ORIGINAL ARTICLE

ISSN 1413-3555
Rev Bras Fisioter, São Carlos, v. 16, n. 6, p. 479-86, Nov./Dec. 2012

Behavior of respiratory muscle strength in morbidly obese women by using different predictive equations

Comportamento da força muscular respiratória de obesas mórbidas por diferentes equações preditivas

Eli M. Pazzianotto-Forti[1,2], Fabiana S. Peixoto-Souza[1], Camila Piconi-Mendes[2], Irineu Rasera-Junior[3], Marcela Barbalho-Moulim[4]

Abstract

Background: Studies on the behavior of respiratory muscle strength (RMS) in morbidly obese patients have found conflicting results. **Objectives:** To evaluate RMS in morbidly obese women and to compare the results by using different predictive equations. **Method:** This is a cross-sectional study that recruited 30 morbidly obese women and a control group of 30 normal-weight women. The subjects underwent anthropometric and maximal respiratory pressure measurement. Visual inspection of the Bland-Altman plots was performed to evaluate the correlation between the different equations, with a p value lower than 0.05 considered as statistically significant. **Results:** The obese women showed a significant increase in maximal inspiratory pressure (MIP) values (-87.83±21.40 cmH_2O) compared with normal-weight women (-72±15.23 cmH_2O) and a significant reduction of MIP (-87.83±21.40 cmH_2O) according to the values predicted by the EHarik equation (-130.71±11.98 cmH_2O). Regarding the obtained maximal expiratory pressure (MEP), there were no between-group differences (p>0.05), and no agreeement was observed between obtained and predicted values of MEP and the ENeder and ECosta equations. **Conclusions:** Inspiratory muscle strength was greater in the morbidly obese subjects. The most appropriate equation for calculating the predicted MIP values for the morbidly obese seems to be Harik-Khan equation. There seem to be similarities between the respiratory muscle strength behavior of morbidly obese and normal-weight women, however, these findings are still inconclusive.

Keywords: morbid obesity; maximal respiratory pressures; respiratory muscles; reference values; physical therapy.

Resumo

Contextualização: Estudos sobre o comportamento da força muscular respiratória (FMR) em obesos mórbidos têm produzido resultados conflitantes. **Objetivos:** Avaliar a FMR de obesas mórbidas e comparar com os valores preditos por diferentes equações matemáticas encontradas na literatura. **Método:** Estudo transversal realizado com 30 obesas mórbidas e grupo controle constituído por 30 eutróficas. Foram avaliadas as características antropométricas e as pressões respiratórias máximas. Foi utilizada análise visual de Bland-Altman para avaliar o viés de concordância entre as equações estudadas, considerando significativo p<0,05. **Resultados:** As obesas mórbidas apresentaram aumento significativo nos valores obtidos de pressão inspiratória máxima (PImáx) (-87,83±21,40 cmH_2O) em comparação com as eutróficas (-72±15,23 cmH_2O) e redução significativa da PImáx (-87,83±21,40 cmH_2O) segundo os valores previstos pela equação EHarik (-130,71±11,98 cmH_2O). Quanto à pressão expiratória máxima (PEmáx), não houve diferenças nos valores obtidos entre os grupos (p>0,05), assim como não foram observadas concordâncias dos valores obtidos e previstos de PEmáx segundo as equações ENeder e ECosta. Na análise de Bland-Altman, foi observada maior validade na equação de Harik-Khan para predizer a PImáx nas obesas, já, para a predição da PEmáx, não foi possível visualizar qual das equações apresentou maior validade. **Conclusões:** Mulheres obesas mórbidas apresentaram maior força muscular inspiratória do que eutróficas. Das três equações utilizadas, a de Harik-Khan parece ser a mais apropriada para calcular os valores de referência das medidas de PImáx para obesas mórbidas. Mulheres obesas mórbidas e eutróficas parecem apresentar semelhança no comportamento da força dos músculos expiratórios, entretanto esses achados são inconclusivos.

Palavras-chave: obesidade mórbida; pressões respiratórias máximas; músculos respiratórios; valores de referência; fisioterapia.

Received: 01/10/2012 – **Revised:** 03/15/2012 – **Accepted:** 06/26/2012

[1]Postgraduate Physical Therapy Program, Universidade Metodista de Piracicaba (UNIMEP), Piracicaba, SP, Brazil
[2]Faculty of Physical Therapy, Universidade Metodista de Piracicaba (UNIMEP), Piracicaba, SP, Brazil
[3]Gastroenterology and Obesity Surgery Center of Piracicaba, Piracicaba, SP, Brasil
[4]Postgraduate Physical Therapy Program, Universidade Federal de São Carlos (UFSCar), São Carlos, SP, Brasil
Correspondence to: Eli Maria Pazzianotto Forti, Rodovia do Açúcar, Km 156, Taquaral, Bloco 7, Sala 33, CEP 13400-911, Piracicaba, SP, Brasil, e-mail: empforti@unimep.br

Introduction

Obesity is the most common metabolic disease worldwide, and its prevalence has been strongly increasing[1]. Obesity is considered a significant risk factor for cardiovascular diseases, type 2 diabetes, rheumatoid arthritis and neoplasms[2-4]. Obesity is also associated with the development of respiratory diseases such as sleep apnea and hypoventilation syndrome[3].

