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Comparison of three protocols for measuring the maximal respiratory pressures[1]

Comparação de três protocolos na mensuração das pressões respiratórias máximas

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Abstract

Introduction: To avoid the selection of submaximal efforts during the assessment of maximal inspiratory and expiratory pressures (MIP and MEP), some reproducibility criteria have been suggested. Criteria that

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stand out are those proposed by the American Thoracic Society (ATS) and European Respiratory Society (ERS) and by the Brazilian Thoracic Association (BTA). However, no studies were found that compared these criteria or assessed the combination of both protocols. **Objectives**: To assess the pressure values selected and the number of maneuvers required to achieve maximum performance using the reproducibility criteria proposed by the ATS/ERS, the BTA and the present study. **Materials and method**: 113 healthy subjects (43.04 ± 16.94 years) from both genders were assessed according to the criteria proposed by the ATS/ERS, BTA and the present study. Descriptive statistics were used for analysis, followed by ANOVA for repeated measures and *post hoc* LSD or by Friedman test and *post hoc* Wilcoxon, according to the data distribution. **Results**: The criterion proposed by the present study resulted in a significantly higher number of maneuvers (MIP and MEP – median and 25%-75% interquartile range: 5[5-6], 4[3-5] and 3[3-4] for the present study criterion, BTA and ATS/ERS, respectively; p < 0.01) and higher pressure values (MIP – mean and 95% confidence interval: 103[91.43-103.72], 100[97.19-108.83] and 97.6[94.06-105.95]; MEP: median and 25%-75% interquartile range: 124.2[101.4-165.9], 123.3[95.4-153.8] and 118.4[95.5-152.7]; p < 0.05). **Conclusion**: The proposed criterion resulted in the selection of pressure values closer to the individual's maximal capacity. This new criterion should be considered in future studies concerning MIP and MEP measurements.

Keywords: Respiratory Function Tests. Muscle Strength. Protocols.

Resumo

Introdução*: Para evitar a seleção de esforços submáximos durante as medidas das pressões inspiratórias e expiratórias máximas ($PI_{máx}$ e $PE_{máx}$), alguns critérios de reprodutibilidade têm sido sugeridos, destacando-se os propostos pela ATS/ERS e pela SBPT. Entretanto, não foram encontrados na literatura estudos que confrontem esses dois critérios, ou que investiguem a combinação de ambos.* ***Objetivos****: Avaliar os valores pressóricos selecionados e o número de manobras necessárias para se alcançar a capacidade máxima por meio do emprego dos critérios de reprodutibilidade propostos pela ATS/ERS, pela SBPT e pelo presente estudo.* ***Materiais e métodos****: Foram avaliados 113 indivíduos saudáveis (43,04 ± 16,94 anos), de ambos os sexos, considerando-se os critérios de reprodutibilidade propostos pela ATS/ERS, pela SBPT e pelo presente estudo. Análise estatística realizada com estatística descritiva, seguida do teste ANOVA para medidas repetidas (*post hoc *LSD) ou do teste de Friedman (*post hoc *Wilcoxon), segundo a normalidade dos dados.* ***Resultados****: O critério proposto resultou em um número de manobras significativamente maior ($PI_{máx}$ e $PE_{máx}$ – mediana e intervalo interquartílico 25%-75%: 5[5-6], 4[3-5] e 3[3-4] para este estudo, SBPT e ATS/ERS, respectivamente; p < 0,01) e na seleção de valores pressóricos mais elevados ($PI_{máx}$ – média e intervalo de confiança 95%: 103[91,43-103,72], 100[97,19-108,83] e 97,6[94,06-105,95]; $PE_{máx}$ – mediana e intervalo interquartílico 25%-75%: 124,2[101,4-165,9], 123,3[95,4-153,8] e 118,4[95,5-152,7] para este estudo, SBPT e ATS/ERS, respectivamente; p < 0,05).* ***Conclusão****: O critério proposto resultou em valores pressóricos mais próximos da real capacidade máxima dos sujeitos avaliados. Este novo critério deve ser considerado em estudos futuros relacionados às medidas de $PI_{máx}$ e $PE_{máx}$.*

Palavras-chave*: Testes de Função Respiratória. Força Muscular. Protocolos.*

Introduction

Measurements of maximal respiratory pressures (MRP) represent the most common non-invasive method used in clinical practice to assess respiratory muscle strength (1). The reliability and validity of maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were previously studied and are considered appropriate (1, 2).

