10.5005/jp-journals-10036-1092

ORIGINAL ARTICLE

# Level of Physical Exercise Capacity, Respiratory Muscle Strength and Peak Expiratory Flow Rate in Healthy Adolescents

[1]Shruti P Nair, [2]Bela Agarwal, [3]Monal Shah, [4]Shradha Sawant, [5]Nikita Sinha, [6]Vijayendra Rajguru, [7]Rajani Mullerpatan


## ABSTRACT

**Introduction:** The maturation of respiratory system in children leads to changes in value of respiratory parameters like peak expiratory flow rate (PEFR), maximum inspiratory pressure (MIP), maximum expiratory pressure (MEP), and 6-minute walk distance (6MWD). Accurate analysis and clinical decision-making in disease state require reference values for different ages. The current study was undertaken to study pulmonary function and exercise capacity in children and adolescents.

**Materials and methods:** After obtaining Institutional Ethical approval and parental informed consent, 262 subjects aged 9 to 15 years were recruited for the study. They were divided into two age groups, i.e., preadolescent (9–12 years) and early adolescent (13–15 years). Demographic details including age, sex, height, weight, and body mass index (BMI) were noted. Physical activity rating (PAR) scale was used to denote physical activity levels. Peak expiratory flow rate was measured using standard Mini-bell peak flow meter (PFM). The parameters MIP and MEP was measured using micro respiratory pressure meter, and 6-minute walk test (6MWT) was performed as per American Thoracic Society (ATS) guidelines.

**Results:** A significant difference was noted between the two groups in PEFR, MIP, MEP, and 6MWD ($p = 0.00$). Age showed a strong positive correlation with PEFR ($r = 0.613$, $p = 0.000$), MIP ($r = 0.676$, $p = 0.000$), and MEP ($r = 0.658$, $p = 0.00$) whereas showed a strong negative correlation with 6MWD ($r = –0.605$, $p = 0.00$). Height showed a strong positive correlation with MEP ($r = 0.720$, $p = 0.000$) whereas a strong negative correlation with 6MWD ($r = –0.42$, $p = 0.00$). Weight showed a weak negative correlation with 6MWD ($r = –0.328$, $p = 0.00$). Gender difference was noticeable in 6MWD and PEFR ($p = 0.00$) but not in MIP ($p = 0.45$) and MEP ($p = 0.44$). Almost 22.10% of early adolescents were overweight compared to only 7.7% seen in preadolescent group.

**Conclusion:** PEFR and respiratory muscle strength was higher in early adolescents as compared to pre-adolescents. However, exercise capacity reflected by 6 MWD was found to be lower in early adolescents in comparison to pre-adolescents. These findings could be used while interpreting the outcome measures utilized while treating patients and for goal setting in cardiopulmonary rehabilitation in clinical practice.


**Keywords:** Maximum expiratory pressure, Maximum inspiratory pressure, Peak expiratory flow rate, 6-minute walk test.

[1,3-6]Lecturer, [2]Associate Professor, [7]Professor and Director

[1-7]MGM Institute's University Department of Physiotherapy Navi Mumbai, Maharashtra, India

**Corresponding Author:** Shruti P Nair, Lecturer, MGM Institute's University Department of Physiotherapy, Navi Mumbai Maharashtra, India, Phone: +919769323125, e-mail: shrutinair 2008@gmail.com

**How to cite this article:** Nair SP, Agarwal B, Shah M, Sawant S, Sinha N, Rajguru V, Mullerpatan R. Level of Physical Exercise Capacity, Respiratory Muscle Strength and Peak Expiratory Flow Rate in Healthy Adolescents. MGM J Med Sci 2016;3(2):66-71.

**Source of support:** MGMIHS

**Conflict of interest:** None

## INTRODUCTION

Chronic respiratory diseases, cardiovascular diseases, cancer, and diabetes are some of the most prevalent non-communicable diseases in India. Out of which, 11.8% of total deaths is from chronic respiratory diseases.[1] Most of the Asian countries including India and China account for a huge burden in terms of absolute numbers of patients.[2] Respiratory infections have been found to be more prevalent among school going children.[3-6] They may be more vulnerable to the effects of air pollution than adults owing to incomplete lung maturation at birth. Lungs do not complete their growth until full adult stature is achieved in adolescence.[7] In developing countries, these childhood respiratory diseases have significant adverse effects on the child's daily physical activities, schooling, family life, and finances.[8]

In an era of evidence-based treatment, the methods are mainstay in the management of these debilitating conditions. The clinical evaluation prior to and during treatment helps in setting the clinical goal. Pulmonary function tests are an essential component for evaluating the lung functions. For undertaking these tests, a specialized laboratory is required. Moreover, these tests are time consuming and expensive. In order to overcome these impediments, clinical assessment tools like peak expiratory flow rate (PEFR), respiratory pressures, and 6-minute walk test (6MWT) are utilized to assess respiratory functions. The results obtained through these tools are simple, reliable, reproducible, and easily measurable.

