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Maximal Respiratory Static Pressure and Maximal Voluntary Ventilation as a Measurement of Respiratory Muscle Strength and Their Co-rrelation with Various Physiological and Spirometry Parameters in Normal Healthy Indian Adults

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Abstract

Background: The strength of respiratory muscles can be evaluated from static measurement or inferred from dynamic measurement such as maximal voluntary ventilation. The primary aim of this study was to establish correlation between PImax, PEmax, MVV and various physiological, anthropometry and spirometry parameters in healthy Indian adults. These relatively simple non invasive measurements, apart from having a role in the diagnosis and prognosis of a number of neuromuscular and pulmonary diseases, have been associated with health status, physical fitness and even post surgical and general morbidity and mortality. Reference values from these important measurements, as for most biological variables should ideally be derived from randomly selected geographically related population. The purpose of this study is to find out normal values for a randomised sample of urban population and its co-relation with physiological, anthropometric and spirometry parameters. With this main objective we retrospectively evaluated 103 non smoking healthy adults (20-80 years) data were collected from the records of all healthy persons who underwent pulmonary function test in the department of respiratory medicine Jaslok Hospital Mumbai between October 2010 to August 2012.

Results: In our study mean PImax was 59.8951c m +24.49023, with male and female values were 66.7600 + 24.48717cm and 50.6900 +21.50713 cm respectively. Mean PEmax was 67.3636 c m+23.63529, with male and female values were 75.8012+23.27025 cm and 56.0496+ 19.132337cm respectively. Mean MVV was 97.6900 L/min+31.04196 with male and female were 115.6236+24.93948 and 73.6427+20.34229 respectively.

Conclusion: In our study PImax, PEmax and MVV values were lower in females than males. It had significant positive or negative correlation with various anthropometric, physiological and spirometry parameters. The results of this study can be used to predict respiratory muscle strength in healthy adults, which can be used for required assessment of respiratory function and also aid in the planning of treatment and rehabilitation.

Key words: Maximal Respiratory Static Pressure (MRP); PImax(MIP); PEmax(MEP); Maximal Voluntary Ventilation (MVV); RM; Total Lung Capacity (TLC); Residual Volume (RV);

Introduction

Measurement of maximal respiratory pressure is a simple, quick and non invasive clinical procedure for determining inspiratory and expiratory muscle strength both in healthy subject and in patients with pulmonary or neuromuscular diseases, in the later group MRP is both indicative of ventilatory capacity as well as a useful value in assessing the degree of abnormality. Ventilation plays a key role in the adequacy of the internal gas exchange, the ultimate lung function. The appropriateness of the ventilatory pump is intrinsically linked to the ability of the force generator units (i.e. the respiratory muscles) to provide the required output. RM strength can be directly measured using statistic pressures or inferred from some dynamic maneuvers such as maximal voluntary ventilation [1,2,9]. MIP is the greatest sub atmospheric pressure that can be generated during inspiration against an occluded airway. MEP is the highest pressure that can be developed during a forceful expiratory effort against occluded airways and MVV is the largest volume that can be ventilated during 10 to 15 seconds interval with voluntary efforts. The relationship of these pressures to age, sex and general muscular development has been described [11]. Normal values have been reported for these relationship and these are most frequently derived from the regression equation of Black and Hyatt [11]. The functions of the respiratory muscles are difficult to study directly since muscle's complex origins and insertions [4,5]. Furthermore their product, which is the pressure generated within thoracic cavity, depends on the co-ordinate action of many muscles, the individual functions of which may be difficult to distinguish in life [4,6]. The respiratory muscles pump is vital for the movement of air to the level of gas exchange in the respiratory system. The respiratory muscles include the diaphragm as the major muscle of inspiration along with intercostals and scalene muscles. MIP is a measure of inspiratory muscle strength (diaphragm and other inspiratory muscles), while MEP reflects the strength of the abdominal muscles and other expiratory Muscle [7]. Impairment of the respiratory pump compromises ventilation, gas exchange and tissue respiration, respiratory muscles weakness increases the relative load for breathing, this can lead to clinical consequences such as dyspnea in paired exercise performance, ineffective coughing, respiratory insufficiency, weaning failure and death. Respiratory muscles assessment is required in order to individually tailor and design pulmonary rehabilitation programs for the optimization of physical and social performance [8]. The available studies that report reference values of Pimax, PEmax and MVV, shows wide variability, not only between individuals, but also between studies. Most of the studies for normal values based on western studies and its co-relation with various anthropometrics and physiological variation which is not suitable for clinical assessment in an Indian population, therefore it is essential to establish co-relation with various variability through our study.

Interpretation

Abnormal respiratory muscle strength is identified by comparing the MIP and MEP to a reference value or the lower limit of normal. When lung hyperinflation exists the MIP should be compared to the expected MIP.

Reference range

The reference is sometimes referred to as the normal, the definitive reference range have not been established for the MIP or the MEP. Various studies showed wide variability.

Lower Limit of Normal

The lower limit of the normal range (LLN) corresponds to the fifth percentile and is approximately 50 percent of the predicted value. MIP and MEP values below the LLN are considered abnormal. There is no upper limit of normal for measures of respiratory muscle strength.

Expected MIP

Patients with lung hyperinflation due to severe airway obstruction may generate a low MIP despite normal inspiratory muscle strength. This is due to shortening of diaphragmatic muscle fibers and the mechanical disadvantage conferred by lung hyperinflation, in such patients MIP should be compared to an expected MIP instead of the reference range or LLN. When the MIP is lower than the expected MIP than respiratory muscle weakness should be suspected. An alternative noninvasive method should be performed to confirm inspiratory muscle weakness.

