International Journal of Health Sciences and Research
Vol.10; Issue: 11; November 2020
Website: www.ijhsr.org
Original Research Article *ISSN: 2249-9571*

Respiratory Muscle Strength in Children in Age Group 7-12 Years: A Cross-Sectional Observational Pilot Study

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ABSTRACT

Background: Assessment of respiratory muscles is important for early diagnosis of respiratory weakness and to prevent respiratory disorders as well as to quantify severity and prognosis of respiratory diseases.
Objectives: To obtain normal values for Maximal Inspiratory pressures (MIP) and Maximal Expiratory pressures (MEP) as well as to compare these values between boys and girls and to correlate it with age and BMI in children in age group 7-12 years.
Methods: In this cross sectional observational study, demographic and anthropometric data were assessed as well as respiratory muscle strength (MIP and MEP) was assessed in a total of 191children (95 boys and 96 girls; mean age 9.77+/-1.69).
Results: Boys had higher MIP and MEP values. There was a moderate correlation between MIP and age and height as well as MEP and age and height. Other variables were not significantly correlated.
Conclusion: This study provides reference values for assessing respiratory muscle strength. The values obtained showed that age and height have influence on them. Thus MIP and MEP can be used as a means of diagnosis, prognosis as well as monitoring the progress of the patients undergoing respiratory muscle training in the presence of respiratory muscle weakness.

Key words: maximal inspiratory pressure, maximal expiratory pressure, respiratory muscle strength, children.

INTRODUCTION

Muscles in the human body have two functions: to develop force and to shorten. In the respiratory system, force is usually estimated as pressure and shortening as lung volume change or displacement of Chest wall structures. To test respiratory muscle properties, pressures can be measured either during voluntary manoeuvres or during involuntary contractions, notably in response to phrenic nerve stimulation. [1]

Measurement of these pressures is done by measuring the inspiratory pressure that a subject can generate at the mouth (PI max) or expiratory pressure (PE max).

This is a simple way to measure inspiratory and expiratory muscle strength. The pressure measured during these manoeuvres reflects the pressure developed by the respiratory muscles (P mus).[3]

These measures reflect global respiratory muscle strength for clinical evaluation leading to muscle weakness as well as physiological studies.

Respiratory muscle weakness is present in many patients and may represent as a significant problem for several reasons.

It is a common feature of several diseased conditions and is associated with a higher morbidity and mortality. Hence recently, there has been increasing awareness that respiratory muscle weakness can be a compounding factor in many diseases such as malnutrition, chronic obstructive pulmonary disease, congestive heart failure, etc.

It has also been shown in a cross-sectional survey in 1987 and 2001 in the Netherlands, the most frequent reason for children consulting a general practitioner was respiratory morbidity, accounting for about 25% of all consultations by children. About 10% of consultations are for asthma, with the other main respiratory diseases being bronchiolitis, acute bronchitis and respiratory infections, thus leading to affection of respiratory muscles. [4]

Hence, leading to increasing importance of measuring of respiratory muscle strength in order to detect respiratory muscle weakness and to quantify its severity as well as determine optimal long-term management. [47]

The most widely used test of global inspiratory and expiratory muscle strength are the static maximum pressures measured at the mouth (PImax and PEmax).

The MIP is a measure of inspiratory muscle strength produced by a sub-atmospheric pressure and the MEP is a supra-atmospheric pressure which can be developed in an effort of the abdominal and intercostal muscles. PI max is measured at or close to Residual volume (RV) & PE max at or close to total lung capacity. (TLC)

Residual volume (RV) is the volume of gas remaining in the lung after a maximal expiration.