Studies on the behavior of respiratory muscle strength (RMS) in morbidly obese patients have produced conflicting results. According to Magnani and Cataneo[5], neither excess body mass nor fat distribution in the upper region promote respiratory muscle dysfunction. On the other hand, respiratory muscle dysfunction has been reported in this population, which could be due to an increase in tensile strength caused by excessive adipose tissue in the thoracic cage and abdomen that could lead to a mechanical disadvantage in the respiratory muscles[6,7].

However, there are also reports that RMS increases in morbidly obese patients, which could be justified by adaptations in the skeletal muscle fibers and the musculoskeletal structures due to the daily physical effort involved in movement and in maintaining the body in an erect position[8,9]. Tanner et al.[10] investigated rectus abdominis muscle fibers in obese during bariatric surgery, and found a high percentage of type II fibers, which are related to low resistance and high contraction power.

A reduction in respiratory muscle strength may delay or compromise postoperative evolution in the morbidly obese patients, especially those who underwent to bariatric surgery[11]. It is known that RMS is associated with age, gender, body mass, height and body surface area[12]. In this context, equations have been formulated to obtain predictive values for normal RMS in different populations[13], but not for obese patients.

However, there is no study that either provides recommended RMS values specifically for the morbidly obese population or that indicates which of the mathematical formulas available in the literature best apply to this population. Therefore, the objectives of this study were to evaluate this population's RMS and to compare these estimates with the predictive values for different mathematical equations available in the literature.

Method

Population studied

This cross-sectional study involved 60 adult women who were divided into 2 groups of 30 participants each: a morbidly obese group (BMI 44.7±4.11 kg/m²) and a normal-weight control group (BMI 22.1±1.8 kg/m²). The volunteers were told about the study's objectives and signed an informed consent form. The study was approved by the Research Ethics Committee of the Universidade Metodista de Piracicaba (UNIMEP), Piracicaba, SP, Brazil, (reference number 19/10).

The morbidly obese women were screened in a Bariatric Clinic where meetings were held with the multidisciplinary team to prepare for gastroplasty, and the normal-weight women were recruited from the community with an invitation to participate in the study.

The inclusion criteria were: morbidly obese women (BMI≥40 kg/m²) and normal-weight women (BMI between 18.5 and 24.9 kg/m²) aged between 25 and 50 years with a sedentary lifestyle, (i.e., scoring up to 8[16] on the Baecke, Burema and Frijters Questionnaire[14] (validated in Brazil by Florindo and Latorre[15])), with no comorbidities such as systemic arterial hypertension, diabetes, cardiovascular or pulmonary diseases, with no alterations in the thoracic and/or abdominal region that would affect respiratory dynamics, who did not use tobacco and who could understand how to perform the maneuvers.

Pre-operative medical records were used to verify that there were no comorbidities among the morbidly obese participants. The health status of normal-weight volunteers was determined using standardized questions based on current guidelines for pulmonary function tests[17].

To verify that the volunteers had no respiratory disorders, spirometric testing, i.e., forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1) and FEV_1/FVC rate above 80%, were conducted. To perform the tests, an ultrasonic computerized spirometer with a flow sensor (*Microquark; Cosmed, Roma, Italy*) was used according to *American Thoracic Society* guidelines[18]. Values were expressed as a percentage of the predicted Brazilian population estimates[19].

Anthropometric evaluation

The volunteers were barefoot and wearing light clothing, remained in an upright standing position for the anthropometric assessments. Body weight was measured using a properly calibrated digital scale (*Filizola*®, Brazil) with a 300 kg maximum capacity and an absolute error (precision) of 100 g. Height was verified using a wall stadiometer (*Wiso*) with a resolution in millimeters.

The BMI was calculated using the weight/height² (kg/m²) equation. Neck circumference (NC) was measured at the cricoid cartilage level[20]. Waist circumference (WC) was measured at the midpoint between the margins of the last rib and the upper margins of the iliac crest. Hip circumference was measured at the level of the greater trochanter of the femur[21].

Evaluation of maximal respiratory pressures

An analog vacuum manometer *(Critical Med, USA, 2002)* with an operating range of 0 to ±300 cmH_2O was used to measure maximal respiratory pressure (MRP). This model is composed by a hard plastic mouthpiece with a small hole of 2 mm in internal diameter, which serves as a relief valve for preventing elevated pressure in the oral cavity due to the simultaneous contraction of facial muscles and the closing of the glottis[22]. A disposable cardboard mouthpiece was used (De Marchi).

