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Original Research Article

Normative Value of Chest Expansion in Healthy Children Between 5 to 12 Years of Age Group

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ABSTRACT

Background: Chest expansion measurement is included as a standard mode of measurement to evaluate patient's baseline status of respiratory function. There are various anatomical and physiological differences between adult and paediatric respiratory system hence, adult values of chest expansion cannot be used as reference values in paediatric population. Also, there is lack of recent data that has evaluated chest expansion values in paediatric age group. So, the present study was undertaken to find out normal chest expansion values in children between 5-12 years of age. It is important to know the reference value for precise interpretation.

Methodology: A cross sectional observational study was carried out in 600 children between age group of 5-12 years and with normal BMI(without H/O any cardiac/respiratory illness, musculoskeletal or neurological diseases, spinal deviations, cough and cold). Chest expansion measurements were assessed in sitting position at three levels that is, 2nd, 4th and 6th intercostal spaces(ICS), using an non- elastic measuring tape. It was taken as thoracic circumference at the end of maximum exhalation and inspiration. An average of three such readings at each level was taken into consideration.

Results: To find value of chest expansion at 2^{nd}, 4^{th} and 6^{th} ICS levels a average values of the three measurements taken at each level at same time was taken into consideration.

Conclusion: The normative values of chest expansion in healthy children between age group of 5-12 years is 2^{nd} Intercostal space- 1 inch/ 2.5 cm, 4^{th} Intercostal space- 1 inch/2.5 cm, 6^{th} Intercostal space- 1.7 inch/ 4.25cm.

KEY WORDS: Chest Expansion, Normative Values, Children, Paediatric.

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INTRODUCTION

When breathing normally, inspiration occurs actively and expiration passively. The pump handle movement, predominant in upper thorax, occurs on inspiration and there is an increase in the anteroposterior diameter of thorax. In the bucket handle movement there is an increase in transverse diameter of lower thorax [1]. The transverse diameter of thorax is greater than the anteroposterior diameter giving it an ellipsoid shape with the ratio 7:5 [2]. The variations between anatomy, physiology and biomechanics of respiratory system of adult and paediatric population is well known [3].

In the new-born the lung thorax compliance

per unit vital capacity, is comparatively larger than in the adult, whereas during the first few days of life it is smaller, over the tidal volume range [4].

Development of alveoli in human lung continues and it is generally completed by 10 years of age, most of which occurs in the first half of post natal year. The number of alveoli increases with increase in height [5].

There is significant change in the compliance, muscle action and configuration of the chest wall from infants to adults. Cartilaginous and extremely compliant chest wall of new born allows necessary distortion for the infant's thorax to travel through the birth canal. The rib cage of an infant has more horizontal alignment of ribs. The angle of insertion of the coastal fibres of diaphragm is more horizontal as compared to adult [6]. As an infant ages rib ossification starts, muscles of thorax start to mobilize the thorax rather than providing stability. With head control, infants start gaining accessory muscle use for ventilation. The action on thorax is improved by the movement of muscles attached on the increasing angle of ribs. Whereas, the diaphragm in adults is in elliptical shape and ribs slope downward. These are few anatomical variations in adult and paediatric rib cage. Also, compared to older children and adults, younger children have different respiratory and cardiovascular physiology and are also at increased risk of perioperative respiratory and cardio circulatory complications [7].

The 2019 report of the National Health Portal of India, stated that 41,996,260 cases and 3,740 deaths from respiratory infections were recorded across India in 2018. The contribution of India in global population is 18%, with severe acute respiratory infection (SARI) as one of the prominent causes of mortality in children of more than 5 years of age. Among many diseases, respiratory diseases count for the majority of all paediatric hospital visits and hospitalisations all over the world, with significant morbidity and mortality [8].

Spirometry, commonly referred as lung function test assessment is a procedure that measures the rate of change in lung volumes during forced breathing manoeuvres and is also used to determine diagnosis, prognosis, and also monitor and manage patients with a variety of respiratory diseases. The lung volume size and airway size changes as the age increases in children during dynamic developmental phase. Parameters like weight, height, age, sex, environmental factors, ethnicity, prematurity, patient cooperation, effort and also technical factors influence readings obtained by spirometry. A survey was conducted by Dombkowski*et al*. to assess the usage of spirometry by physicians in paediatric primary care who were treating children with asthma and established that only half of physicians were utilizing spirometry and nearly half did not interpret the spirometry results accurately and highlighted the underuse of spirometry in paediatric population [9].

