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ORIGINAL ARTICLE

RELATIONSHIP BETWEEN MAXIMUM MEAN PRESSURE AND PEAK PRESSURE OBTAINED BY DIGITAL MANOMETER DURING MAXIMAL RESPIRATORY PRESSURE

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KEYWORDS
Respiratory function tests, Respiratory muscles, Respiration, Work of breathing,

Background: Measurement of Maximal Respiratory Pressure (MRP) by manometers is a useful procedure in evaluating respiratory muscle strength. Digital manometers allow the acquisition of pressure curves and calculation of several variables, among them Maximal Mean Pressure (MMP) and Peak Pressure (PP). Objective: The main objective was to determine if a difference exists between the variables MMP and PP during the MRP measurement, using different interfaces, as well as establish whether there is an association between values observed.

Methods: Fifty healthy, non-obese, active volunteers were assessed, with a mean age of 26±5 years and confirmed normal pulmonary function. A digital manometer and four different interfaces were used to measure MRP. The paired t-test was applied to compare MMP and PP and Pearson's correlation was used to evaluate the association between the two variables, with a significance level of 0.05.

Results: Comparison between MMP and PP for both maximal inspiratory pressure and maximal expiratory pressure showed a significant difference in the four interfaces studied ($p<0.001$). A high-magnitude correlation was recorded when comparing the two variables for both MRP tests ($r=0.99$; $p<0.001$).

Conclusion: MMP demonstrated a significant correlation with PP. Thus, the latter may be an alternative for measuring MRP in specific cases, since a strong association was observed with MMP despite the significant difference.

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INTRODUCTION

Respiratory muscle strength conditions can be assessed by measuring maximal respiratory pressures (MRP), which consists of determining maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP). MIP and MEP are defined as respiratory pressure an individual is able to produce from the mouth, reflecting the synergistic action of inspiratory or expiratory muscles[1,2], respectively.

These tests are widely used in clinical practice by physiotherapists and for different research protocols, involving diagnostic procedures[3-5] and investigating responses to therapeutic interventions[6-8]. MIP is more sensitive to muscular weakness[2], while MEP is an important parameter of the ability to cough and expectoration[9].

Different aspects can influence MRP tests. Although recommendations involving all the different factors are not available, the presence of an air leak approximately 2 mm wide[10] and a maximum of five efforts to achieve reproducibility in each MIP and MEP test[1,3] are well-established. Recent research showed no difference in maximal mean pressure inspiratory or expiratory values measured with different interfaces[11].

Recommendations of the Brazilian Thoracic Association[1], the American Thoracic Society and European Respiratory Society (ATS/ERS)[2] emphasize the need to sustain pressure for at least one second. Sustained pressure, denominated maximum mean pressure (MMP), is the most commonly reported measurement. It was first studied by Hamnegard et al[12] and measured for both MIP and MEP. Two previous investigations evaluated the difference between MMP and peak pressure (PP). Windisch et al.[13] performed a study based on MIP in healthy subjects, while Brunetto & Alves[14] analyzed both MRP measurements in healthy individuals and those with chronic obstructive lung disease.

The clinical relevance of this comparison is based on the known association between these two variables since, in the absence of a digital manometer, peak pressure is more easily viewed with an analog manometer, even when it has no pointer exclusively indicating peak pressure.

Considering other aspects not yet established in MRP measurement, as well as varying recommendations regarding the need to standardize them[1-3,14-16], it is important to investigate the relationship between MMP, as a variable of sustained pressure, and PP which reflects the point of highest pressure exerted during an MIP or MEP test.

In this context, the main objective of the present study was to determine whether differences exists between the variables MMP and PP when measuring maximal inspiratory and maximal expiratory pressures, obtained with a digital manometer using four different interfaces. It also sought to establish if there is an association between values observed for these two pressures for both MIP and MEP.

MATERIALS AND METHODS

Sample

Participants were selected by convenience sampling from the institutional community[17].

The following inclusion criteria were observed: age between 20 and 50 years[18]; body mass index (BMI) not indicative of malnutrition (<18 kg/m2) or obesity (>30 kg/m^2)[19]; no current or previous smoking history or occupational exposure to risk environments[3,20]; no evidence of thoracic deformities1; or reported neuromuscular, respiratory and/or cardiac disease[15]; no fever in the last three weeks prior to testing, flu and/or cold in the week before the test[15]; not using drugs such as oral corticoids, central nervous systems depressants, barbiturates and/or muscle relaxants[15]; exhibiting spirometry parameters within predicted normal values for the Brazilian population[20].

