DOI: 10.1590/1809-2950/19020327042020

ORIGINAL RESEARCH

Brazilian equations: inspiratory muscle force

Equações brasileiras: força muscular inspiratória

Ecuaciones brasileñas: fuerza muscular inspiratoria

Isabela Maria Braga Sclauser Pessoa[1], Débora Alves Pinheiro[2], Myrna Amaral Dias Falcão[3], Paloma Ferreira de Araújo[4], Patrícia Marília Martins[5], Marcelo Velloso[6]

ABSTRACT | Respiratory muscle strength (RMS) (maximal inspiratory pressure [MIP] and maximal expiratory pressure [MEP]) vary when estimated by prediction equations. This study will verify whether the classification of MIP obtained by the prediction equations proposed by Brazilian authors is similar and concordant. The sample consisted of 18 stable patients with cardiorespiratory and neurological dysfunctions and respiratory muscle weakness. The MIP was measured by the analog compound gauge and compared to the prediction equations of Brazilian authors. Only two authors found inspiratory muscle weakness (p<0.0001). Assessing the agreement among authors (BIAS), there was a low agreement between the values predicted by the equations, except among the authors who detected inspiratory muscle weakness in the evaluated patients.
Keywords | Reference Values; Muscle Strength; Respiratory Muscles.

RESUMO | A força dos músculos respiratórios (FMR) – pressão inspiratória máxima [PImáx] e pressão expiratória máxima [PEmáx] – apresentam variação quando estimadas por equações de predição. O objetivo deste estudo foi verificar se a classificação da PImáx obtida pelas equações de predição propostas por autores brasileiros é semelhante e concordante. A amostra foi constituída por 18 pacientes estáveis com disfunções cardiorrespiratória, neurológica e fraqueza muscular respiratória. A PImáx foi medida pelo manovacuômetro analógico e comparada com as equações de predição de autores brasileiros. Apenas dois autores detectaram fraqueza muscular inspiratória (p<0,0001). Ao avaliar a concordância entre autores (Bias), verificou-se baixa concordância entre os valores preditos pelas equações, exceto entre os autores que detectaram fraqueza muscular inspiratória nos pacientes avaliados.
Descritores | Valores de Referência; Força Muscular; Músculos Respiratórios.

RESUMEN | La fuerza muscular respiratoria (MRF) (presión inspiratoria máxima [MMAX] y presión espiratoria máxima [Mepmax]) varían cuando se estima por ecuaciones de predicción. El objetivo de este estudio era verificar si la clasificación del MIP obtenida por las ecuaciones de predicción propuestas por los autores brasileños es similar y concordante. La muestra consistió en 18 pacientes estables con debilidad cardiorrespiratoria, neurológica y muscular respiratoria. Mmax fue medido por el manovacuómetro analógico y comparado con las ecuaciones de predicción de autores brasileños. Solo dos autores debilidad muscular inspiradora (p<0.0001). Al evaluar la concordancia entre los autores (Bias), hubo una baja concordancia entre los valores predichos por las ecuaciones a excepción de los autores que detectaron debilidad de los músculos inspiratorios en los pacientes evaluados.
Palabras Clave | Valores de Referencia; Fuerza Muscular; Músculos Respiratorios.

Study carried out at the Clinical School (*Clínica escola*) of the Pontifical Catholic University of Minas Gerais, Betim, Minas Gerais, Brazil.
[1]Pontifical Catholic University of Minas Gerais (PUC) - Belo Horizonte (MG), Brazil . E-mail: isa.sclauser@terra.com.br.
Orcid: 0000-0002-2352-8954
[2]Pontifical Catholic University of Minas Gerais (PUC) - Belo Horizonte (MG), Brazil . E-mail: deborafap@hotmail.com.
Orcid: 0000-0002-8986-7799
[3]Pontifical Catholic University of Minas Gerais (PUC) - Belo Horizonte (MG), Brazil . E-mail: myrnaadf@gmail.com.
Orcid: 0000-0001-6222-0293
[4]Pontifical Catholic University of Minas Gerais (PUC) - Belo Horizonte (MG), Brazil . E-mail: palomafisio.ferreira@gmail.com.
Orcid: 0000-0003-4611-871X
[5]Pontifical Catholic University of Minas Gerais (PUC) - Belo Horizonte (MG), Brazil . E-mail: patriciamartinsfisio@hotmail.com.
Orcid: 0000-0002-5840-4767
[6]Federal University of Minas Gerais (UFMG) – Belo Horizonte (MG), Brazil. E-mail: marcello.vel@gmail.com. Orcid: 0000-0001-9361-8149

