Respiratory Muscle Strength Explained by Age and Weight in Female and Male

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Objective: *To determine the relationship between respiratory muscle strength and age, sex, height and weight.*
Material and Method: *Maximal inspiratory mouth pressure (MIP) and maximal expiratory mouth pressure (MEP) were assessed in 249 subjects aged 30-70 years using a mouth pressure meter. MIP was performed 10 times at residual volume, whereas MEP was performed 12 times at total lung capacity. Pearson's correlation was used to assess the association between respiratory muscle strength and characteristics data. Multiple linear regressions were used to establish the prediction equation of respiratory muscle strength.*
Results: *MIP decreased at ages beyond 60 years ($p<0.05$) but age had no effect on MEP in both sexes. MIP was correlated with age, weight and height in males, and with age and weight only in females; whereas, MEP was not correlated with age, height and weight in either sex. Predicted MIP regression equations are MIP_{female} = 77.57-0.59 age+0.62 weight (r^2 = 0.164, p = 0.004), MIP_{male} = 124.39-0.91 age+0.63 weight (r^2 = 0.175, p = 0.08).*
Conclusion: *Sex, age and weight factors should be considered for MIP measurement.*

Keywords: *Maximal inspiratory mouth pressure (MIP), Maximal expiratory mouth pressure (MEP), Age, Sex, Height, Weight*

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Respiratory muscle strength can be quantified by measuring maximum inspiratory mouth pressure (MIP) and maximum expiratory mouth pressure (MEP)[1]. The MIP is an index of the strength of the inspiratory, whereas the MEP measures the strength of the expiratory muscles[2]. Measurement of MIP and MEP is a simple, quick and non-invasive clinical procedure for determining respiratory muscle strength[2-4].

The characteristics data such as age, sex, height and weight are the factors that influence respiratory muscle strength. Many studies[3-5] have demonstrated that respiratory muscle strength decreases with age. Black and Hyatt[4] stated that MIP decreased in females when their age is older than 50 years and MEP decreased with age in both sexes; whereas, Ringqvist[3] demonstrated that both MIP and MEP decreased when age is greater than 50 years. In addition, they found MIP and MEP values in males were higher than in females in all age ranges. The study of Wilson[6] and Harik-Khan[7] demonstrated a correlation between respiratory muscle strength and height in females. On the contrary, Enright[2] showed no correlation between respiratory muscle strength and height; however, they found a correlation of weight and respiratory muscle in both sexes. Their results were similar to McConnell[8] who found poor correlation between respiratory muscle strength and height. Nevertheless, Harik-Khan[7] found weight correlated with respiratory muscle strength in both sexes. Up to now, the correlations between characteristics of subjects and respiratory muscle performance are still controversial. Therefore, the purposes of this study were (1) to determine the relationship between respiratory muscle strength and characteristics data of subjects, i.e. age, sex, height and weight, and (2) to construct a regression equation of respiratory muscle

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strength.

Material and Method

This cross-sectional study consisted of 122 female and 127 male volunteers. All subjects were non-smokers with no cardiopulmonary diseases or musculoskeletal or neurological disorders that interfered with respiratory muscle strength testing. They all had sedentary or active habitual physical activity according to a modified Baeck questionnaire[9] and had no prior experience with a respiratory muscle strength measurement. Informed written consent and approval by the ethics committee on research involving human subjects from the Faculty of Medicine, Siriraj Hospital, Mahidol University were obtained.

Respiratory muscle strength was measured using a mouth pressure meter (Spirovis, COSMED pulmonary function equipment, Italy) connected with a flanged mouthpiece. Maximal inspiratory mouth pressure (MIP) was measured at residual volume (RV). Subjects were instructed to 1) inhale to total lung capacity, 2) exhale slowly to residual volume and then 3) inhale maximally. Maximal expiratory mouth pressure (MEP) was measured at total lung capacity (TLC). Subjects were instructed to 1) exhale to residual volume, 2) inhale slowly to total lung capacity and then 3) exhale maximally. MIP was measured 10 times per test and MEP was measured 12 times per test. Each maneuver was separated by a one minute resting period. The values of MIP and MEP were acceptable when sustained for at least one second. The highest value of MIP and MEP was recorded.

One-way ANOVA was used to test the differences of MIP and MEP among age groups in each sex. Post-hoc analysis between age groups was performed by Tukey's method. Pearson's correlation coefficients were used to calculate the correlation between respiratory muscle strength (MIP and MEP) and characteristics data (age, height and weight) with a significance level of 5%. Multiple linear regression analysis was used to produce prediction equations for MIP and MEP with characteristics data.