Exclusion criteria were: inability to understand and/or execute research protocol procedures and displaying the following vital data alterations: blood pressure at rest (BP) greater or equal to 180/110 mmHg[11] and/or saturation of peripheral oxygen (SpO2) lower than 90%[11] and/or heart rate (HR) higher than 85% of maximum heart rate[11].

The study was approved by the Institutional Research Ethics Committee under protocol ETIC 556/08 and all participants gave written informed consent.

Measurement Instrument

A digital manometer was used to measure MRP, developed in partnership with the Center for Studies and Research in Biomedical Engineering (NEPEB-UFMG) and the

Laboratory of Assessment and Research of Cardiorespiratory (LabCare-UFMG)[21]. MRP was measured using four different interfaces, defined in accordance with scientific society guidelines[1,2], a review study[22] and research conducted with Brazilian physiotherapists[23]. The interfaces selected consisted of a tube connected to a mouthpiece containing a 1.8 mm air leak[1,10].

Variables studied

The variables maximum mean pressure (MMP) and peak pressure (PP) were analyzed using MANOVAC 3.0 graphical interface software from the digital manometer. MMP is calculated first by finding the peak pressure value and subsequently the pressure is calculated around this point and encompasses the highest values included in a one-second period[12] and PP represents the highest-pressure value obtained during the test[12]. Figure 1 depicts an MEP test using the software interface.

Procedures

Data collection occurred over two days and all procedures were carried out by the same investigator. On the first day, participants were interviewed regarding health history and physical activity, in addition to completing the self-administered Human Activity Profile (HAP)[24] questionnaire. This was followed by measurement of body weight and height (Filizola digital balance, São Paulo-SP, Brazil), blood pressure (Littman Classic II stethoscope, 3M Center, St. Paul-MN,USA and a Tycos sphygmomanometer, Welch Allyn Inc. Corporate Headquarters, New York-NY,USA), respiratory rate (RR) (Sport Timer stopwatch, Hong Kong, China), hear rate (HR) and oxygen saturation (SpO_2)(PM-50, Biomedical Electronics, Nanshan, Shenshen-PR, China). Pulmonary function testing was then performed according to Brazilian Thoracic Association[25] guidelines, with a spirometer (Vitalograph 2120, Vitalograph, Ennis, Ireland) calibrated prior to the test. Subjects were selected based on pulmonary function and instructed to return for a second day of data collection.

The second day involved electronic randomization of the measurement (MIP or MEP) and the order of interfaces: Interface A (30x2 cm corrugated plastic tube and smooth plastic mouthpiece - Hudson RCI, Temecula- CA,USA); Interface B (30x2 cm corrugated plastic tube with a flanged silicone mouthpiece - ST3-NS, São Paulo-SP, Brazil); Interface C (50x0.5 cm transparent silicone tube and smooth plastic mouthpiece - Globalmed, Porto Alegre-RS, Brazil); Interface D (50x0.5 cm transparent silicone tube and flanged silicone mouthpiece). A disposable biological filter was used (Vida Tecnologia Biomédica, São Paulo-SP, Brazil).

Vital signal were then recorded and participants were instructed regarding tests. For MRP testing, subjects remained seated and each received a standardized verbal command[1].

For MIP measurement, individuals were instructed to perform three respiratory cycles, followed by expiration to residual volume, which subjects identified by raising their right hand. At this moment the investigator simultaneously closed the occlusion valve and participants executed a maximal inspiratory effort.

In order to determine MEP, individuals were asked to perform three respiratory cycles followed by inspiration until total lung capacity. Subjects signaled this moment by raising their right hand and the investigator then simultaneously closed the occlusion valve, at which time participants executed a maximal expiratory effort. The investigator supported the facial muscles during testing to avoid accumulation of air in the lateral oral cavity[15]. A nose clip[3,15] was used for all tests, with ideal test time of three seconds[12], and individuals were instructed to position the mouthpiece between their teeth and hold it firmly with their lips to prevent air leakage[12].

Participants breathed through the interface during all tests, as well as during tidal volume and maximum effort level cycles. A one-minute interval[3,15] was applied between every test with each of the four interfaces. Prior to the experiment, subjects were instructed not to perform strenuous physical activity in the 12 hours before the test[26]. Following measurement with the first randomly chosen interface and maximum pressure, a five-minute interval was enforced, after which vital signs were assessed. If these had not returned to baseline parameters, an additional five-minute interval was imposed followed by re-measurement.

