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NORMATIVE VALUE OF MAXIMAL STATIC RESPIRATORY PRESSURES IN HEALTHY CHILDREN BETWEEN AGE GROUP 8-12 YEARS

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Abstract

Background: The maximal static respiratory pressure (MRP) assessment is vital for both clinical reasoning and respiratory system growth and development. The predicted normal values of maximal inspiratory pressures (PImax) and maximal expiratory pressures (PEmax) published for the western population may not be appropriate for Indian children because of the ethnic difference and large inter-subject variations of PImax and PEmax values. Objective: The purpose of the study was to establish normative values of MRP in healthy children aged 8-12 years. Methods: A cross-sectional study was conducted among nine government and public schools of Bangalore, India. We assessed the anthropometric measures (height, weight, BMI, waist-hip ratio, pulmonary function tests) and MRP for 887 children (490 boys and 397 girls) following guidelines by American Thoracic Society/European Respiratory Society. Results and conclusion: The mean of PImax and PEmax were 60.83+19.5 and 62.26+18.13 cmH2O, respectively. The mean of PImax was relatively lower by mean of 15.32 cmH2O when compared from Brazilian, 12.2 cmH2O from Mexican, and 16.23 cmH2O from the Australian population. Similarly, the mean of PEmax of the current study was relatively lower by mean of 27.625 cmH2O when compared from Brazilian, 21.845 cmH2O from Mexican, and 24.365 cmH2O from the Australian population. This states that ethnicity has a strong influence on respiratory muscle strength. Thus, the study provides the normative data for maximal static respiratory pressures for healthy children aged 8-12 years in Bangalore, India

Introduction:

Respiratory muscle strength reflects the function of respiratory muscles[1]. Maximal static inspiratory (PI_{max}) and expiratory (PE_{max}) mouth pressures, the simplest measures of respiratory muscle strength, play an important role in evaluating the extent and severity of respiratory muscle weakness[2]. Among children, these measures are being used in rehabilitation programs to determine the respiratory muscle strength after the treatment and for successfully weaning children from mechanical ventilation systems[1,3,4].

Several studies established reference values for respiratory muscle strength both in children and adolescents have shown great interindividual variability[1]. This has been attributed to differences in geographical, social, and anthropometric variables or variability of equipment and techniques employed[5]. The predicted equations available in the literature, demonstrate that the variables age[6-11], height,[6,9,11]weight[9,10], and gender[1] contribute to differences in lung recoil, airway-alveolar differential growth, chest wall compliance and dimensions influencing the respiratory muscle strength[1,5].

Previous studies[12,13] have stated that the respiratory muscle strength varies significantly when compared to Caucasian children inferring that because of large variability between population the normative values derived in the western population may not be suitable for the Indian population. However, there is no published data on respiratory muscle strength in the south-Indian children. Therefore, the present study aimed to measure maximal static respiratory pressure in children aged 8-12 years and to derive the normative values for clinical practice.

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Material and Methods:

Recruitment

A time-bound cross-sectional study was conducted from July 2019 - March 2020. The study protocol was approved by the Institutional Research Committee. The study was registered under the clinical trial registry India (number: CTRI/2019/08/020512). Additionally, the district health officer, district education officer, and block education officer were approached to seek their permission before testing and gathering data.

The list consisting of a total of fifty-one schools was obtained from the authorities. The principals of twenty-three government, local, public, and aided schools were approached conveniently for the conduction of the study within the school premises. Out of which nine schools permitted conducting the study within the school premises. All parents or legal guardians of the children aged 8-12 years of those respective nine schools received a letter explaining the study along with the written informed consent form and the questionnaires consisting of the overall health status, physical activity, and diet and lifestyle of the child.

The children eligible to participate in the study were children between the age group 8-12 years of both genders, enrolled in government, local public, and aided schools in urban Bangalore, India, and able to understand and perform the procedure. The children who had cardio-respiratory disorders; congenital malformation of the respiratory tract; recent respiratory tract infection, cold and/or cough, and recurrent upper airway infection in the four previous weeks and those children without the informed written consent by parents and/or legal guardians were excluded.