Test characteristics

Test characteristics of the MIP and MEP have been scarcely studied, it appears that a normal MIP reliably excludes respiratory muscle weakness (good negative predictive value), but a low MIP does not confirm inspiratory muscle weakness (poor positive predictive value), the poor positive predictive value reflects the high frequency of falsely low MIP measurements due to unrecognized poor efforts or technique. Given these characteristics, clinicians must accept the uncertainty that exists when MIP or MEP is close to LLN or when the test quality is poor in such situations the test can be repeated or an alternative test of respiratory muscle strength can be performed.

Detecting a change

Detecting a change in respiratory muscle strength can be useful for identifying improvement or progression of a disease, however true change must be distinguished from normal variation. Studies in healthy individuals demonstrate that 95% of normal test to test variation has a magnitude less than 25 cm H2O. Ideally such a study should be performed by each laboratory using patients with neuromuscular diseases, in the absence of such data it is reasonable to use a change of more than 25 cm H2O as a threshold to identify true change of respiratory muscle strength.

Factors causing low MIP and MEP

A low or slightly low MIP and MEP can also be due to factors other than respiratory muscle weakness, such factors includes: Older age, Female gender, Weak handgrip strength, malnutrition, obesity (>220pounds,>33 BMI, large waist size or high percent body fat), poor health, low physical activity, low education, short stature, smoking, suboptimal technician coaching. In addition it can be falsely low due to problems related to patient's efforts and technique, pressure gauge accuracy and the patient-device interface.

Alternative Tests

This is the most common test of respiratory muscle strength although alternative methods exist. The sniff nasal inspiratory pressure (SNIP), also known as the sniff nasal inspiratory force (SNIF) is a noninvasive test of respiratory strength, advantages includes the simplicity of the maneuver and the absence of a mouthpiece, which is particularly helpful for patients who have facial (bulbar) weakness. The sniff nasal inspiratory pressure is performed by wedging a catheter into one nostril and instructing the patient to sniff through unobstructed nostril, the pressure measured in obstructed nostril is an indicator of respiratory muscle strength. The SNIP correlates strongly with trans-diaphragmatic pressure and the MIP in patients who do not have severe airway obstruction; however it provides no information about expiratory strength. In one study the mean SNIP in Japanese men and women were -77 and 60 cm H2O respectively while the LLN for the same were 33 and 29 cm H2Orespectively. Transdiaphragmatic pressure during inspiration, expiration sniff, cough or phrenic nerve stimulation test is the best measure of respiratory muscle strength. However the technique is complex invasive (requires insertion of esophageal and gastric balloon catheters) and performed in only specialized centers.

Indications

- Respiratory muscle weakness is suspected, such as a patient with dyspnea, weak cough, and known neuromuscular disease.
- Spirometry detected a pattern of restriction: reduced forced expiratory volume in one second, reduced forced vital capacity, normal FEV1/FVC ratio, and reduced total lung capacity and respiratory muscle weakness is in the differential diagnosis.
- Spirometry detected a low vital capacity of unknown etiology and respiratory muscle weakness is in the differential diagnosis.
- Spirometry detected a low maximal voluntary ventilation maneuver of unknown etiology and respiratory muscle weakness is in the differential diagnosis.
- Evaluation of whether known respiratory muscle weakness has improved, remained stable, or worsened.
- To determine whether there is an increased risk of incident mobility disability in older individuals, hospitalizations and death in patients with COPD, mortality in patients with heart failure.

Aims & objectives

- To study correlation between age, sex and maximal respiratory static.
- pressure and Maximal Voluntary Ventilation.
- To look for a co-relation between maximal respiratory static pressure and anthropometric parameters in normal healthy adults.
- To study the co-relation between maximal respiratory static pressure and spirometry parameter in normal healthy adults.
- To look for co-relation of MVV with various anthropometric & spirometry parameter for assessment of respiratory muscles strength.

Reference range

The reference is sometimes referred to as the normal, the definitive reference range have not been established.