Peak expiratory flow rate is a reliable bedside tool. It can be measured using a relatively inexpensive peak flow meter (PFM) and is of value in identifying and assessing the degree of air flow limitations.[9,10] A good correlation between PEFR and forced expiratory volume ($FEV_1$) has been observed. Peak expiratory flow rate is usually affected by variables, such as, age, height, weight, gender, race, and environmental conditions.[10] Racial variation in lung function parameters has been attributed to different size and shape of ribcage, respiratory muscle strength, and possibly parenchymal lung development. Peak expiratory flow rate values ranging from 144 to 516 L/minutes have been reported by various researchers.[11-14]

Evaluation of respiratory pressure quantifies respiratory muscle strength. Maximum inspiratory pressure (MIP) is a measure of inspiratory muscle strength. Maximum expiratory pressure (MEP) measures the strength of abdominal and intercostal muscles.[15-20] Respiratory pressures have been studied in children with neuromuscular and pulmonary diseases, such as, asthma and cystic fibrosis, besides used in rehabilitation programs, weaning, and postoperative processes.[18] However, literature on healthy Indian children is very scarce.

Cardiopulmonary exercise testing forms an integral role in pulmonary rehabilitation. Six-minute walk test is a submaximal, self-paced, simple, objective, reliable, valid, sensitive, and a reproducible measurement of functional capacity. Its principal advantage is its operational simplicity, low cost, and its better correlation with activities of daily living.[21] It has been used in young children, for whom performing maximal cardiopulmonary exercise tests is problematic, requiring a high degree of coordination and motivation.[21-25]

Adolescence is a period of intense change and ongoing growth of the respiratory system. Till date, whatsoever research studies have been undertaken, they have focused only on adult and pediatric population. But so far no study has been undertaken on transitional stage which goes often unobserved. Efforts have been made to explore the influence of adolescence on respiratory parameters.

## MATERIALS AND METHODS

After seeking ethical clearance from Institutional Ethics Committee, 262 healthy children and adolescents aged between 9 and 15 years were recruited from MGM Primary and Secondary School, Nerul, Navi Mumbai. Parental informed consent was sought. Children were screened using health history questionnaire. Children with active illness, such as, fever, cold, cough, acute exacerbation of respiratory conditions, cardiac illness, congenital or acquired neuromuscular diseases, cognitive issues, psychiatric problems, metabolic, hepatic, renal dysfunctions, and recent surgeries were excluded. The sample studied was selected during the school timings as per their availability. Subjects were divided into two age groups – group A: Preadolescents (9–12 years) and group B: Early adolescent (13–15 years). The outcome measures evaluated were anthropometric measurements (weight in kg and height in cm), BMI (weight/height$^2$), PEFR (L/minutes), MIP (cm $H_2O$), MEP (cm $H_2O$), and 6MWD (m). Sitting hours were calculated based on total time spent in school, including nonparticipation in any extracurricular activities. To denote physical activity levels, physical activity rating (PAR) scale was used. In all tests, 262 children and adolescents participated. Each subject was given a prior practice test to ensure familiarity and to enable them to perform each test as per guidelines.

Peak expiratory flow rate was recorded using Mini-bell PFM (manufactured by Forumed Health care Products, Horts, 3 Street Pals 17256 Girona, Spain). Subjects were instructed to breathe and blow into the mouthpiece as quickly and as hard as he/she can. The best of three readings was recorded.

The respiratory pressure was recorded using a noninvasive Micro RPM (respiratory pressure meter) (Manufacturer: CareFusion Respiratory, 22745 Savi Ranch Pkwy, Yorba Linda, CA, USA) (Fig. 1). To record MEP, the subjects were instructed to insert the mouthpiece into the mouth ensuring that the flange was positioned over the gums and inside the lips and that the "bite blocks" were between the teeth. They had to inhale to total lung capacity and then exhale with as much effort as possible through the controlled leak of the meter for at least 2 seconds. The reading displayed showed the maximum MEP over 1 second. To record MIP, the subjects were instructed to exhale to residual volume and then to inhale through the mouthpiece with as much effort as possible for at least 2 seconds. The reading displayed the maximum MIP that was sustained over 1 second.