Total lung capacity (TLC) is the total volume of gas in the lungs after maximum inspiration. TLC is the volume reached at the end of maximal inspiration, usually determined by lungs that cannot be expanded further, even by very large negative pressure, but if inspiratory muscles are weak; their maximum effort may not be enough to fully expand the lung. [3]

So, the measurement of maximum inspiratory pressure (PI max) or the maximum static expiratory pressure (PE max) that a subject can generate at the mouth is a simplest and quickest way of directly measuring inspiratory and expiratory muscle strength. [3]

Given the importance of measuring maximal respiratory pressures, several studies have attempted to establish predictive values of MIP and MEP. First such attempts were made by Black and Hyatt who described 5 different methods of the assessment of respiratory muscle strength in healthy subjects of both sexes aged between 20 and 86; using variables such as age and gender. Later, other several authors evaluated the MIP and MEP in healthy people of different races, considering different age brackets and published the results of the reference values of the predictive equations for the calculation of maximal respiratory pressures.[11]

Also, there are many available studies that report reference values for MIP and MEP and also their predictor equations. But all these studies were done in adults. The different populations that have been studied are Caucasians, Iranians, Chinese, Malays, Brazilians, Asians, Thais, Columbia and other populations. However there is a large variability between these different populations and also studies. [9]

For considering different populations or varied age groups it becomes necessary to understand basic difference into the physiology of adult and child respiratory system. The anatomical characteristics of upper respiratory tract of a child is that the nose, nasal passage or the airways, sinuses in infancy are comparatively narrow and mucus rich hence making them more vulnerable to infections and oedema. Thus infections and oedema causes blocking of the nasal cavity leading to difficulty in breathing. The larynx and mucosal membranes are rich in blood vessels and lymphatic tissue which makes them more prone to infections and inflammations causing obstruction of the airways and eventually leading to weakness. Taking into consideration of lower respiratory tract the trachea and bronchial passages are narrow and underdeveloped i.e. being too soft and less of elastic. They also lack efficient mucocliliary movement as compared to adults causing more of retention of secretions. The rib cage being horizontally positioned leads less chest wall movements. The intercostals muscles and the accessory muscles of ventilation are immature. As a result children are more dependent on diaphragm for respiration. Thus placing increased efforts leads to subcostal and sternal recession reducing mechanical efficiency of chest wall. [51]

Thus, the evaluation of respiratory pressures is necessary in children to determine muscle weakness, to quantify the severity of given diseases and for its prognostic value. So that early efforts could be taken not only to improve muscle strength in children but also give reference values for the same. [5] As it help to manage and follow up neuromuscular diseases, pulmonary diseases besides being used in rehabilitation programs, weaning and postoperative processes. [2, 4]

Hence it becomes necessary to establish normal values separately for adults and children considering various variables.

The American Thoracic Society stated that the reference values of MIP and MEP important measure as well as of other biological variables should ideally be derived from a random selection, geographically related to the population to ensure greater accuracy and predictive power.

Thus various studies have been taken up all across the places.

A study finding the normal values of MIP/ MEP was done in 2015 in Indian adults were comparatively lower to that of the western population suggesting change in the anthropometric measurements do affect the values of MIP/MEP thus directly commenting on respiratory muscle strength.

Veena Kiran Nambiar et al in 2015, gave the decade wise mean values for MIP and MEP as a reference to determine respiratory muscle strength in normal Indian adult population. Also MIP and MEP mean values were significantly higher in males as compared to females across the decades. Age showed a statistically significant correlation with both MIP and MEP with Pearson's correlation coefficient. Also, MIP and MEP were correlated with height and weight.

The percentage of lean body mass being higher in men is one of the reasons for the difference in the values of MIP/MEP in males as it is reported that strength is proportional to the cross – sectional area of the muscle [47]..

Body mass index (BMI) also correlated positively with MIP and MEP with both genders. The pulmonary function and respiratory muscle strength increased with a small increase in body weight. The relationship of weight with MIP is based on higher percentage of lean mass of respiratory muscles and that of MEP correlated negatively with weight. The increase in visceral fat around the abdomen affects the diaphragm mass influencing respiratory muscle performance. [47]

There were studies conducted to find normal values of MIP/MEP in children in Brazil and UK but there is a scarcity of data in children in Indian Population.[2]

As per the best knowledge there are no studies undertaken so far in India.

But, the reproducibility of the evaluation tests in the paediatric population is very important due to the need for cooperation in order to perform the manoeuvres properly. In 2012 Joa˜o Paulo Heinzmann-Filho et al generated reference values for respiratory muscle strength in healthy children aged three to twelve years. Also they evaluated respiratory muscle strength in a subgroup of individuals at two different times; it showed an ICC of 0.98 for MIP and of 0.97 for MEP. These results show that, although they include the preschool age group, the tests presented excellent reproducibility. Even evaluating reproducibility only in the preschool age group, the values (0.94 for MIP and 0.92 for MEP) remain within an excellent range. The technique was performed by a single evaluator and using a three-week interval, diminishing the learning effect, helps to reduce the variability between tests.

