Peak Expiratory Flow Rate in Normal School Children of Bangladesh, 5-15 Years.

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INTRODUCTION

Pulmonary function tests of various types are utilized clinically and epidemiologically to measure functional status in order to assess the disease (Lebowitz,1991). Though they do not provide a specific diagnosis, they help us to understand the physiology, course and progress of the respiratory diseases, assess the severity and help in the management of number of respiratory diseases (Swaminathan,1999). Pulmonary function testing in a child differs from that in adult, largely because of the volume change that occurs from birth through the period of growth to the adulthood. These differences influence technique, methodology and interpretation (Kulpati and Talwar,1992; Polger and Promodhat,1971; Sly and Robertson, 1990). However, most of them are cumbersome, expensive and difficult to obtain reproducible results in children.

The peak expiratory flow rate(PEFR) measurement is simple, reproducible and reliable way of judging the degree of airway obstruction in various obstructive pulmonary diseases, specially asthma. Peak expiratory flow rate is easily measured by using a mini-Wright's peak flow meter (mWPFM) (Wright,1978), which is easy to use, reliable and can be recorded even by the patients or by the parents at home (Wille and Svensson,1989; Perks, Tams, Thompson, 1979; deHamel, 1982; Burns, 1979 ; Perks, Cole, Steventon,1981). This instrument is cheap, portable, understandable and useful for physicians in managing children with respiratory diseases, particularly valuable for assessing children aged as low as 3 years, as younger children can not perform the other pulmonary function test reproducibly (Milner and Ingram,1970).

Asthma is the most common chronic inflammatory disease in children (Direkwattanachai,Limkittikul, Kraisarin,1999) and is a major global health problem which exerts a substantial burden on the family, health care services and on the society as a whole (Mutius,2000; Kabir,Rahman,Hassan,2000). Prevalence of asthma in children is increasing day by day globally supported by

different studies in different countries (Shamssain and Shamsian,1999; Austin and Russell,1997; The ISAAC steering committee,1998; Austin, Kaur, Anderson,1999). Though prevalence of childhood asthma of our country previously was not known but recently one study showed that prevalence of recent wheeze 9% and current asthma 7.1%, the study was conducted nationwide (Kabir,Hassan, Rahman,1999). Another study showed that the prevalence of wheeze and asthma is in children of coastal community of Bangladesh is 11.8% which is very high (Kabir,Rahman,Mannan,1998). Contrary to popular belief, asthma is more prevalent in rural areas and district town than metropolitan cities (Ruhulamin,Hassan,Kabir,1999). So all simple devices and skill should be applied for preventing and treating the such chronic pulmonary disease. During the past decade, understanding of asthma self management has developed greatly, and there is a general agreement that more effective methods of educating patients are needed to reduce morbidity and mortality from the disease (Crear,1987; Goldstein,Geen,Perker, 1983; Clark,1989).

PEFR measurement can reveal the diurnal variability of airway of patient has been suffering from reactive airway disease but not in normal children (Sly,Hibbert,Sci,1986; Hetzel and Clark,1980); that gives the early clue to have the diagnosis and management. Fall of peak expiratory flow rate in a child with asthma is impending sign of acute asthma. The response to treatment can be monitored by using serial PEFR measurement (Swaminathan, Venkateson, Mukunathan,1993). Peak expiratory flow rate measurement gives the idea of status of airway caliber of respiratory system and regulatory function of respiration which some times affected by certain progressive neurological disease. As no physician can understood the status of progress and treatment of diabetes mellitus without doing simple blood sugar test, no clinician could not manage a patient with potential renal failure without an estimation of blood urea level, PEFR can be used as pulmonary function test in the same way (Dugdale and Moeri,1968; Swaminathan, 1999). The occurrence of diurnal variation of symptoms and airway resistance in asthmatic children are well perceived, thereby early intervention of treatment pattern and efficacy of drug can be

documented by measurement of peak flow rate(Epstein, Fletchar, Oppenheimer,1969; Ho, Ngiam,Koh,1983). PEFR can be used not only to see the airway obstruction, can be used to classify the severity of diseases of airway obstruction and its management and as a guide line of admission and discharge of asthma patients (Taylor,1994).

Nomograms and regression equation for predicting PEFR from height are available for Western children (Godfrey, Kamburof, Nairn,1970) and normal value of PEFR in relation to height, age, sex and weight are present in the different countries (Pande, Mohan, Kchilnani,1997; Host, Host, Ibsen,1994; Graft, Harfi, Tipirneni,1993; Udupihille,1994; Jaja and Fagbenro, 1995; Joshi,1996; Nairn, Bennett, Andrew,1961) but no national standard value is available in Bangladesh which is really essential.

HYPOTHESIS : Peak Expiratory Flow rate (PEFR) in Bangladeshi normal children is different from that of other countries.

OBJECTIVES

1. To establish normal values of Peak expiratory flow rate (PEFR) in normal children of Bangladesh (aged 5-15 years).
2. To find out the correlation of various anthropometric parameters with PEFR.
3. To compare PEFR of Bangladeshi children with that of other countries.

LITERATURE REVIEW

DEVELOPMENT OF RESPIRATORY SYSTEM

The respiratory system is an outgrowth of the ventral wall of the foregut, and the epithelium of the larynx, bronchi and alveoli are of endodermal origin. The cartilaginous and muscular components are mesodermal origin. In the forth week of development the trachea is separated from the gut by the esophagotracheal septum, thus dividing the foregut into lungs anteriorly and esophagus posteriorly (Sadler,1995).

Complete development of the respiratory system occurs through three distinct processes-

1) Morphogenesis or formation of all the necessary structures: Morphogenesis of the respiratory system is divided into five periods that includes- Embryonic periods(4-6 weeks), Pseudoglandular period (6-16 weeks), Canalicular period (between 16 weeks and 26-28 weeks), Sacular period(26 weeks to birth) and Alveolar period(32 weeks of gestation-2 years of age). Morphogenesis of respiratory system is regulated by some genes(HOX gene family) and expression of some of these genes are controlled by retinoic acid. This may be related to possible therapeutic role of retinoic acid at later stages of lung development or in injured lungs.

2) Adaptation to air breathing: The transition from placental dependance to autonomous gas exchanges require adaptive changes in the lungs. These changes include the production of surfactant in the alveoli, the transformation of the lung from a secretory to a gas exchanging organ and establishment of parallel pulmonary and systemic circulations.

3) Post natal development: The post natal development of the lungs can be divided into two phages-

First phage, extends from birth to 18 months, in this phage there is disproportionately increase in the surface and volume of the compartments involved in gas exchange. This process is particularly active during early infancy and, contrary to the previous belief may reach completion within the first 2 years instead of the first 8 years of life.

Second phage, all compartments grow more proportionately to each other. Alveolar and capillary surface expand in parallel with somatic growth. Final size of the lungs depend on factors such as subjects level of activities and prevailing states of oxygenation(altitude) (Haddad and Fontan, 2000).

DIVISION OF RESPIRATORY SYSTEM

A. According to functions of the respiratory system

a) ***Air conducting division*** **:** Composed of small cavity, nasopharynx, larynx, trachea, bronchi and bronchioles.

b) ***Respiratory division*** **:** Composed of respiratory bronchioles, alveolar ducts, atrium, alveolar sac and alveoli (Janquira, 1998; Bannister,1995).

B. According to size of the airway

a) ***Large airway*** **:** When size is more than 2mm.

b) ***Small airway*** **:** When size is less than 2mm (Sly, 2000).

C. Clinical division of respiratory system

a) ***Upper respiratory tract*** **:** This includes the nose, nasopharynx and oropharynx

b) ***Lower respiratory tract*** **:** This includes inlet of larynx, larynx, trachea, bronchi and lungs. Clinical division largely related to spread of infection rather than any further anatomical concept (Bannister, 1995; WHO ARI manual,1993). But some authors describe upper respiratory tract includes nose to larynx (upto lower border of cricoid cartilage) and lower respiratory tract includes trachea to lungs (Crompton,1999)

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LUNGS

The lungs are a pair of respiratory organs situated in the thoracic cavity. They are spongy in texture and right lung is about 60 gm heavier than the left. Both lungs have apex, base, costal and medial surfaces, and anterior, posterior and inferior borders. Right lung is divided by two cleft (oblique& horizontal fissure) into 3 lobes; left lung is divided by a single cleft (oblique fissure) into two lobes. The left upper lobe has a lingular segment corresponding to the middle lobe of the right lung. Each lung has a hilum through which principal bronchi enter the lungs along with arteries, and veins and lymphatics come out.

Each lung lobe is divided into bronchopulmonary segments which are defined as the tertiary or segmental bronchi together with the portion of the lung lobe they supply. These bronchopulmonary segments, ten in number in each lung, are roughly pyramidal in shape, their apices towards the hilum, their bases lying on the surface of the lung.

The trachea bifurcates into right and left principal bronchi. The right principal bronchus, shorter and more vertical than the left, is about 2.5 cm long and enters the root of the right lung opposite the 5^{th} thoracic vertebra. The left principal bronchus, narrower than the right, is nearly 5 cm long and enters the root of the lung opposite the 6^{th} thoracic vertebra (Snell,1995). On entering the lungs, the primary bronchi giving rise to 3 bronchi in the right lung and two in the left lung, each of which supplies a pulmonary lobe. Each lobar bronchus gives of repeated branches to supply bronchopulmonary segment, and by further ramification in ends to atrium. Atrium then leads to rounded alveolar sacs (Snell, 1995, Bannister, 1995).

The wall of the intrathoracic airways contain a spiral layer of smooth muscle which is functionally a syncytium. On contraction, this smooth muscle produces narrowing and shortening of airway. Functional airway smooth muscle reaches

upto respiratory bronchioles by term. So, failure of wheezy infant to responds to bronchodilators can not, therefore, be ascribed to absence of smooth muscle in the airway (Mckenzie and Silverman, 1998). The intrapulmonary bronchi are lined by pseudostratified ciliated columnar epithelium with some goblet cells. In smaller bronchioles, the goblet cells disappear and ciliated cells are low columnar to cuboidal. Scattered among them are few clara cells and neuroendocrine cells. Terminal bronchioles are lined by ciliated cuboidal cells. Their walls contain more smooth muscle. Respiratory bronchioles are lined by ciliated cuboidal cells which become simple cuboidal in smaller one. It is then continuous with the squamous epithelium of alveolar sacs and alveoli.

The epithelium of the alveoli is flat and called type I and type II pneumocytes. Type I cells completely cover the luminal surface of the alveoli and type II secretes surfactant. The air in the alveoli is separated from capillary blood by 3 layers of cells and membrane referred to collectively as the blood-air barrier (Bannister,1995) :

a) The cytoplasm of the epithelial cells
b) The fused basal lamina of closely apposed epithelial and endothelial cells.
c) The cytoplasm of the endothelial cells.

Particles of less than 300 Da size, if lipid soluble are readily absorbed. Breaks in the intercellular junction may enhance absorption. Cigarette smoke is a potent causes of such breaches. Exposure to smoke in early childhood may lead to increase respiratory disease by this mechanism (Mckenzie and Silverman, 1998).

The bronchial arteries supply nutrition to the bronchial tree and to the pulmonary tissue. Bronchial system drains mainly into the pulmonary venous system. The pulmonary circulation serves the respiratory function and the bronchial arteries are the source of nutrition. Lung tissue is supplied by sympathetic nerves derived from T_2 –T_5 and parasympathetic nerves derived from vagus.

There are two sets of lymphatics, both drain into the bronchopulmonary nodes:

Superficial vessels drain the peripheral lung tissue beneath the pulmonary pleura and flow round the borders of the lung and margins of the fissures.

Deep lymphatics drain the bronchial tree, pulmonary vessels and connective tissue, septa and accompany them towards the hilum, where they drain into the bronchopulmoanry nodes. From upper lobes lymphatics drain to superior tracheobronchial lymph nodes and from lower lobes to the inferior tracheobronchial lymph nodes.

ANATOMICAL DIFFERENCE BETWEEN THE LUNGS OF CHILDREN AND ADULT

There are several anatomical differences between the lungs of child and the lungs of the adult:

1) Conducting airways are proportionately larger than the respiratory airways in children compared with adult.
2) Airway resistance is more in the newborn and young child than in adult.
3) The diameter of the conducting airways are small in the infant than adult and more easily obstructed by inflammation, by mucus secretion and by the foreign bodies.
4) The chest wall and supportive structure of infants are softer so that chest wall retraction during respiratory distress is greater in infants than in older patients.
5) Airway of young infant contain relatively more mucous glands than the airway of adult and there are also age differences in the composition of the mucus. Increased volume of mucus possibly contributes to airway obstruction in infants.
6) The airway are probably more collapsible in response to pressure changes in early life than in adult.
7) In infants, the collateral pathway of ventilation (the pores of Kohn and canal of Lambert) are less developed but in adult they are well developed and prevent collapse distal to occlusion of small bronchus or bronchioles (Haddad and Fontan, 2000).