Six-minute walking test was performed according to ATS guidelines. The subjects were asked to walk as far as possible for 6 minutes, but not to run or jog. They walked back and forth along a straight flat corridor of 30 m demarcated by cones. They were permitted to slow down, to stop, and rest as necessary. They were allowed to lean against the wall for resting and resume walking as soon as they were able to do so. Encouragement was given every minute using standard ATS phrases in an even tone. Subjects were asked to report symptoms like chest pain, intolerable dyspnea, dizziness, leg cramps which were additional test termination criteria.[21] Pulse

**Fig. 1:** Micro RPM (respiratory pressure meter)

and respiratory rate, blood pressure, and rate of perceived exertion using modified Borg scale were recorded before and after the test until they recovered to basal levels. Numbers of laps walked were recorded and 6MWD was calculated as follows: 6MWD = (Number of laps × 30) m.

## RESULTS

Data was analyzed using Statistical Package for the Social Sciences (SPSS) 16 software. Normal distribution of data was analyzed using kurtosis–skewness test. The outcome variables were compared between the two groups. The statistical significance was assessed using Student's t-test. Pearson's test of correlation was used to analyze correlations between age, height, weight, and respiratory parameters. Details of demographic and clinical respiratory variables have been presented in Table 1.

Early adolescent group demonstrated a higher MIP, MEP, and PEFR ($p = 0.000$) and lower 6MWD as compared to preadolescents (Table 1). Analysis of correlation coefficient with demographic features of age, height, and weight revealed that age had strong positive correlation with PEFR ($r = 0.613$, $p = 0.000$), MIP ($r = 0.676$, $p = 0.000$), and MEP ($r = 0.658$, $p = 0.00$), whereas it showed strong negative correlation with 6MWD ($r = -0.605$, $p = 0.00$) (Figs 2 to 5). Height showed a strong positive correlation with MEP ($r = 0.720$, $p = 0.000$) whereas strong negative correlation with 6MWD ($r = -0.42$, $p = 0.00$). Weight

**Table 1:** Demographic and clinical parameters of subjects aged 9 to 15

| *Variables (n = 262)* | *Preadolescents (n = 167)* | *Early adolescents (n = 95)* | |
|---|---|---|---|
| | *Mean ± SD* | | *p-value* |
| Height (cm) | 139.9 ± 8 | 154.1 ± 9.2 | 0.000* |
| Weight (kg) | 36.9 ± 7.8 | 48.3 ± 11.3 | 0.000* |
| BMI (kg/m$^2$) | 18.7 ± 3.2 | 20.2 ± 3.5 | 0.001* |
| PEFR (L/cm) | 191.4 ± 49.2 | 255.6 ± 44.6 | 0.000* |
| MIP (cm $H_2O$) | 28.3 ± 13.1 | 53.8 ± 21.6 | 0.000* |
| MEP (cm $H_2O$) | 41.9 ± 15.9 | 65.1 ± 17.5 | 0.000* |
| 6MWD (m) | 709.8 ± 61.4 | 606.9 ± 92.7 | 0.000* |
| Sitting (hours) | 8.87 ± 1.2 | 9.2 ± 1.3 | 0.032* |
| PAR | 2.2 ± 0.6 | 2.3 ± 0.6 | 0.428 |

*Level of significance $p \leq 0.05$; PAR: Physical activity rating; BMI: Body mass index; PEFR: Peak expiratory flow rate; MIP: Maximum inspiratory pressure; MEP: Maximum expiratory pressure; 6MWD: 6-Minute walk distance