Results

The subjects of each sex were divided into four age groups: 30-39, 40-49, 50-59 and 60-70 years. Age, height and weight of the female subjects were 49.6±3.3 years old, 154.9±2.1 cm and 59.4±3.5 kg, whereas for male subjects were 49.0±13.0 years old, 165.6±2.0 cm and 68.4±3.0 kg, respectively. MIP and MEP values of subjects are shown in Table 1. From ANOVA and Tukey's post-hoc analysis, it was found that MIP of age range 60-70 were significantly lower than that of the age ranges of 30-39 and 40-49 in both sexes ($p = 0.02$ and $p = 0.004$ for female; and $p<0.001$ and $p = 0.001$ for male, respectively). No significant differences in MEP were found among age ranges for both sexes. MIP had a significantly negative correlation with age and positive correlations with weight in both sexes (Fig. 1); whereas, a significant low positive correlation was found with height in males. On the other hand, MEP had no correlation with age, height and weight in either sex (Table 2). Because of the significant correlation between MIP and subjects' characteristics, only multiple linear regression equations for MIP were proposed as follows:

$$MIP_{(female)} = 77.57\text{-}0.59\ age + 0.62\ weight$$
$$(R^2 = 0.146,\ p = 0.004)$$

Table 1. MIP and MEP of female and male subjects at the age range of 30-70 years old

		Age range (year), Mean±SD			
	Gender	30-39	40-49	50-59	60-70
MIP (cm H_2O)	Female (n = 122)	93.13±26.38 (n = 30)	94.20±29.96 (n = 30)	84.41±24.097 (n = 32)	1.90±20.75* (n = 30)
	Male (n = 127)	133.27±23.94 (n = 33)	131.38±30.11 (n = 32)	118.16±31.17 (n = 31)	105.81±18.09* (n = 31)
MEP (cm H_2O)	Female (n = 122)	94.45±31.19 (n = 30)	95.03±33.99 (n = 30)	99.94±28.83 (n = 32)	79.90±25.55 (n = 30)
	Male (n = 127)	177.03±42.42 (n = 33)	184.25±47.43 (n = 32)	159.10±55.24 (n = 31)	160.32±45.98 (n = 31)

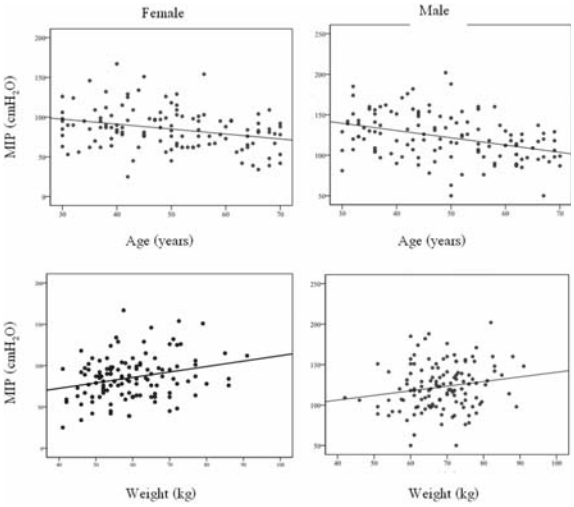
MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure
* = significant difference from the age range of 30-39 and 40-49 ($p<0.05$) within the same sex

$MIP_{(male)}$ = 124.39-0.91 age+0.63 weight
(R^2 = 0.175, p = 0.018)

These equations showed highly significant explanations (p = 0.004 and = 0.018) of MIP by subjects' age and weight.

Discussion

Many investigators have demonstrated the negative correlation between age and MIP[2-4]. In addition, this study also found the decrease of MIP after age over 60 years in accordance with previous studies[3-5]. The aging process is associated with a reduction in the diaphragmatic and respiratory accessory muscular mass, as well as with a decline in the work output for the same level of neural stimulation and changes in the elastic recoil properties of the lung and chest wall[2]. Therefore, advanced age reduces the capacity of the respiratory muscle to generate pressure. However, this study did not find the reduction of MEP with age. This result is in accordance with the result of Wilson[5]. They found that MEP in women (n = 87) did not correlate with age. MEP in age groups of 50-59 and 60-70 in men and 60-70 in women in this present study tended to be lower than younger age groups in both sexes; however, these differences were not statistically significant. Further study in this issue is warranted.



MIP = maximal inspiratory pressure

Fig. 1 Scatter plots between MIP vs. age and weight of female (n = 122) and male (n = 127) subjects.

In the present study, the authors found a correlation of MIP with weight in both sexes similar to Enright[2] and McConnell[7] while correlation with height was found only in males. This may be explained by the results of Schoenberg in 1978[10]. They reported that weight affected lung function values. It has been suggested that the lung function increment with weight was due to the enlarged muscle bulk. Weight effect may also augment diaphragmatic muscle mass and increase respiratory muscle strength. This study also showed a correlation between MIP and height in males. This may be explained by the work of Carpenter in 1999[11]. They suggested that height showed a linear relationship with MIP. Similarly, pulmonary function studies have found that lung volumes are directly related to height due to the increase in intrathoracic space. In contrast with other studies[3,4,6,7], the present study found no correlation of MEP with height and weight.This may be the result of the small range of height and weight in the study population. Further investigations of weight and height effects on MEP will need to be explored.