Corresponding address: Isabela Maria Braga Sclauser Pessoa – Rua do Rosário, 1081 – Betim (MG), Brazil – Zip Code: 32604-115 – E-mail: isa.sclauser@terra.com.br – Funding source: nothing to declare – Conflict of interests: nothing to declare –Presentation: Mar. 9th, 2020 – Accepted for publication: Feb. 16th, 2021 – Approved by the Ethics Committee of the Pontifical Catholic University of Minas Gerais s: CAAE nº 56300416.1.0000.5137.

INTRODUCTION

The respiratory muscle strength (RMS) is reflected by the pressure developed by them (motive pressure of the respiratory system), which controls ventilation and is recorded as maximum respiratory pressure (MRP)[1]. The classic maneuver to assess inspiratory muscle strength is one in which the subject generates maximum static inspiratory effort, that is, a maximum inspiratory pressure (MIP) against an occluded mouthpiece [1,2].

Since the 1960s, several authors[3-5] have evaluated MIP in individuals from different countries and age groups, establishing reference values. These values were reported as mean and standard deviation or median and, in some studies, prediction equations were proposed. The literature, however, shows great variation between the values predicted for MIP [4,5].

Inspiratory muscle training is known to maximize the ventilatory reserve in individuals with pulmonary, cardiac and neurological disorders; it also improves dyspnea symptoms and cough effectiveness[6,7]. According to the American Thoracic Society / European Respiratory Society (ATS / ERS)[1] and the Brazilian Society of Pulmonology and Tisiology (Sociedade Brasileira de Pneumologia e Tisiologia – SBPT)[2], MIP values lower than $-80cmH_2O$ allow the presence of ventilatory muscle weakness to be ruled out. The correct classification of MIP, based on the predicted value, is necessary to develop the appropriate physiotherapeutic treatment plan.

In Brazil, four groups of researchers[5,8-10] proposed prediction equations for MRP. Considering Brazilian studies which compare prediction equations, and also the values obtained and predicted by these authors in a sample of individuals with respiratory muscle weakness, this study intends to verify whether the classification of the MIP obtained by prediction equations proposed by Brazilian authors is similar and concordant.

METHODOLOGY

This is an observational, descriptive and cross-sectional study. The study was approved by the Human Research Ethics Committee (*Comitê de* Ética *em Pesquisa em Seres Humanos* - CEP) of the Pontifical Catholic University of Minas Gerais (PUC-Minas), CAEE nº 56300416.1.0000.5137, and all participants signed an informed consent form. The sample was of convenience and the individuals were selected from the Clinical School of PUC-Minas from August to December 2016.

Inclusion criteria were: individuals with pulmonary, cardiac and neurological disorders with a MIP value>−80cmH2O; without cognitive impairment, assessed by the Mini-Mental State Examination (MMSE); who did not present contraindications to the performance of MRP, according to the Brazilian Society of Pulmonology and Tisiology (Sociedade Brasileira de Pneumologia e Tisiologia – SBPT)[2], hemodynamically stable, with blood pressure (BP) at rest lower than 160 / 110mmHg; peripheral hemoglobin oxygen saturation (SpO2) greater than 88% and heart rate (HR) lesser than 100 bpm. Individuals with an inability to perform the research protocol procedures were excluded.