PHYSIOLOGY OF RESPIRTORY SYSTEM

The obvious goal of respiratory system is to provide oxygen to the tissues and to remove carbon dioxide. To achieve this, respiration can be divided into four major functional events:

1) Pulmonary ventilation, which means the inflow and outflow of air between the atmosphere and the lung alveoli.
2) Diffusion of oxygen and carbon dioxide between the alveoli and blood.
3) Perfusion of the lungs by the flow of blood through the pulmonary capillary which transport O_2 and CO_2 to and from the cell.
4) Regulation of ventilation and other factors of respiration.

PULMONARY VENTILATION

Mechanics of pulmonary ventilation: The lungs can be expanded and contracted in two ways- 1) by downward and upward movement of the diaphragm to lengthen or shorten the chest cavity and 2) by elevation and depression of the ribs to increase and decrease the anteroposterior diameter of the chest cavity (Guyton,1996).

The mechanics of respiration is done by the process of inspiration and expiration. Inspiration is an active process. The movement of the diaphragm account for about 75% of changes in intrathoracic volume (Ganong,1999). Diaphragmatic contraction increases vertical diameter of the chest cavity and contraction of external intercostal muscles draw the ribs laterally increase transverse diameter (Bucket handle effect) and elevates the anterior end of the ribs thereby draw the sternum forward and increase the anteroposterior diameter of the chest cavity (Pump handle effect) (Snell,1995). During quiet breathing the intrapleural pressure at the base of the lungs which is about –2.5 mm Hg (relative to atmospheric) at the start of inspiration, decreases to about –6 mm Hg. The lungs are pulled into a more expanded position. The pressure in the airway becomes slightly negative and air flows into the lung. At the end of inspiration, the lung recoil pulls the chest back to the expiratory position, where the recoil pressures of the lungs and chest wall balance. The pressure in the airway

becomes slightly positive and air flows out of the lungs. Expiration during the quiet breathing is positive in the sense that no muscles which decreases intrathoracic volume contract. However, there is some contraction of the inspiratory muscles in the early part of expiration. This contraction exerts a breaking action on the recoil forces and slows expiration. This expiration is a passive process, accompanied by elastic recoil of lung and chest wall.

Work of breathing : The work of inspiration can be divided into three different fractions 1) that required to expand the lungs against its elastic forces, called the elastic work or compliance works 2) that required to overcome the viscosity of the lungs and chest wall structures, called tissue resistance work; and 3) that required to overcome airway resistance, called airway resistance work. During quiet respiration no muscle work is performed during expiration. In heavy breathing or when airway resistance used tissue resistance are great, expiratory work does occur. This is specially true in asthma in which airway resistance increases many fold (Guyton,1996) During nasal breathing in infancy, about 50% total resistance is nasal, 25% from glottis and large central airway and remainder 25% from peripheral. Thus infant are prone to respiratory difficulty with upper airway obstruction (Mckenzie and Silverman,1998).

Compliance of the lungs: The extent to which the lung expand for each unit increase in transpulmonary pressure is called their compliance (Stretchability). The normal total compliance of both lungs in an adult averages about 200 ml/Cm of H_2O pressure, that is 1 cm of H_2O transpulmonary pressure changes – lungs expands 200 milliliters (Guyton,1996; Ganong,1999).

Surfactant : Surfactant is a surface tension lowering agent lining the interior of the alveoli produced by type II alveolar epithelial cells. Surfactant is a mixture of Dipalmitoylphosphatidyl choline (DPPC), phosphatidyl glycerin, other lipid and proteins. It prevents collapse of the alveoli at expiration and prevents pulmonary oedema. Surfactant is important at birth for normal breathing (Ganong,1999).

Dead space and uneven ventilation : Since gas exchange in the respiratory tract occurs only in the terminal portions of the airways, the volume of air that merely fills the conducting passage without taking part in the gas exchange is called the dead space. In an average man it is equal to 150 ml and children is 2.2 ml/Kg (Silverman,1998). Because of this dead space, the amount of air ventilating the alveoli or alveolar ventilation is (500-150)X12 or 4.2L/m. Because of the dead space, rapid, shallow breathing produces much less alveolar ventilation than slow, deep respiration at the same respiratory minute volume (tidal volume times respiratory rate).

It is convenient to distinguish between the anatomic dead space (respiratory tract volume excluding the alveoli) and the physiological (total) dead space (volume of air not equilibrating with blood). In health, the two dead spaces are identical; but in disease states, some of the alveoli may be underperfused or some may be overventilated. The volume of air in the nonperfused alveoli and any volume of air in the alveoli in excess of that necessary to arterialize the blood in the alveolar capillaries are part of the physiological dead space (Ganong, 1998).

Lung volumes and capacities: The amount of air that moves into the lungs with each inspiration or the amount that moves out with each expiration is called the “tidal volume”. The air inspired with a maximal inspiratory effort in excess of tidal volume is the “inspiratory reserve volume”. The volume expelled by an active expiratory effort after passive expiration is the “expiratory reserve volume” and the air left in the lungs after a maximal expiratory effort is the “residual volume”. The space in the conducting zone of the airways occupied by gas that does not exchange with blood in the pulmonary vessels is the “respiratory dead space”. The volume of air that can be forcefully expired after a normal expiration is called “inspiratory capacity” and the volume of air that remains in lung after a normal expiration is called “functional residual capacity” which is the sum of expiratory reserve volume and residual volume. ”Total lung capacity” is the volume of air that remain in lungs after forceful inspiration “The vital capacity” is the amount of

air that can be forcefully inspired after a forceful inspiration, is frequently measured clinically as an index of pulmonary function. The fraction of the vital capacity expired in 1 second is 'timed vital capacity', also called "forced expired volume in 1 second or FEV_1" gives additional information; the vital capacity may be normal but the FEV_1 greatly reduced in diseases such as asthma. The amount of air inspired per minute is "pulmonary ventilation" or "respiratory minute volume" is normally about 6 L (500 ml/breathX12 breaths/min) in adult.

DIFFUSION

Diffusion of gases across the respiratory membrane in the lungs occurs passively along concentration gradient of different gases. CO_2 is 20 times more diffusible than O_2. Therefore the pressure differences that cause CO_2 diffusion are far less than the pressure differences required to cause O_2 diffusion. O_2 flows "downhill" from the air through the alveoli and blood into the tissues, whereas CO_2 flows "downhill" from the tissues to the alveoli. In each minute 250 ml of O_2 is taken up by the body and 200 ml of CO_2 is excreted. In the blood is mainly transported in combination with hemoglobin, and the oxygen-hemoglobin dissociation curve relating the percentage saturation of the O_2 carrying power of the hemoglobin to tissue. Percentage saturation of O_2 is influenced by P^H , temperature and 23DPG. When ↓ P^H, ↑Temperature, ↑23DPG, these causes shifting of the curve to the right means increase dissociation of O_2 from hemoglobin,↓affinity of hemoglobin and increase P_{50} (PO_2 at which hemoglobin is half saturated) and vice versa (Ganong,1998).

CO_2 is chiefly carried as bicarbonate and in combination with proteins, besides the small fractions of both gases dissolved in plasma. Alveolar ventilation is closely related to CO_2 excretion. If alveolar ventilation is reduced in proportion to CO_2 excretion, the arterial PCO_2 will rise and if alveolar ventilation become excessive, the arterial PCO_2 will fall. PCO_2 reflects alveolar ventilation and the production of CO_2.

PERFUSION

It is the flow of mixed venous blood through the pulmonary arterial circulation, distribution of blood to the capillaries of the gas exchange units and removal of it from the lungs through pulmonary veins. The pulmonary blood flow is not distributed uniformly throughout the lungs; it is greatest in the dependent regions and least in the superior regions. Regional blood flow is also governed by local factors, the most important of which is vesoconstriction secondary to alveolar hypoxia. Thus blood flow is diverted from poorly ventilated areas, and the matching of ventilation and perfusion is preserved. The ratio of pulmonary ventilation to pulmonary blood flow for the whole lung at rest is about 0.8 (4.2L/min ventilation divided by 5.5L/min blood flow). Ventilation perfusion ratio is altered in many cardiorespiratory diseases (Ganong,1998).

REGULATION OF RESPIRATION

Rhythmical discharges originating from the ‘respiratory center’ in the brain stem provide the basis for co-ordinated respiratory movements. From the respiratory center impulses travel in the autonomic fibres to reach the spinal motor neurons which drive the respiratory muscles. Impulses mediating conscious changes in breathing travel via the pyramidal tracts. The activity of the respiratory center is modified by a variety of chemical and neural stimuli so that respiration can meet the changing metabolic needs of the body. Chemical stimuli arises from peripheral and central chemoreceptors, sensitive to changes in H^+, CO_2 and O_2 concentration of the blood. Ventilation is increased when the peripheral chemoreceptors in carotid and aortic bodies are stimulated by hypercapnia, acidosis or hypoxia. Central chemoreceptors in the brain stem are stimulated by increased in H^+ concentration of CSF. A rise in PCO_2 of the arterial blood is accompanied by increasing acidity of both blood and CSF, and therefore stimulates both central and peripheral chemoreceptors.

PULMONARY FUNCTION TESTS (PFT)

Function of the respiratory system is to provide sufficient oxygen and wash out carbon dioxide from the body. Optimum gas transfer is effected by ventilation and perfusion, depend on many variables. Many of these factors can be measured to study composite pulmonary function. Dynamic lung volumes and capacities can be assessed , so also the pressures, and flow-volume rates. Lung compliance and elasticity, airway resistance and respiratory rate contribute to the ultimate function. Finally, the effect of respiratory function can be monitored by arterial blood gas estimation which reflects adequacy of ventilation, perfusion and diffusion. Theoretically, all the above mentioned parameters can be studied to assess pulmonary function (Amdekar and Ugra,1996).

The major clinical indication for performing pulmonary function tests are as follows (Swaminathan, 1999):

1) To determine if symptoms and signs such as dyspnoea, cough and cyanosis are of respiratory origin.
2) To characterize pulmonary diseases physiologically. Although PFTs are not diagnostic for a specific pulmonary disorder, they may suggest disease etiology.
3) To monitor the course of lung function impairment. PFTs often provide more sensitive, objective and quantitative information concerning changes in lung function than patient history and physical examination.
4) To determine the effectiveness of therapy e.g. aerosol bronchodilator treatment in asthma and steroids in interstitial lung diseases.
5) To assist in the preoperative planning of general anesthesia and in anticipating the need for postoperative oxygen and or assisted ventilation. Preoperative pulmonary function evaluation is particularly important in patients with chest wall deformities e.g. scoliosis, collagen vascular diseases and neuromuscular diseases.

TYPES OF PULMONARY FUNCTION TESTS

1. **Ventilatory function** can be assessed by :
   - Spirometry : It will give the results of the volumes and flow rates, flow volume loops peak expiratory flow rate, Volume-Time Curve combined resistance of lung and airway.
   - Bronchial provocative tests : Aerosol bronchodilators, histamine, methacholin and exercise challenge.
   - Peak expiratory flow rate (PEFR) : Can be measured by peak flow meter.
   - Plethosmography : To see [will give the results of total lung capacity (TLC), Functional residual capacity (FRC), Residual volume (RV), and Air way resistance (R_{aw})], total lung volume.
   - Gas dilution : (helium dilution in closed circuit or N_2 wash out in an open circuit)- For lung volumes(Total lung capacity).
   - Oesophageal pressure : For lung volumes (Total lung capacity)
   - Single breath or multiple breath nitrogen (N_2) wash out : To see distribution of ventilation
   - Forced oscillator : To see respiratory resistance (airway, lung and chest wall resistance)
   - Pneumotachograph : To see flow.
   - Ventilatory response to exercise or sleep study by- pediatic pneugram.

2. Diffusion of gas (Gas exchange) can be assessed by-
   - Blood gas analysis : To see gas exchange. O_2 and CO_2 through the respiratory membrane.
   - Measurement of diffusing capacity: The carbon monoxide (CO) method.
   - Pulse oximetry: To see oxygen saturation.