The MicroRPM (Micro Medical/Care Fusion, Kent, United Kingdom) is a modern manometer that was recently used in studies that recorded MIP and MEP.

AIM: To find values of respiratory muscle strength in children in age group of 7- 12 years

OBJECTIVES:

- To obtain normal values for Maximal Inspiratory pressures (MIP) and Maximal Expiratory pressures (MEP) in children in age group 7-12 years.
- To compare MIP and MEP in boys and girls.
- To find correlation of MIP/MEP with age and BMI.

MATERIALS AND METHODS

- **Type of Study design:** Cross-sectional observational pilot study
- **Setting:** Schools across city.
- **Duration of study:** 12 months
- **Study population:** Boys and girls in the age group 7- 12 years.
- **Method of selection of Study subjects**

Inclusion criteria

Boys and girls within the age group of 7-12 years were included in this study. [4]

Exclusion criteria:

Children with prior history of any cardio- respiratory, musculoskeletal and neuromuscular conditions, recurrent or active wheezing were excluded from the study.

The children who had respiratory infections on the day of the test or who could not perform the manoeuvres acceptably and reproducibly also were excluded.

- **Method of selection of comparison / control group:**

Ethical clearance from the ethical committee of the institute was obtained.

Permission from the Principal of college of Physiotherapy was taken.

Prior permission of the Principals of the schools included in the study was acquired.

Subjects were selected as per inclusion and exclusion criteria.

Detailed information was provided to the the parents or legal guardians of participants. Since the age group for the study was 7yrs up to 12yrs assent was acquired

Each subject has undergone a formal evaluation:

- Base line demographic data
- Anthropometric data of children like age, height (cm), weight (kg) and BMI was calculated using the formula (weight in kg/ height in meter square.)
- Children undergoing any physical training for any sports, karate, yoga, etc. (regular / season sport).
- Patient assessment sheet
- MIP in cm of H2O and MEP in cm of H2O was measured with a portable Respiratory Pressure Meter (Micro RPM).

Position for measurements: Standing: The subject was advised to adopt a comfortable stance. [6-7]

STATISTICAL ANALYSIS

All data were analyzed using Statistical Package for Social Science (SPSS) 21 with level of significance for all statistical tests set at $p \leq 0.05$. Preliminary analysis (Kolmogorov-Smirnov test) revealed that data was normally distributed (P > 0.05). Mean baseline demographic values were calculated for continuous variables. Correlations were calculated between age, weight, height, BMI, MIP best and MEP best using Pearson's correlation coefficient. Independent student t-test was used to calculate difference between genders.

RESULTS

191 participants (96 girls, 50.26%) and (95 boys, 50.26%) were recruited for this study.

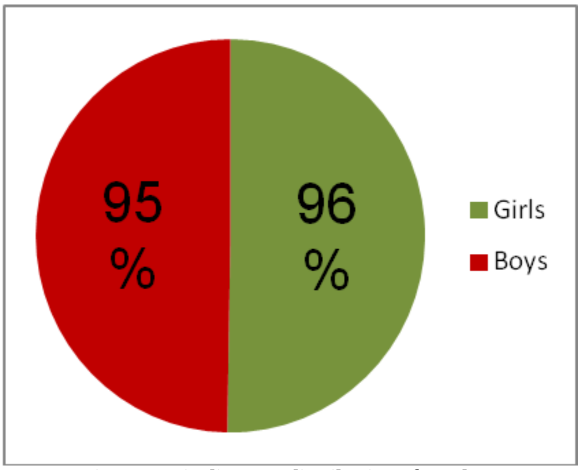

Figure 1: Pie diagram:distribution of genders

Table 1: Descriptive statistics

	Mean	Std. Deviation
AGE	9.77	1.69
HEIGHT cm	125.59	10.36
WEIGHT kg	35.50	8.93
BMI	22.32	4.20
MIP in cm of H_2O	63.84	14.58
MEP in cm of H_2O	74.93	15.61

Correlation coefficients among variable are listed in Table 2.