On the first day, individuals were submitted to anamnesis, including the collection of vital data: PA (TYCOS®, São Paulo, Brazil), FC and SpO2 (NONIN®, model 9500, Plymouth (MN), USA) and anthropometric data, such as waist circumference and waist-to-hip ratio (WHR), using an inelastic plastic tape measure[11], weight (TANITA®, model BC-543, London, United Kingdom), height (Standard Sanny®, model ES2030, São Paulo, Brazil) and body mass index (BMI)[12] obtained by dividing weight (kg) by height^2 (cm^2)[11]. Individuals over 60 years of age were submitted to cognition assessment using the MMSE questionnaire [13]. In order to characterize the sample, the medical diagnosis of individuals was considered by means of the International Statistical Classification of Diseases and Related Health Problems (ICD).

In the second meeting, the MIP of the individuals was measured by a compound gauge, previously calibrated analog (WIKA®, model Type 213.53, Brazil), graduated in cmH2O, with a range variation ± 150cmH2O, silicone tube, type interface/mouthpiece rectangular[14], with a leakage hole of 2mm indiameter[2]. All individuals received instructions and demonstrations prior to testing. The nose clip usage and sitting position were recommended, with feet and trunk supported[1,2].

The MIP measurement was performed from the residual volume (VR)[1,2] and all participants performed at least five maneuvers with an interval of one minute between them. The pressure measurement was considered complete when the individual performed three acceptable maneuvers with two reproducible (two with a variation equal to or less than 10%, with the highest pressure)[1], as long as this was not the last test performed[2]. The highest

MIP value was submitted to analysis. Measured values for each individual were compared to those proposed by Brazilian authors Neder et al.[8], Costa et al.[9] , Simões et al.[10] and Pessoa et al.[5].

The program G*Power 3.1 (Statistical Power Analyzes) was applied for the sample calculation. Because the value predicted in the sample calculation was low (n=7), it was decided to analyze the power of the study at the end of the collections. Data were presented as measures of central tendency, measures of variability and percentage. The distribution of variables was verified by the Shapiro-Wilk test. The analysis of variance (ANOVA) for repeated measures was used to compare the MIP values predicted by the Brazilian equations in relation to the values obtained by the individuals in the RMS assessment, followed by the Bonferroni *post-hoc* test. The Bland-Altman method was performed to assess the agreement of the predicted values, based on the graphical visualization of the dispersion between the difference and the mean of the variables. Statistical analysis was performed using the Statistical Package for the Social Science program (SPSS 20.0.0) The level of significance considered was 5% ($p < 0.05$).

RESULTS

A total of 23 individuals were recruited, aged between 20 and 89 years old, both sexes. Five of them were excluded - two for not meeting the acceptability and reproducibility criteria of the MIP test, two for not having inspiratory muscle weakness and one for not achieve a sufficient score in the MMSE. The final sample consisted of 18 individuals, 6 with heart disease, 10 with pneumopathy and 2 with neurological dysfunction (Table 1).

Table 1. Anthropometric and clinical characterization of the sample (N=18)

Parameters	Individuals with pulmonary, cardiac and neurological disorders
Gender (F / M)	10 / 8
Age (years) Sedentariness	57 (13,56) 18
BMI (kg/m²)	24,08 (4,58)
WHR (cm)	F: 0,877±0,1 / M: 0,94±0,1
MMSE (points)	24,44 (3,63)
Peak MIP (cmH_2O)	50,00 (16,18), min=25 / max=78
Sustained MIP (cmH_2O)	48,11 (18,83), min=20 / max=78
Peak MEP (cmH_2O)	50,66 (18,92), min=20 / max=98
Sustained MEP (cmH_2O)	48,72 (19,52), min=20 / max=98

Data presented as mean and standard deviation (SD); N: number of participants; F: female; M: male; BMI: body mass index; WHR: waist-hip ration; MMSE: Mini-Mental State Examination; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; min: minimum value; max: maximum value.

Table 2 shows the comparison between the values obtained by the patients with those predicted for MIP. When comparing the predicted value for the peak and sustained MIP with the average obtained for the population, Costa et al.[9] , Simões et al.[10] showed no significant difference (p=0.90 and p=0.56, respectively). Significant differences were observed between the results of the prediction equations among Brazilian authors ($p < 0.01$).

The Bland-Altman analysis showed the high bias values and the marked dispersion of the values predicted by different Brazilian authors for MIP (Figure 1).

