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ORIGINAL RESEARCH

Manovacuometry performed by different length tracheas

Manovacuometria realizada por meio de traqueias de diferentes comprimentos

La realización de la manovacuometría con tráqueas de distintas longitudes

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ABSTRACT | Manovacuometry is a simple, fast, and non-invasive test, with maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) obtained to assist respiratory muscle assessment. Currently, there is a wide variety of models and brands of manovacuometers with different trachea diameters and lengths. However, the interference of these models in the measurements obtained by these equipments needs to be investigated. Thus, this study mainly aimed to verify the influence of tracheal length on maximal respiratory pressures (MRP), obtained by an analog manovacuometer, in healthy individuals. Our secondary objective was to verify the correlation between measurements. Fifty individuals, aged 18 to 30, of both sexes, were evaluated by spirometry and manovacuometry. MIP and MEP were performed using tracheas with same internal diameter (0.5 cm) and 30 cm, 60 cm, and 90 cm length. Significantly lower MIP values were observed when comparing a 90 cm trachea to 30 and 60 cm tracheas (Friedman's ANOVA test and Wilcoxon test with Bonferroni adjustment). Tracheas with 30, 60, and 90 cm length and same diameter did not affect MIP and MEP values, except the 90 cm trachea for MIP values, which may interfere in the physical therapy clinical practice. Further studies are required to analyze the need for standardizing the trachea length used in manovacuometers.

Keywords | Respiratory Muscles; Healthy Volunteers; Physical Therapy Modalities.

RESUMO | A manovacuometria é um teste simples, rápido e não invasivo por meio do qual a pressão inspiratória máxima (PImáx) e a pressão expiratória máxima (PEmáx) são obtidas, a fim de auxiliar na avaliação muscular respiratória. Atualmente, há grande variedade de modelos e marcas de manovacuômetros, com diferentes diâmetros e comprimentos de traqueias, no entanto, a interferência desses modelos nas medidas obtidas por esses equipamentos necessita de investigação. Desta forma, o objetivo primário deste estudo foi verificar a influência do comprimento de traqueias nas pressões respiratórias máximas, obtidas por meio de manovacuômetro analógico, em indivíduos saudáveis e, secundariamente, se há correlação entre as medidas. Foram avaliados 50 indivíduos, de 18 a 30 anos, de ambos os sexos, por meio da espirometria e manovacuometria. As PImáx e PEmáx foram realizadas com uso de traqueias de mesmo diâmetro interno (0,5 cm) e comprimentos de 30, 60 e 90 cm. Foram observados valores significativamente menores de PImáx obtidos com a traqueia de comprimento de 90 cm comparados às PImáx obtidas com as traqueias de 30 e 60 cm (teste de Friedman's ANOVA com teste de Wilcoxon com ajuste de Bonferroni). As traqueias de 30, 60 e 90 cm de comprimento e mesmo diâmetro não influenciaram os valores de PEmáx e PImáx, exceto a traqueia de 90 cm para os valores de PImáx, o que pode interferir na prática clínica fisioterapêutica. Novos estudos são necessários

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para analisar a necessidade de padronização do comprimento da traqueia utilizada em manovacuômetros.
Descritores | Músculos Respiratórios; Voluntários Saudáveis; Modalidades de Fisioterapia.

