COMPARATIVE STUDY ON PULMONARY FUNCTION TESTS IN CHILDREN- SWIMMERS VERSUS NON SWIMMERS

DISSERTATION SUBMITTED FOR

M.D., BRANCH - V (PHYSIOLOGY)

APRIL - 2015

THE TAMILNADU

DR. M.G.R. MEDICAL UNIVERSITY

CHENNAI, TAMILNADU.

BONAFIDE CERTIFICATE

This is to certify that the dissertation titled **"COMPARATIVE STUDY ON PULMONARY FUNCTION TESTS IN CHILDREN- SWIMMERS VERSUS NON SWIMMERS"** is a bonafide record work done by **Dr. M.VISHNU PRIYA,** under my direct supervision and guidance, submitted to The TamilNadu Dr. M.G.R. Medical University in partial fulfillment of University for **M.D., Branch- V (Physiology).**

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DECLARATION

I, **Dr. M.VISHNU PRIYA,** solemnly declare that the dissertation titled **“COMPARATIVE STUDY ON PULMONARY FUNCTION TESTS IN CHILDREN-SWIMMERS VERSUS NON SWIMMERS”** has been prepared by me. I also declare that this work was not submitted by me or any other for any award, degree, diploma to any other University board either in India or abroad. This is submitted to The TamilNadu Dr. M.G.R. Medical University, Chennai in partial fulfillment of the rules and regulation for the award of **M.D. degree Branch- V (Physiology)** to be held in **April- 2015.**

Place : Madurai **Dr. M.VISHNU PRIYA**

Date :

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CONTENTS

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ABSTRACT

INTRODUCTION:

Active children are more likely to mature into physically active adults. When it comes to swimming, being in water is fun for children. This study compares the lung functions between children swimming regularly for the past two to three years and non-swimming children.

AIM AND OBJECTIVES:

To assess the pulmonary ventilation of the swimming and non-swimming children by recording Forced Vital Capacity (FVC), Forced Expiratory Volume in first second (FEV_1), Forced Expiratory Volume percentage (FEV_1 %) and Peak Expiratory Flow Rate (PEFR) with the help of a spirometer and to compare the values between them.

MATERIALS AND METHODOLOGY:

This study was conducted in our Institute. Ethical committee of our College granted approval for the study.

Study Group: 60 male and female children of age 8 to 12 years, from Dr. M.G.R. Stadium, Race Course, Madurai who has been swimming regularly for the past two to three years.

Control Group: Age, Sex and BMI matched 60 children who have not indulged in any sports activity.

Methodology: After getting informed written consent from the parents, basal anthropometric and cardiovascular parameters were recorded. The pulmonary functions were measured using portable spirobank-G. Spirometry was performed with the subject in the sitting position, head slightly elevated and nose clips applied. After taking a deep breath the subjects were asked to expire as fast and forcibly as possible into the mouth piece. The readings with the highest value were included for the study.

RESULTS:

Statistical analysis by student's t- test revealed that the anthropometric and basal cardiovascular parameters did not vary significantly between the study and control group **('p' > 0.05).** The pulmonary function tests show an increase in swimmers when compared with non swimmers **('p' < 0.05).**

CONCLUSION:

The present study concludes that exercise in the form of swimming for more than two years produces a significant improvement in the pulmonary functions which is directly proportional to the duration of swimming. Hence swimming inculcated at an early age makes the children grow into a healthy, confident and self- esteemed adults.

KEY WORDS:

Pulmonary function tests, spirometry, swimming, children.

INTRODUCTION

Children and sports go hand in hand. The importance of sports in the development of a child is a massive one. Active children develop into physically active adults. Physical activity and sports in children reduces the risk of obesity. It also increases their cardiovascular fitness, causes improvement in coordination and balance. Physical activity ensures them better sleep and improved social skills. Reducing sedentary time is equally important as increasing the exercise time for the health of an individual.

These days, physical fitness is well thought-out as the ability of the body to function competently and effectively both during work and leisure activities to be healthy, to be free from diseases and to face emergency. Physical strength is achieved through exercise, right nutrition and enough rest.

Children gain many benefits by being introduced to sports at an early age. They acquire physical exercise, become stronger and competitive, they realize the importance of team work and coordination, they learn to respect others, their self-esteem gets boosted and they appreciate the importance of hard work.

