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Original Article

Normative Values and Calculation Formulas of Respiratory Muscle Strength of Adults in Turkish Society: A Population-based Study

Esra Pehlivan[1], Halit Çınarka[2], Kürşad Nuri Baydili[3], Mehmet Burak Uyaroğlu[1], Pınar Baştürk[1], Amine Ataç[4]

[1]Department of Physiotherapy and Rehabilitation, University of Health Sciences Türkiye Faculty of Hamidiye Health Sciences, İstanbul, Türkiye
[2]Department of Chest Disease, University of Health Sciences, Yedikule Chest Diseases and Thoracic Surgery Training and Research Hospital, İstanbul, Türkiye
[3]Health Services Vocational School Health Institutions Management Program, University of Health Sciences, İstanbul, Türkiye
[4]Department of Physiotherapy and Rehabilitation, İstanbul Gedik University Faculty of Health Sciences, İstanbul, Türkiye

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Abstract

OBJECTIVE: This study aimed to establish normative values for maximum inspiratory pressure and maximal expiratory pressure in the Turkish population while creating specific equations to calculate these values.

MATERIAL AND METHODS: The study involved 219 healthy adults, with a minimum of 50 individuals in specific age ranges: 20–29, 30–39, 40–49, and 50–60 years. Each age group comprised at least 25 males and 25 females. Participants were required to be free from health conditions influencing respiratory muscle strength and non-smokers. Measurements of maximum inspiratory pressure and maximal expiratory pressure were recorded for all participants.

RESULTS: As a result of the regression analysis performed for the maximum inspiratory pressure values, the model *P* value was < .001, and the R^2 value was found to be 0.261. The equation obtained as a result of the model was: 82.583 − 3.218 × gender − 0.093 × age + 9.534 × height + 0.343 × weight. As a result of the regression analysis performed for maximal expiratory pressure values, the model *P* value was <.001, and the R2 value was found to be 0.285. The equation obtained as a result of the model was: 157.165 − 35.522 × gender − 0.271 × age–42.036 × height + 0.787 × weight.

CONCLUSIONS: The newly developed equations offer valuable tools for evaluating respiratory muscle strength in the Turkish population. These results confirm the importance of using maximum inspiratory pressure and maximal expiratory pressure to monitor changes in each patient, while also emphasizing the necessity of reliable reference equations.

KEYWORDS: Maximal inspiratory pressure, maximal expiratory pressure, maximal respiratory pressures, respiratory muscle, predictive value of tests, race factors

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INTRODUCTION

Respiratory muscle weakness is a condition that can be detected in all chronic diseases and in healthy people. There are studies showing that respiratory muscle weakness is associated with myocardial infarction, stroke, and related mortality.[1] Determining the loss of respiratory muscle strength is beneficial when making the decision to use special rehabilitation methods for patients,[2] and when deciding when to extubate patients on mechanical ventilation.[3]

The mouth pressure measurement is the most commonly used method in the clinic to determine respiratory muscle strength. It is a non-invasive, easily applicable technique.[4] As a result of this measurement, two main parameters, maximal inspiratory pressure (MIP), and maximal expiratory pressure (MEP), are determined. MIP is one of the indicators of the strength of inspiratory muscles, especially the diaphragm. Clinical decisions are made by comparing the data obtained from the patient with the normative values, although these are known to vary according to demographic characteristics and race.[5,6]

There are no respiratory muscle strength normative values specific to the Turkish population. It is common practice in this population to evaluate respiratory muscle strength by comparing it with the typical or expected values of International values[7] that do not share the same anatomical features as the Turkish population, and this can result in diagnostic errors. The aim of this study is to obtain reference MIP and MEP values for the Turkish society by measuring the respiratory muscle strength of healthy adults in different age groups, based on the city of İstanbul (Table 1).