Since 1960, several groups of researchers have established normal values for MRP, especially for MIP (3-14). It is hypothesized that differences of normal values among the numerous studies may be explained by individual factors such as sex, age, height, weight, fitness level and smoking status, as well as methodological factors related to the execution of procedures and data analysis (1, 2, 15-17).

Among the methodological factors identified in the literature, emphasis is given to the the test completion criterion, e.g., the total number of maneuvers performed, referred to as reproducibility, and the impossibility of reaching the higher value in the last maneuver (3, 6, 9, 10), related to the learning effect of the MRP tests (6).

Studies on healthy adults (18) and on patients with chronic respiratory disorders (19) demonstrated a learning effect in relation to the number of maneuvers required to achieve the maximum capacity. The learning effect was also documented in the study by Enright et al. (7), which used a sample of 2,871 healthy older adults between the ages of 65-85 years. This study standardized a maximum of five maneuvers and found a strong learning effect during the measurements of MIP, with the highest value recorded in the fifth maneuver.

To standardize the measurement procedure of MRP, both the Brazilian Thoracic Association (BTA) (20) and the American Thoracic Society together with the European Respiratory Society (ATS/ERS) (1) published guidelines in 2002 for testing MRP. According to the BTA (20), the minimum number of maneuvers to be performed is three, and the reproducibility of the measurement is assured by the presence of at least two MRP values that do not differ more than 10% from one another. Additionally, if the higher MRP value is reached on the last attempt, the test should be continued until a lower value is produced. On the other hand, the ATS/ERS (1) recommend a minimum of three maneuvers, and the reproducibility is defined by the measurement of three values that vary less than 20% from one another (1). However, there are no studies in the literature that compare the use of these two different criteria, alone or in combination, to assess reproducibility on selected pressure values. With this context, the aim of this study was to evaluate the number of maneuvers required for an individual to reach the maximum capacity during the MRP measurements, as well as to compare the pressure values selected from the use of the reproducibility criteria proposed by ATS/ERS (1), the BTA (20) and the criterion proposed by the authors. This last criterion was created from a combination of the reproducibility criteria mentioned above associated with the performance of a greater number of MIP and MEP maneuvers.

Materials and method

Sample

The study sample was composed of volunteers of both sexes, selected in the internal and external community of the University where the study was conducted. Inclusion criteria consisted of healthy adults between the ages of 20 and 89 and body mass index (BMI) within healthy limits (18.5 kg/m^2 and 29.9 kg/m^2). Exclusion criteria consisted of a history of smoking or exposure to smoking, a history of neuromuscular, respiratory and/or heart disease, presence of cognitive deficits, presence of fever in the previous three weeks and/or flu in the week before the test, use of oral medications such as steroids, central nervous system depressants, barbiturates and/or muscle relaxants, spirometric parameters outside the limits predicted for the Brazilian population (21), performance of exhaustive exercise in 48 hours prior to the test, teeth absence, presence of limiting muscle pain in the upper limbs, blood pressure (BP) greater than or equal to 160/100 mmHg at rest and/or peripheral hemoglobin saturation (SpO_2) less than 90% and/or heart rate (HR) 85% of maximal HR before execution of the maneuvers and inability to understand and/or perform the procedures in the study protocol. Study was interrupted if the patient reported the respiratory and/or muscle discomfort during testing.

The study was approved by the Ethics Committee of the institution (CAAC 0425.0.203.000-10) and all participants signed an informed consent, in accordance with Resolution 196/96 of the National Health Council.