3. Perfusion can be assessed by catherization.

4. Ventilation-perfusion can be assessed by radionuclide lung scan.

VENTILATORY FUNCTION TESTS

Spirometry

Spirometry is indicated in all the children with diagnosis of asthma, chronic/recurrent cough or wheeze, exercise induced cough or breathlessness and with recurrent respiratory manifestations (Amdekar and Ugra,1996). Spirometry can be reproducibly done from the age of 5 years but these values should be interpreted with individual considering age, sex, height and nutritional status (Faridi et al,1994; Chowgule et al,1994). Subdivision of lung volumes show changes in different lung diseases that help us to understand the nature of the defect.

Spirometry measures the volume of air exhaled from the lungs during a maximal expiratory maneuver. The forced vital capacity is the total volume of air that can be exhaled after a full inspiration. Though it is measured by spirometry, it is technically a volume and not a flow rate. Forced expiration is begun at TLC and ends at RV and usually takes less than 3 seconds. Forced expiratory volume in 1 second FEV_1) is the volume of air forcefully expired from full inflation in the first second. Both FVC and FEV_1 are recorded in litres. Healthy children are able to exhale>80% of their FVC in 1 second. There is a trend for the FEV_1/FVC ratio to decrease slightly after early adulthood. Since children younger than 7 years may not inspire to TLC or exhale to RV, valuable information concerning airway function in this age group can be obtained by a partial ‘flow volume curve’ measuring maximal expiratory flow at FRC (V_{max} FRC). Any spirometer must calculate or display the FVC, FEV_1, and PEFR. Healthy children and adolescents aged 6 years to 16 years perform pulmonary function studies as reproducibly as healthy adults (Chowgule et al,1994).

Interpretation of spirometry: Spirometry not only allows the characterization of a patients lung function against reference values but also defines the disease class. Most lung diseases can be classified as obstructive, restrictive or mixed-type processes. The VC is decreased in both obstructive and restrictive disease but while the RV is increased due to gas trapping in obstructive disease resulting

in an increased RV/TLC ratio, the RV, FRC and TLC are all proportionately reduced in restrictive disease. Since the flow rates are not affected in most restrictive lung disorders, the FEV_1/FVC ratio will be normal but this is reduced in obstructive diseases. Thus the FEV_1/FVC ratio usually allows disease classification without the need to measure lung volumes if the facilities do not exist (Table 1).

The configuration of the flow-volume and volume-time curves when taken from a maximal forced expiration can provide valuable information about the disease class when compared with the normal curve. In obstructive diseases, flow decreases rapidly as gas exhaled giving a flow volume curve which is convex towards the volume axis. In restrictive disease, the curve shape is normal but smaller than the normal curve.

Spirometric data interpretation should include an assessment of the quality of the study. The following criteria have been laid down for an acceptable test :

(a) Appropriate curve shape which is artifact free

(b) Sustained expiration for at least 3 seconds

(c) At least 3 forced vital capacities within 10% of the best effort and

(d) Satisfactory effort by the patient as observed by the tester.

Table 1 : Obstructive versus restrictive lung disease

	Obstructive	**Restrictive**
Spirometry		
FVC	Normal or reduced	Reduce
FEV_1	Reduced	Reduced
FEV_1/FVC	Reduced	Normal
FEF_{25-75}	Reduced	Normal or reduced
PEFR	Normal or reduced	Normal or reduced
Lung volumes		
TLC	Normal or increased	Reduced
RV	Increased	Reduced
RV/TLC	Increased	Unchanged
FRC	Increased	Reduced

FEV_1: Forced Expiratory Volume in one second

FVC : Forced Vital Capacity

FEF: Force expiratory flow

PEFR: Peak expiratory flow rate

RV : Residual Volume

TLC : Total Lung Capacity

FRC: Functional residual capacity

Problems are usually due to inadequate patient effort or coughing and can be corrected by additional instruction, encouragement or allowing the patient to rest. Forced expiratory at 25% to 75% of FVC ($FEF_{25\%-75\%}$) is a more sensitive indication of mild small airways obstruction than FEV_1. Its disadvantage lies in a wide range of normal and also that the value can change depending on the lung volume at which it is measured (Swaminathan,1999).

Bronchial provocative tests

Following provocation and challenge test done to see hyper responsiveness of the airway when spirometry shows normal value in suspected cases-

a) *Pharmacological challenge test :* It is done by solution histamine and acid phosphates of methacolin. This is given by aerosol by nebuliser at regular interval until 20% fall in PEFR or FEV_1. Amount required in patient of airway reactive disease is lower than that of normal person.

b) *Exercise challenge test :* It is considered when exercise induced bronchial asthma is suspected. Child is allowed to run for 5-6 minutes at a rate sufficient to produce a heart rate >170 beats/m. The fall in PEFR or $FEV_1$15% from previous base line values will be considered positive.

c) *Bronchial provocation with aerosolized antigen :* It is risky procedure confined to laboratories only (Wilson and Silverman,1995).

Body plethosmography, gas (helium) dilution and oesophageal pressure technique

Direct measurement of lung volume (TLC,FRC and RV) and R_{aw} were measured. These methods are used to determine absolute lung volume, usually at FRC. Body plethosmography is preferable both for procedural and technical reasons but the instrument may not be available everywhere. With the rapid electrically activated mouth shutter used in plethosmography, it is possible to obtain the measurement of thoracic gas volume (TGV) which is the same as FRC. It is also possible to repeat this measurement until a consistent minimal value for each patient is determined. The calculation of lung volume by this technique is based on Boyle's law which states that the product of pressure and volume of gas remain constant, in a closed space at a fixed temperature. It is also possible to perform spirometry in the body plethosmograph itself, either using a pneumotachygraph or by connecting the mouth piece to a spirometer. If the child is afraid of being confined alone, the study can be performed with the child seated on an adult's lap. Hence, both lung volumes and flow rates can be measured using a body plethosmograph.

Airway resistance (R_{aw}) in older children is usually assessed using the body plethosmograph. Almost half the total airway resistance in children may be from the upper airway so direct measurement of R_{aw} may not clearly represent resistance in the pulmonary airways. Resistance is usually converted to its reciprocal, airway conductance (G_{aw}) because this value is linearly related to lung volume. Conductance can then be normalized for increases in lung volume with growth by dividing it by FRC (specific airway conductance, SG_{aw}). SG_{aw} changes little during childhood in normal. Airway resistance is measured because spirometry only assesses the combined interaction of lung recoil and airway resistance and cannot distinguish which of these has resulted in a given change in lung function. However, in most clinical situations, children can be managed without measurement of R_{aw} as decreased flow is rarely due to abnormal lung recoil.

Gas dilution method is simple. A known concentration of gas (usually helium which is nonabsorbable, inert) is breathed in a closed circuit and allowed to equilibrate with as already in the lung. FRC or RV are calculated from measuring gas (Spiro and Roberts,1991).

Estimation of FRC by the helium dilution method is less reliable in the younger child because it requires more cooperation and does not measure poorly ventilated or non-ventilated areas of the lung. However, this method is relatively inexpensive and useful in children without obstructive airway disease. If the TGV measured by plethosmography exceeds the FRC (He) by more than 400 ml, it indicates significant gas trapping. Once the patient's FRC (or TGV) and vital capacity is known, the residual volume (RV) can be calculated. RV is one of the most variable measurements of lung function in children and must be interpreted with caution. RV cannot be measured by a spirometer, only calculated indirectly which may not be accurate.

Total lung volume is accurately measured by oesophageal pressure technique in which balloon contain catheter placed in the lower third of the oesophagus,

balloon is inflated by 0.3-0.5 ml air then with help of plethysmographic pressure changes total volume is calculated.

Total lung volume is over estimated by plethysmograph and under estimated by helium dilution in airway obstructive (moderate to severe) disease, in this case oesophageal pressure technique is accurate (Rodenstein and Stanescu, 1982).

Pediatric pneumogram

Quantification of ventilatory pattern during sleep is useful in diagnosis of respiratory control disorders specially in infants with apnoea. In this group all apnoea longer 15 seconds are abnormal. Heart rate below 80 up to 3 months, below 70 for 3-6 months, and below 60 over 6 month of age, are abnormal if sustained for 10 seconds. Any apnoea with bradycardia or, cyanosis is abnormal. Periodic breathing should not exceed 4% of total sleep time, except in preterm infants (Kulpati and Talwar, 1992).

Forced oscillator

The child sat by the equipment and breathed quietly through a pneumotachograph via a soft rubber mouth piece. Superimposed on the child's breathing was a sine wave of airflow transmitted at a frequency of the respiratory tract (5-7 Hz). Airflow was measured by the pneumotachograph, and mouth pressure by a strain gauge transducer connected to a side arm close to the mouth. After amplification, the flow and the pressure signals were recorded simultaneously on a direct writing recorder. Total respiratory resistance was derived from the pressure/flow relation recorded at the mid inspiratory point (Cogswell, Hull, Milner, 1975).

Single breath or multiple breath N_2 wash out

The most sensitive test of the uniformity of ventilation is the slope of phase III of the single breath N_2 wash out curve. When elevated above 2.5% N_2/L, it indicates non-uniform distribution of ventilation. The closing volume or phase IV

of the curve reflects the elastic properties of the lung and is elevated in small airway disease.

Forty breath nitrogen washout curve is more difficult to perform. If elevated it also indicates non uniform distribution of ventilation and can provide data regarding the size of the poorly ventilated lung compartment.

ASSESSMENT OF PULMONARY GAS EXCHANGE OR DIFFUSION

Blood gas analysis

Arterial blood gas analysis provides the most sensitive index of lung function [oxygen (O_2) uptake and alveolar ventilation] in infants and children. The arterial O_2 tension is generally the most sensitive index of lung disease and is most likely to be abnormal in patients with apparently minimal lung disease. The arterial CO_2 tension reflects the adequacy of alveolar ventilation.

Arterial samples must be collected free of air bubbles and analyzed as soon as possible, preferably within 15 minutes. Polypropylene syringes are acceptable for transport or storage of the specimen. If necessary, arterial samples may be stored for up to three hours in “melting ice” (4^0C) without interfering significantly with the results.

Filling the dead space of most syringes and needles with heparin when withdrawing small samples of blood can lead to under estimations of the Pco_2 by 10 to 30%, depending on the size of the sample and the syringe. The volume of heparin used should be less than 10% of the sample size.

In small infants in whom frequent arterial samples are required, sample size may be no greater than 0.5 ml. In older children a larger sample size should be obtained (Winkler , Huntington, Wells, 1974; Hansen and Simmons,1977). The radial and temporal arteries are the most accessible superficial arteries in newborn infants whereas radial artery is often most accessible in children. The Allen test to determine ulnar artery patency should be performed prior to radial artery puncture. Temporal artery puncture should be avoided and placement of

an indwelling temporal artery catheter has been associated with focal brain necrosis.

Measurement of diffusing capacity

The carbon monoxide method (DL_{co}) : A small amount of CO is breathed into the alveoli and the partial pressure of the CO in the alveoli is measured from appropriate alveolar air samples. The carbon monoxide pressure in the blood is essentially zero because hemglobin combines with this gas so rapidly that its pressure difference of CO across the respiratory membrane is equal to its partial pressure in the alveoli. Then, by measuring the volume of CO absorbed in a period of time and dividing this by the alveolar carbon monoxide partial pressure, one can determine accurately the CO diffusing capacity.

To convert CO diffusing capacity to O_2 diffusing capacity, the value is multiplied by a factor of 1.23 because diffusion coefficient for oxygen is 1.23 times that for CO. Thus for average diffusing capacity for CO in young man 17 ml/min/mm Hg and that for O_2 is 21 ml/min/mm Hg (Guyton and Hall,1996).

Pulse oximetry

Noninvasive means of measuring oxygen saturation of hemoglobin. Pulse oximetry is extremely reliable and relatively inexpensive compared with blood gas analysis. It exploits the light absorbency properties of hemoglobin. deoxygenated blood absorbs more light in the red spectrum. Oxygenated blood absorbs more infrared light. The pulse oximeter measures the visible and infrared absorbencies and calculates the oxygen saturation. The light source and sensor of the oximetry probe must be placed directly opposite each other in an accessible place (e.g nail-bed of the finger or toe, ear lobe). The pulse meter must exactly match that of the patient. To know if the reading is reliable, the pulse rate recorded on the pulse meter must reflect the true pulse of the patient- hence the term *“pulse-oximeter”*. Cross check by counting the radial pulse or auscultate the heart. Unless these two are correlated (which can only be confirmed by an independent pulse count) the oximetry reading is not reliable.

