ORIGINAL RESEARCH

Comparison of measured and predicted values for maximum respiratory pressures in healthy students

Comparação dos valores medidos e previstos de pressões respiratórias máximas em escolares saudáveis

Comparación de los valores medidos y previstos de presiones respiratorias máximas en escolares sanos.

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ABSTRACT | Respiratory Muscle Strength is an important tool to diagnose different disorders. Reference equations considered different populations and methodologies. However, there is no agreement on what is the ideal equation to use. The aim of this study was to compare and correlate the measured values of maximal respiratory pressures with those demonstrated by equations described in literature. The sample consisted of 90 healthy individuals aged from 6 to 12 years old. Anthropometric, spirometric and manometric measurements were performed. The comparison between measured and predicted values was significantly different, showing the mean male maximum inspiratory pressure (MIP) (80.65±26.78) to be higher than that predicted by Wilson et al. (67.40±5.65, p<0.001) and Schmidt et al. (70.69±21.70, p<0.05). The mean male maximum expiratory pressure (MEP) (84.35±23.16) was lower than the one predicted by Domènech-Clar et al. (92.25±16.90, p<0.01) and higher than the one predicted by Schmidt et al. (72.78±13.62 p<0.001). The mean of female individuals' MIP (76.14±26.08) was higher than that predicted by Wilson et al. (57.96±6.04, p<0.001), Schmidt et al. (68.54±7.08, p<0.01), and Domènech-Clar et al. (67.61±11.17, p<0.01). The mean female MEP (74.55±20.05) was higher than the ones predicted by Wilson et al. (66.65±9.55, p<0.001) and lower than the one predicted by Domènech-Clar et al. (81.16±14.37, p<0.01). The correlations between measured and predicted values were from low to medium magnitude (range r=0.1 to 0.5) being significant for males when MIP was correlated with that predicted by Wilson et al. (p<0.01) and Domènech-Clar et al. (p<0.05). For females, both correlations were significant (MIP p<0.01; MEP p<0.05). It was concluded that the equations failed to predict the values of maximum respiratory pressures, reinforcing the need for new equations of respiratory muscle strength.

Keywords | muscle strength; reference values; respiratory muscles.

RESUMO | A Força Muscular Respiratória é uma ferramenta capaz de diagnosticar diferentes desordens. As equações de referência até hoje descritas consideram diferentes populações e metodologias. Entretanto, não há consenso quanto a qual equação é ideal para se utilizar. O objetivo deste estudo foi comparar e correlacionar valores medidos de pressões respiratórias máximas com aqueles previstos por equações descritas na literatura. A amostra foi de 90 indivíduos saudáveis de 6 a 12 anos. Foram realizadas antropometria, espirometria e manovacuometria. A comparação dos valores medidos e previstos diferiu significativamente, apresentando pressão

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Presentation: Nov. 2012 – Accepted for publication: Aug. 2013 – Financing source: none – Conflict of interests: nothing to declare – Approval at the Ethics Committee n. 0063.0.203.000-10.

inspiratória máxima (PImáx) média (80,65±26,78), no sexo masculino, maior que a prevista por Wilson et al. (67,40±5,65; p<0,001) e Schmidt et al. (70,69±21,70; p<0,05). Pressão expiratória máxima (PEmáx) masculina média (84,35±23,16) foi menor que a prevista por Domènech-Clar et al. (92,25±16,90; p<0,01) e maior que a prevista por Schmidt et al. (72,78±13,62; p<0,001). Pressão inspiratória máxima feminina média (76,14±26,08) foi maior que a prevista por Wilson et al. (57,96±6,04; p<0,001), Schmidt et al. (68,54±7,08; p<0,01) e Domènech-Clar et al. (67,61±11,17; p<0,01). Pressão expiratória máxima feminina média (74,55±20,05) foi maior que a prevista por Wilson et al. (66,65±9,55; p<0,001) e menor que a prevista por Domènech-Clar et al. (81,16±14,37; p<0,01). As correlações entre valores medidos e previstos foram de baixa a média magnitude (variação entre r=0,1 e 0,5), sendo significativas para o sexo masculino quando a PImáx foi correlacionada à prevista por Wilson et al. (p<0,01) e Domènech-Clar et al. (p<0,05). Já para o sexo feminino, ambas as correlações foram significativas (PImáx p<0,01; PEmáx p<0,05). Concluiu-se que as equações não conseguiram predizer os valores de pressões respiratórias máximas, reforçando a necessidade de novas equações de força muscular respiratória.