RESUMEN | La manovacuometría es una prueba sencilla, rápida y no invasiva por la cual se obtienen la presión inspiratoria máxima (PImax) y la presión espiratoria máxima (PEmax), con el objetivo de ayudar en el examen muscular respiratorio. Hoy día se encuentran una gran variedad de modelos y marcas de manovacuometros, con diferentes diámetros y longitudes de las tráqueas, pero hacen falta estudios sobre la interferencia de estos modelos en las mediciones por este instrumento. En este texto se propone examinar en sujetos sanos, en primer lugar, la influencia en la longitud de las tráqueas en las presiones respiratorias máximas, obtenidas por manovacuometros analógicos, y en segundo lugar comprobar la existencia de correlación entre las mediciones. Se evaluaron a cincuenta sujetos entre 18 y 30 años de edad, tanto varones como mujeres, empleando la espirometría y la manovacuometría. Se midió la PImax y la PEmax empleando tráqueas de mismo diámetro interno (0,5 cm) y con longitudes de 30, 60 e 90 cm. Se observaron valores significativamente menores de PImax con la tráquea de longitud de 90 cm en comparación con las PImax con las tráqueas de 30 y 60 cm (prueba de *Friedman's ANOVA*, la de *Wilcoxon* con ajustes de Bonferroni). Las tráqueas de 30, 60 y 90 cm de longitud y mismo diámetro no influyeron en los valores de la PEmax y de la PImax, con excepción de la tráquea de 90 cm en los valores de la PImax, lo que puede interferir la práctica clínica fisioterapéutica. Se necesitan más estudios para evaluar la necesidad de estándares de la longitud de tráqueas empleadas en manovacuometros.
Palabras clave | Músculos Respiratorios; Voluntarios Sanos; Modalidades de Fisioterapia.

INTRODUCTION

Manovacuometry, also known as maximal respiratory pressures (MRP), consists of measuring maximum static respiratory pressures by a classic and reliable equipment, named manovacuometer[1-4]. This is a simple, fast, non-invasive, volunteer, and effort-dependent test, in which the maximal inspiratory pressure (MIP) and the maximal expiratory pressure (MEP) are obtained[5,6]. These are indexes of inspiratory and expiratory muscle force and their respective values represent the force generated by the set of inspiratory and expiratory muscles, obtained at mouth level[3,5,6].

Its applicability is large and aims to identify clinical changes, such as muscle weakness[7] and ability to cough and expectorate (reflected by the MEP). Thus, it helps the diagnosis of neuromuscular and progressive diseases, the prescription of respiratory muscle training programs[3,7,8], the weaning from mechanical ventilation[9], and the assessment of responsiveness to interventions[2,5,6,10].

MIP and MEP are generated during maximum inspiration and expiration against an occluded airway[11], respectively, and the values obtained depend on the elastic retraction strength of the pulmonary system, on the respiratory muscle itself, on the instructions provided, and on the collaboration of the individual to perform the maneuver[11]. Therefore, procedure standardization is necessary[3,11,12]. Studies have investigated other variables able to affect the values obtained, such as, for example, types of equipment, buccal pieces[8,10], tracheas, manometers, air-escape orifice, use of nose clip, volunteer's posture when performing the tests, rest time between repetitions and between tests, maximum pressure definition, and lung (that in which the maneuver is carried out) volume determination[4-6].

In their studies, Onaga et al.[8], Koulouris et al.[13], and Gibson[10] concluded that different buccal types strongly influence measures of respiratory muscle pressures.

Currently, there is a wide range of models and brands of manovacuometers with different diameters and lengths of tracheas. However, the influence of these models on the measures obtained by such equipment is not clear.

The existing standardization refers to the presence of air-escape orifice (1-2 mm diameter) and a maximum of eight efforts for each test (with at least three acceptable and two reproducible)[5-6]. Therefore, given the small number of studies on the topic, it is important to compare the data obtained by different lengths of tracheas, which justifies our position of assisting the standardization method of such measures.

This study mainly aimed to analyze the influence of tracheas' length in the maximum respiratory pressures, obtained by analog manovacuometers, in healthy individuals. Secondarily, it aimed to verify the correlation between the maximal respiratory pressure (MRP) measures obtained with different lengths of tracheas.

METHODOLOGY

Sample

This study's sample consisted of 50 healthy individuals, of both sexes, aged 18 to 30, with body mass index between 18 and 29.9 kg/m^2[14], and who belonged to the community of São Carlos, SP, Brazil and surroundings. Individuals in the following conditions were excluded: respiratory and neurological diseases and/or temporomandibular joint syndrome; use of any type of medicines that could interfere and change MRP values; smokers and ex-smokers.

To determine the sample size, the previous study of Onaga et al.[8] was used, considering the MEP variable as primary outcome. Calculation was carried out by the GPower software, version 3.1, adopting 95% confidence level and 80% study power. A number of 38 individuals was suggested to detect a 0.42 effect size. However, 50 individuals were included in this research.