Before testing, the volunteers were shown the correct way to perform the maneuvers, i.e., keeping the lips firmly in place around the mouthpiece so that no air could escape[23].

Maximal inspiratory pressure (MIP) was measured from the residual volume, and maximal expiratory pressure (MEP) was measured from the total lung capacity. There was a 1 min interval between measurements[24]. The volunteers were instructed to avoid puffing out their cheeks in order to prevent air leakage. The position reached at the end of the maximal force was maintained to ascertain plateau pressure[25]. While performing these measurements, the volunteers remained seated with their feet supported and used a nose clip.

All volunteers performed a minimum of three, and maximum of five times of the maximal inspiration and expiration maneuver, provided each maneuver was technically acceptable and reproducible, i.e., without air leakage, sustained for at least 1 second and similar to the other values (≤10%). When an exceptionally high value (>10% above previous attempts) was obtained in the final maneuver, the test continued until a value close to it (≤10%) was obtained. As such, the number of maneuvers could exceed five attempts. The highest value was used in the data analysis[25,26].

The values obtained for maximal respiratory pressures were compared to the predicted values for MIP and MEP using the equations proposed by Harik-Khan, Wise and Fozard[12], Neder et al.[25] and Costa et al.[27], as described below:

Harik-khan (EHarik): Harik-Khan, Wise and Fozard[12] Equation

Women: MIP=171-0.694 x age +0.861 x body mass (kg) -0.743 x height (cm)

Neder (ENeder): Neder et al.[25] Equation

Women: MIP=-0.49 x age+110.4
MEP=-0.61 x age +115

Costa (ECosta): Costa et al.[27] Equation

Women: MIP=-0.46 x age +74.25
MEP=-0.68 x age+119.35

Statistical analysis

Data distribution was verified using the Shapiro-Wilk test, and once normality was confirmed, the data were expressed as means and standard deviations.

To compare the anthropometric characteristics, physical activity level and RMS values obtained between the groups, Student's *t*-test was used for parametric data and the Mann-Whitney test for non-parametric data.

To compare the MIP and MEP values obtained with those predicted for subjects of normal weight, the Friedman test was used for MIP, and repeated measures ANOVA with Bonferroni *post-hoc* was used for MEP. For the morbidly obese, repeated measures ANOVA with Bonferroni *post-hoc* was used for MIP and MEP.

Visual inspection of the Bland-Altman plots was carried out to evaluate the agreement bias between the equations studied. The statistical significance level adopted was $p<0.05$. All statistical procedures were performed in *BioStat* 5.0 and *Medcalc* 12.2.1 (*MedCal Software*, Mariakerke, Belgium).

Results

Table 1 shows that there were no between-group statistical differences in age or height. In relation to body mass, BMI, WC, WHR and NC, the morbidly obese women had significantly higher values than the normal-weight subjects. There were no between-group significant differences in the FVC and FEV_1/FVC ratio values; FEV_1 was significantly lower in the obese women. There were no significant differences found in the volunteers' physical activity level (Table 1). The morbidly obese subjects returned significantly higher MIP values than those of normal weight.

Regarding the differences between the MIP values obtained and the values predicted by the equations, the values predicted by the EHarik equation for the morbidly obese were significantly higher than those obtained. There was no difference between the values obtained and those predicted by the ENeder equation; the values predicted by the ECosta equation were significantly lower than those obtained. There was a significant difference between the values predicted by the three equations, as shown in Table 2.

Regarding the normal-weight volunteers, there was no difference in the values obtained and those predicted by the EHariK equation; the values predicted by the ENeder equation were significantly higher than those obtained, and the values predicted by the ECosta equation were significantly lower than those obtained (Table 2).

There were no between-group differences in the obtained MEP values. However, there was a significant statistical difference between the MEP values obtained and those predicted by the ENeder and ECosta equations. There was no difference between the equations for predicted MEP values (Table 3).

For MIP, the statistical graph analysis from the Bland-Altman test between the obtained values and those predicted by the EHarik equation showed a mean difference of -7.7 cmH_2O and an agreement interval of -38.9 cmH_2O to 23.6 cmH_2O. The obtained values and those predicted by the ENeder equation produced a mean difference of -23.5 cmH_2O and an agreement interval of -52.3 cmH_2O to 5.3 cmH_2O. The obtained values and those predicted by ECosta showed a mean difference of 11.8 cmH_2O and an agreement interval of -17.1 cmH_2O to 40.6 cmH_2O. Regarding MEP, the Bland-Altman graph analysis between the obtained values and those predicted by ENeder showed a mean difference of 14.4 cmH_2O and an agreement interval of -53.2 cmH_2O to 24.1 cmH_2O. The values obtained and those predicted by ECosta showed a mean difference of -16.1 cmH_2O and an agreement interval of -54.9 cmH_2O to 22.6 cmH_2O (Figures 1 and 2).