The following reference ranges (Table 4) were extracted from studies of reasonable quality that evaluated individuals in different age. The mean maximal inspiratory pressure (shown on vertical axis in cm H2O) declines with age during adulthood and is lower in women than male. Measurement of maximal inspiratory pressure, maximal expiratory pressure and maximal voluntary ventilation generated at mouth is an accepted non invasive clinical method for evaluation of the strength of respiratory muscles; however the choice of normal values for this measurement is made difficult by the wide variation in normal values reported in the literatures. In the healthy subjects mean values ranging from 89 to 146 cm. H2O have been reported for MIP and published value for MEP in adult male subjects ranging from 130 to 247 cm.H2O [1,2]. Leech et al studied 924 healthy caucasian adults and found respiratory pressures were positively correlated with weight but not to height or age, have reported a mean value of MEP in male adolescent of 131 cm, where as Cook et al reported a mean value of 198 cm H2O a difference of 50% [12]. Leo Black, Robert Hyatt. et al. studied MRP in 120 healthy subjects (60 males and 60 female) between 20 to 74 years of age, there was no significant regression of PImax, PEmax below 55 years of age, but above 55 years PEmax in males and females and PImax in males decreased with age [11]. Another study by H.Willson, N.T Cook et al in 370 normal healthy adults and children, in male PImax and PEmax were significantly correlated with age ($p<0.001$ and <0,005 respectively), whereas in females they were correlated with height ($p<0.0035$ and 0.005) [12]. Robert J. Smith. et al. reported a mean value of MIP in females ranged from mean values of 86 to 108 cm H20 and for male 114 to 149 cm H20 [22]. Another study by I. Odd Chorob, et al (Pol Meruker Lekariski2002) in 166 clinically normal subjects (79 females and 87 males), in females PImax ranged 38 to104cm H2O with average 60 cm H2O, PEmax ranged 46- 104 cm H2O with average 87.5 cm H2O [8]. In male PImax was 40-120 cm.H2O with average 73.2cm, PEmax ranged 46-140 cm H2O with an average of 115.9.cm H2O. PImax was negatively correlated with age, in both groups. There was no correlation between PImax, PEmax and height in female groups. There was positive correlation between PImax, PEmax and weight in both groups (males and females). In a study done by Mc Elvancy G, Blackie S.et al. MIP and MEP in 64 normal females and 40 normal males older than 56 years of age no correlation was found with age [23]. Predicted normal values for MRP in caucasian adults and children by S.H. Wilson, NT Cook. et al. MIP and MEP measurement in 370 normal male and female, in male PImax and PEmax were significantly correlated with age ($p<0.001$ and 0.035 respectively) whereas in females they were correlated with height ($p<0.035$ and <0.0respectively) [12]. In both boys and girls PImax was related with weight ($p<0.0001$ &<0.01respectively) and PEmax to age ($p<0.0001$ for both). Another study done by Babak Amra, Hasan Salehi. et al. they analyzed 224 male and 211 females mean value for MIP were 9.78 kPa for male and 7.61 kPa for females, mean value for MEP was 13.11 kPa for male and 10.21 kPa for female, the reported values were markedly less than American and European studies [36]. In this study age showed a negative correlation with MIP for both male and female. In a study done by A. Johan, C.C. Chan. et al. for measurement of MRP (MIP,MEP) in adults Chinese Malayas and Indians, MIP in male Chinese was 88.7+ 32.5, Malaya was 74+22.7 and Indians was 83.7+30 cm H2O [14]. MIP in female was 53.6+20.3 in Chinese 50.7+18.3 in Malaya, and 50.0+15.2 in Indian, MEP in male was 113.4+41.5 in Chinese 94.71+23.4 in Malaya and 98.4+22.2 cm H2O in Indians. In females MEP values were 68.3+24 for Chinese, 63.61+ 21.6 for Malaya and 62.2+20.4 for Indians. In a study done by Raida I, Harik Khan. et al. (Baltimore Longitudinal study of aging) measured MIP in 668 men and women they analyzed 139 male and 128 female in healthy subgroup with wild age range (20-90 years) mean MIP was 102.2+29.4(range 33.0 to 173.2) in men and 72.4+23.3(range21.0.to 126.6) in females [3]. In the youngest group (age <39.9 yrs.) the mean values for men and women were 117.6 cm H2O and 79.5cm respectively and it decreases with age. MIP reaches an average of 66.0 cm H2O and 45.5 cm H2O respectively for men and women in older age group (age >75 yrs.). Mean MIP value for females in each age group were approximately 70% of the values of the males. Age was found to be negative predictor, PEF was positive for male subjects. For females age and height were found to be negative predictor, whereas FVC, PEF and weight were positive predictor.

There are few Indian studies done

a) Dr. Devasahayam, Christopher. et al. at Christian Medical College Vellore 400 healthy volunteers (242 males and 158 females) between 15 to 78 years of age [34]. The mean MIP (PImax) was 10.59 kPa for male and 7.65 kPa for females, mean MEP (PEmax) was 12.94 kPa for males and 8.86k kPa for females. Both values being higher in male than in females, For PImax significant correlation was found with age, weight, PEF, FEV1 in both men and women. For PEmax significant correlation was found with age, weight, FEV1, PEF and FVC in men and women, in addition there was significant correlation with height in females.

b) Study done by Misri Z.K., Sabir R.C. et al. at Kasturba Medical College Mangalore, 200 medical students (100 boys and 100 girls) were evaluated [35]. The values for PEmax and PImax were lower in females and this was in agreement with previous report by Black and Hyatt. No significant correlation was found between age and respiratory pressure in both male and females. There was significant correlation between MIP and body weight in females ($p<0.001$). BSA showed significant correlation with height and weight ($p<0.01$) with both male and female.

c) In another study done by A.Gopalkrishna, K.Vaishali. et al. at Kasturba Medical College Mangalore, they studied 250 healthy normal subjects [33]. In males PImax values correlated positively with height, weight, BMI, however PImax and PEmax were negatively correlated with age. For females PImax and PEmax showed positive correlation with height, weight, BMI and had moderately negative correlation with age, compared to previous studies this study showed lower mean value for adults, mean PImax for males was 75.35+ 20.89, mean PEmax was 93.39+ 20.21 cm, H2O, for females mean PImax was 48.80+16.91 and mean PEmax was 60.65+20.28 cm H2O [2,3,7,9]. There was significant correlation of PEmax with age for male and female subjects ($p<0.05$) and PImax for male subjects ($p<0.05$). However there was no correlation of PImax with age for female subjects ($p>0.05$). For females a significant correlation was found with height, weight and BMI. This may be explained by the fact that decreased muscle mass and strength fall with increasing age in males.

Material and Methods

Study design the present study was conducted in retrospective manner at jaslok hospital and research centre mumbai india between october 2010 to august 2012 of normal healthy individuals who fulfill the criteria mentioned below their pft test records (spirometry maximal static respiratory pressure and maximum voluntary ventilation)along with age sex, anthropometric parameter were checked. Subjects were included in the study if they did not meet any of the exclusion criteria.

Criteria For Selection

Inclusion Criterias

- All healthy persons between 20 to 80 years.
- Nonsmokers.

Exclusion Criteria

- Current respiratory complaints.
- History of smoking.
- History of serious pulmonary disease.
- Cardiac and neuromuscular disease.
- Physical findings suggesting cardiopulmonary disease.
- Evident chest deformity and neuromuscular deficit.