A demographic and family health questionnaire gathering information regarding personal and family health status. A diet and lifestyle questionnaire were given to gather information regarding transportation to school, activities performed, television (TV) time, TV in the bedroom, quality and quantity of sleep, perception of health, and diet[14]. The test-retest reliability was ranging from 0.37-0.78 and gross miss-classification for all four groups was $<5\%$[15,16]. A Short form- international physical activity questionnaire (IPAQ) gathers information regarding total sitting time (min/day) during one day of the week and the total sitting time on the weekend. Children were evaluated according to the frequency and duration of moderate and vigorous physical activity and any walking done for at least ten minutes in the last week[17,18]. The test-retest intra-class-correlation of moderate physical activity, vigorous physical activity, and moderate to vigorous physical activity range from 0.73-0.95 ($P<0.001$)[19]. These 3 questionnaires filled up by the parents after giving the consent.

Measurements:

All the measurements were taken within the school premises during the regular school course and without disturbing the regular schedule of the school by a single investigator between 9 am-4 pm.

Height, waist, and hip circumference and weight were measured following the standard procedure with a precision of 0.5 cm, 0.1 cm, and 100 g respectively, and waist and hip circumference were measured. Body mass index (BMI) (kg/m^2) was calculates as: body weight (in kg)/$(\text{height})^2$ (in meters^2).

Forced vital capacity (FVC), forced expiratory rate in 1^{st} second (FEV_1), and FVC/ FEV_1 were recorded using a portable handheld digital spirometer with the excellent inter-rater reliability (>0.75)[20] and following American Thoracic Society/European Respiratory Society guidelines[21]. A resting period of 1 minute was allowed between each FVC, FEV_1, and FVC/FEV_1 manoeuver. The manoeuver was stopped with a minimum of 3 and a maximum of 8 manoeuvers were concluded. The best of the values for each FVC, FEV_1, and FVC/FEV_1 maneuver was taken into consideration for analysis.

The maximal respiratory pressures (MRP) using a handheld manometer MicroRPM (Care Fusion, San Diego, California, USA) following American Thoracic Society/European Respiratory Society guidelines[22]. The reliability with interclass correlation coefficient for the device was 0.86-0.90[23]. The device was connected to

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a semirigid and flat from the upper portion mouthpiece with wings in its extremes ensuring good adjustment to the lips and to avoid an increase in intra-oral pressure caused by contraction of buccinator muscles.

The children were instructed to exert maximum inspiratory effort starting from the residual volume for assessment of maximal inspiratory pressure (PI_{max}) and were asked to exert maximum expiratory effort starting from total lung capacity for assessment of maximal expiratory pressure (PE_{max}). A resting period of 1 minute was allowed between each PI_{max} and PE_{max} maneuver. The maneuver was stopped with a minimum of 3 and a maximum of 5 maneuvers were concluded. The best of the values for each PI_{max} and PE_{max} maneuver was taken into consideration for analysis.

Measurement for pulmonary function test (PFT) and MRP were taken in sitting with back against the chair, head in a neutral position, chest forming 90^0 with their hips and arms resting on lower limbs, and wearing a nose clip to avoid the air leakage. Maneuvers were verbally explained and visually demonstrated by the investigator before gathering test data. Verbal encouragement was given whenever necessary because these are an effort-dependent test.

Statistical Analysis:

Data were analyzed using SPSS statistics software version 22.0, with a significance level of 5%. Data normality was verified by the Shapiro Wilkins test. Descriptive statistics were expressed as the mean and standard deviation. One-way analysis of variance (ANOVA), followed by Tukey's post hoc test, was used to determine whether there was a significant difference in the maximal respiratory pressures between the 5 ages assessed. Non-paired Student's t-test was applied to verify inter-gender differences. The 3^{rd}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 97^{th} smoothing percentiles were chosen by gender and age for reference values. The lower limit of normal (LLN) was calculated by subtracting a value two times greater than the standard deviation of the measurements from mean maximal respiratory pressures.

Result:

A total of 1344 questionnaires were handed out at 9 participating schools. Of the 895 that were returned, 8 children were not included in the study based on inclusion and exclusion criteria. Results from the remaining 887 children (290 boys and 397 girls) were analyzed in the study with the mean age for boys being $9.86+ 1.26$ and for girls being $9.73+ 1.29$. PI_{max} and PE_{max}values were normally distributed (Shapiro-Wilkins test).