Instruments

To access the MRP, a digital manometer (NEPEB-LabCare/UFMG) was used, in which the pressures are measured by means of a pressure transducer with an operating range of 500 cmH_2O (22). A flanged silicone mouthpiece and a leak hole of 2 mm as recommended by ATS/ERS (1) were used. The MRPs were operationalized by the 1-sec average computation ($PMed_{max}$) (23-25).

The manometer was calibrated using a digital gauge (PC507, Hotek Technologies, Tacoma, Washington) and a pneumatic pump (8111-300, Presys, São Paulo, Brazil) as established by Ferreira et al. (22).

Procedures

The initial evaluation included demographic data, examination of body mass and height (anthropometric balance, Filizola Ind Ltda, São Paulo, SP, Brazil), BP (stethoscope, Littman Classic II, 3M Center, St. Paul, MN, USA, and sphygmomanometer, Tycos, WelchAllyn Inc. Corporate Headquarters, New York, NY, USA); HR and SpO_2 (pulse oximeter, Nonim, USA). Next, volunteers over the age of 60 answered the mini-mental state examination, with cutoffs set at 18/19 for illiterates and 23/24 for educated (26). The pulmonary function test (FX™ Pony, Cosmed, Rome, Italy) was performed next, according to the criteria of acceptability, reliability and graduation of quality proposed by BTA (27).Values predicted for the Brazilian population were used as reference (21). After resting for approximately 10 min, subjects performed the measurement of MRP. All procedures were performed by the same examiner in a single visit and were stopped according to pre-established criterion.

Maximal respiratory pressures measurements

Subjects were evaluated in a sitting position with their legs and trunk supported, using a nose clip. For MIP measurement, participants were instructed to breathe smoothly, according to the verbal command of "Put the air out, put air in". Two to three breaths in tidal volume level (VT) preceded the MIP test. Next, expiration to residual volume (RV) was requested, with the participant raising his own hand to indicate appropriate stop time. At this time, the participant was asked to generate a maximal inspiratory effort and, simultaneously, the examiner proceeded to close the orifice occlusion. The verbal command of "Put all the air out and fill the lungs with air" was used (20, 25).

The same procedure was used for the measurement of MEP with the exception of the final verbal instruction, which consisted of the solicitation of an inspiration till total lung capacity (TLC) was achieved, followed by maximum expiratory effort (20, 25). The minimum operating time was 1.5 sec; thus, the maximum pressure sustained for a second could be observed (1).

Reproducibility criteria

The MRP values measured were obtained after analysis from the reproducibility criteria proposed by ATS/ERS (1), BTA (20) and by the present study. The ATS/ERS (1) recommends conducting three acceptable measures of less than 20% variance from one another. The BTA (20) recommends that there should be at least two measurements whose values are less than 10% different. The BTA also recommends that if the highest value is reached on the last attempt, the test should continue until a lower value is produced (20). In the proposed protocol, the subject should perform at least five maneuvers with three measures of less than 20% variability, and the highest measure should not be the last.

Data analysis

Data were processed by three different versions of the software Manovac (3.0 Manovac, Manovac 4.0 and Manovac 4.1). The Manovac 3.0 was programmed to meet the BTA criteria (20) by selecting values from the two reproducible, acceptable maneuvers of less than 10% variance. Additionally, the analysis was set to ensure that the last test was not the one with the highest value. The Manovac 4.0 was programmed to meet the criteria of ATS/ERS (1) by selecting three reproducible maneuvers of less than 20% variation, with no restriction on the value achieved in the last maneuver. To implement the criterion proposed by the present study, the Manovac version 4.1 enabled the selection, from all acceptable maneuvers, of three reproducible maneuvers with less than 20% variation, as long as the last maneuver performed was not the one of the highest value. Only acceptable maneuvers were considered valid (no air leaks and duration of at least 1.5 sec) (20), and statistical analysis was used for the greatest values of MIP or MEP achieved considering each criterion investigated.