Measurements

- Age was recorded as per last birth date
- Standing Height was measured in nearest centimeters .
- Weight was recorded in kilogram
- B.M.I. was calculated from height and weight.

Test Procedure

Spirometry test was performed on JAEGER MS PFT analysis unit, which was caliberated daily, all tests were conducted by same technicians and the test were performed as per ATS guidelines.

Maximum static pressure measurement

Was done as per ATS/ERS statements for respiratory muscles testing [18]. All tests were carried out with JAEGER MS PFT analyzer unit, all tests were conducted by the same technician, all persons were explained about procedure and motivated. The subjects remained seated with the trunk at an angle of 900 to the hip and feet on the ground wore a nose clip with normal mouthpiece, which is attached to a short rigid tube with a valve system to allow normal breathing followed by either maximal inspiratory or expiratory maneuver. A tube connected to spirometer at the distal end of the tube with a small leak to prevent glottis closure during the PImax maneuver and to reduce the use of buccal muscles during PEmax maneuver. For measurement of PImax the subject was asked to make a maximal inspiratory effort starting from the residual volume (RV), whereas for PEmax a maximal expiratory effort starting from total lung capacity (TLC) was elicited subjects exhale as hard as possible against closed shutter [7]. The inspiratory and expiratory pressures maintained for at least 2 seconds so that the maximal pressure sustained for 1 second can be recorded. All the subjects performed at least three reproducible maneuvers each maintained at least one second until three technically adequate efforts had been made, one minute rest was ensured between efforts. For data analysis the highest value was recorded.

Maximal voluntary ventilation

MVV is the largest volume that can be breathed into and out of the lungs during a period of 10-15 seconds interval with maximal voluntary efforts, in this study subject wore nose clip and breathed deeply (with a volume greater than tidal volume but lower than vital capacity) and rapidly for a 15 seconds interval with flow measured by a Fleish No. pneumatograph. After discarding the first three to five breaths the subjects were actively encouraged to maintain the same volume and frequency by following an online display of the maneuver on a computer screen (ie the end expiratory remained relatively constant). At least two acceptable maneuvers (with no more than 10% difference between them) were obtained and flow integration the highest value was recorded by extrapolating the 15 seconds accumulated volume to 1 minute (l/min, body temperature, ambient pressure, saturated with water vapour BPTS).

Stastical Analysis

Stastical analysis was performed for all measured parameters using SPSS (Stastical Package for Social Sciences) for windows (version-14.0). In all the subjects the values for the maximal respiratory pressure and maximal voluntary ventilation were plotted against the four variables (age, height, weight, BMI). Standard descriptive statistics based on mean and standard deviation (SD) for quantitative variables, a stepwise linear and multiple regression analysis being used. This analysis was used to obtained prediction equation for variable were in the multiple regression for all groups. Pearsons co-rrelation co-efficient test was performed to asses possible co-relation between Pimax, PEmax and MVV values and anthropometric and spirometry parameters.

alysis

The validity of MIP,MEP and MVV are directly related to the quantity of the test. Potential sources of errors that should be considered include

- Persons effort and technique
- Pressure gauge accuracy — most common cause of errors
- Person device interface.
- The technologist should acts as an enthusiastic and encouraging coach eliciting maximal effort from the person for each maneuver. Most clinical laboratory performed only five measurements.

Observation and Results

All participants completed each of the physical assessments and results are presented in this section for all participants. Total103 subjects were evaluated for our study out of which 59 were males and 44 were females between the age of 20 to 80 years Figure1. Mean age was 43.17+15.669 with mean age for males and females were 41.37+ 16.197 and 45.59+14.768 respectively. Physical characteristics of the participants are presented in Table1. The females displayed a significantly reduce stature than males with higher B.M.I. Pulmonary function was determined via spirometry with results reported in Table 2. Respiratory Muscle strength results for males and females showed some interesting findings, with scores for PImax and PEmax and MVV presented in Table 3. We tried to correlate the various anthropometric and spirometry parameters with that of maximal respiratory pressure and maximal voluntary ventilation values.

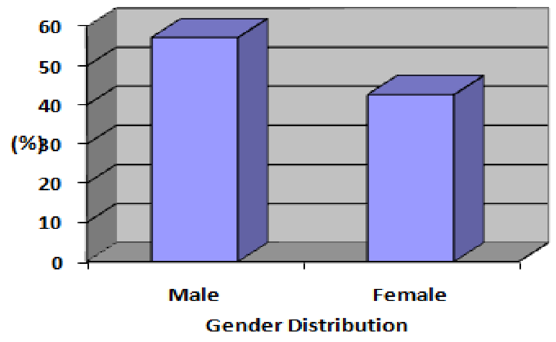

Figure 1: Out of 103 participants 59(57.3%) were males and 44 (42.7%) were females

Table 1: Frequencies

Sex wise distribution of study population:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 Male	59	57.3	57.3	57.3
	2 Female	44	42.7	42.7	100
	Total	103	100	100	

Table 2: presents the physical characteristics of the study group

SEX		AGE(yrs.)	BMI	HT(c m)	WT(kg)
1 Male	Mean	41.37	25.0844	167.9	70.91
	N	59	54	59	59
	Std. Deviation	16.197	3.26276	6.999	10.547
2 Female	Mean	45.59	26.4253	155.41	44
	N	44	44	44	44
	Std. Deviation	14.768	3.98833	7.54	11.263
Total	Mean	43.17	25.7136	162.56	67.98
	N	103	103	103	103
	Std. Deviation	15.669	3.65913	9.506	11.328
	Minimum	20	18.5	137	43
	Maximum	80	39.14	183	104

In our study when entire group was taken together results of maximal static pressure and maximal voluntary ventilation are shown in table 3: Mean Pimax, PEmax and MVV were 59.8951cm+ 24.49023 (range 35.4048 to 84.38533), 67.3636 cm+23.63529 (range 43.62831 to 90.99889), 97.6900 L/ min.+ with 31.04196 (range 54.8104 to 128.73116) respectively.