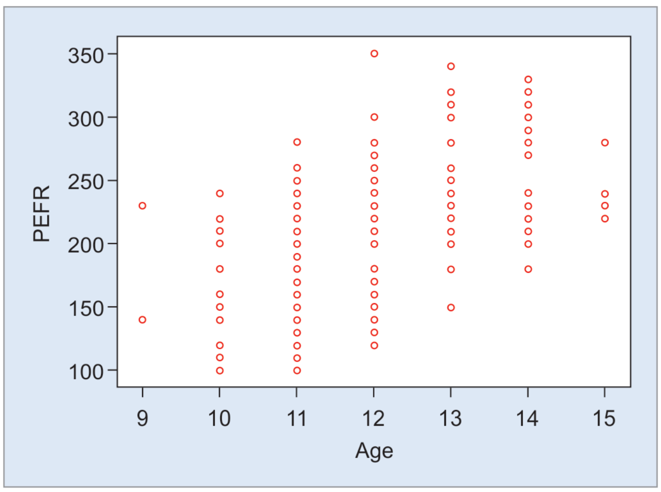


**Fig. 2:** Correlation between age and PEFR

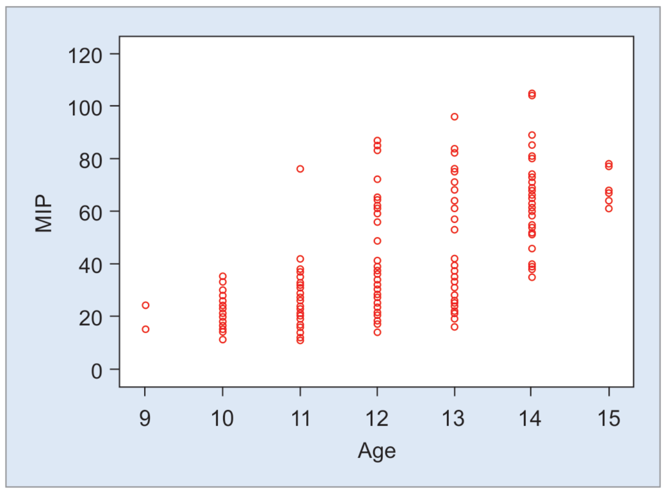


**Fig. 3:** Correlation between age and MIP

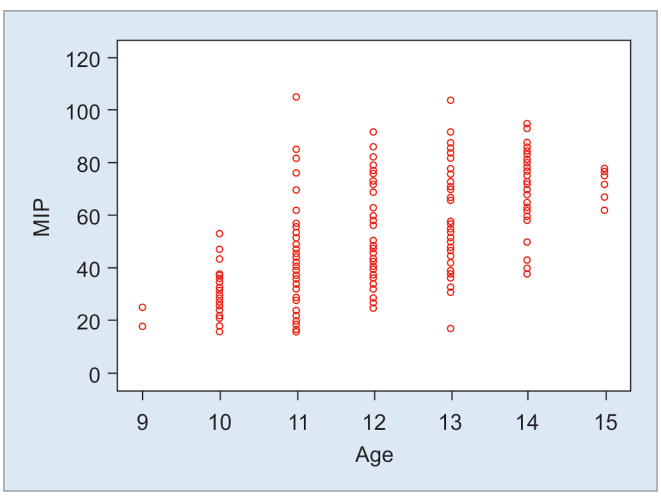


**Fig. 4:** Correlation between age and MEP

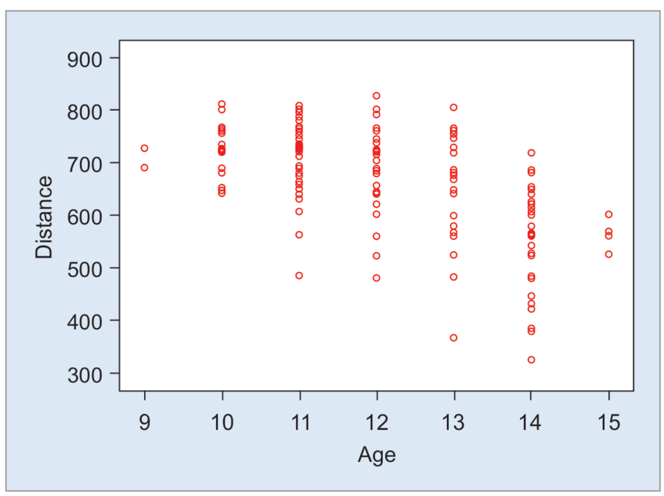


**Fig. 5:** Correlation between age and 6MWD

showed a weak negative correlation with 6MWD (r = –0.328, p = 0.00). According to Asian guidelines of BMI in children,[26] 22.10% subjects of early adolescent group were overweight compared to only 7.7% subjects of preadolescent group. Similarly, 1.05% subjects of early adolescent group were found to obese compared to 0.05% subjects of preadolescent group. Gender-wise comparison revealed that boys had higher PEFR (p = 0.008) and 6MWD (p = 0.000) as compared to girls in both groups. In addition, MIP (p = 0.459) and MEP (p = 0.440) were not significantly different between genders (Tables 2 and 3).