Indications for pulse oximetry*:* Any condition for which a patient may require supplemental O_2. Any patient with respiratory complaint. Elevated respiratory rate(tachypnoea). All pneumonia patients. All patients with wheezing, with or without pneumonia. Any patient in respiratory distress (tachypnoea and danger signs)- chest indrawing, cyanosis, lethargy, inability to feed. Complaint of chest pain, with or without shortness of breath (i.e. suspected myocardial infarction cases). Status epilepticus patients, septic patients, comatose patients or lethargic patients with no sign of dehydration.

However, the accuracy depends on adequate perfusion. Its utility may be limited in patients with significant vasoconstriction and poor peripheral perfusion (Frankel,2000).

ASSESSMENT OF PULMONARY PERFUSION

Methods of measurement of pulmonary circulation : Assessment of circulatory function in the pulmonary vasculature depends on measuring pulmonary vascular pressures and cardiac output. Clinically, these measurements are commonly made in intensive care unit, capable of invasive monitoring and in cardiac catheterization laboratories. With a flow directed pulmonary artery (Swan-Ganz) catheter , pulmonary arterial and pulmonary capillary wedge pressures can be measured directly, and cardiac output can be obtained by the thermodilution method. Pulmonary vascular resistance can be calculated according to the equation-

$$PVR = 80(PAP-PCW)/CO$$

Where,

PVR= Pulmonary vascular resistance (dyne's/cm^5)

PAP= Mean pulmonary artery pressure (mm Hg,15 mm Hg)

PCW= Pulmonary capillary wedge pressure(mm Hg)

CO= Cardiac output (L/min)

The normal value for pulmonary vascular resistance is approximately 50-150 dynes/cm^5

(Weinberger and Dragen,1998)

VENTILATION-PERFUSION BY LUNG SCAN

Various techniques exist to demonstrate uneven pulmonary ventilation and perfusion, by measuring the alveolar-arteriolar difference for O_2, CO_2 , or for inert gases such as He or N_2. These tests require arterial blood, but Klocke and Rahn have proposed urine examination to estimate arterial N_2 concentration. Radionucleotide lung scan technique using radioactive krypton, xenon, CO_2 and macroaggregates of radioactive human albumin are also available to study ventilation and perfusion.

REFERENCE VALUES OF PULMONARY FUCTION TESTS

Lung volumes and flow rates vary with age, sex and ethnic group. Lung volumes in adult Indian and Bangladeshi patients have been shown to be 15-20% lower than Caucasian values (Faridi et al,1994; Choudhury et al,1997). In children it is particularly important to have age and sex matched reference values from a control population.

When a patient's performance is evaluated against reference values from a similar population, it is called *referenced testing*. A patient's performance when tested against his or her own past performance is referred to as *longitudinal testing*. This is particularly valuable when observing a positive response to treatment or confirming progression of disease (Swaminathan,1999; Pfaff,1994).

PEAK EXPIRATORY FLOW RATE (PEFR)

Definition

Peak expiratory flow rate is the maximal expiratory flow rate sustained by a subject for at least 10milliseconds expressed in Litre per minute (L/min) (Wright and Mc Kerrow,1959; Leiner, abramowitz, Small, 1963; Perks, Cole, Steventon, 1981; Jain, Kumar, Sharma, 1982). PEFR had been used as measurement of ventilatory capacity for long since mainly because of a much simpler and less tiring procedure than maximum voluntary ventilation (MVV), single forced expiration in a simplified device required for measurement (Brown and Sly,1980; Cross and Nelson,1991).

Physiological consideration and historical background

The basis of most of the various single-breath methods is the same: the volume of air expired is measured against time by means of a spirometer with either a recording drum or a timing device. There are some differences of opinion about the most suitable interval of time over which to measure the volume and about the relative merits of a recording drum or a timing device, but it is generally agreed that methods of this kind are clinically valuable and give results which are comparable with those of the M.V.V. All the methods, however, suffer from the disadvantage that the necessary apparatus is cumbersome and normally requires connection to an electric supply. Attention has therefore been directed to the possibility of using the maximum forced expiratory flow rate (or “peak flow rate”), instead of what is in effect the average for a limited time, as a measure of ventilatory capacity; such a measurement seemed likely to lend itself to the use of a simpler instrument, consisting merely of a flowmeter with a device for recording the maximum flow.

According to Donald (1953) the empirical use of a measurement of this kind is very old. “The physician asked a patient with respiratory disease to whistle or blow a candle out was crudely assessing the maximum respiratory velocities”.

Donald suggested that a “simple, whistle-like instrument” might be developed and might become a standard clinical tool.

Later on the instrument, called a “pneumometer” incorporates an aneroid manometer fitted with a device for recording the maximum flow rate. Rates up to about 700 L/min. can be recorded. Pneumotachograph has led to many observations of the expiratory flow pattern, but no systematic attempt to use the peak flow rate as a physiological measurement in its own right appears to have been made.Pneumotachograph themselves have had very low resistances (of the order of 2 mm. H_2O/100 L/min) which gave a linear relationship between flow and pressure. Both the earlier and the latest forms of pneumotachograph suffer from the disadvantage of being fairly complicated and not easily portable. A much simpler and more robust and portable instrument, designed specifically for measuring the peak flow rate, called by them the “puffmeter”. Wright and McKerrow described the peak flow meter in 1959. Since that time the instrument has been used widely and has been found reliable over long periods. The Wright peak flow meter depends upon the rotation of a vane attached to a spiral spring (Wright and McKerrow,1959). Movement of the vane uncovers an annular orifice and the point at which pressure behind the vane balances the force of the spring depends upon the flow rate. The standard Wright’s peak flow meter ranges from 50-1000 L/min and weight 900 gm. Later on various portable smaller and cheaper instruments suitable for domiciliary practice have been developed.

The peak flow gauge (Ferraris Development and Engineering Co. Ltd, London N18 3JD, UK) correlates closely with the PFM (Bhoomkar et al,1975) but is too bulky to be carried easily. The pulmonary monitor (Perks et al,1981; Vitalograph Ltd, Maids Moreton House, Buckingham MK18 ISW, UK) is pocket-sized, reliable and gives reproducible values that correlate well with the PFM (Haydu et al, 1976). Unfortunately the monitor has a scale differing from the standard PFM. This would make comparison between trials difficult. Lastly a mini-Wright peak flow meter (MPFM) has become available (Airmed, Clement Clarke International

Ltd, Airmed House, Edinburgh Way, Harlow, Essex CM20 2ED, UK; Wright,1978; Perks et al,1979).

mini-Wright Peak Flow Meter (mWPFM)

This instrument is simpler version of the Wright peak flow meter now used worldwide. Measurements with this instrument correlate well with peak expiratory flow rate measurements from the larger Wright peak flow meter (AirMed,Ltd., Harlow, England), with observed correlation generally higher than 0.90 (Cook, Evans, Scherr, 1989; Wright,1978; Brown and Sly,1980; Levin and Gold,1981). The instrument is a light plastic Cylinder measuring 15x5cm weighing 72 gm (without mouth piece). It consists of a spring piston that slides freely on a rod within the body of the instrument (Figure 2A). The piston drives an independent sliding indicator along a slot marked with a scale graduated, low range from 50-350 L/min and high range from 60-800 L/min. The indicator records the maximum movement of the piston, remaining in that position until return to zero by the operator. In use the machine must be held horizontally with air vents uncovered (Wright,1978; Perks et al,1979). The instrument may be cleaned easily in running water or in a detergent solution. Details of washing and sterilization methods are supplied in leaflet along with the meter. Studies involving long term use of this device, particularly the miniWright peak flow meter, has demonstrated that performed well for many months and with as may as 4000 blows (Burn,1979; Lebowitz et al,1982). Performance of accuracy of the miniWright peak flow meter meets national asthma education programme (NAEP) guideline variation <± 5% with standard Wright peak flow meter (Clement Clarke int. Ltd, 1997).

Factors affecting the peak expiratory flow rate (PEFR)

Anthopometric measurements*:* Standing height is the best single predictor in childhood for PEFR. It has more or less linear relationship with weight, body surface area and chest expansibility (Primhak et al,1984; Chowgule et al,1995).

Age and Sex*:* Age has linear relationship with PEFR but sex has no significant relation with PEFR in children when height is considered (Nairn et al,1960). But age has curvilinear in male and linear relationship in female of adult (Malik et al,1980). When only age is considered, PEFR differs in both sexes (Carson, Hoey, Taylor, 1989).

Malnutrition*:* Current malnutrition impairs the PEFR (Primhak and Coates,1988) and chronic malnutrition is associated with reduction in PEFR/Age, perhaps because of slow growth of the large airways (Carswell et al,1980).

Environmental effect: Smoking and environmental tobacco smoke increases airway variability, thereby affect pulmonary function test as a PEFR (Fielder et al,1999; Frischer,1993; Gregg and Nunn,1989). Summer time particulate air pollution have independent effect on PEFR and are associated with decline in PEFR in children (Neas et al,1996; Neas et al,1995).

Respiratory tracts and thoracic cage: The PEFR occurs early in the expiration and is dependent on personal effort, large airway resistance, possible compressive effect of the manoeuvre on the intrathoracic airway (Swaminathan,1999; Primhak et al,1984; Empey,1972; Pfaff and Morgan,1994). Thoracic cage deformity and respiratory tract infection including microfilaremia has adverse effect on PEFR (Enarson,1984).

How to use mini-Wrght peak flow meter

The purpose and technique of the test should be explained to the subject followed by a demonstration of its performance. Person should perform the test in standing position holding the peak flow meter horizontally without interfering with the movement of the marker (arrow) or covering the slot. He or she should asked to take deep breath then exhale it by forceful expiration as fast as possible after maintaining air tight seal between lip and mouth piece of the instrument. Reading should be taken keeping the instrument horizontal position (Gregg and Nunn,1973; Lebowitz,1992). Besides this, distributor of miniWright peak flow meter supply leaflet which contains detail procedure with demonstration (Fig 2A). The process of daily recording of PEFR has depicted clearly (Fig 2B).

Clinical interpretation of values of PEFR

Personal based value of PEFR can be compared to normal reference population and also with predicted value from regression equation (Pande,1986; Nunn and Gregg,1989). Diurnal variation in PEFR is a good indicator of circadian bronchial lability responsiveness. PEFR records with diurnal variation of 20% or more is a good clinical and occupational indicator of asthma (Lebowitz,1992; Sly,1986).
PEFR variability- diurnal variation in peak flow rate expressed as the formula as follows (Hassan, Hossain, Mahmud,1999)-

$$\textbf{Daily variability} = \frac{HighestPEFR - LowestPEFR}{HighestPEFR} \times 100$$

Bronchial provocation test by exercise in 'exercise induced asthma' is diagnostic when PEFR falls 15% of personal based after exercise and reversibility of airway obstruction is evidenced by an increased in PEFR more than 20% after an adequate dose of nebulized bronchodilator is diagnostic for asthma (Silverman,1998) but bronchial reversibility of an increased at least 10% in PEFR after aerosol therapy is strongly suggestive of asthma (Sly,2000).

Self management of bronchial asthma is advised to maintain a peak flow chart and personal based result should be interpreted in following ways-

Green zone (Safe zone) - 80-100% of personal best result
Yellow zone (Zone of alert)- <80%->50% of personal best result
Red zone (Zone of emergency)- <50% of personal best result (Cross and Nelson,1991; Hassan et al, 1999)

Beasley et al presented a much more detailed plan, based on the first PEFR on the day *before bronchodilator.* The important element of this scheme is as follows: If the PEFR is ≥70% of personal best, then maintainance regimen of twice daily inhaled bronchodilator and inhaled corticosteroid is continued. A value <70% of personal best result requires a period of doubling of the inhaled corticosteroid dose. At <50% of personal best result, a course of oral steroid is

triggered, and the patient makes telephone contact with the physician (Cross and Nelson, 1991).

Peak flow monitoring specially valuable for detecting deterioration of asthma, for predicting acute exacerbation of asthma and its management. Availability of peak flow measurement not only allows formulation of a management plan with criteria for both intensification of therapy and recourse to medical assistance. Regular measurement of peak flow allows objective determination of effect of therapy (Linna,1993; Boggs, Wheeler, Washbouron, 1998; Jose, Garcia, Santos, 1995). Peak flow measurement can be used to titrate maintenance treatment and deserve wider use in monitoring the adequacy of treatment of asthma (Glass,1989).