Statistical analysis

For data analysis, we considered the number of maneuvers required to reach the maximum capacity and the value of $PMed_{max}$ obtained separately, by adopting the reproducibility criteria recommended by the BTA (20), the ATS/ERS (1) and the present study.

Initially, the exploratory data analysis was conducted using descriptive statistics and the assessment of normality (Kolmogorov-Smirvov). Afterwards, in cases where the data were normally distributed, we used ANOVA for repeated measures, followed by post-hoc LSD. For data with distributions that differed from normal, the Friedman's test was used, followed by post hoc Wilcoxon. A significance level of 5% was established.

Results

Initially, 121 volunteers were contacted. Eight were excluded due to obstructive or restrictive disorders in pulmonary function testing, were contacted. The final sample consisted of 113 volunteers. Table 1 shows the demographic and anthropometric characteristics as well as individual spirometric variables assessed.

Table 1 - Demographic, anthropometric and spirometric data for 113 subjects

Variables	Volunteers
Age (y)	43.04 ± 16.94
Gender	71 F / 42 M
Body mass (kg)	66.98 ± 12.36
Height (cm)	166 ± 11
BMI (kg/m^2)	24.26 ± 2.8
FEV_1 (% of predicted)	93.4 ± 13.66
FVC (% of predicted)	93.71 ± 13.73
FEV_1 / FVC (%)	81.75 ± 5.58

Note: Data presented as mean and standard deviation (except for Gender). y = years; F = female; M = male; BMI = body mass index; FEV_1 = forced expiratory volume in one second; FVC = forced vital capacity.

Figure 1 shows the number of maneuvers required to achieve the maximum capacity. The number of maneuvers was greater with the criterion proposed by this study, both in relation to the protocol of the BTA (20) (MIP and MEP – median and interquartile range 25%-75%: 5 [5-6] x 4 [3- 5]; $p < 0.001$) and the ATS/ERS (1) (MIP and MEP – median and interquartile range 25%-75%: 5 [5-6] x 3 [3-4], $p < 0.001$). When the protocols of the BTA (20) and the ATS/ERS (1) were compared, the greatest number of maneuvers was observed using the protocol of the BTA (20) for both the MIP measurement ($p < 0.001$) and for the MEP measurement ($p < 0.01$).

Figure 2 shows the values of $PMed_{max}$ selected from the use of each of the reproducibility criteria studied. It can be observed that use of the criterion proposed by this study resulted in the selection of MIP and MEP measures that were significantly higher (MIP – mean and 95% confidence interval: 103 [91.43 to 103.72], 100 [97.19 to 108.83] and 97.6 [94.06 to 105.95]; MEP: median and interquartile ranges 25%-75%: 124.2 [101.4 to 165.9], 123.3 [95.4 to 153.8] and 118.4 [95.5 to 152.7] for the present study criterion, BTA and ATS / ERS, respectively; $p < 0.05$). When the protocols of the BTA (20) were compared to the ATS/ERS (1), higher values were observed with the use of the BTA protocol (20) for both the MIP measurement ($p = 0.023$) and for the MEP measurement ($p = 0.002$).

Discussion

There were two main results of the study. First, a greater number of maneuvers (MIP and MEP) was necessary to achieve the reproducibility criterion proposed by this study in relation to the other criteria evaluated. Second, the use of the criterion proposed by the present study resulted in significantly higher pressure values for both MIP and MEP measurements.

The measurement of MRP at the mouth is easily accomplished and presents good patient tolerance. These are features that, combined with the development of portable measuring instruments, contributed to the spread of this method of assessment and increase in its popularity. However, given that MIP is volitional, understanding and cooperation of the individuals evaluated are required. Thus, low values of MIP and MEP may not necessarily reflect reduced muscle strength. Instead, the values may just be the result of individuals' lack of motivation and/or coordination among individuals. Thus, it is not easy to truly ensure that maximum efforts are being made during assessments (1).