**Table 2:** Gender-wise comparison of parameters of subjects aged 9 to 15 years

| *Variables (n = 262)* | *Boys (n = 137)* | *Girls (n = 125)* | |
|---|---|---|---|
| | *Mean ± SD* | | *p-value* |
| Age (years) | 12.01 ± 1.26 | 12.10 ± 1.50 | 0.606 |
| Height (cm) | 146.77 ± 11.74 | 143.22 ± 9.51 | 0.007* |
| Weight (kg) | 42.86 ± 11.96 | 38.96 ± 8.75 | 0.003* |
| BMI (kg/m$^2$) | 19.57 ± 3.49 | 18.90 ± 3.18 | 0.104 |
| PEFR (L/cm) | 223.50 ± 59.91 | 204.96 ± 51.44 | 0.008* |
| MIP (cm $H_2O$) | 36.61 ± 18.96 | 38.53 ± 22.50 | 0.459 |
| MEP (cm $H_2O$) | 51.20 ± 19.70 | 49.30 ± 20.15 | 0.440 |
| 6MWD (m) | 693.66 ± 65.15 | 649.52 ± 105.01 | 0.000* |
| Sitting (hours) | 9.12 ± 1.31 | 8.84 ± 1.21 | 0.07 |
| PAR | 2.34 ± 0.61 | 2.14 ± 0.61 | 0.01* |

*Level of significance p ≤ 0.05

**Table 3:** Gender- and age-wise comparison of parameters of subjects aged 9 to 15 years

| | *Boys* | | |
|---|---|---|---|
| | *Preadolescent (n = 90)* | *Early adolescent (n = 47)* | |
| | *Mean ± SD* | *Mean ± SD* | *p-value* |
| Sitting (hours) | 8.98 ± 1.29 | 9.38 ± 1.31 | 0.088* |
| PAR | 2.38 ± 0.63 | 2.26 ± 0.57 | 0.252 |
| Height (cm) | 141.22 ± 8.11 | 157.38 ± 10.23 | 0.000* |
| Weight (kg) | 38.22 ± 8.42 | 51.74 ± 12.76 | 0.000* |
| BMI (kg/m$^2$) | 18.97 ± 3.36 | 20.73 ± 3.47 | 0.005* |
| PEFR (L/cm) | 200 ± 52.96 | 268.51 ± 45.11 | 0.000* |
| MIP (mm Hg) | 28.91 ± 12.41 | 51.36 ± 20.66 | 0.000* |
| MEP (mm Hg) | 43.12 ± 15.89 | 66.68 ± 16.90 | 0.000* |
| 6MWD (m) | 716.62 ± 53.55 | 648.74 ± 62.81 | 0.000* |
| | *Girls* | | |
| | *Preadolescent (n = 77)* | *Early adolescent (n = 48)* | |
| | *Mean ± SD* | *Mean ± SD* | *p-value* |
| Sitting (hours) | 8.71 ± 1.16 | 9.04 ± 1.29 | 0.154 |
| PAR | 2.04 ± 0.55 | 2.31 ± 0.66 | 0.010* |
| Height (cm) | 138.43 ± 7.73 | 150.90 ± 6.65 | 0.000* |
| Weight (kg) | 35.26 ± 6.62 | 44.90 ± 8.54 | 0.000* |
| BMI (kg/m$^2$) | 18.44 ± 2.91 | 19.64 ± 3.49 | 0.051* |
| PEFR (L/cm) | 181.30 ± 42.56 | 242.92 ± 40.79 | 0.000* |
| MIP (mm Hg) | 27.49 ± 13.94 | 56.23 ± 22.41 | 0.000* |
| MEP (mm Hg) | 40.36 ± 15.85 | 63.62 ± 18.02 | 0.000* |
| 6MWD (m) | 701.80 ± 68.99 | 566.75 ± 99.25 | 0.000* |

*Level of significance p ≤ 0.05

## DISCUSSION

Adolescence is characterized by a surge of growth hormones that leads to rise of all physiological functions. It is a transitional stage of physical and psychological human development that generally occurs during the period from puberty to adulthood. Average onset of puberty varies from 11 to 13 years in Indian children owing to variations in socioeconomic and nutritional status.[27-30] Some of the most significant components of pubertal development involves distinctive physiological changes in individual's height, weight, body composition, circulatory, and respiratory systems. Hormonal influence triggers the behavioral and physical changes. During adolescent growth spurt, there is a rapid increase in the individual's height and weight resulting from the simultaneous release of growth hormones, thyroid hormones, and androgen. It has been studied that these effects were reflected in the results of commonly utilized pulmonary function tests.[31]