PEFR is highly sensitive and accurate index of airway obstruction (Gregg,1987). It can be used as a guideline of admission and discharge of asthma when:

PEFR value >60% of expected- Admission probably unnecessary

40-60% of expected- Consider admission

<40% of expected- Admission probably necessary

(Taylor,1994)

Peak flow measurement is sensitive to the muscles of respiration (Lockhart,1960). So, serial measurement of PEFR in Gullain Barre syndrome or progressive flaccid paralysis to predict the involvement of respiratory muscle is clinically important to give warning of the hypoventilation and need for ventilatory support (Brown and Sly, 1980).

METHODOLOGY

STUDY PERIOD

The study period was between 1st January, 1999 and 30th September, 2000, for a period of twenty one months.

PLACE OF STUDY

The study was carried out in the 5 different schools in Dhaka city (Viqarun Nisa Noon School and College; Dhanmondi Govt. Boys; Sher-E-Bangla Nagar Govt. Boys; Sher-E-Bangla Nagar Govt. Girls school and Primrose KG school, Shyamoly), in the capital city of Bangladesh.

TYPE OF STUDY

This was a prospective cross sectional study.

DATA COLLECTION PROCEDURE

Considering the age (5-15 years) and socioeconomic status (higher, middle and lower class) the students from 5 different schools in Dhaka city were included in the study. Permission was taken from Principals/Headmasters of the institute. From each school targeted samples were selected randomly as per roll number in the class. All the selected students were interviewed before inclusion into the study. Informations were taken from the parents regarding the students of KG one to class III and directly from the students of class IV to class X. Students who fulfilled the inclusion criteria were separated, proper clinical examination was conducted and questionnaire were appropriately filled up. Height was measured by stadiometer and weight was recorded by bathroom scale without shoes and minimum clothes.

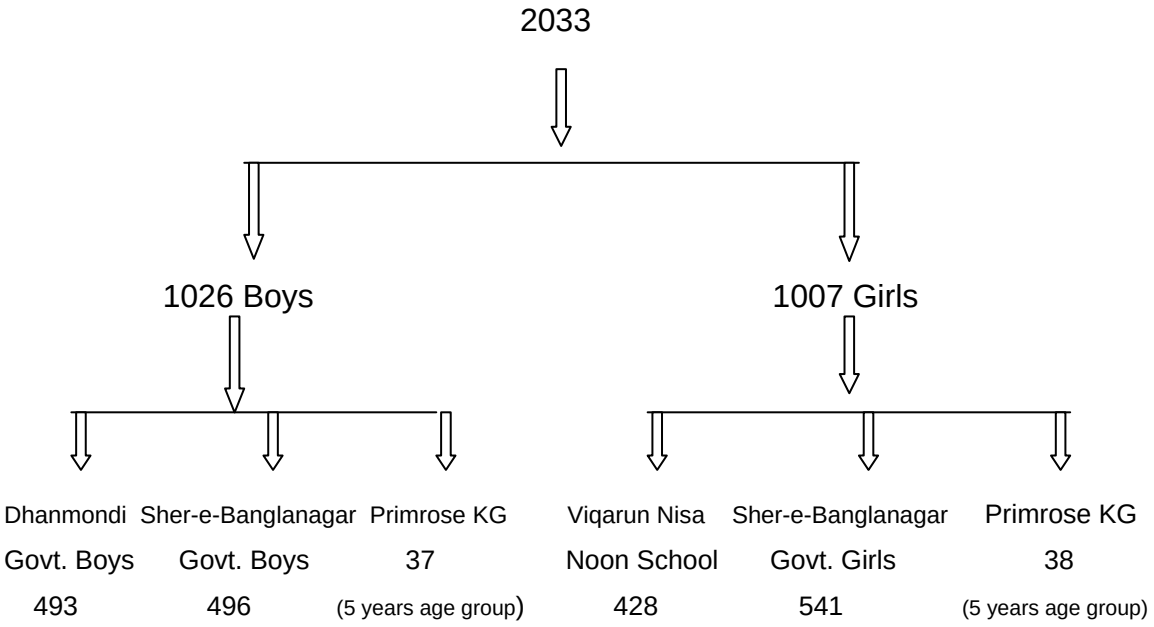
Six [3 low range(50-350 l/min) and 3 high range (60-800 l/min) model] well functioning miniWright Peak Flow Meter (mWPFM) were used to record PEFR (L/min). High range model was used when values >350l/min were found. Before

asking to perform peak flow (10 students in each group), students were demonstrated how to use mWPFM correctly. For each determination the child was instructed to make a maximal inspiratory effort and then to make the maximum and most rapid expiratory effort possible in standing position. Most of the students were given trial 2-4 times then serial 3 blows for PEFR were registered in individual sheet after the child had become familiar with the technique. Average 33 samples were collected in each day of total 62 days visits. Sample collection was started from the second wk. of Feb,2000 and completed by mid July,2000.

Before going to collect the samples at school a pilot programme was conducted under the direct supervision of guide of this thesis to teach the investigator, about the use of mWPFM, to demonstrate the reproducibility of PEFR. Piloting was done at Dhaka Shishu Hospital among the normal dischargable patients of different age and sex who did not suffer from respiratory diseases during the hospital stay.

Sampling: Total more or less 2033 samples with equal proportion of sex from all socioeconomic status were targeted and collection of samples were shown in figure III.

Figure III : Sampling frame



INCLUSION CRITERIA

1. Sex- boys and girls
2. Age- 5 to 15 years
3. Normal healthy school children of Dhaka city

EXCLUSION CRITERIA

1. Children who have been suffering from asthma or having past history of asthma or wheeze.
2. Child having the thoracic deformity, or history of ARI within two weeks.
3. Child having history of atopic condition like eczema, hay fever, or atopic rhinitis.

STATISTICAL ANALYSIS

Statistical analysis was done using the statistical package for the social science (SPSS) program in computer. Linear and multiple regression analysis was performed by using age, weight and height as the independent variables and PEFR as the dependent variable. Independent sample test and group test statistics were also done.

RESULTS

The study population included 2033 children from five different schools of Dhaka city. Table-II shows the distribution of study children according to school. The sample size is nearly similar in all schools except children from Primrose Kinder Garten where only 5 years age group was found.

Table II : Study population according to schools

SL. No.	Name of school	No. of students	Percentage
1	Dhanmondi Govt. Boys	493	24.20
2	Sher-E-Bangla Nagar Govt. Boys	496	24.40
3	Viqarun Nisa Noon School	428	21.00
4	Sher-E-Bangla Nagar Govt. Girls	541	27.00
5	Primrose KG & school	75	3.40
Total		**2033**	**100**

Table III : Sex distribution

Sex	Number	Percentage	M:F ratio
Boys	1026	50.5	1.02:1
Girls	1007	49.5	
Total	2033	100	

Table III shows the sex distribution of study population (n=2033), among which 1026 and 1007 were boys and girls respectively, male female ratio being 1.02:1 (nearly equal).

Table IV : Anthropometric measurements and PEFR (l/min) of study children (n=2033)

Parameters	Sex & No. of samples(n)	Range	Mean	Standard deviation
Age (month)	Boys (n=1026)	61-191	131.89	35.52
	Girls (n=1007)	60-191	127.34	35.87
Height (cm)	Boys (n=1026)	103-185	143.37	17.21
	Girls (n=1007)	100-165	149.98	14.16
Weight (kg)	Boys (n=1026)	14-92	35.58	13.02
	Girls (n=1007)	14-82.50	35.35	12.24
Body surface area (sq.m)	Boys (n=1026)	0.6-2.06	1.16	0.28
	Girls (n=1007)	0.6-1.95	1.15	0.26
PEFR (l/min) Average of 3	Boys (n=1026)	113.3-633.3	349.2	109.5
	Girls (n=1007)	100-533.3	308	88.8
PEFR (l/min) Best of 3	Boys (n=1026)	120-640	359.9	110.7
	Girls (n=1007)	110-540	319.2	90.1

Table IV shows the anthropometric parameters and PEFR with its descriptive statistics of 2033 normal students. Their age ranged between 5 years to 15 years 11 months. Range, mean and standard deviation were shown in both sexes. However, average PEFR was calculated from the mean of 3 blows of individual sample. Best of 3 attempt (blow) of PEFR of each sample was considered normal and in all statistical analysis. Variation between highest and average value of PEFR was only 3.0% in boys and 3.5% in girls.

Figure 4 A shows the mean PEFR (regression line)of total sample combined boys and girls and, Fig 4 B shows the mean PEFR (regression line) of boys and girls separately (shown in different colours). The mean PEFR of girls remained linearly always below the boys when mean line compared between the sex.

Figure 5 A and B show the PEFR (l/min) of boys and girls in relation to height with positive correlation when PEFR was considered dependent and height as an independent variable. Their coefficient of correlation was (r=0.926 for boys and r=0.896 for girls) highly significant (*p<0.001)*.

Table V : Regression equation for prediction of PEFR (l/min) from different independent variables.

Model	Sex	Variables		Regression equation PEFR (l/min)	SEE*
		Dependent	independent		
1	Boys	PEFR	Ht (cm)	= 5.96 x Ht - 494.74	41.70
	Girls	PEFR	Ht (cm)	= 5.70 x Ht - 478.90	40.04
2	Boys	PEFR	Age (mo)	= 2.79 x age - 9.23	48.80
	Girls	PEFR	Age (mo)	= 2.20 x age+38.06	43.09
3	Boys	PEFR	Ht(cm)&Age (mo)	= 4.03 x Ht + 1.03 x age-355.14	38.64
	Girls	PEFR	Ht(cm)&Age (mo)	= 3.49x Ht + 0.98 x age-294.74	36.60
4	Boys	PEFR	Ht(cm), Age (mo) & Wt (kg)	=3.36x Ht + 1.07x age + .89x Wt-295.90	38.26
	Girls	PEFR	Ht(cm), Age (mo) & Wt (kg)	=2.99 x Ht + .95 x age + .75x Wt-247.97	36.43

* Standard error of the estimate

Table V shows the regression equation (derived from the regression analysis and ANOVA test) where PEFR of individual person was considered dependent variable and other anthropometric parameters as independent variables. These regression equations enabled us to construct the nomogram.

Figure 6A & B : Show the nomogram relating to peak expiratory flow rate (PEFR) at ordinate to height at abscissa with mean and 95% confidence limits (both sex) which had been derived from regression equation.

Table VI : PEFR (l/min) of Bangladeshi normal children in relation to height interval (n=2033).

Height interval (cm)	**Boys**		**Girls**		*p* value
	n	PEFR mean *(±SD)*	n	PEFR mean *(±SD)*	
100 – 110	18	164.44 *(28.53)*	20	143.00 *(17.19)*	<.02
110.5 – 120	89	206.29 *(28.29)*	94	193.40 *(38.39)*	<.01
120.5 – 130	157	249.42 *(38.35)*	173	234.79 *(35.28)*	<.001
130.5 – 140	192	311.82 *(41.01)*	176	290.11 *(40.35)*	<.001
140.5 – 150	179	360.94 *(40.52)*	244	349.87 *(48.59)*	<.02
150.5 – 160	178	432.35 *(57.08)*	265	406.79 *(46.44)*	<.001
160.5 – 170	172	494.24 *(45.78)*	35	445.71 *(48.28)*	<.001
170.5 – 180	38	546.57 *(48.72)*			
180.5 – 190	3	550.00 *(50.00)*			
Total	1026		1007		

Table VI : Shows distribution of PEFR (l/min) according to height interval of normal children (5-15 years), in both boys and girls. The values of PEFR of girls were significantly lower than that of boys.

Figure 7 A & B : Scatter diagrams depict the relationship of PEFR (l/min) with age (month) and there positive correlation (r = .898 for boys & r = .878 for girls *p* <.001). But the relationship in case of boys was greater than that of girls.

Figure : 8 A & B : Nomogram relating normal values of PEFR (l/min) derived from regression equation to age (1026 boys and 1007 girls) with 95% confidence limit. PEFR values in boys were higher than that of girls.