There was a moderate correlation between MIP and age (r=.461), height (r=.513) and MEP (r=.846) which was statistically significant ($p < 0.001$). Other variable were not significantly correlated. This was supported with figure 1 and figure 2

Table 2.Pearson Correlation Coefficients

	AGE	HEIGHT cm	WEIGHT kg	BMI	MIP in cm of H_2O	MEP in cm of H_2O
AGE	1.000	.782**	.666**	.252**	.461**	.399**
HEIGHT cm	.782**	1.000	.703**	.141	.513**	.457**
WEIGHT kg	.666**	.703**	1.000	.779**	.285**	.218**
BMI	.252**	.141	.779**	1.000	-.003	-.062
MIP in cm of H_2O	.461**	.513**	.285**	-.003	1.000	.846**
MEP in cm of H_2O	.399**	.457**	.218**	-.062	.846**	1.000

***. Correlation is significant at the 0.01 level*

Figure 2. Scatter plot for MIP and Age

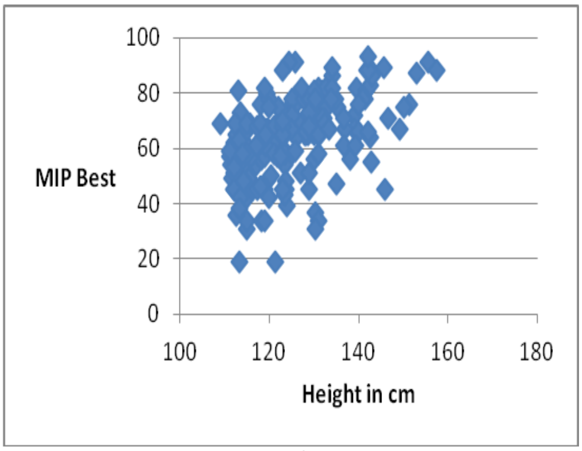

Figure 3: Scatter plot for MIP and Height

Similarly MEP was correlated with age (r=.399), height (r= .457) and MIP (r= .846) which was statistically significant ($p < 0.001$). Other variable were not significantly correlated. This was supported with figure 3 and figure 4.

Thus age and height were the variables which correlated well with both MIP and MEP.