Table 3: Spirometry parameters of the entire study group

SEX		FEV1/FVC%	FEV1 L	FEV1%	FVC L	FVC %
1 Male	Mean	98.3956	2.891	98.7271	3.3141	93.37
	N	59	59	59	59	59
	Std. Deviation	12.69632	0.59676	12.79309	0.6179	12.352
2 Female	Mean	92.2023	1.903	96.6225	2.2518	94.47
	N	44	44	44	44	44
	Std. Deviation	13.10547	0.4466	14.33874	0.53831	12.122
Total	Mean	95.7499	2.4689	97.8281	2.8603	93.84
	N	103	103	103	103	103
	Std. Deviation	13.17363	0.72651	13.44738	0.78618	12.207

In male: Mean Pimax, PEmax and MVV were 66.7600 cm +24.48717(range 42.27283 to 91.24717), 75.8012 cm+23.27025 (range 52.53095 to 99.07145), 115.6236 L/ min+24.93948(range 90.68432 to 139.56308) respectively.

In female: Mean Pimax, PEmax and MVV were 50.0900 cm+ 21.50713(range 31.55763 to 69.72237), 56.0496 cm+19.13237 (range 36.91723 to 75.18197), 73.6427 L/min+20.34229(range 53.30091 to 93.98499) respectively. In female the values of Pimax, PEmax and MVV were lower than males.

a) Correlation of PImax to variables in entire group: Significant positive correlation was found with height (p= 0.002, r=0.298) with absolute value only. Significant negative correlation was found with age (both absolute and percent values p=0.01, r=0.337 and p=0.018, r=0.233 respectively). No correlation was found with weight, and B.M.I.

b) Correlation of PImax to spirometry parameters in entire group: Positive correlation was found between PImax and FEV1/FVC% (p=0.015, r=0.240). Significant positive correlation was found between PImax and FEV1% and FEV1 with absolute values only (P=0.000, r=0.348, p=0.000, r= 0.489 respectively). Significant positive correlation was found between PImax and FVC absolute value only (p=0.000, r=0.420). Significant positive correlation was found between PImax and PEmax both with absolute and percent values (p=0.000, r=0.584and p=0.012, r=0.247 respectively). Significant positive correlation was found between PImax and MVV absolute value only (p=0.000, r=0.468) (Table 4)

Table 4: Mean values of PImax, PEmax and MVV of entire study population

SEX		Pimax kpa	Pimax %	Pemax kpa	Pemax %	MVV L/min	MVV %	Pimax cm	Pemax cm
1 Male	Mean	6.2451	61.576	7.0908	51.36	115.6236	89.298	66.76	75.8012
	N	59	59	59	59	59	59	59	59
	Std. Deviation	2.29066	22.1297	2.17682	15.715	24.93948	16.9971	24.48717	23.27025
2 Female	Mean	4.7418	68.85	5.2432	65.62	73.6427	82.641	50.69	56.0496
	N	44	44	44	44	44	44	44	44
	Std. Deviation	2.01189	35.451	1.78974	24.275	20.34229	18.6084	21.50713	19.13237
Total	Mean	5.6029	64.683	6.3016	57.45	97.69	86.454	59.8951	67.3636
	N	103	103	103	103	103	103	103	103
	Std. Deviation	2.29095	28.6594	2.21097	20.953	31.04196	17.9222	24.49023	23.63529

c) Correlation of PEmax to variables in entire group: Positive correlation was found with height (p=0.000,r=0.460) only absolute value. Significant negative correlation was found with B.M.I. (p=0.016, r=0.252) absolute value only. Significant negative correlation was found with age (p=0.037, r=0.206) absolute value only.

d)Correlation of PEmax to spirometry parameters in entire group: Significant positive correlation was found between PEmax and FEV1 L (absolute value p=0.000, r=0.476), negative correlation with PEmax %-p=0.041, r=0.202 Significant positive correlation was found between PEmax and FVC L(absolute value-p=0.000, r=0.464), PEmax and MVV both absolute and percent values (p=0.000, r=0.520, p=0.001, r=0.317 respectively). PEmax and PImax both absolute and percent values) p=0.012, r=0.247, and p=0.00, r=0.381respectively).

e) Correlation of MVV with variables in entire group: Significant positive correlation was found between MVV and height (p=0.000, r=0.719) with both absolute and percent value (p=0.027, r=0.218). Significant positive correlation was found between MVV and weight (p=0.007, r=0.265). Significant negative correlation was found between MVV and B.M.I. and age (p=0.003, r=0.309, and p=0.000, r=0.521 respectively) only with absolute values.

f) Correlation of MVV with spirometry parameters in entire group: Significant positive correlation was found between MVV and MVV% and spirometry, MVV L and FEV1/FVC% (p=0.000, r=0.403)FEV1%, (p=0.000, r=0.383) FEV1L (p=0.000, r=0.0.839), FVC L (p=0.000, r=0.798) FVC%. No relation with MVV% and FEV1/FVC%, with FEV1% (p=0.046, r=0.197), FEV1L (p=0.023, r=0.224), FVCL (p=0.015, r=0.239).

g) Correlation of PImax to other variables in male subgroup: Significant negative correlation found between PImax and age (p=0.022, r=0.297) with absolute value only. No correlation found with height, weight and B.M.I. (Table-5).