Table 1 represents the anthropometric variables and pulmonary function test, expressed as the mean and standard deviation, according to age and gender. All the anthropometric variables, physical activity levels through IPAQ, and pulmonary function test values were the same in both the genders; except for specific height, weight and BMI were higher in girls than in boys for 10-, 11- and 12-year old children ($p<0.05$). One-way ANOVA tests for age-wise comparison of all the anthropometric variables and pulmonary function test values were increasing across all the age groups ($p<0.05$).

Maximal static respiratory pressure values are increasing significantly across all age groups as shown in table 2. One-way ANOVA test showed that PI_{max} and PE_{max} values increases with the age and are statistically significant ($p<0.05$) except for 9 versus 10 age groups for PI_{max} and 8 versus 9 age groups for PE_{max}. The Independent t-test indicated the mean of maximal respiratory strength values tend to be significantly higher in boys than in girls ($p<0.05$). Figure 1 represents the smoothed centile curves (3^{rd}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 97^{th} percentile) for boys' and girls' values across all age groups for both $PI_{max}$and PE_{max}. Together, these data show that boys performed better on the test at all the age groups when compared to girls.

Tables 3 and 4 represent the age- and gender-specific centiles of both PI_{max} and PE_{max}. In boys, the 50^{th} percentile values for PI_{max}ranged from 49 cmH_2O to 65 cmH_2O and for PE_{max} ranged from 51 cmH_2O to 66.5 cmH_2O. In girls, the 50^{th} percentile values for PI_{max} ranged from 47.5 cmH_2O to 58.5 cmH_2O and for PE_{max} ranged from 54 cmH_2O to 62 cmH_2O. The values for PI_{max} in both the genders suddenly declined

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at 97^{th} percentile for 10- year old age group. In boys, the values were higher across all age groups, with the most apparent gains between the ages of 11 years. In girls, the values were higher between 10-11 years, with the performance values being lower than boys across all the age groups.

Discussion:

The current study represents the normative values for maximum static respiratory pressure for both PI_{max} and PE_{max} among a population-based sample of the government schools from Bangalore, India. These results can be utilized as a baseline for long term physical fitness surveillance in the evaluation of the respiratory system function in preschool and school-age children.

Our value of PI_{max} (60.83(19.5) cmH_2O) was relatively lower by mean of 15.32 cmH_2O when compared from Brazilian[5], 12.2 cmH_2O from Mexican[3], and 16.23 cmH_2O from Australian[24] population. Similarly, the mean of PE_{max} of the current study (62.26(18.13) cmH_2O) was relatively lower by mean of 27.625 cmH_2O when compared from Brazilian[5], 21.845 cmH_2O from Mexican[3] and 24.365 cmH_2O from Australian[24] population. The mean of the current study was also lower in comparison to the study done by Basu et.al.[12] (boys: PI_{max}65.6(21.2) cmH_2 O and PE_{max} 65.3(19.4) cmH_2 O and girls: PI_{max} 66.0(24.0) cmH2O and PE_{max} 60.6(22.8) cmH2O). The low normative values possibly are due to low socioeconomic status, reduced consumption of vegetables and fruits, a decrease in physical activity, and an increase in sedentary behavior in the children. According to Talib et. al.[25] and Aslan et.al.[26], physically active children had increased maximal respiratory pressures.

BMI reflects the body fat distribution in terms of the nutritional level of the child and has shown an influence on respiratory muscle strength[33]. The mean BMI of the current population falls in the underweight category with mean 17.23 Kgm^{-2} in boys and 17.65 kgm^{-2} in girls. The reduced BMI may be associated with reduced skeletal muscle mass. The diaphragmatic muscle, which is the primary muscle of inspiration along with intercostal and abdominal muscle mass, has shown to have low muscle mass leading to reduced respiratory muscle strength in children[27,28].

Physical activity levels have shown to be directly influencing respiratory muscle strength.[25] The current study observed that the physical activity levels decreased with advancing age in boys contrasting with increasing levels of physical activity in girls. The children in the current study achieved only mild-moderate levels of physical activity, in comparison to the recommended levels of physical activity by WHO (60 minutes of moderate-vigorous activity daily)[29]. This could be due to less walking and increased dependence on vehicles for transport and reduced participation in games leading to a reduction in the respiratory muscle strength[30]. An earlier study quoted that 52% of the children achieved a moderate-vigorous level of PA[31], while, Indian children do not achieve recommended levels of PA[30].