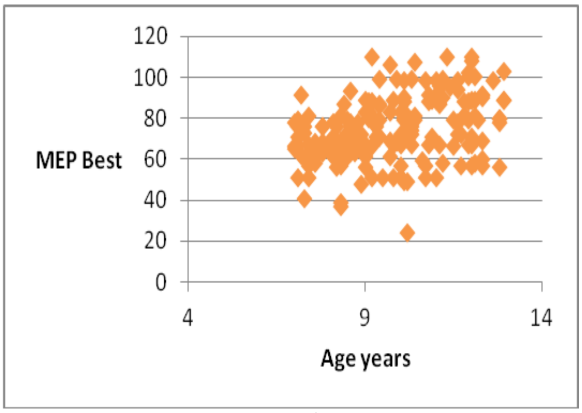

Figure 4. Scatter plot for MEP and Age

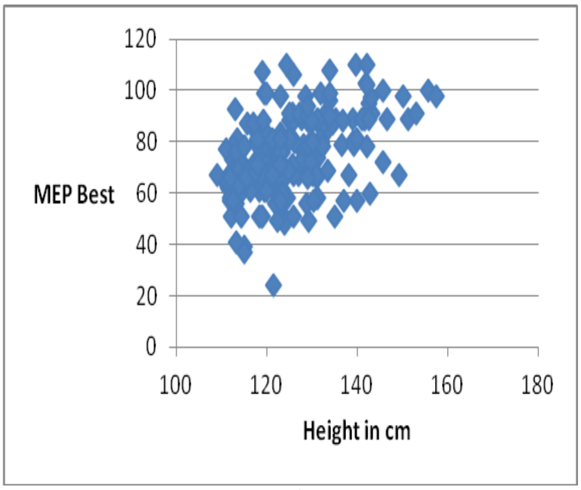

Figure 5. Scatter plot for MEP and Height

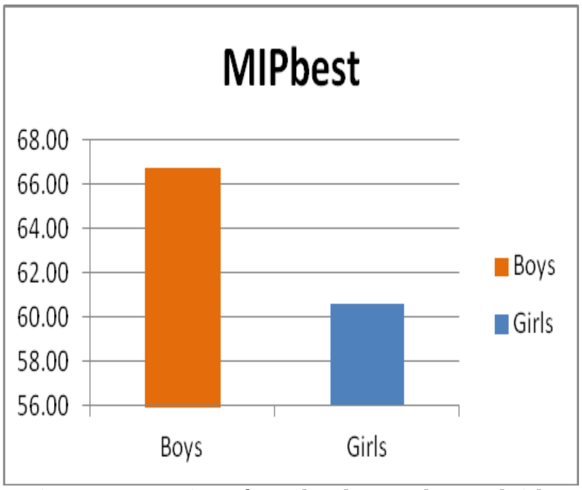

Figure 6. Comparison of MIP best between boys and girls

Table 3 Comparison of MIP and MEP between girls and boys (t-test)

	GENDER	N	Mean	Std. Deviation	P Value
MIP in cm of H_2O	Boys	95	66.72	14.65	< 0.05
	Girls	96	60.60	13.75	
MEP in cm of H_2O	Boys	95	78.31	15.50	< 0.05
	Girls	96	71.05	14.48	

For MIP and MEP values there was a significant difference between boys and girls this was presented in table 3 and supported with figure 6 and 7.

The mean MIP best values in boys and girls were 66.72 (SD ± 14.65) and 60.60 (SD ± 13.75) respectively. Whereas MEP best values in boys and girls were 78.31 (SD ± 15.50) and 71.05 (SD ± 14.48) respectively.

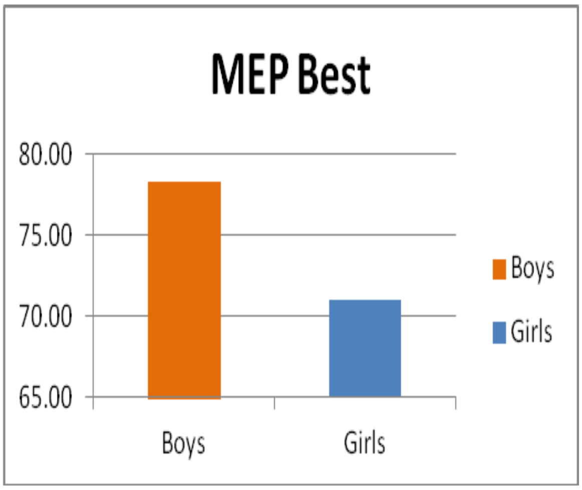

Figure7. Comparison of MEP best between boys and girls

Table 4: Age group wise mean (SD) values for both genders

	Gender	N	MIP Mean (SD)		MEP Mean (SD)	
7 to 8yrs 11months 30days	Boys	33	60.52	11.16	70.85	11.36
	Girls	34	52.06	10.29	63.56	9.11
9 to 10yrs 11months 30days	Boys	35	66.80	14.30	78.29	16.56
	Girls	32	61.34	13.34	73.06	16.01
11 to 12yrs 11months 30days	Boys	27	74.80	15.68	88.20	13.50
	Girls	30	69.50	11.83	77.40	14.37

The age wise mean values for MIP and MEP obtained for both boys and girls can be used as reference values (normative values)

DISCUSSION

To our best knowledge, studies in similar lines have not been published; hence this work could be the first study in the paediatric population in India to establish Mouth Respiratory Pressure reference values as set forth in the methodological recommendations proposed by ATS/ERS; that used digital equipment, which provides highly accurate and valid measures.

The aim of the study was to find the respiratory muscle strength in school going children within the age group of 7-12yrs using a modern manometer known as microRPM. The study considered the population of 191 children divided into gender based groups; also were stratified into smaller groups considering the age group as well. A batch of children was considered while giving instructions or demonstrations for the manoeuvres to be performed. Each child had to perform two manoeuvres one maximum inspiratory pressure through mouth and other maximum expiratory pressure through mouth which gave us the values of MIP and MEP in cm of water respectively. The manoeuvres were performed in standing position with the child attaining a comfortable stance. And these values obtained and the variations found during the study were used for statistical analysis.