Discussion

The analysis of RMS parameters becomes relevant especially when the morbidly obese individual is a candidate for gastroplasty surgery[28]. According to Barbalho-Moulin et al.[29], respiratory muscle dysfunction is the main cause of pulmonary complications after abdominal surgery and, because of this, respiratory muscle training is recommended. This study is informative for physical therapists and health professionals regarding the difficulties in using predictive RMS formulas that do not take body mass into account.

Respiratory muscle function can be severely compromised with obesity, which is due to the load placed on the diaphragm muscle. As a result of the reduced functional residual capacity (FRC), there is an increase in ventilation, and high flows are needed to perform maximal voluntary ventilation[30].

It may be noted that there was no difference between the MIP values obtained and those predicted by the EHarik equation in the normal-weight group. For the equation proposed by Neder et al.[25], however, we noted an overestimation of RMS; on the other hand, the values predicted for MIP by Costa et al.[27] were underestimated.

For the morbidly obese, therefore, depending on which RMS equation is used, three different conclusions could be drawn

Table 1. Age, anthropometric data and values attributed to habitual physical activity in morbidly obese and lean women.

	Morbidly Obese (n=30)	Lean Women (n=30)	p-value
Age (years)	33.06±5.4	30.6±5.4	0.1738
Height (m)	1.62±4.5	1.62±4.9	0.8303
Body weight (kg)	116.8±13.4	58.8±6.1	<0.0001
BMI (kg/m^2)	44.7±4.11	22.1±1.8	<0.0001
WC (cm)	124.1±10.4	78.7±7.4	<0.0001
WHR	0.92±0.07	0.80±0.11	<0.0001
NC (cm)	40.2±2.8	31.8±1.2	<0.0001
FVC (%P)	95.27±15.54	99.10±10.9	0.2749
FEV_1(%P)	88.31±4.31	102.75±13.2	<0.001
FEV_1/FVC (%P)	102.16±6.08	102.81±6.19	0.6834
LPA score	2.11±0.43	1.97±0.6	0.3377
Score LLPA	1.23±1.05	1.36±0.72	0.3418
Total score	3.35±1.28	3.33±1.09	0.9526

Values were expressed as mean and standard deviation. BMI: body mass index, WC: waist circumference, WHR: waist-to-hip ratio, NC: neck circumference, FVC (%P): Forced vital capacity in percentage predicted, FEV_1/FVC (%P), Ratio of FEV_1/FVC in percentage predicted, LPA: leisure physical activity, LLPA: leisure physical activity and locomotion. (*) p<0.05, difference between the values obtained from morbidly obese and lean women.

Table 2. Values of MIP and provided by the equations obtained EHarik, ENeder and ECosta the morbidly obese and lean women in cmH_2O.

	MIP Obtained	EHarik	ENeder	ECosta
Morbidly obese	-87.83±21.40**	-130.71±11.98*#	-94.55±3.05#	-50.37±2.86*#
Lean Women	-72±15.23	-79.76±5.31#	-95.47±2.57*#	-60.23±2.41*#

Values are expressed as mean±standard deviation. EHarik: equation proposed by Harik-Khan, Wise and Fozard[12], ENeder: equation proposed by Neder et al.[25], ECosta: equation proposed by Costa et al.[27]. (*p<0.05) significant difference between the values obtained and provided. (**p<0.05) significant difference between the values obtained from morbidly obese and lean women. (#p<0.05) significant difference between the values provided. MIP: maximal inspiratory pressure.

Table 3. Values of MEP and provided by the equations obtained EHarik, ENeder and ECosta the morbidly obese and lean women in cmH_2O.

	MEP Obtained	ENeder	ECosta
Morbidly obese	85.83±20.76	95.87±3.80*	97.36±4.23*
Lean Women	82.5±19.85	97.04±3.14*	98.63±3.57*

Values are expressed as mean±standard deviation. ENeder: equation proposed by Neder et al.[25], ECosta: equation proposed by Costa et al.[27]. (*p<0.05) significant difference between the values obtained and provided. MEP: maximal expiratory pressure.

for the same value, which confirms the study's hypothesis that the mathematical formulas in question cannot reliably predict the RMS of the morbidly obese. This fact may also explain the different results of studies attempting to evaluate the strength of respiratory muscles in the morbidly obese[28,31,32].