Corresponding author: Esra Pehlivan, e-mail: fztesrakambur@yahoo.com

Table 1. Demographic Characteristics and Respiratory Muscle Strength Values of the Groups

	Group1 (20–29 Years)	Group2 (30–39 Years)	Group3 (40–49 Years)	Group4 (50–60 Years)
Male				
Height, m	1.8 ± 0.07	1.74 ± 0.06	1.73 ± 0.06	1.73 ± 0.06
Weight, kg	79.07 ± 11.24	78.04 ± 10.12	81.17 ± 8.19	82.22 ± 8.2
BMI, kg/m^2	24.44 ± 2.93	25.86 ± 2.64	27.11 ± 2.07	27.37 ± 2.24
MIP, H_2O	103.7 ± 28.66	94.76 ± 30.72	99.07 ± 29.94	101.81 ± 26.38
MEP, H_2O	113.59 ± 40.66	111.72 ± 37.31	117.93 ± 34.04	143.85 ± 56.95
Female				
Height, m	1.64 ± 0.06	1.63 ± 0.04	1.61 ± 0.06	1.62 ± 0.07
Weight, kg	61.78 ± 10.13	63.22 ± 8.65	67.35 ± 9.15	69.48 ± 8.33
BMI, kg/m^2	22.81 ± 3.2	23.85 ± 3.23	25.85 ± 3.2	26.55 ± 2.82
MIP, cm H_2O	69.93 ± 16.47	72.63 ± 31.48	70.92 ± 20.23	67.76 ± 19.24
MEP, cm H_2O	83.14 ± 29.69	68.27 ± 18.48	90.58 ± 34.3	77.92 ± 25.33

BMI, body mass index; MIP, maximal inspiratory pressure; MEP, maximum expiratory pressure.

MATERIAL AND METHODS

Approval for this prospective, cross-sectional study was granted by the Ethics Committee of University of Health Sciences Hamidiye Non-Interventional Research Ethics Committee (Protocol Number: 19/81, date: 11/08/2019) and the study was registered in ClinicalTrial.gov (registration number: NTC0472450). All the study procedures were performed in accordance with the Helsinki Declaration. Written informed consent was obtained from all the study participants.

The study includes students who are working and studying at the Health Sciences University, along with their social and family environments, and cases were collected using stratified sampling, taking into account volunteer recruitment and exclusion criteria (Figure 1).

The study was announced to students and employees of the University of Health Sciences, and cases were collected among students, employees, and their families and social circles. In the research, stratified sampling was done according to age groups and gender. As a result of the sample analysis conducted for the research, it is known that at least 50 individuals from each age group should be included in the sample. In addition to age groups, stratification was also carried out by gender, and at least 25 women and 25 men were included in each age group. At least 50 subjects were enrolled in each of the following age groups: 20–29, 30–39, 40–49, and 50–60 years. The age ranges of the cases were determined based on similar studies.[5,6]

The inclusion criteria were defined as non-smoker status, age 20–60 years, body mass index (BMI) of 18.0–29.5kg/m^2, and no cardiac, neuromuscular, or endocrine disease that may affect respiratory muscle strength. A participant was deemed ineligible for inclusion in the study if they had any respiratory infections or diseases, exhibited sequelae from prior respiratory conditions, experienced anatomical issues, or had other systemic or chronic diseases that could potentially impede spirometric measurements. According to the results of the physician's preliminary examination, non-compliance with spirometric and mouth pressure measurement procedures also led to exclusion from the study (Figure 2).

Procedure

Participants who satisfied the requirements for inclusion and finished the preliminary evaluation provided written informed consent. After the preliminary interviews, respiratory function tests were conducted on subjects deemed suitable for participation. The tests were performed using the Cosmed Pony Fx desktop spirometer in accordance with the guidelines. Any abnormalities in spirometric values were assessed by a chest diseases specialist, and for subjects without abnormalities, mouth pressure measurements were carried out.[8] The mouth pressure measurement was conducted using the Pony Fx Desktop Spirometer (Cosmed Inc., Italy). For MIP measurement, participants were instructed to exhale slowly until reaching the residual volume level, and then to perform a rapid inspiration. During this rapid inspiration, the shutter in the tubing was closed. Participants' inspiratory strength was measured using a pressure gauge against the closed shutter. Standard mouthpieces and nose clips were used during the test. To prevent the spread of unwanted harmful microorganisms, a bacterial filter was incorporated into the setup. Additionally, particular attention was given to ensure that there were no leaks from the lip edges. For MEP measurement, the participant was asked to reach the total lung volume level and then perform a forceful exhalation through the mouthpiece, simulating the act of inflating a balloon, for

Main Points

- This study reveals essential normative values for maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) specific to the Turkish population, bridging a significant gap in respiratory health research.
- By recognizing the variability of normative values across different races, this research underscores the potential impact on precise diagnoses and effective treatment strategies for respiratory conditions.
- Through rigorous regression analysis, the study formulates accurate equations for calculating MIP and MEP values, providing healthcare professionals with robust tools to assess respiratory muscle strength in individuals of Turkish descent.
- By implementing these normative values in clinical and research settings, this study contributes to improved healthcare outcomes and better-informed, decision-making processes concerning respiratory muscle function in the Turkish population.