Descritores | força muscular; valores de referência; músculos respiratórios.

RESUMEN | La Fuerza Muscular Respiratoria es una herramienta capaz de diagnosticar diferentes desórdenes. Las ecuaciones de referencia hasta hoy descritas consideran diferentes poblaciones y metodologías. Entre tanto, no hay consenso en cuanto a que ecuación es ideal para utilizar. El objetivo de este estudio fue comparar y correlacionar valores medidos de presiones respiratorias máximas con aquellos previstos por las ecuaciones descritas en la literatura. La muestra fue de 90 individuos sanos de 6 a 12 años. Fueron realizadas antropometría, espirometría y manovacuometría. La comparación de los valores medidos y previstos difirió significativamente, presentando presión inspiratoria máxima (PImáx) media (80,65±26,78) , en el sexo masculino, mayor que la prevista por Wilson et al. (67,40±5,65; p<0,001) y Schmidt et al. (70,69±21,70; p<0,05). Presión expiratoria máxima (PEmáx) masculina media (84,35±23,16) menor que la prevista por Domènech-Clar et al. (92,25±16,90; p<0,01) y mayor que Schmidt et al. (72,78±13,62; p<0,001). Presión inspiratoria máxima femenina media (76,14±26,08) mayor que la prevista por Wilson et al. (57,96±6,04; p<0,001), Schmidt et al. (68,54±7,08; p<0,01) y Domènech-Clar et al. (67,61±11,17; p<0,01). Presión expiratoria máxima femenina media (74,55±20,05) mayor que la prevista por Wilson et al. (66,65±9,55; p<0,001) y menor que Domènech-Clar et al. (81,16±14,37; p<0,01). Las correlaciones entre valores medidos y previstos fueron de baja a media magnitud (variación entre r=0,1 y 0,5) siendo significativas para el sexo masculino cuando la PImáx fue correlacionada a la prevista por Wilson et al. (p<0,01) y Domènech-Clar et al. (p<0,05). Para el sexo femenino, ambas correlaciones fueron significativas (PImáx p<0,01; PEmáx p<0,05). Se concluyó que las ecuaciones no consiguieron predecir los valores de presiones respiratorias máximas, reforzando la necesidad de nuevas ecuaciones de fuerza muscular respiratoria.

Palabras clave | fuerza muscular; valores de referencia; músculos respiratorios.

INTRODUCTION

Respiratory Muscle Strength is defined as the maximum respiratory pressure measured orally and attributed to an effort to generate pressure alterations[1,2]. It is measured by assessing the pressure after forced inspiration and expiration, thus characterizing the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP), which indicates the strength of inspiratory and expiratory muscles, respectively.

The use of a manuvacuometer was described by Black e Hyatt in 1969 as a simple, inexpensive and noninvasive method[3,4]. This is a diagnostic method[5] which provides guidance to execute the respiratory muscle endurance training protocol[6].

When pressures are different from their predicted values, there is possibly a weakness associated with mechanical disadvantage, thus generating endurance deficit, and inefficacy in coughing and expectorating secretions[7].

In order to obtain respiratory pressure values, it is necessary to compare the measured values with those predicted for a population, considering the age group. Several factors influence these values, such as age, gender, nutritional status, and anthropometric and spirometric variables. However, there is great diversity between the reference values found in literature, and this is due to the different sample selection criteria, equipment, techniques and population[8,9].

According to the review published by Freitas et al., a few studies provide reference equations to predict respiratory muscle strength for healthy children and adolescents[10]. Among the ones that provide predictive equations, there are: Wilson et al.[11], who used weight and age as variables in MIP and MEP equations, respectively, for both genders[11], who used weight, height and age[12]. Besides these ones, which are described in literature, Schmidt et al.[13] published an equation for the Brazilian population which uses variables such as age and height[13].