Table 2.Comparison between the values obtained by the patients versus values predicted for MIP by the equations proposed by the Brazilian authors (N=18)

Authors	MIP Predication	Peak MIP Earn;	Sus. MIP obt	Difference Peak MIP x obtained P-value	Sus. MIP P-value
Neder et al.	93,5 (3,82)			0,00	0,00
Costa et al.	63,01 (5,02)	50,0 (3,81)	48,11 (4,44)	0,56	0,35
Simões et al.	44,74 (8,33)			1,00	1,00
Pessoa et al.	78,15 (4,09)			0,00	0,00

Data presented as mean and standard deviation (SD): MIP pred .: predicted maximum inspiratory pressure; peak MIP obtained: peak inspiratory pressure peak obtained; sus. MIP obtained: sustained maximum inspiratory pressure obtained; dif MIP peak × obt .: difference between the mean of the predicted and obtained maximum inspiratory pressures; P-value: statistical value.

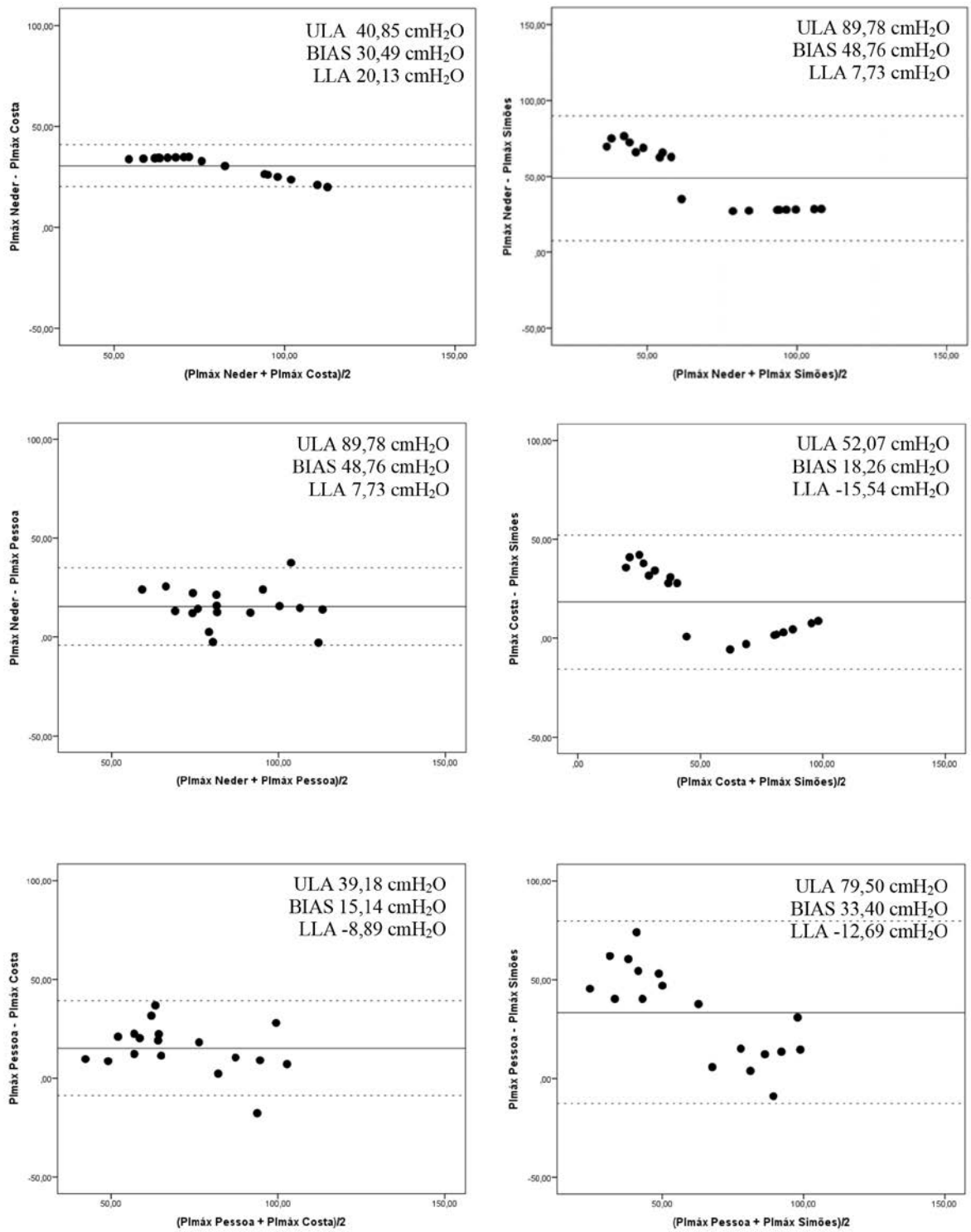

Figure 1. Bland-Altman analysis among the predicted values for the measurements of the maximum inspiratory pressure (MIP).

ULA: upper limit of agreement; LLA: lower limit of agreement.

DISCUSSION

The present study was the first to perform a comparative and concordance analysis between the results of the Brazilian MIP prediction equations in a sample of individuals with respiratory muscle weakness. We emphasize the values predicted for MIP by the equations of Neder et al.[8] and Pessoa et al.[5] showed a statistical difference compared to those obtained by the patients, with the mean predicted value higher than the mean value obtained, which detects the real inspiratory muscle

weakness of the selected sample. Neder et al.[8] and Pessoa et al.[5] showed a greater agreement between the results of the prediction equations.

Until the 1950s, the great variability of MRP values between the studies carried out caused the researchers to question the usefulness of testing[3]. in 1958 Shephard et al., cited by Ringqvist[3], reported that the variability of data hitherto recorded in the literature devalued the MRP tests, in addition to have an uncertain theoretical basis.

The finding of the variation between the values predicted by the prediction equations by several authors[15-18] prompted the publication, in 2002, of the international – ATS/ ERS[1] - and national - the Brazilian SBPT[2] – guidelines on the MRP. These guidelines present similar recommendations, although there are points of disagreement. In the international guideline, the importance of using the digital instrument is emphasized to guarantee the validity of the measures. It should be noted that the sustained