Increased growth rate and pulmonary physiological development[32,33] led to a 33% rise in PEFR in early adolescents compared to preadolescents. A strong positive correlation was observed with age (r = 0.613, p = 0.00). Peak expiratory flow rate was found to be higher in boys (223.50 ± 59.91 L/cm) as compared to girls (204.96 ± 51.44 L/cm), which was found to be statistically significant (p = 0.008). This may be attributed to larger lungs per unit of stature of boys than girls. Even though number of alveoli per unit volume and area is identical, alveoli is more in boys than girls resulting in higher lung function. Additionally, girls have been reported to have less strength due to greater amount of fat and less muscle mass, thus leading to lower PEFR. This effect may be exaggerated by increased levels of reproductive hormones on airway diameter at puberty.[34,35]

Early adolescents demonstrated 90.1% higher values of MIP and 55.4% higher values of MEP in comparison to preadolescents (Table 1). Age correlated strongly with MIP (r = 0.676) and MEP (r = 0.658) (p = 0.00). Marly et al[18] attributed this effect to greater muscle area in older individuals. Supporting airway cartilage and small airway muscles is not developed until school age. The effect of compliant bony cartilage and ribs and the fact that younger children primarily use diaphragm and underdeveloped intercostals could contribute to lower respiratory pressures in preadolescents. The overall mean value for MIP and MEP was found to be 37.53 ± 20.71 cm $H_2O$ and 50.29 ± 19.90 cm $H_2O$ respectively. Compared to values reported previously, the current study recorded lower mean values for respiratory pressures. Geographical variations, different nutritional status, poor motivation in our subjects, and deliberate leak in the mouthpiece of apparatus may have led to lower mean values. Studies have found MIP and MEP values higher in males than females.[19,20] However, in our study the difference was statistically insignificant.

Six-minute walk distance was found to be reduced in early adolescents compared to preadolescents ($p = 0.000$). It showed a strong negative correlation with age ($r = –0.604$) and height ($r = –0.42$), whereas a weak negative correlation with weight ($r = –0.328$). It is known that age, height, weight, and gender independently affects the 6MWD in healthy adults.[21] Increased weight must have escalated the workload for a given amount of exercise, probably resulting in shorter walking distance.[36] Almost 22.10% of the early adolescents were overweight compared to only 7.7% in the preadolescent group. This could be the probable reason for a lesser 6MWD as noted in them. Another reason for reduced endurance levels in early adolescents could be due to adoption of a sedentary lifestyle owing to higher academic stress and different leisure pursuits. This could be supported by increased sitting hours noted in the early adolescent group ($p = 0.032$). Factors, such as, motivation, attitude toward physical activity, and musculoskeletal pain might affect 6MWD.[21] These factors were beyond the scope of the study. The clinical tools were not included to measure specific motivation levels. Ulrich et al[37] have found the similar findings wherein 6MWD has been found to have increased until puberty and then has flattened. However, pubertal changes were not studied in depth and stands as a limitation. Distance covered by boys was significantly greater than girls ($6MWD_{boys} = 693.6$ m ± 65.1, $6MWD_{girls} = 649.52$ m ± 105.01, $p = 0.00$) by 6.8%. The influence of gender on the distance walked might be attributed to the greater absolute muscle strength, muscle mass, and increased height of boys in comparison to girls. During adolescence, though there has been an increase in strength in both the genders, the percentage of body fat in boys remains the same, whereas the percentage of body fat in girls increases significantly contributing to lesser walk distance in girls.[23-25]

The age at which the pubertal growth spurt occurs and the speeds with which adolescents experience puberty vary greatly and may affect physical activity.[9,32-34] Growth of the respiratory system is an ongoing process and is said to be completed by the age of 10 to 11 years. A significant effect of adolescence on respiratory parameters has been observed. Early adolescents have demonstrated higher values of PEFR, MIP, and MEP than preadolescents, suggesting a scope for intervention to enhance respiratory functions at this age. However, 6MWD has been found to be reduced with age, most likely due to increased percentage of overweight in higher age group. This could be a likely indication for the inclusion of weight reduction program as a part of clinical management and goal setting for cardiopulmonary rehabilitation in clinical practice.