Therefore, considering there is no consensus concerning the use of predictive equations of respiratory strength, the objective of this study was to test the efficacy of the equations mentioned in literature, such as the ones established by Wilson et al.[11], Domènech-Clar et al.[12] and Schmidt et al.[13], by comparing and correlating their predictive values with values measured in a population of healthy children and adolescents.

METHODOLOGY

The sample consisted of 90 students aged between 6 and 12 years old, who practiced regular physical activities, with eutrophic body mass index, non-smokers, without chest wall deformities or pulmonary disease, and normal pulmonary function. The informed consent form was signed by parents or adults in charge. Individuals with chronic diseases, cognitive deficit, rheumatic or cardiovascular disorders, chronic pneumopathies, acute exacerbation and controlled medication were excluded.

All of the volunteers were enlightened as to the study according to resolution n. 196/96 of the National Health Council. The study was approved by the Research Ethics Committee of *Universidade Federal de Minas Gerais* (UFMG), protocol n. 0063.0.203.000-10, and data collection began after the protocol was approved and the informed consent form was signed. Afterwards, adults in charge and participants were scheduled for an interview, when anamnesis was conducted. At the end of the study, adults in charge returned to the school for a feedback regarding the results.

Aiming to characterize the studied population, all of the participants were submitted to an evaluation of the respiratory system, anthropometric measurement (weight, height[14], arm circumference and triceps skinfold[15,16]), analysis of pulmonary function[17,18], and respiratory muscle strength.

For spirometry, a spirometer of the VITATRACE VT 130 brand was used, which traced forced expiratory curves and basal respiratory cycles, from which values regarding pulmonary functions were determined according to the standardization by the American Thoracic Society (ATS). The considered acceptance criteria of forced vital capacity (FVC) and reproducibility were: satisfactory beginning of the test, with retro-extrapolation volume lower than 5% of the FVC or 150 mL[17].

In order to measure muscle strength, a portable manovacuometer was used (GER-AR), graded from -300 to +300 cmH_20, in the sitting position, with the trunk placed 90º in relation to the hips, supported upper limbs and nose clip. For MIP, the participant performed maximum inspiration from the residual volume (RV), and, to measure MEP, maximum expiration starting from the total pulmonary capacity (TPC). There were five maneuvers, with the registration of peak pressure values, without leakage, with effort sustained for two seconds. An interval of thirty seconds took place between maneuvers, and there were two minute intervals between MIP and MEP. The difference between maneuvers could not surpass 5%. Out of the five maneuvers, the first and the last ones were ruled out, so there was an average of the three remaining maneuvers[3].

The distribution of samples was verified by the Kolmogorov-Smirnov and/or Shapiro Wilk test. According to distribution, at first the unpaired *t*-test was used to compare genders in relation to mean values of variables. In order to compare the means of measured manometric values and those predicted in literature, the *post-hoc* Student Newman Keuls (SNK) analysis of variance (ANOVA) was used. Pearson's correlation coefficient was used to measure the correlation between measured and predicted values by the reference equations. The considered significance level was 5%.

RESULTS

Out of the 90 students, 51.1% (n=46) were males and 48.9% (n=44) were females, with mean age of 8.71±1.62 for the male gender; and 8.88±1.99 for the female gender, so there were no differences in general age, not even among the variables when genders were compared, except for MEP (p=0.0349) (Table 1).

Table 2 compares the methodology used in this study with that from the authors Wilson et al.[11], Schmidt et al., and Domènech-Clar et al.[12]

Wilson et al.[11] are the only ones who did not use a nose clip. Besides, the age group was similar to the one used by Domènech-Clar et al.[12] The methodology by Schmidt et al. was similar to the one in this study, since it worked with a larger sample and conducted the longest time of sustaining effort (two seconds). Domènech-Clar et al.[12] Obtained the highest number of maneuvers and correlated more independent variables, except when compared to this study.

Figure 1 illustrates the comparisons between measured and predicted valus of MIP and MEP among males, represented by Figures 1A and B, and, for females, represented by Figures 1C and D.

In the male gender (Figure 1A), MIP measured values were different from the predicted values, and the measured ones ($p<0.0001$), as well as those by Domènech-Clar et al.[12] ($p<0.05$) were superior to the values found by Wilson et al.[11]; the measured values were higher than those measured by Schmidt et al.[13] ($p<0.05$).