pressure, in the international guideline, is defined as the measure of the average of the maximum pressure sustained for 1 second (maximum mean pressure). For the Brazilian national guideline, sustained pressure is defined by maintaining the maximum inspiratory and expiratory pressure after the first second (plateau pressure), assuming a value lower than the highest peak pressure (peak pressure). In Brazil, researchers Neder et al.[8], Costa et al.[9], Simões et al.[10] and Pessoa et al.[5] proposed prediction equations for MRP, with the last three authors elaborating their equations after the publication of the guidelines.

The study by Neder et al.[8], regarding the recommendations of the guidelines, did not mention the leakage hole diameter, which serves to prevent the increase in intraoral pressure caused by the contraction of the buccinator muscles. If absent or less than 1mm, the MIP value can be over estimated[2]. In the present study, when observing the average values predicted by Neder et al.[8] for MIP, there is an overestimation when compared to the other authors. This finding is corroborated by the study by Leal et al.[19], who also found overestimated values in the equations of Neder et al.[8] when compared with those of Black and Hyatt[20] and Harink-Khan[21].

On the other hand, it was found that the values predicted by Simões et al.[10] were underestimated in relation to the others - taking into account that this study was carried out with a sample of sedentary individuals, which suggests that the low predicted values are due to a sedentary lifestyle, which can influence the MRP.

Pessoa et al.[5] aimed to establish reference equations for MRP as recommended by the guidelines. Healthy Brazilians were recruited, with no cognitive impairment found by the MMSE; it was the only Brazilian study to use the digital MVC (NEPEB – LabCare / UFMG) with a pressure transducer with an operating range of ±500cmH2O.

It is noted that the study by Neder et al.[8], although carried out before the publication of these guidelines, presented a high rigor in the control of biological variables and had well-defined methodological aspects, similar to the study by Pessoa et al.[5] It was found that only Neder et al.[8] and Pessoa et al.[5] showed significant differences between the values obtained and those predicted for MIP. It is noteworthy that the sample of the present study consisted of individuals with muscle weakness (MIP> −80cmH2O)[1,2]. It appears that both equations are safe to detect inspiratory muscle weakness.