The findings of this study should be viewed in light of its limitations. The present study reveals that findings are based on a convenience sample recruited from a single school. It limits the generalization of its results. Absenteeism and unavailability of higher class students post school hours owing to busy study schedule could have led to unequal distribution of samples in both groups. Motivation levels could have influenced the results of a few tests. Assessing attitudes, behavior, and motivation scores have been beyond the scope of this study.

## CONCLUSION

Exercise capacity measured by 6 Minute Walk Test was lower in early adolescents compared to pre-adolescents suggesting need for increased participation of early adolescents in physical activity. Respiratory muscle strength and PEFR was higher in early adolescents as compared to pre-adolescents indicating ongoing maturation of respiratory system.

## ACKNOWLEDGMENT

Authors would like to be thankful to all school students of MGM Primary and Secondary School, Nerul, Navi Mumbai, Maharashtra, India who had extended their cooperation during the study. In addition, the authors are grateful to Principal, teachers, and parents for their support and granting the permission to undertake the proposed study.

## REFERENCES

1. Bloom DE, Cafiero-Fonseca ET, Candeias V, Adashi E, Bloom L, Gurfein L, Jané-Llopis E, Lubet A, Mitgang E, Carroll O'Brien J, et al. Economics of non-communicable diseases in India: a report by the World Economic Forum and the Harvard School of Public Health. Geneva: World Economic Forum; 2014. 68p. Available from: http://www3.weforum.org/docs/WEF_EconomicNonCommunicableDiseasesIndia_Report_2014.pdf.
2. Aggarwal AN, Chaudhry K, Chhabra SK, D'Souza GA, Gupta D, Jindal SK, Katiyar SK, Kumar R, Shah B, Vijayan VK, et al. Prevalence and risk factors for bronchial asthma in Indian adults: a multicentre study. Indian J Chest Dis Allied Sci 2006 Jan-Mar;48(1):13-22.
3. Paramesh H. Epidemiology of asthma in India. Indian J Pediatr 2002 Apr;69(4):309-312.
4. Ranabir P, Sanjay D, Shrayan P. Prevalence of bronchial asthma in Indian children. Indian J Community Med 2009 Oct; 34(4):310-316.
5. Sutapa A. South Asia Network for Chronic Disease, New Delhi; 2007 [accessed 2015 Mar 27]. Available from: http//www.sancd.org/uploads/pdf/Asthma_factsheet.pdf.