Due to the conflict between the obtained MIP measurements and those predicted by the EHarik equation for normal-weight volunteers, greater agreement was found between the obtained and predicted values from the Bland-Altman visual analysis, considering that there was no reason for

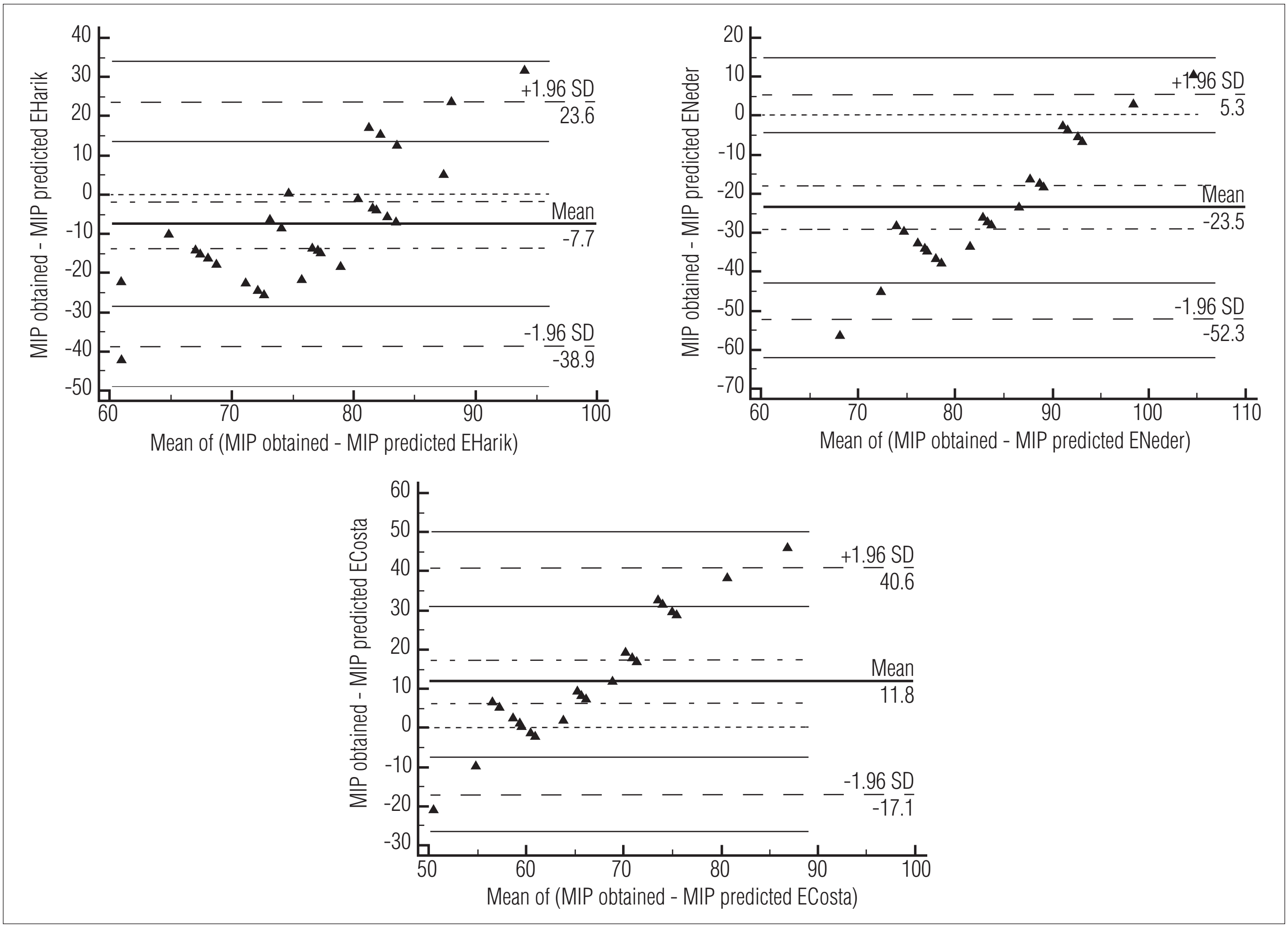

Figure 1. Concordance between the mean values of MIP (obtained and predicted) for EHarik, ENeder ECosta, using Bland-Altman plots. Mean± standard deviation (SD) 1.96 (in cmH_2O), 95%CI vs. mean differences between the mean values (obtained MIP - MIP provided).