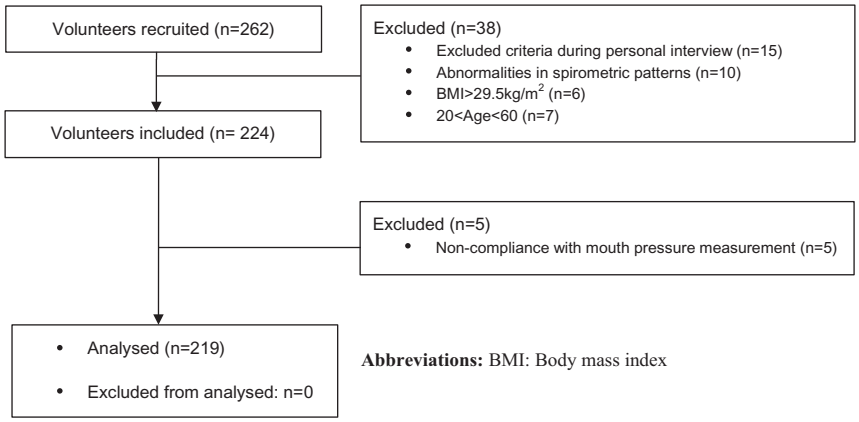

Figure 1. Study flowchart.

at least 1.5 seconds. In the meantime, the pressure created by rapid expiration was measured by sensors. The shutter opened after 1.5–2.0 seconds, and the test was terminated. In cases where multiple tests were required, a maximum 3–5 tests were performed and the participant rested for at least 1 minute between each test. Care was taken to ensure that there was no more than a 10 cm H_2O difference between the measurements. The highest rating achieved was recorded and compared with the expected value.[4] All measurements were performed by the same person.

Statistical Analysis

Data obtained in the study were analyzed statistically using the Statistical Package for the Social Sciences version 25 software (IBM Corp., Armonk, NY, USA). The measurement results were presented as arithmetic mean and standard deviation values. Estimation equations for MIP and MEP values were created using multiple linear regressions, and the mean values of the measured and estimated values according to gender and age groups were presented. The Type I error rate was taken as 0.05 in the study (Figure 3).

Sample Analysis

Sample analysis was performed using G Power statistical software. The estimated effect size was taken from a similar study on this subject. The sample size required was calculated as a minimum of 200 people, with at least 50 in each of the age ranges of 20–29, 30–40, 40–49, and 50–60 years, based on a 95% confidence level, 80% power, and 0.176 correlation coefficient.[5]

RESULTS

The study included 219 healthy adult Turkish individuals. The gender distributions were: group 1: 27 males and 29 females, group 2: 25 males and 30 females, group 3: 30 males and 26 females, and group 4: 27 males and 25 females. The BMI values of all the groups were <29.5 kg/m^2. The demographic characteristics of the age groups according to gender and the mouth pressure measurement results are given in Table 1.

As a result of the regression analysis performed for MIP values, the model *P* value was < .001, and the R2 value was found to be 0.261. The equation obtained as a result of the model was: 82.583 – 23.218 × Gender – 0.093 × Age + 9.534 × Height + 0.343 × Weight (Table 2).

As a result of the regression analysis performed for MEP values, the model *P* value was < .001, and the R2 value was found to be 0.285. The equation obtained as a result of the model was: 157.165 – 35.522 × Gender – 0.271 × Age– 42.036 × Height + 0.787 × Weight (Table 3).

DISCUSSION

Maximum inspiratory and expiratory pressures, which are indicators of respiratory muscle strength, may vary according to race. According to the models obtained in this study, the mean MIP value of the Turkish population can be estimated using the formula: 82.583 – 23.218 × Gender – 0.093 ×