There are plenty of choices when it comes to picking up a sport that a child enjoys. Most children do not like the thought of exercising. When it comes to water sports and especially swimming, they are the favourite forms of exercise for children. Most children enjoy being in water. Children swim eagerly as it is joy for them.

The joy of messing around in the water allows them to exercise without even knowing it. Swimming provides toning and stretching exercises. It burns lots of calories. Swimming is an exercise using minimal expenditure and hence can be done by a person throughout his life time thereby keeping himself fit. Swimming is a type of aerobic exercise.

Various studies show that swimming is an excellent activity for children with many health benefits.

- Children who swim have a physical advantage than others by having increased vigour and strength. They also have increased joint mobility. The movements done during swimming are very useful for their body.

- They have strong and flexible muscles.

- They are also advanced in hand eye coordination, problem solving and socializing.

- They also develop psychomotor skills as they understand the concepts of distance and movement.

- The movements made by kids during swimming stimulate the nerve fibres in the brain. This increases their intelligence.

- Cognitive and social skills are improved. The cardio respiratory system is also strengthened.

- Swimming helps in cooling the body temperature and increases hunger.

The Centre Board for Disease Control and Prevention postulates that swimming can decrease anxiety and improve the mood. As swimming burns off the energy, it is good for these children. Though it is good for their health, it might save their life too. However, during swimming they need supervision and guidance.

Swimming is multi-dimensional. It may be done as recreational, occupational or as a competitive sport. In our country, swimming is looked upon as a sporting event, as a general activity and even as an occupation.

Previous studies by **Lakera SC et al.,** in **1984** have shown that the maximum effects on the lungs are produced by swimming than sports of other kind. During childhood and adolescence, there is a correlation between anatomical and physiological growth of lung, chest cage and airway.

As a child grows the lungs also grow proportionate to the height. Thus with each year the volume of the lungs and the maximal flow rates also increases. Girls obtain maximum lung volumes at early years when compared to boys. Even then, boys have lung volumes more than girls.

As per the study by **Nilesh Netaji Kate et al., 2012**, swimming for more than two years causes a major enhancement of the lung functions. This development is directly proportional to the duration of swimming.

Hence, this study is carried out to compare the lung functions between children swimming regularly for the past two to three years and non swimming children.

AIM AND OBJECTIVES

1. To compare the basal anthropometric parameters of swimmers and non swimmers.

2. To assess the pulmonary ventilation of the swimming and non swimming children by recording the dynamic lung volumes like Forced Expiratory Volume in first second (FEV_1), Forced Vital Capacity (FVC), Forced Expiratory Volume percentage ($FEV_1\%$) and Peak Expiratory Flow Rate (PEFR) with the help of a spirometer.

3. To compare the spirometric measurements of swimmers and non swimmers.

REVIEW OF LITERATURE

Historical Aspects:

Historically, study data indicates that prolonged aerobic working out programmes does not produce any change in the normal lung **Dempsey et al., 1977**. There are also other studies showing no changes in the lung volume based on height, age and vital capacity in trainings on land practiced for a short period of time **Sinning and Adrian 1968; Reuschlein et al., 1968; Kollias et al., 1972; Raven 1977; Kaufman and Swenson 1981.** Thus the lung size and the pulmonary functions are not affected by regular exercises even if they are of intensive type.

On the other hand, the sport of swimming is exceptional. Swimmers have greater values of lung function tests when compared to controls especially increase in the total lung capacities and the vital capacity **Cordain 1990; Andrew 1972; Zinman, Gaultier 1986; Pherwani 1989; Doherty, Dimitriou 1997**. Swimmers also had improved diffusion capacity of the lungs than non-athletes **Vaccaro 1980; Yost 1981; Miller 1989; Armour 1993.** In **1963, Mostyn et al.,** studied on the diffusion capacity of lungs in sports persons. He concluded that elite swimmers had values higher than other sports men.

At present, we do not know if the increase in the volumes of the lungs in swimmers is due to genetic factors **Barr-Or et al., 1994**,

- changes in the ability of the chest wall to expand **Zauner and Benson 1981**; **Clanton et al., 1987,**

- alveolar hyperplasia or expansion **Zauner and Benson 1981; Armour et al., 1993,**

- due to isotropic growth of the lungs **Courteix et al., 1997,**

- increase in strength of the muscles of respiration **Clanton et al., 1987; Zauner, Benson 1981; Doherty, Dimitriou 1997**, or

- the effect of swimming training practices **Andrew 1972; Cordain, Stager 1988; Clanton et al., 1987**.