This study was approved by the Research Ethics Committee of Universidade Federal de São Carlos (UFSCar) (protocol number 042/2011). All participants were informed about the experiment characteristics and signed the Informed Consent Form.

Experimental procedure

Individuals who agreed to participate in the study filled out a standardized assessment form containing personal data. All of them underwent anamnesis and physical examination that collected anthropometric data, medications used, and smoking habit information. The short version of the International Physical Activity Questionnaire (IPAQ) was applied to evaluate physical activity level[15].

Height and body mass measures were obtained using biometric scale (Welmy®, 110FF model, São Paulo, SP, Brazil), and then the body mass index (BMI) was calculated. Subjects were submitted to spirometry and manovacuometry tests. Data collection was carried out in a single day by the same evaluator.

Spirometry: A portable spirometer (NDD EasyOne™, Zurich, Switzerland) was used, following the standards of the American Thoracic Society/European Respiratory Society (ATS/ERS)[16]. The values obtained were compared to those predicted by Knudson et al.[17].

Respiratory muscle pressures: they were measured with the subject on standing position using a nose clip, by an analog manovacuometer (Ger-Ar, São Paulo, Brazil) calibrated in cmH_2O, with a −300 to +300 cmH_2O operational limit, scale ranging each 10 cmH_2O, equipped with a buccal adapter with an approximate 2 mm diameter orifice, aiming to prevent contraction of facial muscles[10,18-22]. All individuals received standardized verbal stimuli[23].

Measures were registered using tracheas with the same internal diameter (0.5 cm) and 30, 60, and 90 cm lengths (Ger-Ar, São Paulo, Brazil). These trachea lengths were determined according to the manovacuometer models that are commonly available for sale on the market. A rectangle type buccal device was used (Ger-Ar, São Paulo, Brazil), since it is considered more anatomical, allowing less air escape during the execution of maneuvers[8].

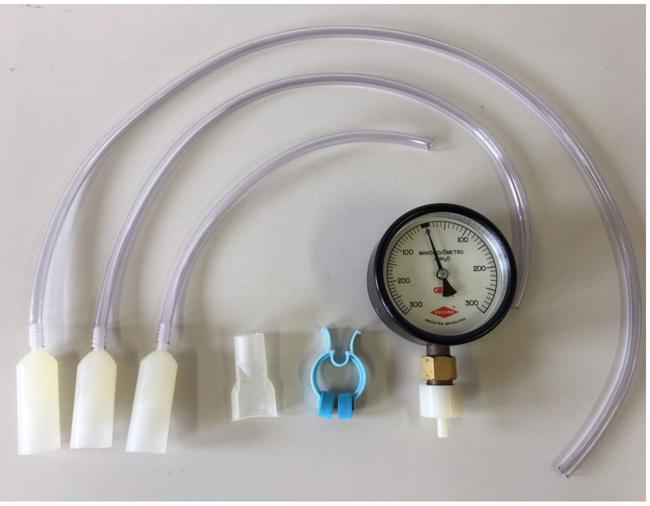

Figure 1. Analog manovacuometer (Ger-Ar) and different tracheas' lengths with respective buccal device adapter and rectangular buccal device used

MIP was obtained by a maximal inspiratory effort maneuver after a maximal expiration, close to the residual volume (RV)[2,21]. MEP was obtained by a maximal expiratory effort, after a maximal inspiration, close to the total lung capacity (TLC)[2,21]. The sequences of MIP and MEP maneuvers and tracheas lengths (30 cm, 60 cm, and 90 cm) to be used were randomly determined through lots, for each individual.

Maneuvers were performed at least three times and, at most, five times, in case there was more than 10% variation between the values obtained[21], and the effort was held by at least three seconds[2,24]. The following intervals were adopted: 15 seconds between measurements, 30 seconds between maneuvers, and one minute between change of tracheas[8]. For statistical analysis, maximum values were considered. The predicted values of MIP and MEP were calculated according to Neder et al.[25].