Table 5: Mean value of PImax, PEmax and MVV as per age and in male sub group

Age group		Pimax cm	Pemax cm	MVV L/min
1.00 upto 30	**Mean**	73.6634	77.4095	140.8644
	Std. Deviation	20.62059	21.94144	20.02683
	N	23	23	23
2.00 31-50	**Mean**	68.6927	82.9858	122.6959
	Std. Deviation	31.17205	25.47858	25.49947
	N	17	17	17
3.00 51 and above	**Mean**	56.6739	67.4258	103.8539
	Std. Deviation	19.41337	21.29099	19.77533
	N	19	19	19
Total	**Mean**	66.76	75.8012	115.6236
	Std. Deviation	24.48717	23.27025	24.93948

h) Correlation of PImax and spirometry parameters in male subgroup: Significant positive correlation was found between PImax and FEV1 % (p=0.007, r=0.349), FEV1 L (p=0.003, r=0.386), FVC L (p=0.019, r=0.304) and Pimax % and FEV1 p=0.012, r=0.326),FEV1 L (p=0.012, r=0.327) , FVC L (p=0.046, r=0.261),with MVV (p=0.004, r=0.371). Significant positive correlation was found between Pimax and PEmax and MVV both absolute and percent values, correlation was more significant with absolute functional parameter values than percentage predicted values. However PImax had no significant correlation with FEV1/FVC ratio.

i) Correlation of PEmax to other variables in male subgroup: No correlation found between PEmax and age, height, weight, and B.M.I.

j) Correlation of PEmax and spirometry parameters in male subgroup: Significant positive correlation found between PEmax value and FEV1 L (p=0.029, r= 0.285) FVC L (p=0.043, r=0.264), with MVV (p=0.002, r=0.387) MVV% (p=0.000, r=0.262), correlation was more significant with absolute functional and percent parameter, correlation was more significant with MVV parameters among all functional parameters. However PEmax had no significant correlation with FEV1/FVC ratio.

k) Correlation of MVV to variables in male subgroup: Significant positive correlation found between MVV value and height with absolute value only (p=0.000, r= 0.8487). Significant negative correlation was found between MVV and age with absolute value only (p=0.000, r=0.575). Negative correlation was found with B.M.I. with absolute value only(p=0.016,r=0.326).Correlation of MVV with spirometry parameters in male subgroup: Significant positive correlation was found between MVV and FEV1/FVC % (p=0.004, r=0.365), FEV1 L(P=0.000, R=0.699), FEV1 % (p=0.000, r=0.404), FVC L (p=0.000, r=0.673),FVC %(p=0.019, r=0.306). No correlation was found with MVV% value.

l) Correlation of PImax to other variables in female subgroup: Significant negative correlation was found between PImax value and age (p=0.024, r=0.339), both with absolute and percent value (p=0.049, r=0.298) no correlation with height, weight and B.M.I. (Table-6).

Table 6: Mean value of PImax, PEmax, and MVV in female subgroup as per age

1.00 upto 30	**Mean**	64.781	62.817	97.4848
	Std. Deviation	12.2044	17.06233	15.85331
	N	8	8	8
2.00 31-50	**Mean**	51.1038	55.031	82.5159
	Std. Deviation	23.66648	18.019	19.24992
	N	19	19	19
3.00 51 and above	**Mean**	43.5963	54.0034	65.3478
	Std. Deviation	19.87184	21.50664	18.49246
	N	17	17	17
Total	**Mean**	50.69	56.0496	73.6427
	Std. Deviation	21.50713	19.13237	20.34229
	N	44	44	44

m) Correlation of PImax to spirometry parameters in female subgroup: Significant positive correlation was found between PImax and FEV1 L (p=0.009, r=0.388) FEV1% (p=0.025, r=0.338), with PEmax (p=0.004, r=0.428) and PEmax % (p=0.023, r=0.342) correlation was most significant with absolute value. However Pimax had no significant correlation with FEV1/FVC% , FVC,FVC% and MVV.

n) Correlation of PEmax to other variables in female subgroup: Significant positive correlation was found between PEmax value and height (p=0.013, r= 0.373), with absolute value only.

o) Correlation of PEmax to spirometry parameters in female subgroup: Significant positive correlation was found with FEV1 L(p=0.045, r=0.304), Pimax (p=0.004, r=0.428), PImax% (p=0.023, r=0.342), MVV (p=0.049, r=0.299) correlation was most significant with absolute MVV than percentage predicted values. However PEmax had no significant correlation with FEV1/FVC,FEV1%, FVC, FVC%.

p) Correlation of MVV to other variables in female group: Significant positive correlation found between MVV value and height (p=0.009, r=0.529) both absolute and percent values. Significant negative correlation was found between MVV and age (p=0.000, r=0.0612) .No correlation was found with weight and B.M.I.

Table 7: Mean value of PImax, PEmax and MVV in entire group as per age

1.00 upto 30	**Mean**	71.3713	73.6438	129.0245
	Std. Deviation	19.03109	21.51987	27.96615
	N	31	31	31
2.00 31-50	**Mean**	59.4097	68.2319	101.4897
	Std. Deviation	28.48794	25.76953	30.17956
	N	36	36	36
3.00 51 and above	**Mean**	50.4984	61.0874	85.226
	Std. Deviation	20.4496	22.15306	26.71788
	N	36	36	36
Total	**Mean**	59.8951	67.3636	97.69
	Std. Deviation	24.49023	23.63529	31.04196

q) Correlation of MVV to spirometry parameters in female sub group: Significant positive correlation found between FEV1 (p=0.0000,r=0.720), FEV1% (p=0.003, r=0.439), FEV1/FVC% (P=0.040,R=0.311), FVC L (p=0.000 , r=0.556). Correlation is more significant with absolute value of MVV (Table-7).