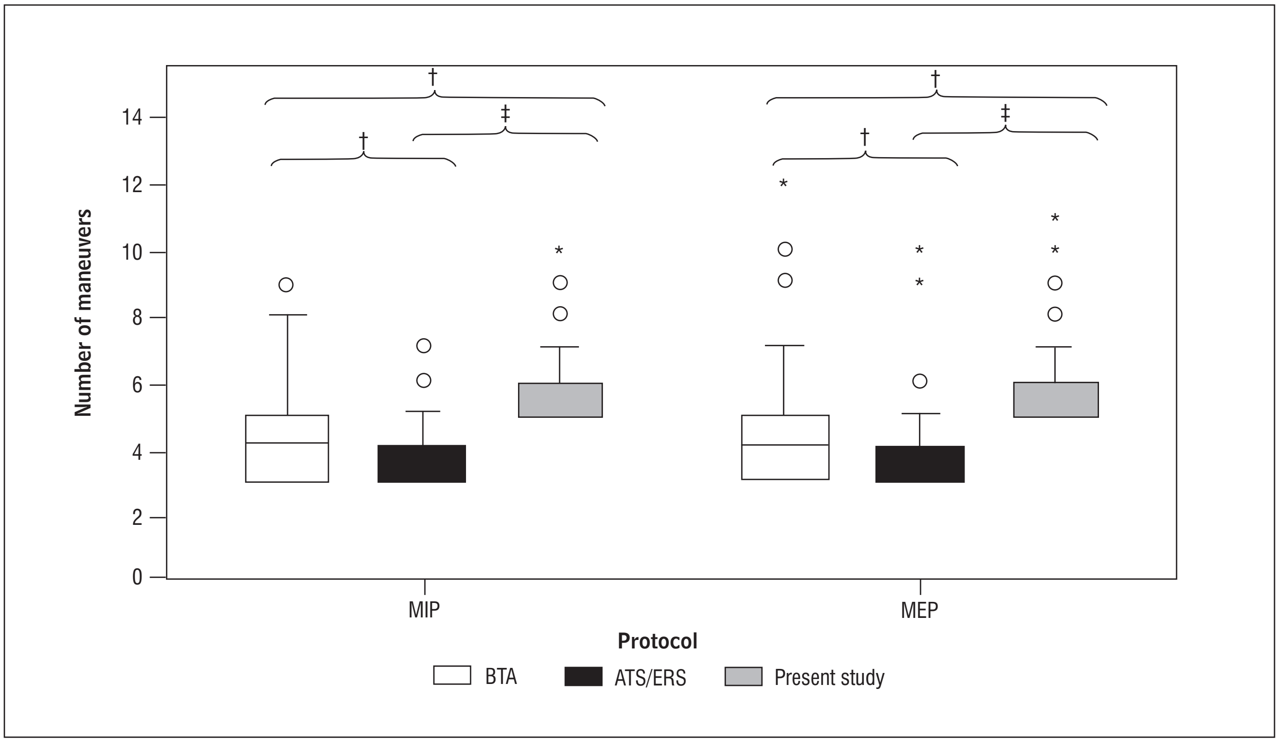

Figure 1 - Number of maneuvers required to achieve the reproducibility criteria proposed by the Brazilian Thoracic Association (BTA), by the American Thoracic Society/European Respiratory Society (ATS/ERS) and by the present study

Note: MIP refers to maximal inspiratory pressure and MEP refers to maximal expiratory pressure. ° Outlier. * Extreme. Friedman test with Wilcoxon post hoc. † Different from SBPT. ‡ Different from ATS/ERS.