Table VII : PEFR (l/min) of Bangladeshi normal children in relation to age interval (n=2033)

Age interval		**Boys**		**Girls**		***p***
Month	Year	n	PEFR mean *(±SD)*	n	PEFR mean *(±SD)*	**value**
60 – 71	5	59	194.40 *(41.03)*	69	177.97 *(40.96)*	<.02
72 – 83	6	65	213.53 *(31.53)*	82	209.39 *(35.49)*	.46
84 – 95	7	80	244.62 *(34.41)*	92	235.00 *(49.09)*	.09
96 – 107	8	74	264.45 *(35.73)*	92	265.43 *(42.22)*	.87
108 – 119	9	89	305.39 *(49.45)*	82	287.56 *(43.67)*	<.01
120 – 131	10	104	337.41 *(43.34)*	98	318.57 *(44.72)*	<.01
132 – 143	11	134	358.50 *(49.69)*	91	341.75 *(49.45)*	<.01
144 – 155	12	120	408.91 *(54.81)*	125	365.84 *(49.14)*	<.001
156 – 167	13	102	445.78 *(54.41)*	132	398.10 *(44.53)*	<.001
168 – 179	14	102	496.56 *(61.65)*	87	418.96 *(44.61)*	<.001
180 –191	15	97	509.07 *(51.13)*	57	445.08 *(39.19)*	<.001
Total		1026		1007		

Table VII: demonstrates the distribution of PEFR according to age interval in boys and girls. Independent sample test showed that among age categories of 6,7 and 8 years, the mean difference of PEFR value between boys and girls had no significant difference but the values were lower in girls than that of boys. However in all other age categories the mean values of PEFR between boys and girls had significant difference (range of significance $p<.02$ to $p < .001$)

Figure : 9 A & B : Show scatter diagram of PEFR (l/min) in relation to weight (kg) of boys and girls which revealed positive correlation coefficient with highly significant relationship.

Figure : 10 A & B : Scatter diagram show PEFR (l/min) in relation to body surface area (sq.m) with positive correlation with highly significant relationship.

Table VIII : Correlation coefficient (r) and level of significance between PEFR (l/min) and anthropometric parameters.

Parameters	Correlation with	Correlation Coefficient	*P* value
Height			
Boys (n = 1026)	PEFR	r = .926	<.001
Girls (n = 1007)		r = .896	<.001
Age			
Boys (n = 1026)	PEFR	r = .898	<.001
Girls (n = 1007)		r = .878	<.001
Body surface area			
Boys (n = 1026)	PEFR	r = .849	<.001
Girls (n = 1007)		r = .837	<.001
Weight			
Boys (n = 1026)	PEFR	r = .827	<.001
Girls (n = 1007)		r = .809	<.001

Table VIII : Shows the summary of correlation coefficient (r value) and the level of significance between different anthropometic parameters and PEFR in case of boys and girls. Highly significant correlation was observed in all anthropometric parameters but height correlated with PEFR (l/min) more than any other parameters.

Table IX : Comparison of normal PEFR applying different model of regression equation in different age group.

Parameters				PEFR (l/min)			
Age	Height (cm)	Weight (kg)	Sex	Model 1 (Ht)	Model 2 (Age)	Model 3 (Ht&Age)	Model 4 (Ht,Age,Wt)
6 yr. (72 mo)	114	20	boys	184	192	179	181
			girls	171	186	173	177
9 yr. (108mo)	131	27	boys	286	292	288	283
			girls	269	272	268	265
12yr.(144mo)	145	35	boys	370	392	377	376
			girls	348	355	353	348
15yr.(180mo)	163	50	boys	476	493	487	487
			girls	450	434	450	447

Df 14 t = o.145 p> 0.1 (Between model 1 & model 2)

Table IX : Shows the PEFR values obtained by applying regression equation on different age groups considering similar height and weight of both the sexes. It observed that values in model- 2 based on age alone was always higher than the values calculating from any other model but difference was not significant (p>0.1).

Figure 11 A, demonstrates the comparison of mean PEFR(l/min) value of Bangladeshi boys (indicated by continuous mean line) with British boys(indicated by interrupted mean line) and figure 11B, depicts the comparison of mean PEFR (l/min) in Bangladeshi girls (line indicated by continuous mean line) with British girls (indicated by interrupted line). It reveals that mean values PEFR of Bangladeshi boys and girls become lower initially up to few centimeter of height then PEFR value become marginally higher when height is increasing.

Table X : Comparison of PEFR values of the present study with other studies

Studies	120 cm (Height)		140 cm (Height)		160 cm (Height)	
	Boys	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
Present study, 2000	*220*	*205*	*340*	*319*	*458*	*433*
Bejaponpitak et al,1999; Thiland	236	214	306	283	377	352
Host et al,1994; Denmark.	236	219	321	308	420	416
Udupihille,1994,Srilanka	271	254	403	367	507	478
Swaminathan et al,1993;Madras.	205	193	386	272	368	350
Kashyap et al, 1992;Tribal, Indian.	202	170	304	263	405	352
Sanz et al, 1990;Australia.	252	237	352	341	452	445
Carson et al, 1989;Dublin.	222	213	342	324	461	435
Malik et al, 1981/82;Punjab.	222	216	320	314	418	412
Wall et al 1982; North America.	240	228	327	319	450	427
Parmar et al, 1977; India.	198	229	300	312	400	398
Godfrey et al, 1970; UK.	212	211	318	317	423	422

Table X : Comparison of values of PEFR (l/min) Predicted from regression equation in relation to height in studies of different places of the world. It revealed that excepting a few studies PEFR value obtained in present study was more or less similar with other studies.

DISCUSSION

Peak expiratory flow rate (PEFR) of 2033 normal children (5 to 15 years) from 5 different schools were measured to understand the normal value among Bangladeshi children (Table II), male female ratio being 1.02:1 (Table III). This study found the difference of values of PEFR (liter/minute) between the boys and girls in relation to height, weight, age, body surface area, specially in respect to height. PEFR values of girls (in relation to height) were always lower than that of the boys (figure 4B) which was statistically significant (TableVI). The difference of PEFR in boys and girls were also observed by other investigators (Host et al ,1994; Kashyap, Puri, Bansal, 1992 and Parmar et al,1977). But some studies (Godfrey, Kamburof, Nairn,1970; Badaruddin et al,1992; Murray and Cook' 1983) observed equal values of PEFR in both the sexes.Excepting 6,7 and 8 years age group PEFR values in relation to age were also significantly lower in girls than boys. However, the factors that determine PEFR, are predominantly expiratory muscle effort, lung elastic recoil pressure and air way size (Primhak et al,1984). The muscle effort intern depends on the physical strength and physical activity. It is possible that this lower values in girls were due to physiological reason and better performance of the boys.

The positive correlation of PEFR with height, age, weight and body surface area was observed in both the boys and girls which means that the value of PEFR increased with increase in those anthropometric parameters. The most significant correlation was observed between PEFR and height (Fig 5A and 5B, TableVIII) similar to other studies (Godfrey et al, 1970; Malik et al,1981; Malik et al,1982; Sagher, Rushdi,Hweta,1999). Thus the height had been found to provide a good basis for prediction of normal values of PEFR (Murray and Cook,1963). Other investigators (Dugdale and Moeri, 1968 ; Nairn et al ,1960) also found the superiority of height as an independent parameter which correlated well in PEFR and with other ventilatory functions. Pulmonary measurements such as forced vital capacity(FVC), forced expiratory volume in one second (FEV_1) and peak

expiratory flow rate (PEFR), (which are volumetric) are best correlated with height (Primhak et al,1984). One study (Chowgule et al, 1995) observed that, for clinical evaluation of child's lung function, height was the best independent parameter in comparison to age and weight. Several recent studies (Udapihille,1994; Sagher et al,1999; Benjaponpitak et al,1999) had also shown the highest correlation coefficient between PEFR with height. Moreover, the superiority of the correlation coefficient for height can be confirmed by simple inspection of scatter diagram (Figure 5A and 5B). There was no disagreement regarding positive correlation of PEFR with height as an independent body parameter. Standing height is the best predictor of PEFR in children (Wall et al,1982) and height should have the first preference for prediction of PEFR because of more accuracy, easily measurable at any place and it's highly significant relationship with PEFR.

Age was the second variable which had positive correlation with peak flow rate (PEFR) in this study (Figure 7 A & B). Correlation coefficient values were less than that of the height but greater than the values observed in relation to body surface area and weight (Table VIII). Our observation was also comparable to the findings of some other studies (Primhak et al ,1984 and Carson et al, 1989). Those studies showed that age had significant effect on PEFR with positive correlation in children. But in adults, PEFR is not increased with age rather it decrease with age (Srinivas, Chia, Poi, 1999).

Significant association was observed between PEFR with body surface area (Figure : 10 A & B) and with body weight (Figure 9 A & B). But the correlation of PEFR with body surface area was more significant than that of weight. On the other hand, the level of significance of correlation of PEFR with body surface area and with weight were less than that of height and age parameters. Such result may be due to wide variation in weight and height within same age groups. This was a possible explanation for wide scatter of PEFR values in the weight (Figure : 9 A & B) and in the body surface area (Figure : 10 A & B).

The ventilatory lung function like maximum breathing capacity (MBC). forced vital capacity (FVC) and forced expiratory volume in first second (FEV_1) has good correlation with peak expiratory flow rate (Kashyap et al,1992; Lockhart et al,1960). PEFR (l/min) values in relation to height interval in the present study were comparable to those obtained in other studies (Benjaponpitak et al,, 1999; Host et al, 1994; Sanz, Mortorell, Snez,1990). The PEFR was more or less similar with those studies in relation to height interval of the children. However some studies (Malik and Jindal,1985; Swaminathan, et al, 1992; Chowsgule et al, 1995) had shown the lower values PEFR than that of present study. This may be due to nature of studied population, socio-economic status and sample size of the study. Our results were close to the results of studies having large sample size (Carson et al, 1989). It is well recognized that peak expiratory flow rate may be different in normal population due to minor error in technique resulting in spuriously low value. Instrument variation may also give different values. Wright Peak Flow Meter (WPFM) will give the lower value than that of the mini Wright Peak Flow Meter (mWPFM) (Wille and Svensson, 1989). We have used 6 well calibrated mWPFM. Distribution of PEFR (l/min) as per age interval of normal children showed comparable values (Carson et al,1989). Boys and girls have significant difference in individual age category (excepting 6, 7 and 8 years age groups) (Table VII) and it was observed more when age increased.

The regression equation for calculation of PEFR (l/min) in children were best when separate equation for boys and girls were calculated. The applied parameters were height, age and height-age combined. When combined height and age were considered as independent variables, PEFR improved slightly than when height and age were considered separately (Table V and Table IX).Studies in neighboring India and Denmark (Verma et al, 2000; Host et al, 1994) observed that accuracy of predicted value of PEFR was more when age was considered along with height, which supporting the finding of the present study. However, addition of multiple variables slightly improved the predicted result (Table IX) but the small increase in accuracy is probably offset by the increase in complexity (Wall, Olsan, Bonn, 1982).

We found very little difference in prediction accuracy of regression equation constructed with standing height or age alone versus those using several anthropometric measurements. (Table IX). Similar results were observed by other studies (Kashyap et al, 1992; Benjaponpitak at al, 1999) also. However PEFR value calculated by applying age (in month), was slightly higher than that of applying other formula but the difference of values were not significant ($t = 0.145$ $p>0.1$). Prediction equation considering age should not be applied beyond the age (60 months to 191months) included in this study. Because, in higher age group there is significant chance of error in the PEFR values obtained from age-based equation.

Nomogram of PEFR (l/min) in relation to height (Figure 6 A & B) of normal boys and girls (5-15 years) can be used with 95% confidence limit. Such nomogram also were formulated by other investigators (Godfrey et al, 1970, Nairn et al, 1961, Malik et al, 1982, Swaminathan 1992 and Sagher, 1999) but there was no difference of PEFR for boys and girls in their studies. However, we have constructed an age based nomogram with 95% confidence limit derived from age based regression equation (Figure 8 A & B) separately for boys and girls. Though there was no study showing age based nomogram but we have constructed it as age correlated with the PEFR close to the height in our study. Verma et al (2000) showed height and age based nomogram for predicting median value of PEFR (l/min). Carson et al (1989) constructed a centile chart to find out normal PEFR in relation to age but such centile chart may overestimate the PEFR value.

When mean PEFR (l/min) values calculated from prediction formula of different studies different height to compare (Table X, and figure 11A and B) our result, it reveal that mean predicted PEFR values of present study was a bit higher with significant difference between boys and girls' values than that of previous British studies (Godfrey et al,1970; Nairn et al,1963; Table X). Difference may be due to instrumental variations (as British studies were done by Wright peak flow meter) and characteristics of studied population. Several studies (Wall et al,1982; Carson et al,1989; Table X) observed significant difference of mean values of

PEFR of boys and girls similar PEFR values which support our findings. PEFR values obtained in present study were also similar with other study (Sanz et al, 1990) but a Srilankan study (Udupihille, 1994) showed the higher values of PEFR (Table X) than that of present study. However, those findings suggest that PEFR in population of present study has difference in comparison to other countries but similar to most of the countries.