The MEP was also different in the male gender (Figure 1B). Domènech-Clar et al.[12] presented values that were higher than all the others; and measured values ($p<0.0001$ and those by Wilson et al.[11] ($p<0.0001$) were higher than the ones by Schmidt et al.[13].

As to MIP for the female gender (Figure 1C), the measured and predicted values were also different from each other. Measured values were higher to all of the predicted values. The values by Schmidt et al.[13] ($p<0.0001$) and Domènech-Clar et al.[12] ($p<0.0001$) were higher than the values by Wilson et al.[11].

In MEP, also in the female gender (Figure 1D), Domènech-Clar et al.[12] presented higher values in relation to all of the others. Besides, measured values ($p<0.0001$) were higher to those found by Wilson et al.[11].

Figure 2 presents dispersion diagrams in the male gender with MIP and MEP measured and predicted by the equations of Wilson et al.[11], Domènech-Clar et al. and Schmidt et al.[13], respectively. The MIP values measured in the male gender presented moderate and significant association with the values predicted by Wilson et al.[11] ($r=0.3137$ and $p=0.00337$) and Domènech-Clar

Table 1. Comparison between the studied variables according to gender

Variable	Male (n=46)*	Female (n=44)*	p-value
Age (years)	8.71±1.62	8.886±1.99	0.6599
Weight (kg)	30.53±7.54	31.50±10.60	0.6162
Height (cm)	134.00±9.35	135.70±9.35	0.5305
BMI	16.99±2.33	16.85±2.27	0.7720
Arm circumference (cm)	19.70±2.99	19.89±2.78	0.7556
Skinfold	12.74±4.16	13.07±4.53	0.7205
FVC	1.94±0.40	1.95±0.61	0.9432
FEV1	1.80±0.65	1.75±0.56	0.7129
TI (VEF_1/FVC)	0.94±0.33	0.89±0.04	0.3891
MIP (cmH_2O)	80.65±26.78	76.14±26.08	0.4202
maxPE (cmH_2O)	84.35±23.16	74.55±20.05	0.0349**

*Mean±standard deviation; **p<0.05, by the unpaired *t* test.
BMI: body mass index; FVC: Forced vital capacity; FEV1: forced expiratory volume in the 1st second; IT: Tiffeneau Index ; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure

Table 2. Methodological comparison of the equations proposed by Wilson et al.[11], Schmidt et al.[13] and Domènech-Clar et al.[12] and the methodology used in this study