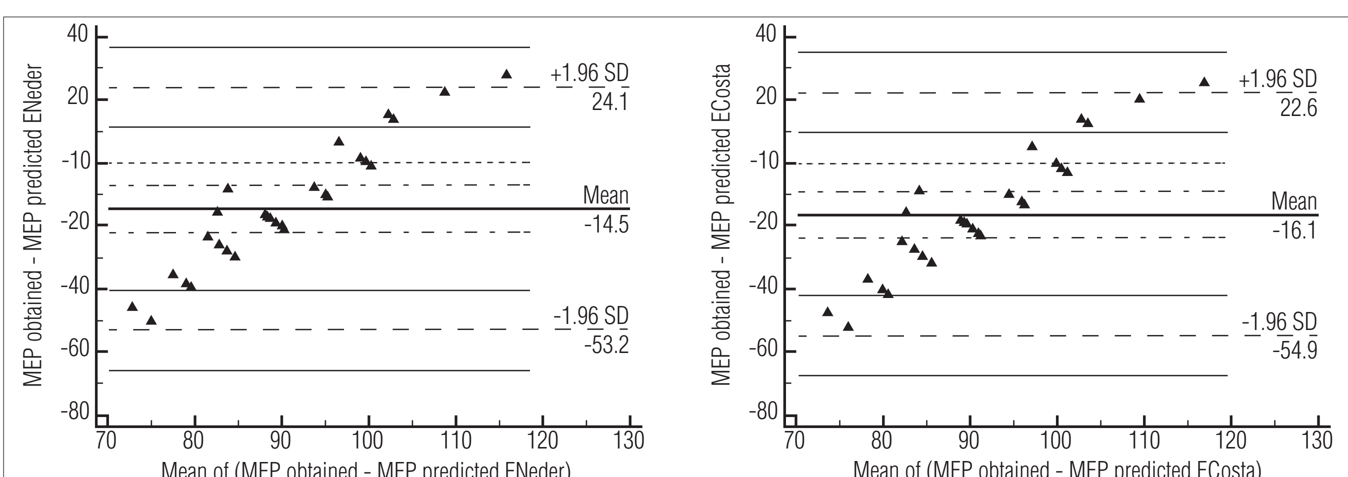

Figure 2. Concordance between the mean values of MEP (measured and predicted) for ENeder ECosta, using Bland-Altman plots. Mean±standard deviation (SD) 1.96 (in cmH_2O), 95%CI vs. mean difference between the mean values (obtained MIP - MIP provided).

normal-weight volunteers to have reduced or increased RMS. Since this formula is the only one that includes the volunteers' body mass and height, it was selected in this study as the most reliable for measuring the maximal respiratory pressure of the morbidly obese. This being the case, it can be confirmed that the inspiratory muscle strength of obese subjects is reduced.

This result may be explained by a restriction of the thoracic cage resulting from the excessive deposit of fat in the thoracoabdominal region, which would alter the mobility of the diaphragm muscles[33]. Apart from this, in obese patients, the weight of the abdomen brings the diaphragm to the cephalic position in the supine position, leading to closure of the small air passageways at the base of the lungs and intrinsic positive end expiratory pressure, resulting in increased ventilatory work and consequent muscle disadvantage[34].

The EHarik equation for MIP was most suitable for the control group. This result was also found by Leal et al.[35], who evaluated the respiratory pressure of 475 healthy sedentary adults and concluded that the most suitable equations for that population were Harik-Kahn and Wise and Fozard[12] for MIP, which consider body mass, age and height and the Neder et al.[25] equation for MEP, which considers age. However, since the predicted values of Neder et al.[25] fit those of normal weight subjects in the present study, the equation was not considered as suitable for predicting expiratory muscle strength in morbidly obese patients.

In another study published by Parreira et al.[36], it was concluded that the equations proposed by Neder et al.[25] could not predict MIP or MEP values in a population of healthy non-obese individuals, and these differences were attributed to methodological differences between the studies.

As in the present study, other researchers using the Neder et al.[25] equations have found contradictory results regarding RMS behavior in the morbidly obese. Magnani and Cataneo[5] performed a study with a group of obese individuals who had been recommended for bariatric surgery (with an average BMI of 44.42 kg/m^2) and observed that both the MIP and MEP were within normal limits. Castello et al.[28] found that morbidly obese women had lower values for MIP (76% of the predicted) and for MEP (67% of the predicted) compared to normal-weight women in the same age range. It could be said that the results for the obese individuals in this study were similar to those of Castello et al.[28], but the values predicted by Harik-Kahn, Wise and Fozard[12] for MIP and those of Neder et al.[25] and/or Costa et al.[27] for MEP would have to be taken into account.

The results obtained for MIP, considered separately, corroborate those of Costa et al.[32], who evaluated 57 obese individuals and 46 sedentary normal-weight individuals, confirming that obese individuals have greater MIP and MEP than normal-weight individuals. Costa et al.[32] did not calculate predicted values according to established equations, although they highlighted the importance of a normal-weight control group for evaluating RMS due to the numerous different equations for estimating pressure values.

The increased respiratory muscle strength in the obese participants may be explained by an adaptation to the chronic overload that accompanies obesity, shown by the greater quantity of type II fibers and the reduced quantity of type I fibers[37]. However, because of the difference between obtained and predicted MEP values in the normal-weight subjects and the fact that the Bland-Altman analysis indicated the predicted values were overestimated, the expiratory muscle strength of the morbidly obese in this study remains inconclusive.