Similarly, physical activity and aerobic fitness are positively associated with lung volumes[32]. The current study has shown the mean values of FEV_1, FVC, and FVC/FEV_1 in the current study are 1.06 L, 1.45 L, and 73% in boys and 1.04 L, 1.42 L and 73% in girls, respectively and are increasing with increasing age in both the genders. Although, the mean of the lung volumes is reported to be lower when compared to previously published studies[1,33,34]. The current study exhibits lower BMI and increased sedentary lifestyle which could have possibly lead to a reduction in muscle mass owing to reduced overall physical fitness which has seen to have negatively impacted the lung volumes and capacities[35].

The result of the present study is showing the normative data of PI_{max} and PE_{max} in the current population. The 50^{th} percentile values of PI_{max} ranged from 49 cmH_2O to 65 cmH_2O and for PE_{max} ranged from 51 cmH_2O to 66.5 cmH_2O in boys. Similarly, in girls, the 50^{th} percentile values for PI_{max} ranged from 47.5 cmH_2O to 58.5 cmH_2O and for PE_{max} ranged from 54 cmH_2O to 62 cmH_2O. These findings can be utilized to compare the values between the countries, as a medium of physical fitness in the evaluation of the respiratory muscle strength among children.

There are several limitations in the current study like body mass index can be evaluated using standardized equipment for accuracy and objective evaluation of physical activity levels. Therefore, we suggest studies can be done to investigate whether the level of physical activity and socioeconomic factors may be significant predictors of respiratory muscle strength in children.

Thus, the study proposes the age- and gender-specific normative values for maximal static respiratory pressures for a large, population-based sample of school-going children aged 8-12 years from Bangalore, India. The mean and standard deviation for PI_{max} is 57.84(17.83) cmH_2O in boys and 53.82(16.11) cmH_2O in girls and for $PE_{max,}$ the mean and standard deviation is 60.02(18.12) cmH_2O in boys and 56.42(16.75) cmH_2O in girls aged 8-12 years from Bangalore, India.

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Conflict of interest: None

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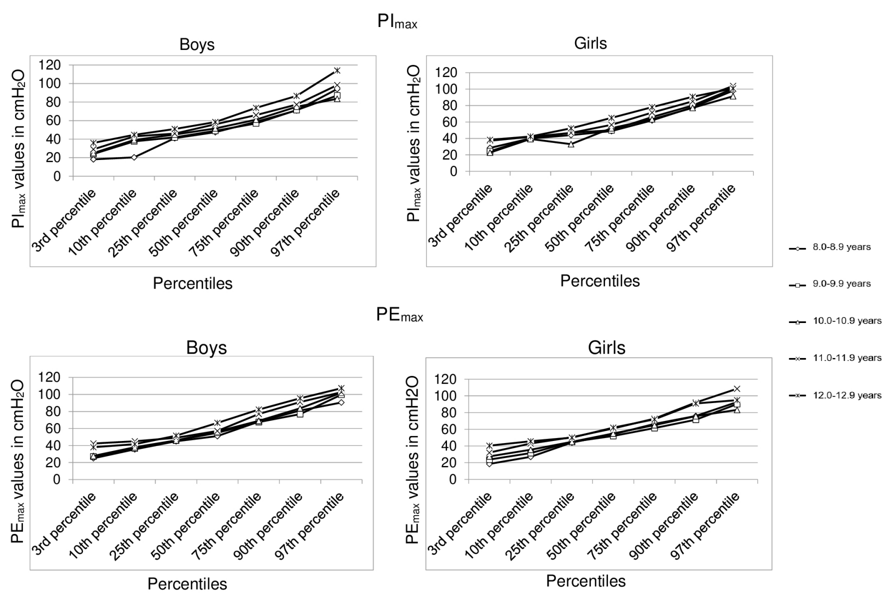

Figure 1: Smoothed centile curves for maximal inspiratory (PI_{max}) and expiratory (PE_{max}) pressures