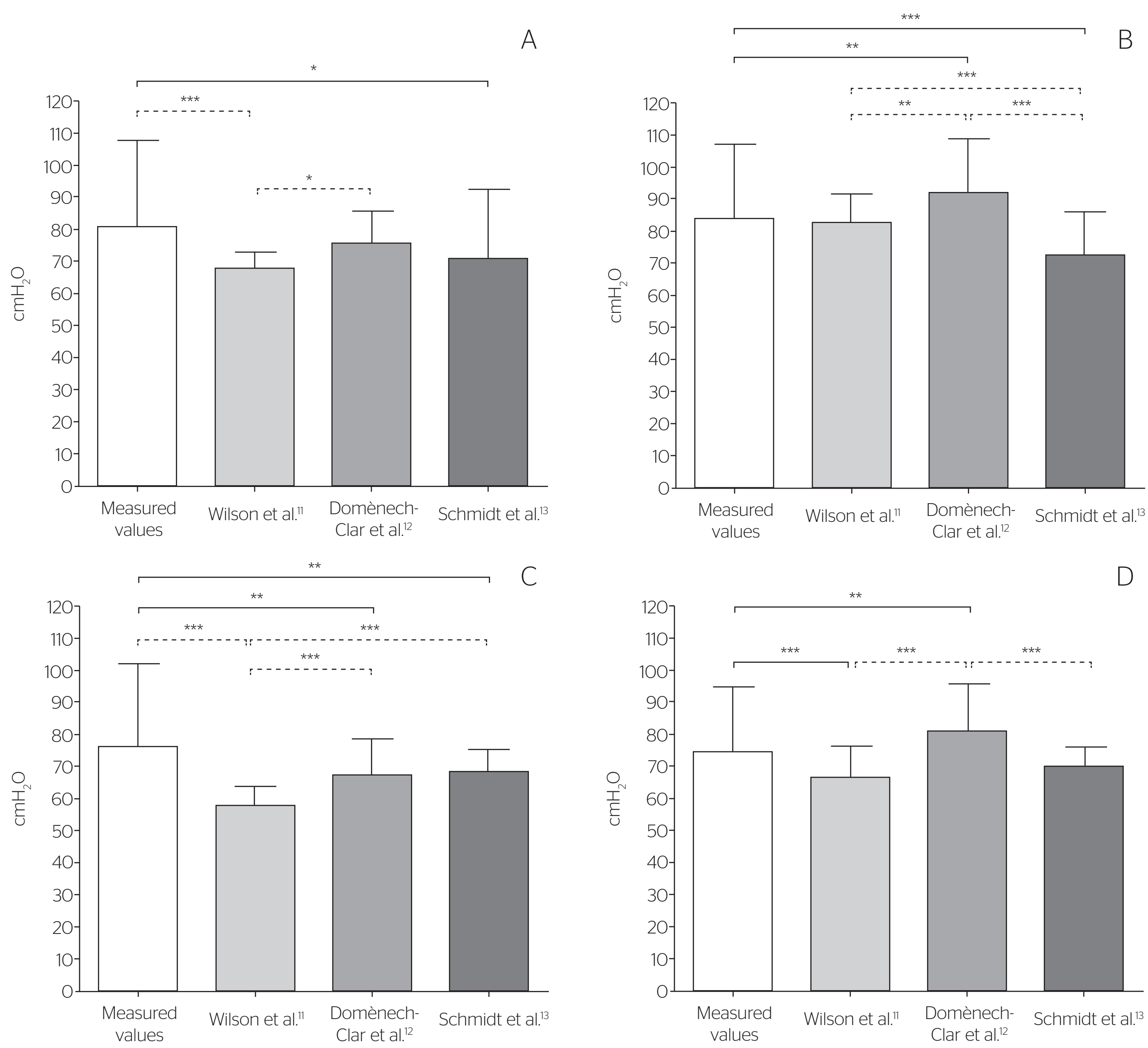
Author	Age group	Sample	Body position	Use of nose clip	Volumes and capacities	Number of maneuvers	Sustaining effort time	Predicted Equations
Wilson et al.[11]	7-17	235 (137 boys and 98 girls)	Sitting	No	MIP from RV and MEP from TPC	3	1 s	Male: PImáx= 44.5+ (0.75 x weight (kg)) e PEmáx=35+ (5.5 x age (years)) Female: PImáx =40+(0.57 x weight (kg)) e PEmáx=24+(4.8 x age (years))
Schmidt et al.[13]	6-14	672 (343 boys and 329 girls)	Sitting	Yes	MIP from RV and MEP from TPC	5	2 s	Male: PImáx= -324.296+ -21.833 x age (years)+4.368 x height (cm) e PEmáx= -1.261+ -9.698 x age (years) +2.579 x height (cm) Female: PImáx= 12.989+1.059 x age (years)+0.34 x height (cm) e PEmáx=53.732+3.702 x age (years)+ -0.122 x height (cm)
Domènech-Clar et al.[12]	8-17	392 (185 boys and 207 girls)	Sitting	Yes	MIP from RV and MEP from TPC	3-9	1 s	Male: PImáx= -27.020-(4.132 x age (years))-(0.003 x height (cm) x weight (kg)) e PEmáx= 7.619+(7.806 x age (years))+(0.004 x height (cm) x weight (kg)) Female: PImáx= -33.854 - (1.814 x age (years))-(0.004 x height (cm) x weight (kg)) e PEmáx=17.066+(7.22 x age (years))
Measured values	6-12	90 (46 boys and 44 girls)	Sitting	Yes	MIP from RV and MEP from TPC	5	2 s	-

maxPI: Maximum inspiratory pressure; MEP: Maximum Expiratory Pressure; RV: Residual Volume; TPC: Total pulmonary capacity; FEV1: forced expiratory volume in the 1st second; FVC: Forced vital capacity et al.[12] (r=0.3672 and p=0.0121) (Figures 2A and B, respectively). By comparing these with Schmidt et al.[13], the association with measured values had low magnitude and was not significant (r=-0.07535 and p=0.6187) (Fugure 2C). For MEP, measured values presented low magnitude association and no statistical significance for the predicted values proposed by the three equations (Figures 2D to F).