Costa et al.[27] conducted a study comparing MIP and MEP measurements in healthy individuals with values predicted by the Neder et al.[25] equations in order to determine reference equations for the Brazilian population. They observed that the predicted value for IP was significantly greater than their obtained value, although there was no difference between predicted and obtained MEP values. They attributed their findings to the fact that the Neder et al.[25] study did not specify the size of the hole in the mouthpiece to reduce buccinator muscle pressure. This information could help explain our findings on the inspiratory muscle strength of normal-weight individuals with respect to the ENeder equation.

Enright et al.[38] reported that the positive predictors for MIP are gender, FVC, handgrip strength and quantity of lean mass. Some studies have specifically shown that obese individuals have greater peripheral muscle strength than normal-weight individuals, which is probably associated with a greater fat-free mass[39,40]. Since the volunteers' body composition was not evaluated in this study, the MRP findings cannot be attributed to the amount of fat.

Bruschi et al.[41] reported great variety in the results of studies on MRP. They attribute the variability to the different methodologies involved, such as the type of mouthpiece, the number of maneuvers performed, body position and differences in the populations studied.

Some limiting factors to be considered for this study are the lack of a cardio-pulmonary test, the lack of a body composition evaluation and the lack of analysis of other RMS studies, especially those involving Brazilian populations.

Conclusion

The inspiratory muscle strength of morbidly obese women in this study was greater than that of normal-weight women. Of the three equations used in this study, that of Harik-Khan et al.[12] seems the most suitable for calculating the MIP measurement reference values of the morbidly obese. Morbidly obese and normal-weight women appear to show similarities in expiratory muscle strength behavior, but these findings are still inconclusive.

Acknowledgements

To the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES/PROSUP) and the *Programa Institucional de Bolsas de Iniciação Científica* (PIBIC/CNPQ) for financial support, and to Maria Imaculada de Lima Montebello for contributing to the statistical analysis.