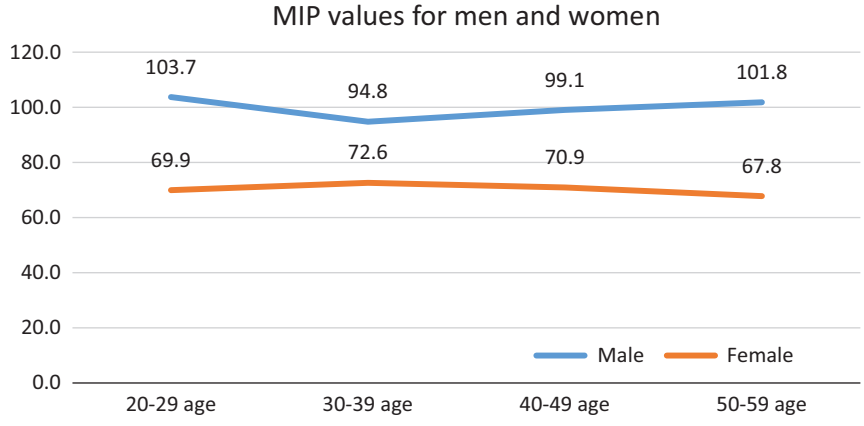

Figure 2. Distribution of MIP values for men and women by age groups.

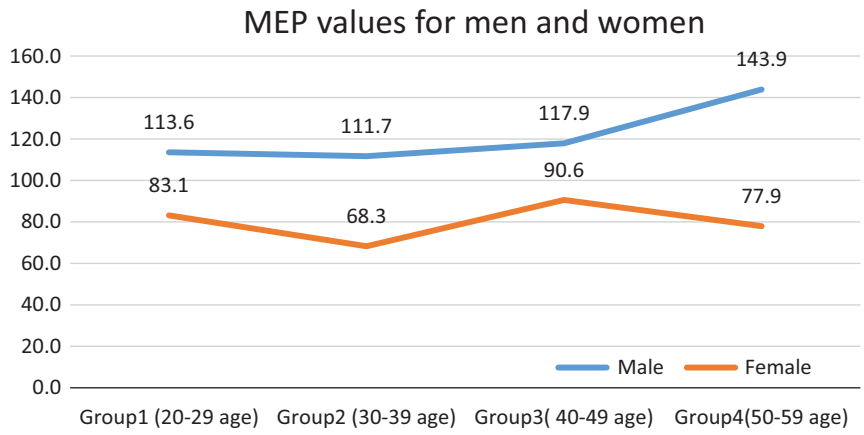

Figure 3. Distribution of MEP values for men and women by age groups.

Age + 9.534 × Height + 0.343 × Weight and the MEP value with the formula: 157.165 – 35.522 × Gender – 0.271 × Age – 42.036 × Height + 0.787 × Weight.

Respiratory muscle dysfunction is a clinical condition that can occur in neuromuscular diseases,[9] long-term mechanical ventilation applications,[10] and chronic respiratory diseases such as chronic obstructive pulmonary disease.[11]

The presence of respiratory muscle weakness is closely related to patient-reported disease symptoms. In a prospective cohort examining the respiratory muscle strength of cases diagnosed with COVID-19, it was found that respiratory muscle strength decreased in parallel with the severity of the disease, and respiratory dysfunction was associated with psychological disorders and decreased quality of life.[12] In another study examining Long COVID-19 symptoms, it was emphasized that respiratory muscle strength is a clinical parameter that should be taken into account when determining the causes of ongoing respiratory symptom.[13] In order to evaluate the respiratory muscle strength level, which is important in revealing the patient's clinical status and determining the cause of the symptoms, real reference values specific to the population and comparisons with these values are needed. The results of the current study have made it possible to determine the normative value for the Turkish population.

Many studies have attempted to determine the reference values of respiratory muscle strength according to different populations.[5,6,14] In a study conducted in Brazil on 60 healthy male and female subjects aged 20–80 years, it was reported that previously used reference values were insufficient to predict the normative MIP and MEP values of the Brazilian population.[6] Researchers have also stated that age is the most effective demographic parameter in the estimation of these values. In a cross-sectional study conducted in the Indian

Table 2. Regression Analysis (MIP)

	B	Std. Error	Beta	*t*	Sig.	95% CI	
(Constant)	82.583	59.479	–	1.388	.166	–34.656	199.822
Gender	–23.218	5.151	–0.391	–4.507	<.001*	–33.371	–13.064
Age	–0.093	0.17	–0.036	–0.545	.586	–0.428	0.243
Height	9.534	34.398	0.028	0.277	.782	–58.269	77.336
Weight	0.343	0.22	0.139	1.56	.120	–0.09	0.776

$R^2 = 0.261$.
*ANOVA $P < .001$.