Discussion

To our knowledge, this is one of the study done in normal healthy adults that analyzes PImax, PEmax, and MVV values and their correlation with age, sex and to various anthropometric and spirometry parameters. In our study mean Pimax was 59.8951 c m+24.49023 (range35 to 95 cm H2O), mean PEmax was 67.3636 c m + 23.63529(range 67 to 140 cm H2O) and MVV was 97.6900+31.04196 (range). Mean PImax, PEmax and MVV for males and females were 66.7600+24.48717, 75.8012+23.27025, 1236.01558 +266.303 and 50.6900+ 21.50713, 56.0496+19.13237 and 787.2408+217.45909 respectively. In view of wide range of variation of maximal respiratory pressure, maximal voluntary ventilation reported in western population. The reported mean value for MIP and MEP in male are75+20 cm H2O, 93+33, mean MIP and MEP in female are 48+16 cm H2O, 60+20 cm H20, mean MVV values were 138+25. cm The measured MIP, MEP and MVV values in our studies were markedly less (16.5%, 30.7% and 20.5%) than those reported in American and European studies however the values were comparable to Asian studies [1-3,14,33,34]. Several factors may contribute to the wide range of values described for adults and adolescent in previous studies.

(1)The first concerns the temporal course of the pressure generated. Rahn. et al. first reported that the maximum expiratory pressure can be sustained voluntarily is about 160 cm H2O, Mills. et al. later showed that values over 260 cm could be obtained by sudden voluntary efforts [11,17]. The measurement of MIP, MEP, MVV may vary markedly with the speed of the maneuver, the response characteristics of the pressure measuring device and the decision of the observer to record either peak or sustained maximal pressure.

(2) Secondly air leaks at the nose and mouth can produce inaccuracy during forced expiratory maneuvers.

(3) Thirdly forced respiratory maneuvers are influenced by motivation.

(4) Finally the number of trials to measure MIP, MEP may affect the MRP recorded Black, Hyatt and Leech who used two or three trials to determine normal values whose results were lower than those of Ringqvist21 because the latter used best of many attempts for measurement of these parameters (> 20) [2,11,21].

While MRP generated are highly dependent on the pulmonary volumes at which they are measured, most studies have stated that measurements were made at or near RV and TLC for MIP, MEP and MVV respectively. A review of reported normal values for MIP, MEP and MVV (Table 4) showed substantial variations most probably a consequences of one or other factors outlined previously. Gibson. et al. while using indentical method as Black and Haytt to this study, collected data from small group of normal caucasian women and obtained a range considerably lower than those of Ringqvist and Black and Hyatt (PEmax 67-140 cm H2O and PImax 35-95cm H20), but very similar to our results [6,11, 21]. In comparison to different Asian studies A. Johan, CC Chan et al Devsahayam. et al. from C.M.C. Vellore, Misri Z.K. et al. Gopalkrishan K.M.C [5,33-35]. Mangalore India our results are similar to above studies Table 4.