Statistical Analysis

Data of this study were analyzed by the Statistical Package for the Social Sciences (SPSS) software for Windows, version 20.0. Data normality was verified using the Shapiro–Wilk test. For sample characterization, descriptive statistics was expressed as median (interquartile range). For analysis of MIP and MEP values, Friedman's ANOVA test and Wilcoxon test with Bonferroni adjustment were used. The correlation between the values obtained with different trachea lengths for MIP and MEP values was obtained by Spearman's correlation coefficient. The significance level adopted was 5%.

RESULTS

Table 1 shows demographic, anthropometric, and spirometric characteristics of the individuals studied.

Regarding the level of physical activity of individuals, verified by the IPAQ[14], 2% of them were classified as very active; 42% as active; 50% as irregularly active (24% irregularly active A and 26% irregularly active B), and 6% as sedentary.

Table 1. Demographic, anthropometric, and spirometric variables of the volunteers

Variables	Values (n=50)
Demographic	
Gender (M/F) (%)	10 (20%)/40 (80%)
Anthropometric	
Age (years)	22.0 (21.0–24.0)
Weight (Kg)	60.5 (55.0–68.0)
Height (m)	1.65 (1.62–1.72)
BMI (kg/m²)	21.9 (19.8–23.6)
Spirometric	
FEV_1 (predicted %)	94.9 (86.8–102.6)
FEV_1 (L)	3.2 (2.9–3.8)
FVC (predicted %)	97.0 (88.8–104.3)
FVC (L)	3.7 (3.2–4.7)
FEV_1/FVC (%)	97.8 (92.0–101.3)
FEV_1/FVC (L)	0.9 (0.8–0.9)
MVV (predicted %)	97.0 (86.7–106.5)
MVV (L/min)	124.9 (108.2–147.5)

The data were expressed as median (interquartile range); M: Male; F: Female; BMI: body mass index; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; FEV_1/FVC: relation FEV_1/FVC; MVV: maximum voluntary ventilation.

Table 2 presents MIP and MEP values obtained by tracheas with different lengths. No statistically significant differences were found among the three types of trachea lengths for the MEP. However, significantly lower MIP values were obtained with a 90 cm trachea length compared to the MIP values obtained with 30 cm and 60 cm tracheas.

Strong positive and statistically significant correlations were observed between MIP values with tracheas of all lengths (30 cm, 60 cm, and 90 cm). The same occurred with MEP values, as shown in Table 3.

Table 2. MIP and MEP values with different length tracheas

Predicted Values	Obtained Value	% Predicted Value	Obtained Value	% Predicted Value	Obtained Value	% Predicted Value	
MIP	MIP-30 cm	MIP-30 cm	MIP-60 cm	MIP-60 cm	MIP-90 cm	MIP-90 cm	*p*-value*
100.1 (98.6–100.7)	100 (90–110)	96.3 (83.9–105.3)	100 (85–110)	91.0 (80.2–109.0)	90 (80–110) § ¥	88.9 (79.1–101.4)	0.0001
MEP	MEP-30 cm	MEP-30 cm	MEP-60 cm	MEP-60 cm	MEP-90 cm	MEP-90 cm	
102.8 (101.0–103.6)	110 (95–125)	97.3 (84.3–117.3)	110 (90–125)	100.0 (82.6–117.1)	110 (90–120)	97.3 (83.7–116.3)	0.076

Data expressed as median (interquartile range).

MIP-30 cm: maximal inspiratory pressure in 30 cm trachea; MIP-60 cm: maximal inspiratory pressure in 60 cm trachea ; MIP-90 cm: maximal inspiratory pressure in 90 cm trachea; MEP-30 cm: maximal expiratory pressure in 30 cm trachea; MEP-60 cm: maximal expiratory pressure in 60 cm trachea; MEP-90 cm: maximal expiratory pressure in 90 cm trachea; *Friedman's ANOVA test and Wilcoxon test with Bonferroni adjustment, $p<0.016$: § Value obtained in MIP-30 cm ≠ MIP-90 cm; ¥ Value obtained in MIP-60cm ≠ MIP-90cm.