Figure 3 presents the same diagrams from the previous figure, however, considering the female gender. Measured values of MIP and MEP presented moderate to significant association with the values predicted by all of the analyzed predictive equations (Figures 3A to F).

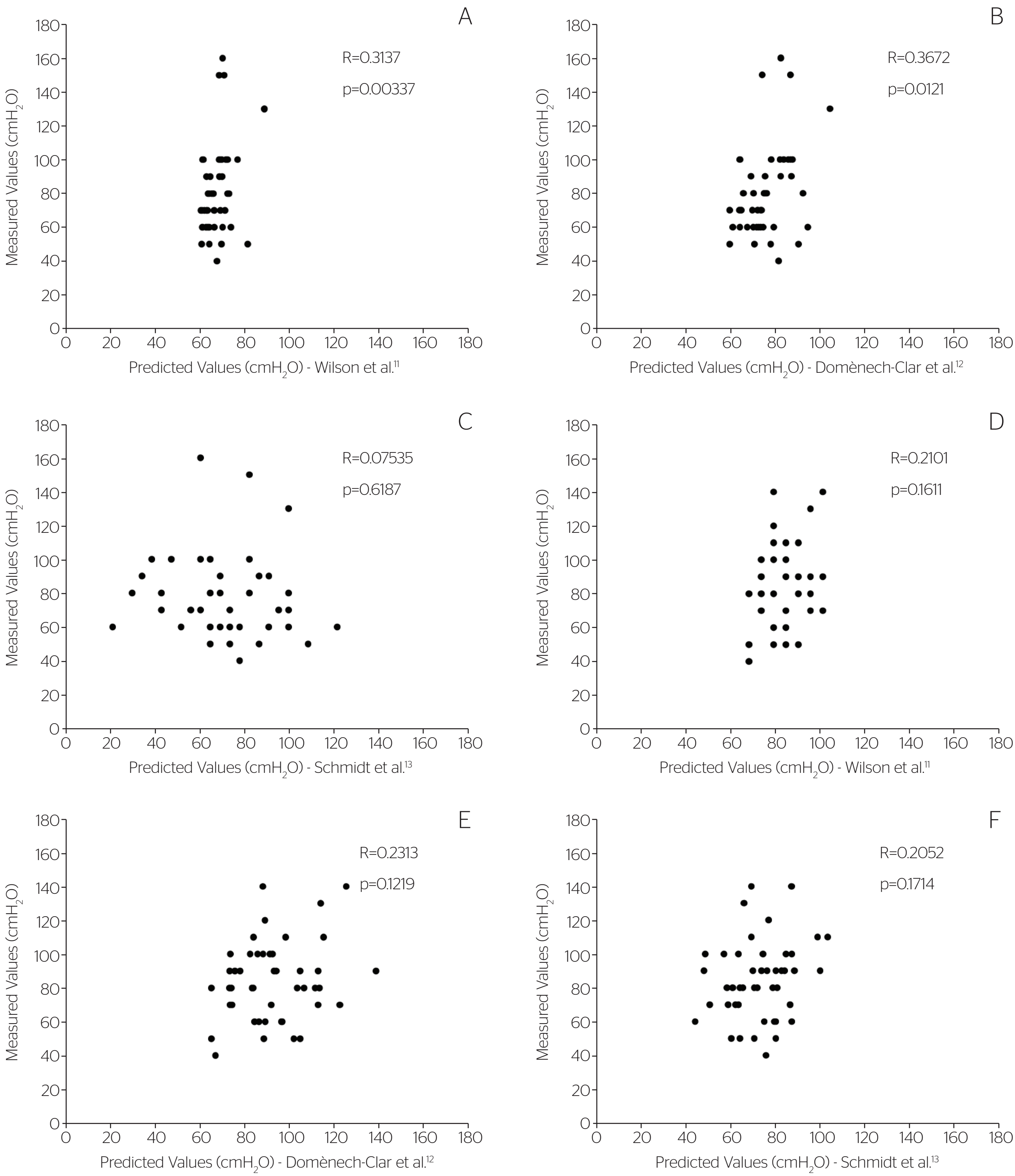
DISCUSSION

The choice of a reference equation is based on a standardized technique and on the proper selection of the population. However, the chosen equation may not characterize the sample in relation to the found maximum pressures[10].