Considering these lacunae in the use of spirometry in paediatric population, non-invasive strategies of monitoring respiratory function have started gaining interest. Assessment of chest wall mobility is considered as crucial tool for assessing abnormal respiratory patterns at rest and during exercise. Respiratory function evaluation tests like chest expansion (CE) may indicate deterioration in respiratory function prior to the commencement of clinical symptoms. Respiratory plethysmography via induction, magnetometry, and optoelectronic plethysmography are non-invasive methods that are thought-about in the literature and found to meet acceptable standards in paediatric population but are costly and require trained technicians. Hence, a cost effective, simple, accurate, and reproducible evaluation strategies and tools are required to assess chest wall mobility in paediatric population. Ravi S. Reddy et al in 2019 has suggested that upper and lower chest expansion measurements performed with an inch tape has shown good intra- and interrater reliability and reproducibility in healthy non-smokers, healthy smokers, and COPD subjects. CE is more useful in clinical practice to evaluate chest mobility and to give indirect information on lung function but interpretation with caution is needed when considering implementation into clinical setting [10].

Normative value of chest expansion is well

established in adults i.e. mean expansion at 2nd and 4th ICS is 2.22 inches and at xiphoid process level is 2.27 inches in females while in males mean expansion at 2nd ICS is 2.76 inches, at 4th ICS is 2.71 inches, and at xiphoid process level 2.99 inches [11].

Though, the Chest expansion assessment is a non-invasive and reliable indicator of lung function and chest mobility it is still not used in paediatric population due to unavailability of its normative values in the age group of 5 to 12 years. This defers clinicians from using this tool though it can serve as most preferred clinical assessment.

There are numerous differences in performance of manoeuvre and acceptability criteria of PFT and different predication equations are used[12]in paediatric lung function evaluation as compared to adult population to accurately predict lung function, similarly clinicians should avoid use of adult reference values of chest expansion in paediatric population. Thus, the need of assessment of chest expansion value in paediatric population is further emphasized.

Knowing the importance of chest expansion as a diagnostic tool in clinical settings, the interpretation is dependent on normative data drawn from normal children to detect variation from normal. However, adult values of chest expansion should not be used as reference for assessing chest expansion in children between 5 to 12 years of age group due to differences in anatomy and physiology of adult and paediatric respiratory system. Thus, the present study was undertaken.

MATERIALS AND METHODS

Study population: A cross sectional observational study was performed on 600 (N=600) healthy children (Sample size estimation was done using the formula $SD^{2*}(Z_{1-á})^2/L2$ that came out to be around 523) and random quota sampling was used as a sampling method to collect the data. Children from community and primary schools of Pune district were chosen for the study. All the children were between the age group of 5-12 years and had normal Body Mass Index(i.e.50 centile) [13].

Whereas, Children with history of any cardiac/ respiratory illness, musculoskeletal or neurological diseases, spinal deviations, cough and cold were excluded from the study.

Methodology: The study protocol was explained to the subjects and consent was taken by the parents. Age and sex of subjects was recorded. Anthropometric measurements like, height was taken using a non-elastic measuring tape and weight with weighing machine was performed with participants wearing light clothes and without shoes.

The subject's chest expansion was taken in sitting position with feet apart (shoulder width) and the upper limb at the sides with the shoulder slight abducted, elbow in semi flexion, wrist extended and placed on the iliac crest, and thumb abducted. The chest expansion was taken as thoracic circumference at the end of exhalation then thoracic circumference at the end of inspiration. The three readings at each ICS(2nd, 4th, 6th intercostal space) was recorded by using an non-elastic measuring tape at the same time with rest period of one minute .

The averages of those three readings was documented as final normative value for that intercostal space.

Statistical analysis: Sample size estimation for cross sectional study was done using the formula $SD^{2*}(Z_{1-á})^2/L^2$. Normative value of chest expansion was assessed by taking average of 3 readings at 2nd, 4th and 6th ICS.

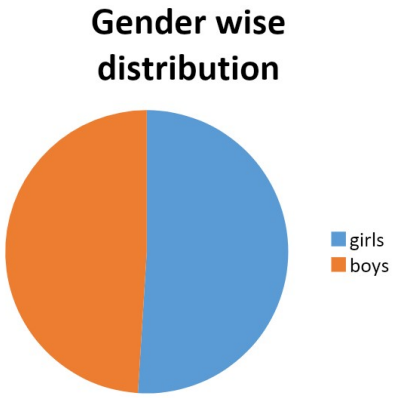
Ethics and consent: This cross sectional observational study was conducted after seeking the approval of Institutional Ethical Committee. The study design was in accordance with the Declaration of Helsinki, revised in 1983. Written Consent was taken from the parents of school children and school principal after completely orienting them to study procedure.

RESULTS

To finding out normative value of chest expansion at three levels, 600 children between the age group of 5-12were selected by random sampling from various schools in Pune, average values of the three readings taken at each ICS were taken into consideration.