A recent systematic review with meta-analysis[4] concluded that biological variables and methodological variables influence the values predicted for MIP. This premise supports the discrepancy between the values of MIPs found among Brazilian authors verified in the present study.

The variation between the results of the prediction equations of the Brazilian authors was observed in the Bland-Altman analysis. The values of the prediction equations for MIP showed little agreement, as can be exemplified by the MIP values proposed by Neder et al.[8] and Simões et al.[10]. The Bias indicates how far the differences between the predicted values differ from the zero value. In addition, the 95% agreement limits or the error, which consists of the dispersion of different points around the mean, were inadequate - indicating that there is a greater difference or less agreement between the predicted values.

It is also noted that, although the equation of Pessoa et al.[5] was created with the digital compound gauge, it can be used in clinical practice when the use of analog equipment is employed - since there was no significant difference between the results of the prediction equations proposed by Neder et al.[8] and Pessoa et al.[5]

In summary, it is suggested that the choice of the equation to be used in clinical practice takes into account: equations that do not overestimate or underestimate the predicted values; similarity with the biological characteristics of the sample regarding the creation of reference values (sedentary lifestyle, for example) and equations created with methodological rigor proposed by the guidelines for MRP.

As a limitation of this study, a low sample number (n=18) is pointed out, although the sample was above

the sample calculation performed initially (n=7). It is important to note that the power of the study was later calculated using the G * Power 3.1 software, which showed a value of 0.99 with a moderate effect size[22].

CONCLUSION

Values obtained and predicted for MIP were not similar between the authors; only Neder et al.[8] and Pessoa et al.[5] detected a significant difference between the values obtained and predicted by the equations. Neder et al.[8] and Pessoa et al.[5] showed greater agreement in the predicted MIP values, although the values between the four Brazilian equations showed a significant difference.