PEFR (l/min) predicted from height based regression equation was the most consistent finding in a good number of studies (Benjaponpitk et al, 1999; Sanz et al, 1990; Parmar et al, 1977) including ours. Our results appear to be reliable due to large sample size and high correlation coefficient with body parameters and cab be used as a normal reference value for normal Bangladeshi children (5-15 years).

SUMMARY

This cross sectional prospective study was conducted to establish normal values of PEFR for Bangladeshi children. Peak expiatory flow rate (PEFR) is a lung function test which is easily measurable and reproducible but base line value of PEFR has not been studied in large scale among Bangladeshi children.

A total of 2033 (1026 boys and 1007 girls, nearly equal in ratio) normal children (5 – 15 years), were selected randomly to obtain peak expiratory flow rate (PEFR) from five different school of Dhaka city. The mini-Wright peak flow meter was used to measure peak flow rate in a standard way. The highest of three reading was taken as the correct value. Anthropometric parameters including body weight and height were recorded appropriately and body surface area was calculated. Data were analyzed by SPSS program.

Strong correlation was found between PEFR with height. age, body surface area, body weight and sex. The regression equations for PEFR were determined for boys and girls considering height and age separately as independent variables. Correlation of height with PEFR was the highest in comparison to other anthropometric parameters (age, body weight and body surface area).

The boys had significantly higher values of PEFR than the girls at any height. PEFR values of Bangladeshi children were nearly similar to British and Indian children, similar to North American and recent Western studies but lower than that of Srilankan children. Studies in neighboring countries (Srilanka, India, Thailand) observed that PEFR in boys was significantly higher than the girls which strongly support the findings of the present study. Nomogram were constructed in relation to height and in relation to age separately for boys and girls. Findings of this study suggested to prefer height based nomogram to age based nomogram because height correlated best with PEFR.

CONCLUSION AND RECOMMENDATION

Diagnosis and management of bronchial asthma requires assessment of pulmonary function specially ventilatory functions. The peak expiatory flow rate (PEFR) measurement is a very simple, reliable, reproducible ventilatory function test which can be performed by using mini-Wright peak flow meter (a cheap, portable instrument). This study concluded that :

- There is significant difference of PEFR between Bangladeshi boys and girls (5-15 years).
- Height is the best predictor of PEFR.
- Age, body weight and body surface area also correlate with PEFR but less predictive in comparison to height.
- The PEFR value of Bangladeshi children is nearly similar to the other countries.
- Result of this study can be used as a standard (PEFR value) for Bangladeshi boys and girls.
- Further study is needed to understand the difference (if any) of PEFR between rural and urban normal children of Bangladesh.

BIBLIOGRAPHY

Amdekar YK and Ugra D,(1996) “Pulmonary function tests”; *Indian J Pediatr*; 63:149-152.

Austin JB, Kaur B, Anderson HR, Burr M, Harkins LS, Strachan DP et al, (1999) “Hayfever, eczema, and wheeze: a nationwide UK study (ISAAC, international study of asthma and allergies in childhood)”. *Arch Dis Child*; 81: 225-230.

Austin JB, Russell G,(1997 “Wheeze, cough, atopy and indoor environment in the Scotish Highlands”. *Arch Dis Child*; 76: 22-26.

Badaruddin M, Borhanuddin M, Khatun MF, Ahmad K,(1992) “Peak expiratory flow rate in normal children- A preliminary report”. *Bangladesh J Child Health*. Vol 16(3/4):89-91.

Badaruddin M, Borhanuddin M, Khatun MF, Ahmad K,(1993) “Peak expiratory flow rate and its relation to chest expansion”. *Chest and heart Bulletin* ; Vol XVII, No 1 : 17-19.

Bannister LH (1995) “Respiratory system” In: Williams PL (editor),*Gray’s Anatomy*, 38th edition, pp: 1628-1676, London, ELBS with Churchill Livingstone.

Beasley R, Cushley M, Holgate ST,(1989) “A self management plan in the treatment of adult asthma”. *Thorax*;44:200-204.

Benjaponpitak S,Direkwattanachai C,Kraisarin C,Sasisakulporn C, (1999) “Peak expiratory rate values of students in Bangkok”. *J Med Assoc Thai*; Nov,82(suppl)1:S137-143.

Bhoomkar A, Davies S, Geary M, Hills EA, (1975) “Comparison of peak flow gauge and peak flow meter”. *Thorax*;30:225-227.

Boggs PB, Wheeler D, Washburne WF, Hayati F,(1998) “Peak expiratory flow rate control chart in asthma care: chart construction and use in asthma care”. *Ann Allergy Asthma Immunol*. Dec;81(6):552-562.

Brancazio LR, Laifer SA, Schwartz T,(1997) “Peak expiratory flow rate in

normal pregnancy". *Obstet Gynecol*. Mar;89(3):383-386.

Brown LA and Sly RM,(1980) "Comparison of mini-Wright and standard Wright peak flow meters". *Ann Allergy*;45:72-74.

Burns KL, (1979) "An evaluation of two inexpensive instruments for assessing airway flow". *Ann Allergy* ; 43: 246-249.

Carson JWK, Hoey H, Taylor MRH,(1989) "Growth and other factors affecting peak expiratory flow rate". *Arch Dis child*;64:96-102.

Carswell F, Hellier J, Harland PS, Meakins RH,(1980) "Peak expiratory flow rate and malnutrition". *Trans R Soc Trop Med Hyg*. 74(6):814-816.

Choudhury S, Alam MS, Begum QN,(1997) "Lung function parameters of Bangladeshi male subjects in different living conditions". *Bangladesh Med. Res. Counc. Bull*. 23(1):30-33.

Chowgule RV, Shetye VM and Parmar JR, (1995) "Lung function tests in normal indian children". *Indian Pediatr*. 32(2): 185-191.

Clark NM,(1989) "Asthma self-management education. Research and implications for clinical practice". *Chest*, 95: 1110-1113.

Clarke C,(1997) miniWright peak flow meter. Clement Clarke International Ltd. Edinburgh Way Harlow, Essex CM20 2TT, England. Instruction Leaflet Cat No. 1902091.

Cogswell JJ, Hull D, Milner AD, Norman AP and Taylor B, (1975) "Lung function in childhood- III. Measurement of airflow resistance in healthy children". *Brit. J. Dis. Chest*, 69:177-187.

Connolly CK, (1981) "Variation of peak expiratory flow rate [letter]". *Thorax*;36(3) : 237-238.

Cook NR, Evans DA, Scherr PA, Speizer FE, Vedal S, Branch LG et al,(1989) "Peak expiratory flow rate in elderly population". *Am J Epidemiol*;130(1):66-78.

Creer TL,(1987) "Self-management in the treatment of childhood asthma". *J. Allregy Clin.Immunol*; 80: 500-505.

Crompton GK, Haslett C, Chilvers ER,(1999)"Disease of the respiratory system".

In Haslett C, Chilvers ER, Hunter JAA, Boon NA (editors), Davidson principles and practice of medicine, 18th edition, pp-350. London, Churchil livingstone.

Cross D and Nelson HS,(1991) “The role of the peak flow meter in the diagnosis and management of asthma”. *J Allergy Clin. Immunol*;87(1):120-128.

de Hamel FA, (1982) “The mini Wright peak flow meter as lung function device”. *NZ Med J*; 95:666-669.

Direkwattanachai, Limkittikul-K, Kraisarin-C, Sasisakulporn-C, Benjaponpitak-S,(1999) “Fluticasone propionate and bronchial hyperresponsiveness in childhood asthma”. *Asian-Pac-J-Allergy-Immunol*; 17(2): 63-67.

Drug Ther Bull, (1982) “Self monitoring of peak expiratory flow rate in asthma”. *Drug Ther Bull*. Sep 17;20(19):73-74.

Dugdale AE and Moeri M, (1968) “Normal values of forced vital capacity (FVC), forced expiratory volume($FEV_{1.0}$), and peak flow rate(PFR) in children”. *Arch Dis Child*;43: 229-233.

Empey DW,(1972) “Assessment of upper airways obstruction”. *Br Med J*;3: 503-505.

Enarson DA,(1984) “Microfilaremia and peak expiratory flow rate”. *Philippines. Trop Geogr Med*. Mar;36(1):17-20.

Epstein SW, Fletchar CM, Oppenheimer EA,(1969) “Daily peak flow measurements in the assessment of steriod therapy for airway obstruction”. *Br. Med J*; 25(1):223-225.

Faridi MMA, Gupta P and Prakash A, (1995) “Lung functions in malnourished children aged five to eleven years”. *Indian Pedtiatr*. 32(1): 35-42.

Fielder HMP, Lyons RA, Heaven M, Morgan H, Govier P, Hooper M,(1999) “Effect of environmental tobacco smoke on peak flow variability”. *Arch Dis Child*;80:253-256.

Frankel LR,(2000) “Pulse-oximetry, Monitoring of the critically ill infant and child” In: Behrman RE, Kliegman RM, Tewson HB (editors), *Nelson Text book of Pediatrics* 16th edn pp:249, USA,WB Saunders Co.

Frischer T, Khur J, Meinert R, Stat D, Karmaus W, Urbanek R, (1993)

"Influence of maternal smoking on variability of peak expiratory flow rate in School children". *Chest*; 104(4):1133-1137.

Frostad AB,(1980) "Reproducibility of the nasal provocation test and of measuring peak expiratory flow rate through the nose". *Allergy*. Apr;35(3):253-254.

Ganong WF, (1999)" Pulmonary function" In: *Review of Medical physiology*, 19th edition, 617-649. USA, Appleton & Lange.

Glass R, (1989) "Estimating the ideal peak flow rate". *Australian family physician*, Feb 18(2):168.

Godfrey S, Kamburof PL, Nairn JR , (1970) "Spirometry, lung volumes and air ways resistances in normal children aged 5-18 years". *Br. J. Dis. Chest*; 64: 15-24.

Goldstein RA, Geen LW, Perker SR,(1983) "Self-management of childhood asthma". *J. Allregy Clin. Immunol*; 72:522-525.

Graft-Lonnevig-V, Harfi H, Tipirneni-P,(1993) "Peak expiratory flow rate in health Saudi Arabian children living in Riyadh". *Ann Allergy*; 71(5): 446-450.

Gregg I,(1987) "The importance of asthma to general practitioner". *Practitioner* ; 231 : 471-477.

Gregg I and Nunn AJ,(1989) "Peak expiratory flow in symptomless elderly smokers and ex-smokers". *Br Med J*;22 Apr,298:1071-1072.

Gregg I and Nunn AJ,(1973) "Peak expiratory flow in normal subjects". *Br Med J*;4 Aug : 282-284.

Guyton AC and Hall,(1996) "Diffusing capacity of respiratory membrane, Physiological principles of gas exchange" In: *Text book of medical physiology*,9th ed, p-509, USA, WB Saunders Co.

Haddad GG and Fontan JJP,(2000) "The respiratory system, development and function" In: Behrman RE, Kliegman RM, Tewson HB (editors), *Nelson Text Book of Pediatrics*,16th edition,pp:1235-1253, USA, WB Saunders Co.

Hassan MR, Hossain MA, Mahmud AM, Kabir ARML, Ruhulamin M, Bennoor KS, (1999) "National asthma guidelines for medical practioners" Asthma Assocation of Bangladesh. IDCH campus, Mohakhali, Dhaka. 73-94.

Hansen JE, and Simons DH,(1977) “A systematic error in the determination of blood Pco_2”. *Am Rev Respir Dis* 115:1061.

Haydu SP, Chapman TT, Hughes DTD,(1976) “Pulmonary monitor for assessment of airways obstruction”. *The Lancet*;Dec 4:1225-1226.

Helms P,(1993) “Lung function testing”. *Current Paediatrics*, 3:92-95.

Henry RL, Mellis CM, South RT, Simpson SJ, (1982) “Comparison of peak expiratory flow rate and forced expiratory volume in one second in histamine challenge studies in children”. *Br J Dis Chest*. Apr;76(2):167-170.

Hetzel MR and Clark TJ,(1980) “Comparison of normal and asthmatic circadian rythms in peak expiratory flow rate”.*Thorax* ; Oct,35(10):732-738.