Hence, the data were analyzed using Statistical Package for Social Science (SPSS) 21 with level of significance for all statistical tests set at $p \leq 0.05$. Preliminary analysis were done to find whether the data was normally distributed ($P > 0.05$). Mean baseline demographic values were calculated. Correlations were calculated between age, weight, height, BMI, MIP in cm of H_2O and MEP in cm of H_2O also appropriate test was applied to calculate difference between genders.

There may be several factors which contributed to the wide range of values obtained in the previous studies. The measurement of MIP and MEP was also seen varying depending on the type of measuring device used, the technique of measurement, type of the interface used, detectable air leaks and motivation level of the subject. During the measurement, if the subject has been using lot of buccinators muscle activity, also could not generate optimal efforts also did have an effect on the values, which would in turn not truly represent respiratory muscle strength.

In a study done by Dayane Montemezzo et al in 2012 on "Influence of four interfaces in the assessment of Maximal Respiratory Pressures", the influence of four different interfaces on a subjects' capacity to generate Maximal Respiratory Pressures (MRP) and the impact of these interfaces on the repeatability of these measurements were studied. 50 healthy subjects were evaluated and MRP was measured by using different mouth pieces and tubes. They had analysed variables using maximum mean pressure, peak pressure, plateau pressure and plateau variation. They showed that, MIP and MEP values were not influenced by the different interfaces used; suggesting that availability of interfaces and the comfort of the patient can be considered when measuring respiratory pressures. Although the limitation of the study was that they could not generalize it to children and elderly population.[56] But this clause could be considered as the topic of discussion as this study used plastic tube with flat ends for performing the manoeuvres. And the children could efficiently and comfortably perform the manoeuvres after the proper set of instructions.

During the initial attempts of the study air leaks or inefficiency in performing the manoeuvres was observed in children; which was corrected subsequently by giving clear and proper instructions.[57] Also considering the smaller batches of children to give instructions and demonstrations did help to reduce the chances of false results and air leaks.

More the number of attempts given, higher maximal pressures were recorded. Thus in studies done by Ringquist[58], where there were more than ten attempts, higher values were recorded as compared to Black and Hyatt[22] who used two or three trials. Moreover in patients, it is practically impossible to give many repetitions, hence in this study only three repetitions were considered with the break of 1 min in each reading and largest value of the readings was considered with taking into considerations of no air leaks and no greater than 10% variations found in between the values[3]

Another factor the can lead to variations in the values is the instrument used to obtain the value. Moreover according to ATS/ERS Guidelines, digital equipment provides valid and highly accurate measures, and in our study the maximal respiratory pressures were measured using a digital manometer, thus providing greater accuracy.[1] So we used a modern digital manometer microRPM which is found to be valid and reliable device for measuring values for MIP/ MEP in cm of H_2O. Thus helping us to establish apt reference values in children.

Standing has been shown to lead to the highest lung volumes. Increased lung volumes in the standing position appear to be related to the increased thoracic cavity volume. The physiology behind it could be; 1. Gravity pulls the abdominal contents caudally within the abdominal cavity, increasing the vertical diameter of the thorax (Castile et al 1982). 2. Unlike positions such as head down and supine (Castile et al 1982, Hough 1984, Michels and Body 1980), the bases of the lungs are not compressed by the weight of the heart and abdominal contents thus allowing the alveoli that may be compressed to reopen and increase lung compliance. 3. The inspiratory muscles are able to expand better (De Troyer and Loring 1995) which aids the diaphragm to contract caudally and thus increase lung volume. Increased lung volume leads to greater elastic recoil (Leith 1968). Further, the contracting diaphragm increases pressure on abdominal and places a slight stretch on them, thus making them more capable of contracting stronger and thus help in the generation of higher MEP. Also a study by McCool and Leith (1987) suggest that expiratory muscles attain their optimal length during standing.

Similarly a study conducted by Segizbaeva (2013), to find effect of position on MIP. They concluded that the value of MIP did not significantly vary in standing position and in the other positions, but did show an exceptional difference in head down position with explanation for it that it affects the chest wall mobility. So in our study we considered standing position to perform the manoeuvres.