Pressure measurement was considered complete when subjects performed at least three acceptable tests (that is, without air leakage between the lips and/or nose clip and minimum duration of one second), of which two were reproducible (i.e., variation less than or equal to 10% of the greatest MMP value, as long as it was not the last value recorded)[1,3,15]. Pressure measurement was interrupted when acceptability and reproducibility criteria were not met in a maximum of eight tests[25,27].

Data collection protocol continued with measurement of the second maximum pressure selected using the second interface, followed by assessment of the remaining interfaces.

The digital manometer was calibrated monthly[28] (PC 507 calibrator and 8111-300 duplex handpump, Presys, São Paulo-SP, Brazil) throughout the data collection period, in accordance with routines established by Ferreira et al.[21] and considering an operating range of ± 500 cmH2O. No adjustments were required during this period.

Statistical analysis

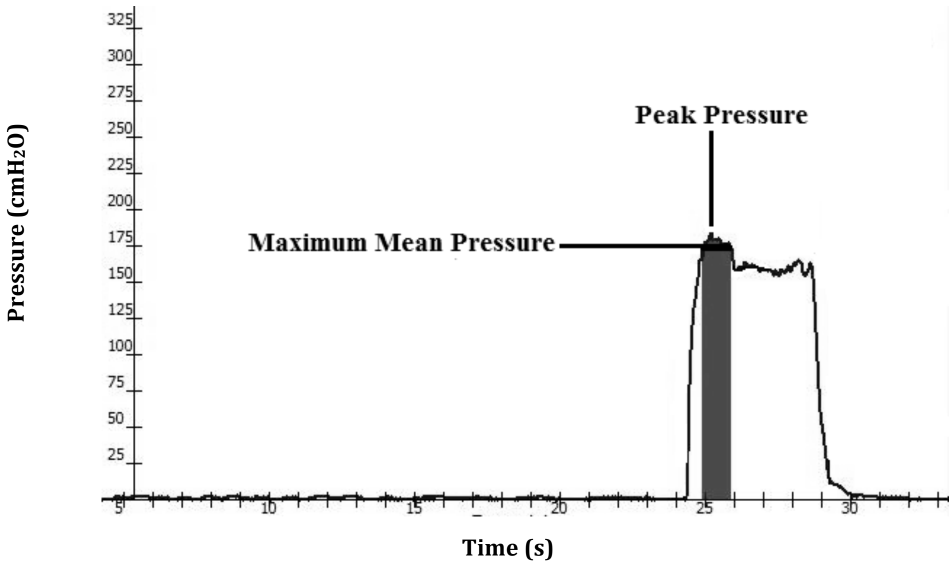
Data were expressed by central tendency and dispersion. The variables age, BMI, spirometry parameters and physical activity score, determined via the human activity profile, were used for sample characterization. Data distribution was assessed using the Shapiro-Wilk normality test. The paired t-test and Pearson's correlation were applied to compare MMP and PP, with a significance level of 0.05[29]. Statistical analyses were processed using Statistical Package for Social Science software (SPSS, Chicago-IL, USA), version 15.0.

RESULTS

Fifty individuals (26 women) were analyzed, and submitted to MRP measurement with four different interfaces. Vital signs (BP, HR and SpO_2) were within normal levels, monitored before, during and after testing.

Table 1 shows demographic, anthropometric, spirometry and physical activity data for the 50 individuals evaluated. Thirty-seven presented with normal BMI and 13 were overweight. Subjects obtaining scores above 74 were considered active[24].

Figure 1: Graphical recording during maximal expiratory pressure measurement



Example of maximal expiratory pressure recorded, identifying the variables studied –maximum mean pressure and peak pressure, using the MANOVAC 3.0 graphical interface.

Table 1: Demographic, anthropometric, spirometric and physical activity data for the 50 participants.

VARIABLES	Mean ± standard deviation
Age (years)	26.36 ± 4.89
BMI (kg/m²)	23.05 ± 3.06
FEV_1 (% of the predicted value)	93.29 ± 0.08
FVC (% of the predicted value)	90.80 ± 0.08
FEV_1/FVC (% of the predicted value)	102.31 ± 0.07
$FEF_{25-75\%}$ (% of the predicted value)	92.61 ± 0.21
AAS	90.16 ± 4.09

BMI: Body mass index, FEV_1: Forced expiratory volume in the first second, FVC: Forced vital capacity, FEV_1/FVC: Ratio between forced expiratory volume in the first second and forced vital capacity, $FEF_{25-75\%}$: Forced expiratory flow at 25-75% of FVC, AAS: Adjusted activity score.