References

1. Sood A. Altered resting and exercise respiratory physiology in obesity. Clin Chest Med. 2009;30(3):445-54.
2. McClean KM, Kee F, Young IS, Elborn JS. Obesity and the lung: 1. Epidemiology. Thorax. 2008;63(7):649-54.
3. Murugan AT, Sharma G. Obesity and respiratory diseases. Chron Respir Dis. 2008;5(4):233-42.
4. Conway B, Rene A. Obesity as a disease: no lightweight matter. Obes Rev. 2004;5(3):145-51.
5. Magnani KL, Cataneo AJM. Respiratory muscle strength in obese individuals and influence of upper-body fat distribution. São Paulo Med J. 2007;125(4):215-9.
6. Weiner P, Waizman J, Weiner M, Rabner M, Magadle R, Zamir D. Influence of excessive weight loss after gastroplasty for morbid obesity on respiratory muscle performance. Thorax. 1998;53(1):39-42.
7. O'Brien PE, Dixon JB. The extent of the problem of obesity. Am J Surg. 2002;184(6B):4-8.
8. Simoneau JA, Veerkamp JH, Turcotte LP, Kelley DE. Markers of capacity to utilize fatty acids in human skeletal muscle: relation to insulin resistance and obesity and effects of weight loss. FASEB J. 1999;13(14):2051-60.
9. Hulens M, Vansant G, Lysens R, Claessens AL, Muls E, Brumagne S. Study of differences in peripheral muscle strength of lean versus obese women: an allometric approach. Int J Obes Metab Disord. 2001;25(5):676-81.
10. Tanner CJ, Barakat HA, Dohm GL, Pories WJ, MacDonald KG, Cunningham PR, et al. Muscle fiber type is associated with obesity and weight loss. Am JPhysiol Endocrinol Metab. 2002;282(6):E1191-6.
11. Eichenberger A, Proietti S, Wicky S, Frascarolo P, Suter M, Spahn DR, et al. Morbid obesity and postoperative pulmonary atelectasis: an underestimated problem. Anesth Analg. 2002;95(6):1788-92.
12. 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.
13. Simões RP, Deus APL, Auad MA, Dionísio J, Mazzonetto M, Borghi-Silva A. Maximal respiratory pressure in healthy 20 to 89 year-old sedentary individuals of central São Paulo State. Rev Bras Fisioter. 2010;14(1):60-7.
14. Baecke JA, Burema J, Frijters JE. A short questionnaire for the measurement of habitual physical activity in epidemiological studies. Am J Clin Nutr. 1982;36(5):936-42.
15. Florindo AA, Latorre MRDO. Validação e reprodutibilidade do questionário de Baecke de avaliação da atividade física habitual em homens adultos. Rev Bras Med Esporte. 2003;9(3):121-8.
16. Neder JA, Andreoni S, Castelo-Filho A, Nery LE. Reference values for lung function tests. I. Static volumes. Braz J Med Biol Res. 1999;32(6):703-17.
17. Pereira CAC. Diretrizes para testes de função pumonar. J Pneumol. 2002;28(3):1-82.
18. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. Eur Respir J. 2005;26(2):319-38.
19. Pereira CAC, Barreto SP, Simões JG, Pereira FWL, Gerstler JG, Nakatami J. Valores de referência para espirometria em uma amostra da população brasileira adulta. J Pneumol. 1992;18(1):10-22.
20. Gonçalves MJ, do Lago STS, Godoy EP, Fregonezi GAF, Bruno SS. Influence of neck circumference on respiratory endurance and muscle strength in the morbidly obese. Obes Surg. 2010;21(8):1250-6.
21. Sievenpiper JL, Jenkins DJ, Josse RG, Leiter LA, Vuksan V. Simple skinfold-thickness measurements complement conventional anthropometric assessments in predicting glucose tolerance. Am J Clin Nutr. 2001;73(3):567-73.
22. Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. Am Rev Respir Dis. 1969;99(5):696-702.
23. Badr C, Elkins MR, Ellis ER. The effect of body position on maximal expiratory pressure and flow. Aust J Physiother. 2002;48(2):95-102.
24. American Thoracic Society/ European Respiratory Society. ATS/ERS statement on respiratory muscle testing. Am J Respir Crit Care Med. 2002;166(4):518-624.
25. Neder JA, Andreoni S, Lerario MC, Nery LE. Reference values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Braz J Med Biol Res. 1999;32(6):719-27.
26. Souza RB. Pressões respiratórias estáticas máximas. J Pneumol. 2002;28(Suppl. 3):S155-S65.
27. Costa D, Gonçalves HA, Lima LP, Ike D, Cancelliero KM, Montebelo MIL. Novos values de referência para pressões respiratórias máximas na população brasileira. J Bras Pneumol. 2010;36(3):306-12.
28. Castello V, Simões RP, Bassi D, Mendes RG, Borghi-silva. A força muscular respiratory é marcantemente reduzida em women obesas mórbidas. Arq Méd ABC. 2007;32(2):74-7.
29. Barbalho-Moulin MC, Miguel GPS, Forti EMP, Campos FA, Costa D. Effects of preoperative inspiratory muscle training in obese women undergoing open bariatric surgery: respiratory muscle strength, lung volumes, and diaphragmatic excursion. Clinics. 2011;66(10):1721-7.
30. Sahebjami H. Dyspnea in obese healthy men. Chest. 1998;114(5):1373-7.
31. Teixeira CA, Santos JE, Silva GA, Souza EST, Martinez JAB. Prevalência de dispnéia e possíveis mecanismos fisiopatológicos envolvidos em indivíduos com obesity graus 2 e 3. J Bras Pneumol. 2007;33(1):28-35.
32. Costa TR, Lima TP, Gontijo PL, Carvalho HA, Cardoso FPF, Faria OP, et al. Correlação da força muscular respiratory com variáveis antropométricas de women eutróficas e obesas. Rev Assoc Med Bras (1992). 2010;56(4):403-8.
33. Parameswaran K, Todd DC, Soth M. Altered respiratory physiology in obesity. Can Respir J. 2006;13(4):203-10.
34. Lin CK, Lin CC. Work of breathing and respiratory drive in obesity. Respirology. 2011;17(3):402-11.
35. Leal AH, Hamasaki TA, Jamami M, Di Lorenzo VAP, Pessoa BV. Comparação entre values de força muscular respiratory medidos e predicted por diferentes equations. Fisioter Pesqui. 2007;14(3):25-3.
36. Parreira VF, França DC, Zampa CC, Fonseca MM, Tomich GM, Britto RR. Pressões respiratórias máximas: values encontrados e preditos em indivíduos saudáveis. Rev Bras Fisioter. 2007;11(5):361-8.

37. Santiago-Recuerda A, Gómez-Terreros FJ, Caballero P, Martin-Duce A, Soleto MJ, Vesperinas G, et al. Relationship between the upper airway and obstructive sleep apnea-hypopnea syndrome in morbidly obese women. Obes Surg. 2007;17(5):689-97.

38. 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.

39. Rolland Y, Lauwers-Cances V, Pahor M, Fillaux J, Grandjean H, Vellas B. Muscle strength in obese elderly women: effect of recreational physical activity in a cross-sectional study. Am J Clin Nutr. 2004;79(4):552-7.

40. Lafortuna CL, Maffiuletti NA, Agosti F, Sartorio A. Gender variations of body composition, muscle strength and power output in morbid obesity. Int J Obes (Lond). 2005;29(7):833-41.

41. Bruschi C, Cerveri I, Zoia MC, Fanfulla F, Fiorentini M, Casali L, et al. Reference values of maximal respiratory mouth pressures: a population-based study. Am Rev Respir Dis. 1992;146(3):790-3.