When different studies were compared, they showed different variables that correlated with our outcome measures for example: Wilson et al. 1984 demonstrated that weight for MIP, and age for MEP, were the only variables that correlated to the values in both genders. In another study, age was the only variable that influenced. On the other hand, Dome `nech-Clar et al. 2003 showed that age, height and weight for MIP of both genders and for the boys' MEP, while for the values in girls only MEP was considered. In this study, although there were statistical differences, in the values of age and height which correlated strongly to moderately where as weight did show a weak correlation

On analysing the results of this study, it was seen that age and gender were the best correlates and predictors for MIP and MEP. Values for MIP and MEP were on an average, were significantly higher in boys as compared to girls, which was consistent with the study done by Erik Hulzebos and et al in 2017 and Theodore Dassios in 2016.[60-61] The percentage of lean body mass being higher in boys could be probably one of the reason for this. It is reported that strength is proportional to the cross – sectional area of the muscle.

Age has a significant influence on maximal respiratory pressures. Age showed a moderate positive correlation (r=.461) with MIP and with MEP (r=.399) which was statistically significant ($p < 0.001$). This was consistent with almost all previous studies, where there was a consistent increase in the values of MIP and MEP with increasing age in both the genders. [3, 60-61] So as the age progresses in childhood, it is seen that there is overall skeletal and physiological maturity in both the genders. Also, as the children grow they develop better cardiovascular, pulmonary, neuromuscular and hormonal systems which eventually govern the factors of growth. This could be assessed on the basis of following heads: increase in height and weight, increase in the bone mineral density or development of bones, increase in muscle mass as well as the girth and the most important factor being the distribution of the fat in the body. In this study it can therefore be concluded that the increase in the values of MIP and MEP could be due to development of the child at every stage which can be correlated with studies done on similar lines. [63-64]

Another variable that correlated well in our study was height; it showed a moderate positive correlation (r=.461) with MIP and with MEP (r=.399) which was statistically significant ($p < 0.001$) A change in height of the child is assessed in terms of centimetres per year. In fact it is said that 50% of the adult height is achieved in childhood; also height increases progressively throughout the childhood. This could be discussed on two heads: 1. skeletal growth and 2. muscle fibre size. This implies that as there is progressive increase in height leads to elongation and development of the bones. This puts stretch on the muscle leading to changes in their composition. Increase in the muscle mass with age appears as a result of hypertrophy primarily. Hypertrophy results from increase in myo-filaments and fibrils. Thus increase in muscle length as young bones elongate results from increase in number of sarcomeres.[60-61, 63-64] Hence this could be the one of the reasons for correlation of height with MIP/MEP in this study.

One of the secondary objectives of our study was to find a comparison between the values of MIP and MEP in boys and girls. It was observed that the values of MIP and MEP in girls were significantly lesser as compared to boys. Values for MIP and MEP were on an average, 6.12 cm of H_2O and 7.62 cm of H_2O higher in boys compared to girls (p value <0.05) This could be explained with the association of FFM with respiratory muscle strength in healthy children and adolescents. For the prediction of PImax and PEmax in boys and girls, FFM seems to be of even greater importance than age. [61] It is found in the literature that at birth 10-12% of the body weight is fat, but during development the fat content reaches approximately 15% of total body weight for males and 25% for females. This difference in body composition is attributed to hormonal variations. Studies also suggest the during the late childhood ie from the age of 8years until the puberty there is progressive increase in the fat deposition in both the genders but in varied proportions In girls the oestrogen concentration have a major influence over their fat deposition. It influences female body growth by distribution of fat in the body whereas in males the testosterone influences increase in protein synthesis thus leading to more muscle mass than fat mass. [63-64] thus in our study; it can be concluded that the body composition has a major influence over the respiratory muscle strength for showing difference in the values of boys and girls.

Thus findings of our study can prove important for clinicians and researchers to evaluate the respiratory muscle strength in children. Also it provided with a reliable, non-invasive, and accurate MIP and MEP measurement tool that is acceptable.

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How to cite this article: Patil P, Deodhar A, Jadhav S. Respiratory muscle strength in children in age group 7-12 years: a cross-sectional observational pilot study. Int J Health Sci Res. 2020;10(11):145-156.

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