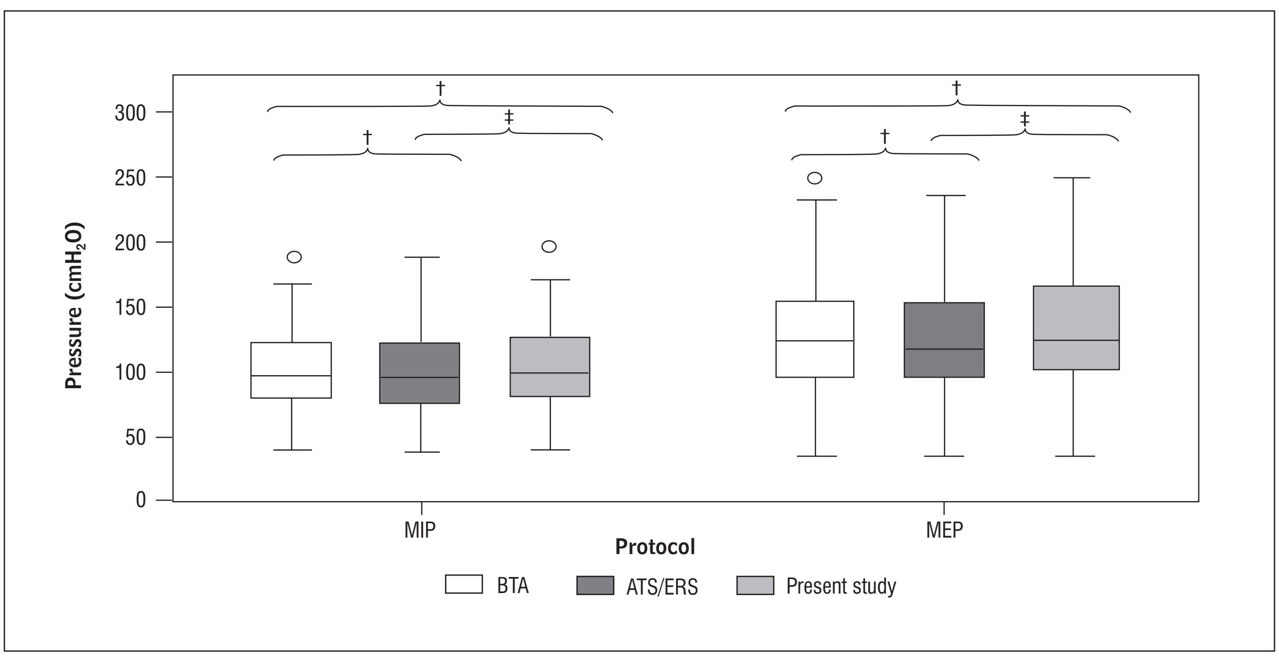

Figure 2 - MIP and MEP values selected using the reproducibility criteria proposed by the Brazilian Thoracic Association (BTA), by the American Thoracic Society / European Respiratory Society (ATS/ERS) and by the present study

Note: MIP refers to maximal inspiratory pressure; MEP refers to maximal expiratory pressure and cmH_2O refers to centimeters of water. ° Outlier. MIP data are expressed as absolute values. MIP measurements: repeated measures ANOVA with LSD pos hoc. MEP measurements: Friedman test with Wilcoxon post hoc. † Different from SBPT. ‡ Different from ATS/ERS.

The literature reports that submaximal inspiratory pressures can be generated with reproducibility similar to maximum pressures (28). In this perspective, the selection of truly maximum effort depends not only on the determination of a maximum range of variation between successive measurements but also on the realization of a greater number of attempts, taking into account the learning effect.

Most studies that have sought to establish reference values of MRP did not take into account the need for further testing if the last maneuver yielded the highest value (4, 5, 7, 8, 11, 13, 14). In some studies, the authors were aware of this. Sachs et al. (29) performed a minimum of five MIP maneuvers and defined a control parameter based on the learning effect. This parameter stated the need to perform three additional maneuvers if the highest value was obtained in the fifth maneuver or if the second highest value was less than 90% of the largest value (maximum 10% variation between the two highest values) (1, 20). Fiz et al. (19) investigated the number of measurements needed to properly evaluate the MIP of individuals with chronic airflow limitation. The volunteers performed 20 consecutive maneuvers and the results indicated that at least nine maneuvers are necessary for maximum and reproducible measurements to be obtained. Volianitis et al. (30) studied healthy subjects and evaluated a protocol of 18 consecutive measurements of MIP, which revealed that MIP measurements yielded progressively higher values until the eighteenth attempt. In both cases, the authors related the results to the occurrence of the learning effect. It is possible that the results of this study also relate to the occurrence of this effect because the use of the present study criterion resulted in the realization of a greater number of MIP and MEP maneuvers, as compared to other protocols, thus providing greater familiarization of individual with the testing procedures.