6. Narayana PP, Prasanna MP, Narahari SR, Guruprasad AM. Prevalence of asthma in school children in rural India. Ann Thorac Med 2010 Apr;5(2):118-119.
7. Selevan SG, Kimmel CA, Mendola P. Identifying critical windows of exposure for children's health. Environ Health Perspect 2000 Jun;108(Suppl 3):451-455.
8. World Health Organization. World health report 2002 – reducing risks, promoting healthy life. Geneva: WHO; 2003. 248p. Available from: http://www.who.int/whr/2002/en/.
9. Harms CA. Does gender affect pulmonary function and exercise capacity. Respir Physiol Neurobiol 2006 Apr 28; 151(2-3):124-131.
10. Amiry AP, Mortazari Z, Monadi M, Bijani A. Normal measurement of peak expiratory flow rate in the high school children in Babol, north of Iran. Casp J Intern Med 2010 Jun;1(3): 98-101.
11. Taksande A, Jain M, Vilhekar K, Chaturvedi P. Peak expiratory flow rate of rural school children from Wardha district, Maharashtra in India. World J Pediatr 2008 Aug;4(3):211-214.
12. Pande JN, Mohan A, Khilnani S, Khilnani GC. Normal values of peak expiratory flow rate in school going children. Indian J Chest Dis Allied Sci 1997 Apr-Jun;39(2):87-95.
13. Swaminathan S, Venkatesan P, Mukunthan R. Peak expiratory flow rate in south Indian children. Indian Pediatr 1993 Feb;30(2):207-211.
14. Sharma M, Sharma R, Choudhary R. Peak expiratory flow rates in children of western Rajasthan 7–14 years of age. Pak J Physiol 2012;8(1):45-48.
15. Swaminathan S, Diffey B, Vaz M. Evaluating the suitability of prediction equations for lung functioning Indian children: a practical approach. Indian Pediatr 2006 Aug;43(8): 680-698.
16. Heinzmann-Filho JP, Vasconcellos Vidal PC, Jones MH, Donadio MV. Normal values for respiratory muscle strength in healthy preschoolers and school children. Respir Med 2012 Dec;106(12):1639-1646.
17. Harik-Khan RI, Wise RA, Fozard JL. Determinants of maximal inspiratory pressure. The Baltimore longitudinal study of aging. Am J Respir Crit Care Med 1998 Nov;158(5 Pt 1): 1459-1464.
18. Marly C, Oliveira G, Lanza FC, Sole D. Respiratory muscle strength in children and adolescents with asthma: similar to that of healthy subjects? J Bras Pneumol 2012 Jun;38(3): 308-314.
19. Wilson SH, Cooke NT, Edwards RH, Spiro SG. Predicted normal values for maximal respiratory pressures in Caucasian adults and children. Thorax 1984 Jul;39(7):535-538.
20. Gopalakrishna A, Vaishali K, Prem V, Aaron P. Normative values for maximal respiratory pressures in an Indian Manglore population: a cross-sectional pilot study. Lung India 2011 Oct-Dec;28(4):247-252.
21. American Thoracic Society. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med 2002 Jul 1;166(1):111-117.
22. Li AM, Yin J, Yu CC, Tsang T, So HK, Wong E, Chan D, Hon EK, Sung R. The six-minute walk test in healthy children: reliability and validity. Eur Respir J 2005 Jun;25(6):1057-1060.
23. D'silva C, Vaishali K, Venkatesan P. Six-minute walk test-normal values of school children aged 7–12 years in India: a cross-sectional study. Indian J Pediatr 2012 May;79(5):597-601.
24. Lammers AE, Hislop AA, Flynn Y, Haworth SG. The six minute walk test: normal values for children of 4–11 years of age. Arch Dis Child 2008 Jun;93(6):464-468.
25. Aquino ES, Mourão FA, Souza RK, Glicério BM, Coelho CC. Comparative analysis of the six-minute walk test in healthy children and adolescents. Rev Bras Fisioter 2010 Jan-Feb; 14(1):75-80.
26. Khadilkar VV, Khadilkar AV, Borade AB, Chiplonkar SA. Body mass index cut-offs for screening for childhood overweight and obesity in Indian children. Indian Pediatr 2012 Jan;49(1):29-34.
27. Virdis R, Street ME, Zampolli M, Radetti G, Pezzini B, Benelli M, Ghizzoni L, Volta C. Precocious puberty in girls adopted from developing countries. Arch Dis Child 1998 Feb;78(2):152-154.
28. Hauspie RC, Das SR, Preece MA, Tanner JM. A longitudinal study of the growth in height of boys and girls of West Bengal (India) aged six months to 20 years. Ann Hum Biol 1980 Sep-Oct;7(5):429-441.
29. Satyanarayana K, Radhaiah G, Mohan KR, Thimmayamma BV, Rao NP, Rao BS, Akella S. The adolescent growth spurt of height among rural Indian boys in relation to childhood nutritional background: an 18 year longitudinal study. Ann Hum Biol 1989 Jul-Aug;16(4):289-300.
30. Kanade AN, Joshi SB, Rao S. Under-nutrition and adolescent growth among rural Indian boys. Indian Pediatr 1999 Feb;36(2):145-156.
31. Steinberg L. Adolescence. New York (NY): McGraw-Hill; 2008 [accessed 2015 Feb 20]. Available from: https://en.wikipedia.org/wiki/Adolescence.
32. Mishra J, Mishra S, Satpathy S, Manjareeka M, Nayak PK, Mohanty P. Variations in PEFR among males and females with respect to anthropometric parameters. IOSR J Dent Med Sci 2013 Mar-Apr;5(1):47-50.
33. Rogol AD, Roemmich JN, Clark PA. Growth at puberty. J Adolesc Health 2002 Dec;31(Suppl 6):192-200.
34. Becklake MR. Gender differences in airway behaviour (physiology) over the human lifespan. Eur Respir Mon 2003;25:8-25.
35. Olfert IM, Balouch J, Kleinsasser A, Knapp A, Wagner H, Wagner PD, Hopkins SR. Does gender affect human pulmonary gas exchange during exercise? J Physiol 2004 Jun 1;557(Pt 2):529-541.
36. Morinder G, Mattsson E, Sollander C, Marcus C, Larsson UE. Six-minute walk test in obese children and adolescents: reproducibility and validity. Physiother Res Int 2009 Jun;14(2):91-104.
37. Ulrich S, Hildenbrand FF, Treder U, Fischler M, Keusch S, Speich R, Fasnacht M.. Reference values for the 6-minute walk test in healthy children and adolescents in Switzerland. BMC Pulm Med 2013;13:49.