Table 3. MIP and MEP values with different length tracheas

MIP			MEP		
	MIP–30 cm			MEP–30 cm	
	r	*p*		r	*p*
MIP–60 cm	0.84	<0.0001	MEP–60 cm	0.86	<0.0001
MIP–90 cm	0.83	<0.0001	MEP–90 cm	0.89	<0.0001
	MIP–60 cm			MEP–60 cm	
	r	*p*		r	*p*
MIP–90 cm	0.86	<0.0001	MEP–90 cm	0.87	<0.0001

MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; MIP–30 cm: maximal inspiratory pressure in 30 cm trachea; MIP–60 cm: maximal inspiratory pressure in 60 cm trachea; MIP–90 cm: maximal inspiratory pressure in 90 cm trachea; MEP–30 cm: maximal expiratory pressure in 30 cm trachea; MEP–60 cm: maximal expiratory pressure in 60 cm trachea; MEP–90 cm: maximal expiratory pressure in 90 cm trachea; r: Spearman's correlation coefficient; p: significance level.

DISCUSSION

Our main result is that we found no significant differences on MEP values between 30, 60, and 90 cm trachea lengths, with positive correlation between them. However, we observed the 30 cm and 60 cm tracheas provided higher MIP values than the 90 cm trachea.

In this study, an analogic manovacuometer calibrated in cmH_2O was used. This choice was made because this type is the most used in clinical practice.

Regarding the buccal device, we have chosen the rectangular format, since, according to Gibson[10], this type has great influence on the measurement of respiratory pressure values. For Onaga et al.[8], the rectangular buccal device guarantees a minor air escape for MEP measures. However, Montemezzo et al.[4] mostly used the tubular type buccal device, while Souza[21] considers the diver type the most indicated one.

In the analysis of some aspects of fluid mechanics, it is possible to better understand the results of this research. According to Munson et al.[26], the final pressure is influenced by three main factors: fluid characteristics (specific mass and viscosity); tube characteristics (diameter, length, and roughness); and user performance (speed and pressure with which the air is propelled at the tube entrance). However, the different lengths of tracheas established in this study were not sufficient to provide differences in the MEP assessment. Nevertheless, this can be verified in the MIP values obtained with the 90 cm trachea, which are lower when compared to the 30 cm and 60 cm tracheas.

Thus, once two of these major factors are guaranteed, such as fluid characteristics and user performance, the only variable factor relates to the tube characteristics. We were careful to minimize performance differences among individuals, by standardizing verbal encouragement and body positioning. The evaluator remained the same during measurements, in such a way that, besides the physical characteristics of each individual, no other factor could affect the acquisition of MIP and MEP values.

In this study, the tracheas' length was the only factor relevant to the equipment that could affect the final pressure value obtained, since we assured diameter and roughness of tracheas were the same. Thus, considering all these factors, we found that the pressure obtained suffered no significant influence from the tracheas' lengths, as there was no significant difference between MEP values, with strong association between the different lengths of tracheas. However, we found that the 90 cm length trachea resulted in lower MIP values when compared to the values obtained with the 30 cm and 60 cm tracheas, suggesting that, from that length, a greater inspiratory effort is required to overcome the resistance of the circuit, which can compromise a reliable assessment of individuals. Even noticing the lower MIP values obtained with the 90 cm trachea, we considered the association between values strong.

Our sample was predominantly formed by females, a factor that may have affected our results and constitute a limitation of the study. Another factor considered as a limitation is the impossibility of identifying the measurement time and the non-visualization of MIP and MEP curve of measures, constituting a disadvantage of the analog manovacuometer. In addition, the 15-second interval established between measurements, although used in a previous study, is different from the most commonly used in the literature, which is close to one minute[27,28].

CONCLUSION

This study showed that 30, 60, and 90 cm tracheas with same diameter did not affect MIP and MEP values, except the 90 cm trachea for MIP values, which may interfere in the physical therapy clinical practice.