According to that the normative values of chest expansion in healthy children between age group of 5-12 years is 2nd Intercostal space- 1.027 inch+/- 0.143/ 2.5 cm, 4th Intercostal space- 1 inch+/- 0.140/2.5 cm, 6th Intercostal space- 1.7 inch+/-0.286/ 4.25cm

Graph 1: shows gender wise distribution. **It depicts that** study populationconsisted of 51% girls and 49% boys.



Graph 2: shows % of study population in particular age group. It depicts that study population was equally distributed in various age groups.

DISCUSSION

The aim of study was to find the normative values of chest wall expansion measurements in healthy children. The need of normative values of chest expansion is important in clinical practice for evaluation of paediatric patient as well as has prognostic value. Chest wall expansion measurement provides measure for chest wall mobility. Chest wall mobility evaluation is important to know in many conditions like myasthenia gravis, fibromyalgia, cardiac and pulmonary diseases. It is an indirect measure of lung function. Also, chest expansion is a reliable tool in assessing effectiveness of medical and physiotherapeutic treatment, progression of cardiorespiratory, musculoskeletal and neurological diseases [14].

Chest expansion assessment can form an integral part of clinical management of patients with respiratory disease but reliable interpretation of results relies on availability of suitable reference data to help distinguish between healthy and diseased.

Measurement of chest expansion was first described by Moll et al. in 1972. Chest expansion measurement has been used in different disease conditions to assess the effects of different treatment techniques, including respiratory muscle endurance training and respiratory muscle stretching. Chest expansion is commonly measured as the difference between the thoracic girth measurement after maximal inspiration and at the end of maximal expiration. Anatomical reference markers for upper chest expansion include the fourth intercostal space, axillary line, and 5th thoracic vertebrae, and lower chest expansion include xiphoid process and 10th thoracic vertebrae. Chest expansion looks to be diverse and variable within healthy and diseased subjects, ranging from 4–7 cm in healthy adult subjects. The normal range of CE decreases with age (50 to 60% between 15 y and 75y) and 20% more in men compared to women [10].

The present study has evaluated chest expansion normative values by assessing it in sitting position. In 2018 a meta-analysis was done by Rattanaporn Sonpeayung, Anong Tantisuwat , Thaniya Klinsophon , Premtip Thaveer atitham, the study analysed which body position is best for chest wall motion in healthy adults by taking readings at 2nd, 4th and 6th intercostal spaces. The outome of this study indicated that the sitting position had an improvement in the rib-cage compartment of the chest wall, whereas in the supine position there was superior enhancement in the part of the abdomen relative to other body positions [15].

This study uses tape measurement which is simple and cheap, to measure chest expansion. The study performed by Bockenhauer et.al has confirmed that the tape-measure method of measuring thoracic excursion at three levels is reliable and useful in a clinical setting [16].

There are various studies showing reference values of chest expansion in healthy adults also comparing those values among males and females like in studies conducted in 2017 by Rajani S. Pagare, Ratnaprabha B. Pedhambkar [11] and a study conducted in the year 2020 byAhmed Hasan Reheem, Hussam Riyadh Dakhil, Muslim Talib Jabbar2 [17], but there is lack of data for chest expansion normative values in children with a specific age group. Our study had 51% of girls and 49% boys in study population(Refer graph1) and almost similar representation of different age group strata (Refer Graph 2) of study population. (N=600). Thus, finding of this study can be generalized to paediatric population and to both genders. Having a set of reference values for Chest expansion measurement for paediatric age group that have been derived from the healthy population makes the most sense.

So, this study would help physiotherapist as well researchers assessing chest expansion values in children at three levels for age group 5-12 years, which could be used as reference values for various interventions. With better standardization, results obtained are meaningful and when interpreted in context of age offer more diagnostic information to better treat the child with lung disease.

Assessing lung function by non invasive, easy, cost effective, bed side clinical methods like chest expansion assessment can prove a superior method and by the normative value provided by this study it would be beneficial to monitor disease severity and progress.

CONCLUSION

The normative values of chest expansion in healthy children between age group of 5-12 years is 2nd Intercostal space - 1.027 inch+/- 0.143/ 2.5 cm, 4th Intercostal space- 1 inch+/- 0.140/2.5 cm, 6th Intercostal space- 1.7 inch+/- 0.286 / 4.25cm.

Author contribution

Aditi Soman: Conception and design, statistical analysis, Drafting the manuscript, Final approval of the manuscript.
Dhanashree Kirtikar: Data collection
Taruna Gambhir: Drafting of the manuscript

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Conflicts of interest: **None**

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