Table 2 depicts comparative data between MMP and PP for MIP and MEP. A significant difference was observed between variables studied for all interfaces (A, B, C and D; $p<0.001$). A significant, high-magnitude correlation was recorded between the two variables in all comparisons, both for inspiratory and expiratory pressure ($r > 0.99$; $p < 0.001$).

DISCUSSION

Primary results of the present study were: 1) a significant difference in MMP and PP values for maximal respiratory pressure tests (MIP and MEP) for the four different interfaces and 2) high-magnitude correlation was recorded between the variables MMP and PP for MIP and MEP, obtained with a digital manometer.

Recommendations by scientific societies emphasize the need to maintain pressure for at least one second[1,2]. MMP was first assessed by Hamnegard et al.[12], who sought to compare MRP values recorded by a portable digital pressure gauge with those obtained by a pressure transducer, considered the gold standard. A total of 24 subjects were analyzed, 13 healthy (mean age of 33 years) and 11 with respiratory diseases (mean age of 51 years).

Table 2: Maximum mean pressure and peak pressure values obtained when measuring maximal respiratory pressures

MRP	IF	MMP (cmH_2O)	PP (cmH_2O)	Dif (cmH_2O)	p value*	r	p value#
MIP	A	104.59 ± 26.79	111.61 ± 27.84	11	p < 0.001	0.991	p < 0.001
	B	107.23 ± 27.22	114.78 ± 28.70	11	p < 0.001	0.990	p < 0.001
	C	106.97 ± 29.46	114.47 ± 31.30	12	p < 0.001	0.993	p < 0.001
	D	107.68 ± 29.23	115.12 ± 30.85	10	p < 0.001	0.991	p < 0.001
MEP	A	107.93 ± 29.22	112.42 ± 29.67	11	p < 0.001	0.997	p < 0.001
	B	117.22 ± 35.08	122.62 ± 35.56	11	p < 0.001	0.997	p < 0.001
	C	111.21 ± 29.23	117.15 ± 31.94	09	p < 0.001	0.995	p < 0.001
	D	115.07 ± 34.64	119.78 ± 35.51	11	p < 0.001	0.997	p < 0.001

MRP: Maximal respiratory pressures, MIP: Maximum inspiratory pressure, MEP: Maximal expiratory pressure, IF: Interfaces, MMP: Maximal Mean pressure, PP: Peak Pressure, Dif: Difference between MMP and PP, *t-test, r: Pearson's correlation, #Pearson's correlation.

Variables of interest, determined by a portable manometer, were MMP and PP. No significant differences were found between values measured using the portable device and those of the gold standard for either MIP or MEP. However, absolute values for the variables assessed were not presented, making it impossible to compare them with those recorded in the present study.

MMP is the most commonly reported variable in the literature. Two previous investigations evaluated the difference between this variable and PP. Windisch et al.[13] examined 533 healthy individuals, with mean age of 36 years, in order to compare these variables based on MIP measurement. PP values were significantly higher then MMP was maintained for one second. Brunetto & Alves[14] recorded similar results when analyzing 105 subjects, 55 healthy and 50 with moderate obstructive pulmonary disease. Findings in the present study corroborate results from these prior investigations, since significant differences were observed between MMP and PP.

Thus, despite the recommendation of sustaining pressure for at least one second[1,2,16] it seems important to consider the measure of the PP variable under specific health conditions. To the best of our knowledge, no other studies have assessed the reproducibility of PP. Windisch, in a personal communication, emphasized that MIP is measured differently in different countries, which may contribute to inconsistencies observed when using predictive equations available in international literature. Moreover, individuals with neuromuscular diseases may have difficulty-sustaining pressure for a second and PP might be an alternative for measuring MIP.

Values for the variables MMP and PP in this study were not influenced by the different interfaces studied. Participants were healthy active individuals, exhibiting no alteration in pulmonary function testing. Furthermore, interfaces were used in random order for each subject assessed in order to minimize the effects of learning.

In conclusion, results of this study demonstrated that the variable MMP was strongly associated with PP for each of the interfaces used to measure MRP. As such, PP may be an alternative for measuring MRP in situations where, depending on individual health status and availability of device, it is difficult to sustain pressure for one second. In these situations, we recommend using the same investigator for serial measurements.

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