Ho TF, Ngiam TE, Koh PK, (1983) “Symptoms and peak expiratory flow rate: response to slow release theophylline preperation”. *Singapore Med J*; 24(5):280-283.

Host-A,Host AH, Ibsen-T, (1994) “Peak expiratory flow rate in healthy children aged 6-17 years”. *Acta- Paediatrics*; 83(12):1255-1257.

Jain SK, Kumar R, Sharma DA,(1982) “Peak expiratory flow rate in relation to anthropometric measurements in normal Indian subjects”. *East Afr Med J*. Sep;59(9):593-598.

Jaya SI and Fagbenro AO,(1995) “Peak expiratory flow rates of Carpet weaving children”. *Indian Pediatrics*;33(2):105-108.

Jose M, Garcia I, Santos PG,(1995) “Asthma self management education program by home monitoring of peak expiratory flow”. *Am J Respir Crit Care Med* Vol 151:353-359.

Joshi SK, Sharma P, Sharma V, Sitaraman S, Pathak SS, (1996) “Peak expiratory flow rates in Nigerian school children”. *Afr. J. Med-Med sci*;24(4):379-384.

Junqueira LC, Crneiro J, Kelley RO, (1998) “The respiratory system” Basic Histology, 9th edition, pp: 327-346, USA, Appleton & Lange.

Kabir ARML, Rahman F, Hasan Q, Ahmed F, Al-Amin, Arif et al,(2000) “Asthma and other atopic diseases in school-age children in Dhaka area using the ISAAC protocol”. *Bangladesh Pediatric Association, Bi-ennial*

conference and scientific programme (Dated 22-23rd June,2000), *Suvenir*: 51.

Kabir ARML, Hassan MR, Rahman AKMF, Mahmud AM, Hossain MA, Hossain BA et al (1999) “First national asthma prevalence study (NAPS) in Bangladesh : Prevalence of asthma features”, 1st international conference on Asthma and chest diseases, Mohakhali, Dhaka. Asthma Association of Bangladesh, p-6.

Kabir ARML, Rahman AKMF, Mannan MA,Chanda SK,Choudhury AT, (1998) “Prevalence of wheeze and asthma in children of a costal community of Bangladesh” : 3rd workshop on asthma and chest diseases, 4th –6th Nov,BCPS auditorium, Mohakhali, Dhaka. Asthma Association of Bangladesh. 2-4.

Kashyap S, Puri DS, Bansal SK, (!992) “Peak expiratory flow rates of healthy tribal children living at high altitudes in the Himalayas”. *Indian Pediatrics*. Vol 29, March: 283-286.

Kulpati DDS, Talwar D, (1992) “Pediatric pulmonary function testing”. *Indian Pediatrics*; 29 : 277-282.

Lebowitz MD, (1991) “The use of peak expiratory flow rate measurements in respiratory disease”. *Pediatr pulmonol*; 11:166-174.

Lebowitz MD, Knudson RJ, Robertson G, Burrows B,(1982) “Significance of individual changes in maximum expiratory flow volume and peak expiratory flow measurements”. *Chest*; 81:566-570.

Leiner GC, Abramowitz S, small MJ, Stenby VB, Lewis WA,(1963) “Expiratory flow rate. Sandard values for normal subjects. Use as a clinical test of ventilatory function”. *Am rev Resp Dis*;88:644-651.

Levin E and Gold MI, (1981) “The mini-Wright expiratory flow meter”. *Can Anaesth Soc J*,May;28(3):285-287.

Lockhart W, Smith DH, Mair A, Wilson WA,(1960) “Practical experience with the peak flow meter”. *Br Med J*. Jan 2:37-38.

Malik SK and Jindal SK, (1985) “Pulmonary function tests in healthy children”. *Indian Pediatrics.* Vol 22,September: 677-681.

Malik SK, Jindal SK, Sharda PK, Banga N, (1981) “Peak expiratory flow rate

of healthy school boys from Punjab". *Indian Pediatrics*. Vol 19, Feb:161-164.

Malik SK, Jindal SK, Sharda PK, Banga N, (1982) "Peak expiratory flow rates of school age girls from Punjab (Second Report)". *Indian Pediatrics*. Vol 18, Aug:517-521.

Malik SK, Jindal SK, Banga N, Sharda PK, Gupta HD,(1980) "Peak expiratory flow rate of healthy North Indian teachers". *Indian J Med Res*. Feb;71:322-324.

Michael D and Lebowitz,(1991) "The use of peak expiratory flow rate measurements in respiratory disease". *Pediatr Pulmonol*;11:166-174.

Milner AD and Ingram D, (1970) "Peak expiratory flow rates in children under 5 years of age". *Arch Dis child*; 45: 780-782.

Murray AB and Cook CD,(1963)"Measurement of peak expiratory flow rates in 220 normal children from 4.5 to 18.5 years of age" *The Journal of Pediatrics*. Vol 62,No. 2:186-189.

Mutius EV, (2000) "The burden of childhood asthma". *Arch Dis Child*; 82(Suppl II) : ii2-ii5.

Nairn JR, Bennett AJ, Andrew JD, Macarthur P, (1961) "A study of respiratory function in normal school children; the peak expiratory flow rate". *Arch. Dis Child*; 36: 253-260.

Neas LM, Dockery DW, Burge H, Koutrakis P, Speizer FE,(1996) "Fungus spores, air pollutants and other determinants of peak expiratory flow rate in children". *Am J Epidemiol*. Apr 15;143(8):797-807.

Neas LM, Dockery DW, Koutrakis P, Tollerud DJ, Speizer FE,(1995) "The association of ambient air pollution with twice daily peak expiratory flow rate measurements in children". *Am J Epidemiol*. Jan 15;141(2):111-122.

Nunn AJ and Gregg I,(1989) "New regression equations for predicting peak expiratory flow in adult". *Br Med J;*198:1068-1070.

Pande JN, Mohan A, Kchilnani S, Khelnani GC, (1997) "Peak expiratory flow rates in school going children". *Indian-J-Chest-Dis-Allied sci*; 39(2): 87-95.

Pande AH,(1986) "Prediction of peak expiratory flow rate from height and weight". *Indian J Pediatr*. Jul-Aug; 53(4):521-523.

Perks WH, Tams IP, Thompson DA, Prowse K, (1979) “An evaluation of the mini Wright peak flow meter”. *Thorax* ; 34: 79-81.

Perks WH, Cole M, Steventon RD, Tams IP, Prowse K, (1981) “An evaluation of the vitalograph Monitor”. *Br J Dis chest*;75: 161-164.

Parmar VR, Kumar L, Malik SK, (1977) ”Normal values of peak expiratory flow rate in healthy North Indian school children,6-16 years of age”. *Indian Pediatrics*.Vol XIV,No. 8:591-594.

Pfaff JK and Morgan WJ, (1994) “Pulmonary function in infants and children. Respiratory Medicine 1”, *Padiatric clinincs of North America*, 41(2): 401-423.

Polgar G and Promodhat V,(1971) “Pulmonary function testing in children :Techniques and standards”. Philadelphia, WB Saunders Co, pp 54-70.

Primhak RA and Coates FS,(1988) “Malnutrition and peak expiratory flow rate”. *Eur Respir J*;1:801-803.

Primhak RA, Biggins JD, Tsanakas JN, Hatzimichael A, Milner RDG, Karpouzas JG,(1984) “Factors affecting the peak expiratory flow rate in children”. *Br J Dis Chest*; 78: 26-35.

Rodenstein DO and Stanescu DC, (1982) “Reassessment of lung volume measurement by Helium dilution and by body plethosmography in chronic air-flow obstruction*”. Am. Rev. Resp. Dis*. 126:1040-1044.

Ruhulamin M, Hassan MR, Kabir ARML, Rahman AKMF, Mahmud AM, Hossain A et al,(1999) “First national asthma prevalence study (NAPS) in Bangladesh :Conclusions and recommendations”. 1st international conference on asthma and chest diseases, Mohakhali, Dhaka. Asthma Association of Bangladesh. 12-17.

Sadler TW, (1995) “Respiratory System” In; *Langmans Medical Embryology*, 7th edition, 240, USA, William and Wilkins.

Sagher FA,Roushdy MA,Hweta AM, (1999) “Peak expiratory flow rate nomogram in Libyan school children. *East Mediterr Health J*;5(3):560-564.

Shamssain MH and Shamsian N (1999) “Prevalence and severity of asthma, rhinitis, and atopic eczema: the north east study”. *Arch Dis Child*; 81:313-317.

Silverman M and McKenzie S (1998) " Respiratory disorder" In: Campbel AGM, McIntosh N (eds), *Forfar and Arneil's Text Book of Pediatrics*,5th edn, 489-501. London, Churchill Livingstone.

Sly PD and Robertson CF, (1990) "A review of pulmonary function testing in children". *J Asthma*; 27: 137-147.

Sly PD, Hibbert ME, Sci MP, Landau LI,(1986) "Diurnal variation of peak expiratory flow rate in asthmatic children". *Pediatr pulmonol*; 2(3): 141-146.

Sly M,(2000) "Allergic disorders, asthma" In: Behrman RE, Kliegman RM, Tewson HB (editors), *Nelson Text Book of Pediatrics*, 16th edition, 664, USA, WB Saunders Co.

Snell RS, (1995) " Thorax" In: *Clinical anatomy for medical students*, 83-84, 5th edn, USA, Appleton & Lange.

Spiro SG and Roberts CM, (1991) "Lung function tests". Medicine International, The Medicine Group (UK) Ltd. 3661-3668.

Srinivas P, Chia YC, Poi PJ, Ebrahim S, (1999) "Peak expiratory flow rate in elderly Malaysians. *Med J Malaysia*;54(1):11-21.

Swaminathan S, Venkateson P, Mukunathan, (1993) "Peak expiratory flow rate in South Indian children" *Indian Pediatr*; 30(2): 207-211.

Swaminathan S, (1999) "Pulmonary function testing in office practice". *Indian J Pediatr*; 66:905-914.

Taussing LM, Chernick V, Wood R, Farrell P, Mellins RB, (1980) "Standardization of lung function testing in children. Proceedings and recommendations of the GAP Conference Committee, Cystic Fibrosis Foundation". *The Journal of Pediatrics*, 97(4): 668-676.

Taylor MR, (1994) "Asthma: audit of peak expiratory flow rate guidelines for admission discharge". *Arch. Dis Child*; 70(5): 432-434.

The international study of asthma and allergies in childhood(ISAAC) Steering Committee. Worldwide variation in prevalence of symptoms of asthma, allergic rhinnoconjunctivitis, and atopic eczema: ISAAC. Lancet; 351: 1225-1232.

Uduphille-M, (1994) "Peak flow rate in Srilanka school going children of Sinhalese ethnic origin". *Respir-Med*; 88(3):219-227.

Verma SS,Sharma YK,Arora S,Bandopadhyay P,Selvamurthy W, (2000) "Indirect assessment of peak expiratory flow rate in healthy Indian children".*J Trop Padiatr* Vol 46:54-55.

Wall MA, Olson D, Bonn BA, Creelman T, Buist AS, (1981) "Lung function in North American Indian Children: Reference standards for spirometry,maximal expiratory flow volume curve and peak expiratory flow". *Am Rev Respir Dis*; 125*:158-162.*

Weinberger SE and Drazen JM (1998) " Disturbances in respiratory functions" In: Fauci AS, Braunwald E,Isselbacher KJ, Wilson JD, Martin JB, Kasper DL (editors), *Harrison's principles of internal medicine*, 14th edition, Vol 2, 1410-1413. USA, McGraw Hill.

WHO CARI Project, (1993) "A mannual for the management of the young child with acute respiratory infection". Directorate General of Health Services, Ministry of Health and Family Welfare, Government of Bangladesh: 2.

Wille S and Svensson K, (1989) "Peak flow in children aged 4-16 years". *Acta Paediatr Scand*; 78: 544-548.

Winker JB, Huntington CB, Wells DE and Befeler B, (1974) "Influence of syringe material on arterial blood gas determinations". *Chest* 66:578.

Wright BM, (1978) "A miniature Wright peak flow meter". *Br Med J*; 2 :1627-1628.

Wright BM and McKerrow CB,(1959) "Maximum forced expiratory flow rate as a measure of ventilatory capacity". *Br Med J*; 21:1041-1047.

Wood DW,(1969) "Pulmonary function testing in children". *Pediatric Clinics of North America* 16(1): 159-175