Our results demonstrated a very strong gender effect, which is consistent with all previous findings reported in the literature [19]. In one study MIP in men was about 30% higher than in women [13]. In our study it is about 30% higher in men than women. RJ Smyth, K.R.Chapman. et al. in a study of 76 adolescent and 36 healthy adults reported MIP and MEP values which is significantly lower in females than males (for male mean MIP and MEP were 107+26 and 114+ for females the values were 76+25 and 86+22 respectively)[22]. Our results showed the importance of age as a significant negative predictor of MIP for both male (p<0.022,r=0.297) and female(p<0.024,r=0.298), a finding consistent with most of the studies including Harik Khan. et al. Vincken. et al. and Babak Amra, Hasan Salehi. et al. Gopalkrishanan. et al. all of these studies used population groups with wide age range [3,29,33,36]. Enright and co-workers had also reported similar results in elderly subjects above 55 years of age [13]. In our study PImax showed no correlation with height, weight and BMI for both sex, a finding not consistent with previous studies, but when entire group was taken into consideration PImax is positively correlated with height (P<0.002,r=0.298). PEmax showed no correlation with age, height, weight and BMI in males, in females there was significant positive correlation seen between PEmax and height (p<0.013, r=0.373), no correlation was seen between PEmax and age weight and BMI in females. Mean MVV value was 97.6900 L/min+31.04196 with male and female values were 115.6236 L/min +24.93948 and 73.6427 L/min +20.34229 respectively. MVV showed significant negative correlation with age in both males and females (p=0.000, r=0.575, p=0.000, r=0.612 respectively), consistent with study done by JA Neder, LE Nevy et al 8, in Brazilian population [8]. Significant positive correlation was seen between MVV and height in both male (p=0.000, r=0.487) and females (p=0.000, r=0.529) a finding seen in above Brazilian population [8]. No correlation was seen with weight in both the sex, but negative correlation was seen with BMI in males only (p<0.16,r= 0.326). Wilson et al found that there was significant correlation with age in adult males and height in female [12]. In our study, age showed significant correlation with PImax, PEmax and MVV value in and both male and female and is consistent with the results of Ringqvist and Vincken et al, both of which used study group with wide age ranges and with Enright et al. in elderly subjects [4,13,21,29]. Berry et al reported a negative correlation between age and MIP, also Black and Hyatt who reported significant negative effect of age only in elderly women [11,15]. The failure to show an effect of age on MIP in a group of younger adults is consistent with previous findings that age related decline in pulmonary function begins in middle thirties, Guleria Jindal et al done a study of subjects between 12.5 to 18.5 years of age and showed a significant correlation with age, weight and height in both sexes [19,24,25]. Wilson et al reported that respiratory pressure in men are related to age and for women a significant relationship was shown only with height, this may be explained by the fact that muscle mass their strength falls with increasing age in men, their peak begins in second or third decade, while in women overall strength may not be related to age to such an extent [12]. In our study we found no correlation between MRP, MVV and body weight a finding not consistent with previous studies by Leech et al Arora Rochester et al, who found out that that diaphragm muscle mass varies almost three fold from atrophy in underweight person, to increased mass in muscular normal subjects [2,6]. Spirometry showed significant positive correlation for PImax in males with all n the parameters like FEV1, FVC, MVV, PEmax, except FEV1/FVC%, in females PImax showed significant positive correlation with FEV1, and PEmax, no correlation was seen with FVC, FEV1/FVC % and MVV values. For PEmax positive correlation was seen with FEV1, FVC%, PImax, MVV, no correlation with FEV1/FVC in males. In females positive correlation with FEV1, MVV and Pimax. No correlation was seen with FEV1/FVC%, FEV1%, FVC, FVC%. Significant positive correlation was seen between MVV and FEV1, FVC, FEV1/FVC in both males and females with absolute and percentage values. Correlation was more significant with absolute values than percent values. Our study suggest strong correlation between PImax, PEmax and FEV1, FVC. Polgar and Weng and other studies done in the past showed a similar results between respiratory muscle strengths and FEV1 and same study showed a positive correlation between respiratory muscle strength and FVC [12,13,24-26,37]. In our study absolute values of FEV1and FVC had better correlation with PImax and PEmax than percent values. Study also highlights relationship between MVV and Pimax, PEmax values amongst all the parameters MVV showed highest positive correlation with respiratory muscle strength, absolute MVV value showed better correlation than percent values. MVV values reflects the respiratory muscle endurance and fatigue. A test of endurance includes more dynamic factors than a test of strength. Measurement of respiratory muscle endurance indirectly assess performance of the inspiratory and expiratory muscles. Age was the strongest negative correlate with the studied dependable variables. The ageing process is associated with a reduction in the total and respiratory accessory muscular mass. Increased compliance of the abdominal compartment in older subjects can dissipate the generated pressure notably in forced expiration decreasing the MRP, as there is decrease in TLC and marked increase in RV with age. Considering the highest values for MIP, MEP are generated in the lowest and the highest lung volumes respectively, these physiological adaptation may also contribute to age related decline in MIP and MEP, MVV. MVV is a test of overall function of respiratory system, it is influenced not only by RM strength, but also by the compliance of the lung thorax system, the condition of the ventilatory control system and its resistance of both airways and tissues. Apart from the reduction in RM strength, aging is associated with reduction in the compliance of the chest wall and increase in both the resistive and elastic work of breathing [13]. It is important therefore to recognize that MVV was used in this study only as an indirect index of RM strength and these other factor should also be considered in the analysis of the results. Our results are similar to Asian studies. Significant correlation was found between maximal respiratory pressure (MIP, MEP) maximal voluntary ventilation with age, height in males. Compared to previous study our study had shown lower mean values for adults, the probable reason could be geographical variations, poor motivation and deliberate leak in the mouthpiece of the apparatus [2,3,7,9]. Several factors contribute to the wide range of values described in previous studies:

(1) Characteristics of the pressure measuring device and diameter of the orifice [1,2,7,15].

(2) Air leak at the nose and mouth.

(3) Motivation and number of trials may affects the MRP and MVV recorded.

In correlation of the variables with MRP our results showed statistically significant correlation of PEmax with age for male and female subjects ($p<0.05$) and PImax with age for male subjects ($p<0.05$) and female subjects. Black and Hyatt3 showed a decrease in the respiratory muscle strength with age, our study also showed decrease in respiratory muscle strength in male with age. Several factors may affect respiratory muscle strength in adults variable changes may occur in skeletal muscle, in the elastic recoil of the lungs, and chest wall and increase in residual volume. Increase in RV occur with age this may lead to an altered force length relationship of the diaphragm and diminished static outward recoil of the chest wall resulting in decreased PImax at RV [1,2]. This increased Rv is not uniform in all person and may contribute to differing PImax values in subjects of the same age. Our study showed decreased PEmax with age in both male and female subjects the probable reasons could be loss of lung recoil and increase in lung compliance in the elderly, which could tend to decrease PEmax. Changes also occur in the thoracic wall involving calcification and stiffening of the articulation of rib cage together with changes in the spinal curvature making chest wall less compliant. Our results showed that respiratory pressures in men are related to age, for female a significant relationship shown with height. This may be explained by that decreased muscle mass and strength fall with increasing age, there is approximately 8-10% decline for every 10 years, with peak decline in 2nd or 3rd decade of life [1,2]. Weight could affect the diaphragm mass exerting an influence on respiratory muscle performance which is not seen in our study.

Conclusion

PImax, PEmax and MVV values were lower in females than males. It had significant negative correlation with age for PImax in males and females both. No correlation was found with height, weight and BMI for both sexes. PEmax showed no correlation with age, height, weight and BMI in males. In females there was significant positive correlation seen between PEmax and height no correlation was seen with age, weight and BMI. MVV showed significant negative correlation with age in both males and females and significant positive correlation with height in both males and females, no correlation was seen with weight in both the sex, but negative correlation was seen with BMI in males only. Spirometry showed significant positive and negative correlation with various parameters. **The results of this study can be used to predict respiratory muscle strength in healthy adults and variability which can be used for required assessment of respiratory function and also aid in the planning of treatment.**

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