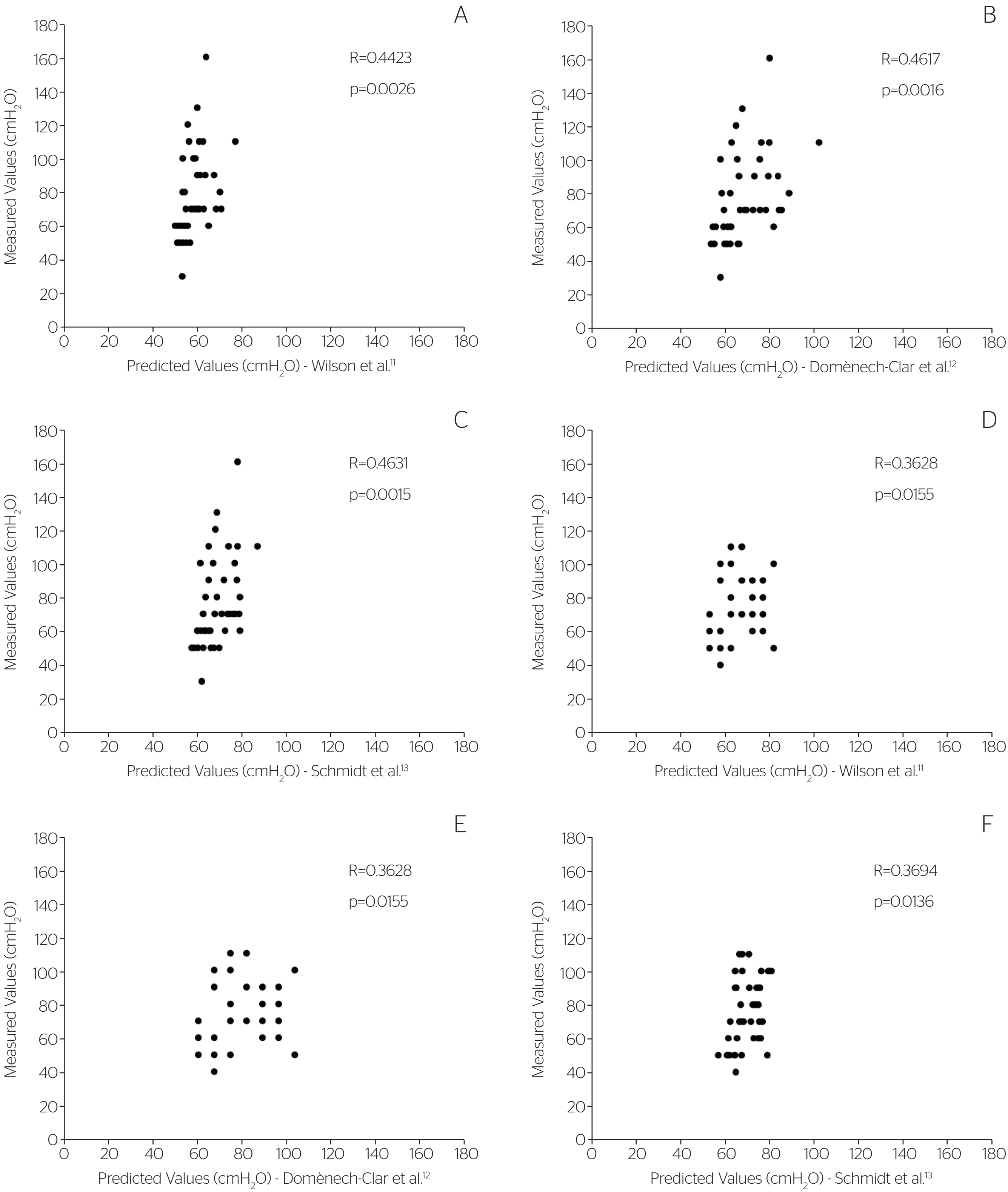
*p<0.05; **p<0.01; ***p<0.001. n=46 (male gender); n=44 (female gender). Mean±standard deviation compared by the analysis of variance post-hoc Student Newman Keuls