REFERENCES

1. Cook CD, Mead J, Orzalesi MM. Static volume-pressure characteristics of the respiratory system during maximal efforts. J Appl Physiol. 1964;19:1016-22.
2. Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. Am Rev Respir Dis. 1969;99(5):696-702.
3. Parreira VF, França DC, Zampa CC, Fonseca MM, Tomich GM, Britto RR. Pressões respiratórias máximas: valores encontrados e preditos em indivíduos saudáveis. Rev Bras Fisioter. 2007;5(11):361-8.
4. Montemezzo D, Velloso M, Britto RR, Parreira VF. Pressões respiratórias máximas: equipamentos e procedimentos usados por fisioterapeutas brasileiros. Fisioter Pesqui. 2010;17(2):147-52.
5. Montemezzo D, Lages AC, Tierra-Criollo CJ, Veloso M, Britto RR, Parreira VF. Relationship between maximum mean pressure and peak pressure obtained by digital manometer during maximal respiratory pressure. J Resp Cardiov Phy Ther. 2012;1(1):915.
6. 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):392-8.
7. Decramer M, Scano G. Assessment of respiratory muscle function. Eur Respir J. 1994;7:1744-5.
8. Onaga FI, Jamami M, Ruas G, Di Lorenzo VAP, Jamami LK. Influência de diferentes tipos de bocais e diâmetros de traqueias na manovacuometria. Fisioter Mov. 2010;23(2):211-9.
9. Bethlem N. Pneumologia. 4ª ed. São Paulo: Atheneu; 2002.
10. Gibson GJ. Measurement of respiratory muscle strength. Respir Med. 1995;89:529-35.
11. Evans JA, Whitelaw WA. The assessment of maximal respiratory mouth pressures in adults. Respir Care. 2009;54(10):1348-59.
12. Brunetto AF, Fregonezi GAF, Paulin E. Comparação das medidas de pressões respiratórias máximas (PImáx, PEmáx) aferidas através de Manuvacuômetro e Sistema de Aquisição de dados (SAqDados). Rev Bras Ativ Fís Saúde. 2000;5(1):30-7.
13. Koulouris N, Mulvey DA, Laroche CM, Green M, Moxham J. Comparison of two different mouthpieces for the measurement of PImax and PEmax in normal and weak subjects. Eur Respir J. 1988;1:863-7.
14. Coutinho WF. Consenso latino-americano de obesidade. Arq Bras Endocrinol Metab. 1999;43(1):21-67.
15. Matsudo S, Araújo T, Matsudo V, Andrade D, Andrade E, Oliveira LC, et al. Questionário internacional de atividade física (IPAQ). Estudo de validade e reprodutibilidade no Brasil. Rev Bras Ativ Fís Saúde. 2001;6(2):5-18.
16. 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.
17. Knudson RJ, Lebowitz MD, Holberg CJ, Burrows B. Changes in the normal maximal expiratory flow-volume curve with growth and aging. Am Rev Respir Dis. 1983;127:725-34.
18. Camelo JS, Terra Filho J, Manço JC. Pressões respiratórias máximas em adultos normais. J Pneumol 1985;11(4):181-4.
19. Green M, Road J, Sieck GC, Similowski T. ATS/ERS Statement on Respiratory Muscle Testing. Am J Respir Crit Care Med. 2002;166(4):518-624.
20. Sobush DC, Dunning M. Assessing maximal static ventilatory muscle pressures using the bugle dynamometer. Suggestion from the field. Phys Ther. 1984;64(11):1689-90.
21. Souza RB. Pressões respiratórias estáticas máximas. J Pneumol. 2002;28(Suppl 3):S155-65.
22. 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.
23. Hautmann H, Hefele S, Schotten K, Huber RM. Maximal inspiratory mouth pressure (PIMAX) in healthy subjects: what is the lower limit of normal? Respir Med. 2000;94:689-93.
24. 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.
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. Munson BR, Young DF, Okiishi TH. Fundamentos da Mecânica dos Fluidos. 4ª ed. São Paulo: Edgar Blücher, 2004.
27. Aldrich T, Spiro P. Maximal inspiratory pressure: does reproducibility indicate full effort? Thorax. 1995;50:40-3.
28. Rochester DF. Tests of respiratory muscle function. Clin Chest Med. 1988;9:249-61.