The criterion of reproducibility proposed by this study resulted in the selection of MIP and MEP measurements that were significantly higher compared to other protocols investigated. However, it can be seen that the pressure values obtained from the use of each criterion, although significantly different, showed median values that were very close together (Figure 2). Therefore, it is possible that in healthy individuals without of respiratory muscles impairment, the selection of a reproducibility criterion has no significant clinical implication because the pressure values tend to appear within normal limits. However, in subjects with suspected respiratory muscle weakness, the option for a more rigorous reproducibility criterion may be clinically significant. The criterion would result in pressure values closer to the actual capacity of the evaluated subjects, which influences the classification of respiratory muscle weakness, especially among patients whose values are situated very close to the lower limit of normality.

Souza (20) shows that, for practical reasons, most authors have limited to five the number of maneuvers performed during the measurements of the PRM to five. Indeed, the performance of an excessive number of maneuvers is questionable in clinical practice, particularly in patients with compromised ventilation and/or respiratory muscle weakness. Thus, regardless of the context of clinical practice or research contexts, selection of submaximal effort when a small number of maneuvers are performed should be considered. The present study criterion appears to be a feasible option in clinical practice because it resulted in the selection of efforts closer to the actual individuals maximum capacity, with the completion of approximately six maneuvers both for MIP and MEP measurements.

The number of maneuvers required to reach maximum capacity using the BTA (20) criterion was also significantly higher as compared to the ATS/ERS criterion (1). This can be partly attributed to greater methodological rigor advocated by BTA (20). After all, aside from establishing a shorter variation interval than that suggested by the ATS/ERS (1) (10% versus 20%, respectively), BTA adds the condition that the last maneuver cannot present the highest value. If this indeed occurs, it is appropriate to conduct additional maneuvers until a lower pressure value is reached. The greatest number of maneuvers from the use of the reproducibility criterion recommended by BTA (20) can justify the selection of higher pressure values in relation to the use of the criterion established by the ATS/ERS (1), which relates to the learning effect.

This study has limitations such as the disproportion between the number of men and women evaluated. This fact was due to the researchers' greater ease in recruiting female volunteers. However, no studies have assessed the influence of gender on the reproducibility of MRP measurements; therefore, we cannot say whether this gender imbalance influenced the results. Additionally, the evaluated sample presented significant age heterogeneity, because this study covered a broad age range, between 20 and 85 years. However, it should be emphasized that the search for a heterogeneous sample was intentional, to increase the external validity of the study, so that the observed results could apply to all adults and not just a certain age group.

Conclusion

The use of the reproducibility criterion proposed by the present study resulted in the selection of higher pressure values than those recommended by the BTA (20) or by the ATS/ERS (1). Thus, the proposed criterion represents a useful alternative for the selection of truly maximum efforts during the measurements of MRP.