Table 3. Regression Analysis (MEP)

	B	Std. Error	Beta	*t*	Sig.	95% CI	
(Constant)	157.165	83.924	–	1.873	.062	–8.26	322.589
Gender	–35.522	7.268	–0.417	–4.887	<.001*	–49.849	–21.196
Age	0.271	0.24	0.074	1.129	.260	–0.202	0.745
Height	–42.036	48.536	–0.085	–0.866	.387	–137.706	53.633
Weight	0.787	0.31	0.223	2.536	.0120	0.175	1.398

$R^2 = 0.285$.
*ANOVA $P < .001$.

Mangalore population, measurements were made in 250 cases. It was similarly reported that the respiratory muscle strength of the healthy local population was lower than that of the normative values calculated according to international standards.[5] In a recent study conducted in Spain, researchers declared the utilization of the largest patient dataset in Europe, employing a method parallel to these studies.[15] Upon examining the averages of respiratory muscle strength data across all these studies, it is observed that the reference values obtained in our study are different. This highlights the rationale and necessity for the implementation of our study.

In a study conducted on a young healthy Arab population, the relationship between respiratory muscle strength and maximal voluntary ventilation values with anthropometric characteristics and physical activity level was investigated. Gender and height were found to be associated with respiratory muscle strength, while physical activity level was not a determining factor.[16] In another study, reference values were calculated according to age and gender.[14] In contrast, there is also a study in the literature which included demographic characteristics such as height and weight, as well as BMI.[5] Gender is a significant determinant for spirometric measurement results[17] and respiratory muscle strength.[18] The chest cage, lung volumes, and cross-sectional areas of respiratory muscles influence these measurement outcomes. It is an interesting result that especially in our study, the MEP value was measured lower in women than in other studies. We think this may be due to demographic variables such as height. In the current study, gender, height, and weight parameters were taken into account in the calculation of reference formulas, similar to the literature. In our study, unlike past reference formulas developed for different populations,[5,19] separate reference formulas for men and women have not been established. This is because regression analyses conducted separately for both gender groups in the study did not yield statistically significant regression models. Therefore, including gender as a variable in the model was deemed unnecessary, and separate calculations for each gender were not pursued.

Different techniques and different devices are used to determine respiratory muscle strength. MIP, sniff nasal pressure, mouth pressure, transdiaphragmatic pressure, and electrical and magnetic phrenic nerve stimulation can be considered the main methods.[20] Of these techniques, mouth pressure measurement is frequently used in clinics as it is not an invasive method and is easy to apply. The technique can be applied with different model devices, and the method of application is standardized according to the European Respiratory Society statement.[21] The measurements in the current study were performed in accordance with these standards. Mouth pressure measurement has been preferred in all of the other studies conducted to determine the reference values of respiratory muscle strength in different societies.[5,6,14]

The study has some limitations. In the current study, there were problems in finding healthy subjects over 60 years of age, so the age range of the study was limited to 60 years, which could be considered a limitation. Our age range had to be limited to 60 years due to the inability to reach a sufficient number of cases over the age of 60 with comorbidities. There is a need for future studies that will include individuals over the age of 60 years. This cross-sectional study was conducted in the city of Istanbul. There is a need for more comprehensive studies on case groups formed from samples from every province of the country. However, the cosmopolitan structure of Istanbul and the immigration from all parts of the country alleviate the effects of this limitation. Another limitation is that passive smoking or cigarette smoke exposure was not questioned. Furthermore, the lack of specified information regarding the subjects' levels of physical activity in the study constitutes a limitation. Given the attempt to include participants from all segments of the community, the situation can be considered as reflecting real-life data that represents the general composition of the community.

With the formulas obtained from the modeling in this study, reference respiratory muscle strength values can be determined according to the demographic characteristics of the Turkish population. However, it is important to note that further studies, including a larger sample from various regions of Turkey, are still needed to prepare new tables or equations based on population-based data, as this study was conducted using an Istanbul-based sample.

Ethics Committee Approval: This study was approved by the Ethics Committee of University of Health Sciences Hamidiye Non-Interventional Research Ethics Committee (approval number: 19/81; date: 11/08/2019).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – E.P.; Design – E.P.; Supervision – H.Ç.; Resources – E.P., H.Ç.; Data Collection and/or Processing – H.Ç., A.A., E.P., P.B., M.B.U.; Analysis and/or Interpretation – K.N.B.; Writing Manuscript – E.P., H.Ç., A.A., P.B., M.B.U., K.N.B.; Critical Review – E.P., H.Ç., A.A., P.B., M.B.U., K.N.B.

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Declaration of Interests: The authors have no conflicts of interest to declare.

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