Figure 1. Differences referring to the maximum inspiratory pressure, in male (A) and female (C) genders, and maximum expiratory pressure, in male (B) and female (D) genders as to measured and predicted values by the equations of studied references



Pearson's linear correlation. n=46

Figure 2. Dispersion diagrams of maximum inspiratory pressure (A, B and C) and maximum expiratory pressure among males (D, E and F) measured and predicted by the equations proposed by Wilson et al.[11], Domènech-Clar et al.[12] and Schmidt et al.[13], respectively



Pearson's linear correlation. n=44

Figure 3. Dispersion diagrams of maximum inspiratory pressure (A, B and C) and maximum expiratory pressure among females (D, E and F), measured and predicted by the equations proposed by Wilson et al.[11], Domènech-Clar et al.[12] e Schmidt et al.[13], respectively

Studies describe that the discrepant values predicted in literature are caused by different methodologies, used mouthpiece, maneuvers, location and population[19]. Selection, sample, equipment and techniques are also variable factors[9].

By comparing the methodology of the mentioned equations and this study, the position of the tests was similar. In Wilson et al.[11], predicted values were lower to the others, which could have been caused by not using the nose clip and aerial escape.

Effort sustaining time ranged from one to three seconds, and all of them began MIP from RV, and max EP from TPC, and such measurement is established by the ATS. Literature shows that, when the measurement of MIP and MEP is originated from RV and TPC, respectively, and also in the functional residual capacity (FRC), there are different results since the elastic gathering does not participate in the final measurement[20].

Sample selection also influences the variability of MIP and MEP final values[9]. This study and the equations found in literature presented similar criteria. Besides, the sample was randomized in Wilson et al.[11] and Domènech-Clar et al.[12] In Schmidt et al.[13], no randomization is described, which may have interfered with the generalization of results. This study was not randomized.

Sample size varied among the studies. This study and the predictive equations were different, and not all of them conducted a previous sample calculation. Another difference in sample selection is the classification of "healthy" subjects. In Wilson et al.[11], Domènech-Clar et al.[12] and in this study, participants underwent spirometry in order to prove the absence of respiratory disorders, which did not happen in Schmidt et al.[13].

The number of maneuvers ranged from three to nine, considering the learning effect. Some authors recommend three to five maneuvers in other to obtain three acceptable ones and two reproducible ones, with difference lower than 5%[21]. This study performed the measurements according to the guidelines proposed by the Brazilian Society of Pneumology and Tisiology (SBPT)[18].

As to gender, studies demonstrate that the strength is more present in the male gender[12,20,22,23]. In the three equations, as well as in values measured in this study, when analyzing normality values, all of the respiratory pressure equations are higher among boys, and MEP values are higher than MIP values in both genders.

For the age variable, it is known that respiratory pressures increase with aging. These findings are frequent, even in studies with different populations at different age groups[20].

As to the correlations between variables, we observed there was some statistical significance between manometric variables with anthropometric and spirometric variables. From the differences found in measured and predicted values, the need to create new equations that could better reflect respiratory strength in the population involved came up.

Population is another factor that influences respiratory pressure. When we compare the values predicted by Schmidt et al.[13] for a sample in Rio Grande do Sul with the ones measured in this study, there is a difference between them, which leads to the conclusion that these reference values were not able to predict the values obtained for the respiratory pressures of the assessed population — which indicates that predictive equations can go through variations between individuals from different ethnic groups[24], different countries or even in the same country[25]. The findings are in accordance with those by Parreira et al.[5], who compared values of the healthy Brazilian population in the state of Minas Gerais with those predicted by the equation of Neder et al.[26], from a sample from São Paulo, and these values were also different.

Therefore, in order for measured and predicted values to be similar, it is important that there is correlation between measurements, however, without statistically significant differences. So, it is possible to conclude that the reference values proposed by the equations of Wilson et al.[11], Domènech-Clar et al.[12] and Schmidt et al.[13] were not good respiratory strength predictors in the studied population, thus reinforcing the need to establish normality values for populations of children and adolescents from different regions in Brazil.

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