From the equations we have proposed, even though R^2 in this study was quite low, most previous studies also had low R^2[5-7]. The ranges are between 0.032-0.42. These wide ranges might depend on the subjects' races and methods of the studies. In a population similar to this study, sex, age and weight factors should be considered in MIP measurement.

The present study ethnic group (Thai population) may be one of the factors that influenced our results. For example, it was found that values of MIP and MEP from this study were lower than those of

Table 2. Pearson's correlation of maximal inspiratory mouth pressure (MIP) and maximal expiratory mouth pressure (MEP) with age, height and weight in both sexes

Gender	Parameters	Age	Height	Weight
Female (n = 122)	MIP	-0.288**	0.090	0.266**
	MEP	-0.170	-0.056	-0.012
Male (n = 127)	MIP	-0.370**	0.217*	0.178*
	MEP	-0.147	0.145	0.074

* = significant difference at $p<0.05$; ** = significant difference at $p<0.01$

Ringqvist[3]. Differences of body anthropometry and lifestyle between Asians and Caucasians may explain the disparities. Values of MIP and MEP, correlation between respiratory muscle strength and subjects' characteristics, and the predictive equation of MIP, all obtained from this study should be used with caution.

Conclusion

MIP decreased with ages over 60 years in both sexes. MIP was correlated with age, weight and height in males, and with age and weight only in females; whereas, MEP was not correlated with age, height and weight in either sex. The proposed regression equation could be applied in clinics and research for an index of respiratory muscle strength in healthy subjects aged 30 to 70 years.

What is already known on this topic?

The MIP and MEP has been used as a simple way to determine inspiratory and expiratory muscle strength for many years. Respiratory muscle strength decreases with age in both sexes. The MIP and MEP values in males are higher than those in females for all age ranges.

What this study adds?

Correlations between other characteristics of subjects and respiratory muscle strength are still controversial. The MIP is correlated with age, weight and height in males, and with age and weight only in females. The MEP is not correlated with age, height and weight in either sex. Therefore, the prediction equations of MIP are proposed.

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Potential conflicts of interest

None.

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ความแข็งแรงกล้ามเนื้อหายใจของหญิงและชายกับอายุ ความสูง และน้ำหนักตัว

วรรธนะ ชลายนเดชะ, อรวรรณ เวอร์เนอร์, สุวรรณี จรูงจิตรอารี, แจ่มศักดิ์ ไชยคุนา

วัตถุประสงค์: เพื่อหาความสัมพันธ์ระหว่างความแข็งแรงของกล้ามเนื้อหายใจกับอายุ เพศ ความสูง และน้ำหนักตัว

วัสดุและวิธีการ: วัดค่าแรงดันสูงสุดที่ปากขณะหายใจเข้า (MIP) และค่าแรงดันสูงสุดที่ปากขณะหายใจออก (MEP) ในกลุ่มตัวอย่างที่มีอายุระหว่าง 30-70 ปี 249 ราย โดยวัดค่า MIP 10 ครั้งที่ปริมาตรปอดตกค้างและค่า MEP 12 ครั้งที่ปริมาตรปอดสูงสุด คำนวณหาค่าสหสัมพันธ์ (MIP และ MEP) กับค่าลักษณะพื้นฐานและสร้างสมการถดถอย เพื่อพยากรณ์ค่าความแข็งแรงของกล้ามเนื้อหายใจ

ผลการศึกษา: ค่า MIP และ MEP ของชายมีค่ามากกว่าหญิง ($p<0.001$) และ ค่า MIP ลดลงเมื่ออายุเกิน 60 ปี ($p<0.05$) แต่อายุไม่มีความสัมพันธ์ต่อ MEP ในทั้งหญิงและชาย ค่า MIP มีความสัมพันธ์กับอายุ น้ำหนักในทั้งสองเพศ แต่สัมพันธ์กับความสูงเฉพาะในเพศชาย ค่า MEP ไม่มีความสัมพันธ์กับค่าลักษณะพื้นฐานในทั้งสองเพศ การศึกษาครั้งนี้ได้นำเสนอสมการถดถอยเพื่อคาดการณ์ค่า MIP คือ MIP_{female} = 77.57-0.59 age+0.62 weight (R^2 = 0.164, p = 0.004), MIP_{male} = 124.39-0.91 age+0.63 weight (R^2 = 0.175, p = 0.08)

สรุป: ปัจจัยที่ควรคำนึงถึงเมื่อวัด MIP คือ เพศ อายุ และน้ำหนัก