside the predicted range. 2- The actual and predicted MIP values in men did not present a significant difference, being of low-magnitude, non-significant correlation; 56% of the individuals presented values within the predicted range. 3- The actual and predicted MEP values in women did not present a significant difference, being of low-magnitude, non-significant correlation; most individuals presented values outside the predicted range. 4- The average of the actual MEP in men was significantly higher than the predicted mean; actual and predicted values had low-magnitude, non-significant correlation; most individuals presented values outside the predicted range.

Considering that the agreement between the actual and predicted values hinges on the inexistence of difference between the values, as well as on their correlation, the equations proposed by Neder et al.[3] were not capable of predicting the MIP and MEP values for the studied population. The analysis of the percentage values which were inside or outside the normality range corroborates this statement, since most of the individuals evaluated did not show values within the predicted range. Although 56% of the men evaluated presented MIP values within the predicted range, this percentage does not seem sufficient to prove that the equation is able to adequately predict MIP values for men.

Thus, it is necessary to reflect on some points. In 2002, the Brazilian Society of Pneumology and Tisiology[21] published a consensus on pulmonary function tests which reported that the great discrepancy among the reference values of maximal respiratory pressures provided by tables and equations can be attributed to the different processes used for the selection of samples, to the small size of some samples, and to the different equipments and techniques. The American Thoracic Society and the European Respiratory Society[22] reported that the variations between the MIP and MEP values reported by several authors presumably indicates differences among the groups studied and in the way the tests were carried out and measured. Bruschi et al.[23] described that in the past twenty years different studies on maximal respiratory pressure were published and they displayed a great variability in the results. These authors reported that the variability could be attributed to the different methodologies used, as well as the kind of mouthpiece, number of maneuvers performed, body position, and differences inherent to the studied populations.

The size of the sample is indicated as one of the factors responsible for the discrepancy observed in the maximal respiratory pressure values.[21] One hundred healthy individuals took part in this study (46 males and 54 females). This way, the number of individuals, as well as their age group (20 to 80) were similar to those found in the research developed by Neder et al.[3].

The criteria for sampling may influence the variability of MIP and MEP values[21]. There was a small difference in the sample selection criteria in this study compared to the one developed by Neder et al.[3], who studied a randomized sample of a population of 8,226 individuals from Universidade Federal de São Paulo, not including students and doctors. No voluntary participation was accepted. Our subjects were recruited in three different cities (Belo Horizonte, Itabira, and Sete Lagoas), and the individuals did not belong to a specific institution, which may be regarded as a limitation of the study. The process of sample selection did not follow randomization criteria, which interfered in the generalization of the results.

Another difference in the sample selection of the two studies is related to the classification of the healthy subjects. The individuals in the study by Neder et al.[3] underwent spirometry and cardiovascular evaluation to confirm the absence of heart or respiratory disorders, respectively. The individuals in our study were classified as healthy according

to their self-reports, followed by standardized questions based on the guidelines for pulmonary function tests[21]. Although the individuals studied were non-smokers or ex-smokers with normal body mass index, and although a standardized questionnaire was used to identify the presence of any pathology, the subjects were not evaluated objectively by the spirometry, which made it impossible to guarantee that all individuals with possible cardiopulmonary diseases were excluded.

Differences in the equipments used to evaluate the maximal respiratory pressures may generate discrepancies in the values observed by different authors[21]. In this study, MIP and MEP were assessed with an equipment similar to the one used by Neder et al.[3], i.e., aneroid manometers with an operational interval of ± 300 cmH_2O. Nevertheless, in the present study we used a device without an escape valve, which may be deemed a limitation. The escape valve is considered an important element in manovacuometry and its lack or presence may influence the measured values.

The way the tests were carried out and measured may also influence the MIP and MEP values[21,22]. No differences were observed between this study and the one developed by Neder et al.[3] as regards the kind of mouthpiece and body position. However, the number of maneuvers used to obtain the MIP and MEP values varied. In the study by Neder et al.[3], the individuals performed from three to five acceptable and reproducible maneuvers. In our study, the measurements of the maximal respiratory pressures were taken according to the guidelines set by the Brazilian Society of Pneumology and Tisiology[5].

Neder et al.[3] concluded that age and gender coud explain 40 to 50% of the respiratory muscle strength variability of the population studied. In spite of that, these authors described the need for equations to be validated in other samples of the adult Brazilian population. The fact that the equations put forward by Neder et al.[3] could only explain 40-50% of the respiratory muscle strength variability can also have contributed to the discrepancy observed between the predicted and actual values.

Our results suggest that the equations proposed by Neder et al.[3] were not able to consistently predict the MIP and MEP values in the population studied, since no agreement between the predicted and actual values was observed. Thus, this study reinforces the recommendation by the Brazilian Society of Pneumology and Tisiology concerning the need for studies related to the parameters of pulmonary function, including maximal respiratory pressures, with the intention of setting reference values for the populations from the different regions of Brazil[21].

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