REFERENCES

1. ATS/ERS. Statement on respiratory muscle testing. Am J Respir Crit Care Med. 2002;166(4):518-624. doi: 10.1164/rccm.166.4.518
2. Souza, RB. Pressões respiratórias estáticas máximas. J Pneumol. 2002;28(Supl 3):155-65. [cited 2021 Mar 4]. Available from:http://www.jornaldepneumologia.com.br/PDF/Suple_137_45_88%20Press%C3%B5es%20respirat%C3%B3rias%20est%C3%A1ticas%20m%C3%A1ximas.pdf
3. Ringqvist T. The ventilatory capacity in healthy subjects: an analysis of causal factors with special reference to the respiratory forces. Scand J Clin Lab Invest Suppl. 1966;88:5-179. [cited 2021 Mar 4]. Available from: https://europepmc.org/abstract/med/4283858
4. Pessoa IMBS, Parreira VF, Fregonezi GAF, Sheel AW, Chung F, Reid WD. Reference values for maximal inspiratory pressure: a systematic review. Can Respir J. 2014;21(1):43-50. doi: 10.1155/2014/982374
5. Pessoa IMBS, Neto MH, Montemezzo D, Silva LAM, Andrade AD, Parreira VF. Predictive equations for respiratory muscle strength according to international and Brazilian guidelines. Braz J Phys Ther. 2014;18(5):410-8. doi: 10.1590/bjpt-rbf.2014.0044
6. Mehta S. Neuromuscular disease causing acute respiratory failure. Respir Care. 2006; 51(9):1016- 21. [cited 2021 Mar 4]. Available from: https://pubmed.ncbi.nlm.nih.gov/16934165/
7. Meyer FJ, Borst MM, Zugck C, Kirschke A, Schellberg D, Kübler W, et al. Respiratory muscle dysfunction in congestive heart failure: clinical correlation and prognostic significance. Circulation. 2001;103(17):2153-8. doi: 10.1161/01.CIR.103.17.2153
8. Neder JA, Andreoni S, Lerario MC, Nery LE. Reference values for lung function tests: maximal respiratory pressures and voluntary ventilation II. Braz J Med Biol Res. 1999;32(6):719-27. doi: 10.1590/S0100-879X1999000600007
9. Costa D, Gonçalves HA, Lima LP, Ike D, Cancelliero KM, Montebelo MI. New reference values for maximal respiratory pressures in the Brazilian population. J Bras Pneumol. 2010;36(3):306-12. doi:10.1590/S1806-37132010000300007
10. Simões RP, Deus APL, Auad MA, Dionísio J, Mazzoneto M, Silva AB. Maximal respiratory pressure in healthy 20 to 89 year-old sedentary individuals of central Sao Paulo State. Rev Bras Fisioter. 2010;14(1):60-7. doi: 10.1590/S1413-35552010000100010
11. Godoy-Matos AF, Oliveira J, Guedes EP, Carraro L, Lopes AC, Mancini MC, et al. In: Diretrizes brasileiras de obesidade 2009/2010 / ABESO – Associação Brasileira para o Estudo da Obesidade e da Síndrome Metabólica. 3rd ed. Itapevi: AC Farmacêutica; 2009 [cited 2021 Feb 20]. p. 7-25. Available from: http://www.saude.df.gov.br/wp-conteudo/uploads/2018/08/2009_DIRETRIZES_BRASILEIRAS_DE_OBESIDADE.pdf
12. Guedes GP, Barbosa YRA, Holanda G. Correlação entre força muscular respiratória e tempo de internação pós-operatório. Fisioter Mov. 2009;22(4):605-14. [cited 2021 Mar 4]. Available from: https://periodicos.pucpr.br/index.php/fisio/article/view/19521
13. Brucki SM, Nitrini R, Caramelli P, Bertolucci PHF, Okamoto IH. Suggestions for utilization of the mini-mental state examination in Brazil. Arq Neuropsiquiatr. 2003;61(3B):777-81. doi: 10.1590/S0004-282X2003000500014
14. Montemezzo D, Vieira DSR, Tierra-Criollo CJ, Britto RR, Velloso M, Parreira VF. Influence of 4 interfaces in the assessment of maximal respiratory pressures. Respir Care. 2012;57(3):392-38. doi: 10.4187/respcare.01078
15. Enright PL, Adams AB, Boyle PJ, Sherriel DL. Spirometry and maximal respiratory pressure references from healthy Minnesota 65- to 85-year-old women and men. Chest. 1995;108(3):663-9. doi: 10.1378/chest.108.3.663.
16. Enright PL, Kronmal RA, Manolio TA, Schenker MB, Hyatt RE. Respiratory muscle strength in the elderly: correlates and reference values: Cardiovascular Health Study Research Group. Am J Respir Crit Care Med. 1994;149(2 Pt 1):430-8. doi: 10.1164/ajrccm.149.2.8306041
17. Vincken W, Ghezzo H, Cosio MG. Maximal static respiratory pressures in adults: normal values and their relationship to determinants of respiratory function. Bull Eur Physiopathol Respir. 1987;23(5):435-9. [cited 2021 Mar 4]. Available from: https://europepmc.org/article/med/3450325
18. Johan A, Chann CC, Chia HP, Chan OY, Wang YT. Maximal respiratory pressures in adult Chinese, Malays and Indians. Eur Respir J. 1997;10(12):2825-28. doi: 10.1183/09031936.97.10122825
19. Leal AH, Hamasaki TA, Jamami M, Lorenzo VAPD, Pessoa BV. Comparação entre valores de força muscular respiratória medidos e previstos por diferentes equações. Rev Bras Fisioter. 2007;14(3):25-30. doi: 10.1590/fpusp.v14i3.76090
20. Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. Am Rev Respir Dis. 1969;99(5):696-702. doi: 10.1164/arrd.1969.99.5.696
21. Harik-Khan RI, Wise RA, Fozard JL. Determinants of maximal inspiratory pressure: the Baltimore longitudinal study of aging. Am J Respir Crit Care Med. 1998;158(5 Pt 1):1459-64. doi: 10.1164/ajrccm.158.5.9712006
22. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale, NJ: Erlbaum; 1988.