References

1. American Thoracic Society/European Respiratory Society. ATS/ERS Statement on respiratory muscle testing. Am J Respir Crit Care Med. 2002;166(4):518-624.
2. Larson JL, Kim MJ. Reliability of maximal inspiratory pressure. Nurs Res. 1987;36(5):317-9.
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.
4. Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. Am Rev Respir Dis. 1969;99(5):696-702.
5. Wilson SH, Cooke NT, Edwards RH, Spiro SG. Predicted normal values for maximal respiratory pressures in caucasian adults and children. Thorax. 1984; 39(7):535-8.
6. 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.
7. 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.
8. 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.
9. 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.
10. Hautmann H, Hefele S, Schotten K, Huber RM. Maximal inspiratory mouth pressures (PIMAX) in healthy subjects — what is the lower limit of normal? Respir Med. 2000;94(7):689-93.
11. Windisch W, Hennings E, Sorichter S, Hamm H, Criée CP. Peak or plateau maximal inspiratory mouth pressure: which is best? Eur Respir J. 2004;23(5):708-13.
12. Simoes RP, Deus AP, Auad MA, Dionisio J, Mazzonetto M, Borghi-Silva A. 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.
13. 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.
14. Gopalakrishna A, Vaishali K, Prem V, Aaron P. Normative values for maximal respiratory pressures in an Indian Mangalore population: A cross-sectional pilot study. Lung India. 2011;28(4):247-52.
15. Fiz JA, Carreres A, Rosell A, Montserrat JM, Ruiz J, Morera JM. Measurement of maximal expiratory pressure: effect of holding the lips. Thorax. 1992;47(11):961-3.
16. Carpenter MA, Tockman MS, Hutchinson RG, Davis CE, Heiss G. Demographic and anthropometric correlates of maximum inspiratory pressure: The Atherosclerosis Risk in Communities Study. Am J Respir Crit Care Med. 1999;159(2):415-22.
17. Wohlgemuth M, van der Kooi EL, Hendriks JC, Padberg GW, Folgering HT. Face mask spirometry and respiratory pressures in normal subjects. Eur Respir J. 2003; 22(6):1001-6.
18. Terzi N, Corne F, Mouadil A, Lofaso F, Normand H. Mouth and nasal inspiratory pressure: learning effect and reproducibility in healthy adults. Respiration. 2010;80(5):379-86.

19. Fiz JA, Montserrat JM, Picado C, Plaza V, Agusti-Vidal A. How many manoeuvres should be done to measure maximal inspiratory mouth pressure in patients with chronic airflow obstruction? Thorax. 1989; 44(5):419-21.

20. Souza RB. Pressões respiratórias estáticas máximas. J Bras Pneumol. 2002;28(Supl 3):S155-65.

21. Pereira CA, Sato T, Rodrigues SC. New reference values for forced spirometry in white adults in Brazil. J Bras Pneumol. 2007;33(4):397-406.

22. Ferreira JL, Tierra-Criollo CJ, Pereira NC, Oliveira Júnior M, Vasconcelos FH, Parreira VF. Maximum respiratory pressure measuring system: calibration and evaluation of uncertainty. SBA Controle & Automação. 2010;21(6):588-97. doi: 10.1590/S0103-17592010000600004.

23. Hamnegard CH, Wragg S, Kyroussis D, Aquilina R, Moxham J, Green M. Portable measurement of maximum mouth pressures. Eur Respir J. 1994;7(2):398-401.

24. Evans JA, Whitelaw WA. The assessment of maximal respiratory mouth pressures in adults. Respir Care. 2009;54(10):1348-59.

25. Montemezzo D, Vieira DS, 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):392-8.

26. Brucki SM, Nitrini R, Caramelli P, Bertolucci PH, Okamoto IH. Suggestions for utilization of the mini-mental state examination in Brazil. Arq Neuropsiquiatr. 2003; 61(3B):777-81.

27. Pereira CAC. Espirometria. J Pneumol. 2002;28(3): 1-22.

28. Aldrich TK, Spiro P. Maximal inspiratory pressure: does reproducibility indicate full effort? Thorax. 1995;50(1):40-3.

29. Sachs MC, Enright PL, Hinckley Stukovsky KD, Jiang R, Barr RG. Performance of maximum inspiratory pressure tests and maximum inspiratory pressure reference equations for 4 race/ethnic groups. Respir Care. 2009;54(10):1321-8.

30. Volianitis S, McConnell AK, Jones DA. Assessment of maximum inspiratory pressure. Prior submaximal respiratory muscle activity ('warm-up') enhances maximum inspiratory activity and attenuates the learning effect of repeated measurement. Respiration. 2001;68(1):22-7.

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