Aerobic Exercise:

Aerobic exercise is a physical exercise of low intensity that utilizes oxygen. The energy needed for swimming is obtained through aerobic metabolism. The increased demand for oxygen from working muscles leadsto increase in heart rate and respiratory rate.

Advantages of doing aerobic exercise regularly are

- Enhanced mental health thereby reducing the stress of the individual; increase in cognition and decrease in the occurrence of depression.

- Aerobic conditioning- Here the muscle fibres of the heart are enlarged and strengthened thereby decreasing the resting heart rate and increasing the inotropic effect of the heart.

- Circulation is enhanced and blood pressure is decreased.

- It increases ventilation of lungs by strengthening the respiratory muscles.

- The total number of red blood cells is increased and therefore transport of oxygen is also increased.

- Reducing the hazard of acquiring Diabetes Mellitus.

There are various performance benefits also which include:

- Increases the aerobic metabolism in the muscles. Thus higher amount of energy can be obtained aerobically even if the severity of exercise increases.

- Increases muscular blood flow by formation of new blood vessels within the muscle sarcomeres.

- Increases the endurance of muscle by storing large amount of carbohydrates and fats.

- Muscle glycogen content is preserved as it makes the muscles to make use of the fats during exercise.

- Recovery rate of muscles from high intensity exercise is increased.

All of the above benefits are acquired with a minimum duration and frequency of exercise. It is recommended to do exercise three times a week each lasting for a minimum of twenty minutes. The Centre for prevention and control of diseases recommends a minimum of two and a half hours of aerobic exercise in a week for adults.

Of all aerobic exercises, swimming is a **moderate intensity exercise.** It helps in effective usage of oxygen by the lungs. Swimming is also a non-impact exercise since none of the joints is in contact with any solid surface. This is the basis for recommending swimming when someone is injured.

A variety of physiological changes occur in the human body when an individual swims continuously. Swimming practiced from early age brings about changes in anthropometric features and muscle characteristics. There is a report demonstrating that regular swimming for 10 weeks increases the myosin type I fibers and decreases type II fibers thereby enhancing the endurance and muscular efficiency. Swimmers grow tall faster; vital capacity increases relative to height; airflow and diffusing lung capacity increases proportional to height. As said by **Jack H Willmore et al.,** in **1994**, swimming is a self-imposed change in a self-environment.

As swimming involves all the muscle groups, oxygen utilization is higher in swimmers. Diaphragm, external intercostal muscles, internal intercostal muscles, sternocleidomastoid, parasternal muscles, scalene and the abdominal muscles including the external and internal obliques constitute the muscles of respiration. These respiratory muscles are essential for delivering oxygen to the tissues and removal of carbondioxide. During exercise these respiratory muscles have an essential role **Amonette and Dupler, 2002; Ratnovsky et al, 2008**.

Many researchers have confirmed the impact of respiratory system on the strength and exercise performance in trained athletes and also in healthy individuals **Boutellier 1992; Suzuki 1993; Gething 2004; Markov 2001; Volianitis 2001; Stuessi 2001; Nicks 2006**.

Respiratory responses to swimming is different from other types of activities because

a) swimming is performed in horizontal position;

b) external pressure is increased;

c) ventilation is restricted;

d) exposure of diaphragm to greater pressure while swimming than other sports and

e) water has higher heat conductance when compared to air.

During swimming, intermittent hypoxia is produced because of breath holding and restricted ventilation in every cycle of respiration. This causes anaerobic process to take place in the human body. The blood levels of lactic acid increases causing a condition called lactic oxygen deficit. This intermittent hypoxia results inalveolar hyperplasia and thus increasing the tidal volume, forced vital capacity and forced expiratory volume in first second than other sports **Meenakshi Sable et al., 2012.**

The more a person swims, the heart rate slows down and the blood pressure improves thereby making breathing easy. Swimming strengthens the body, improves circulation, regulates breathing, helps in improving lung capacity, stimulates circulation and relaxes the mind. Unlike other training exercises, swimming is beneficial for the whole body. Thus it gives an individual overall physical fitness.

Ever since 1960, the lung volumes are found to be larger in young swimmers as reported in various longitudinal and cross-sectional studies **Newman F et al., 1961; Astrand PO et al., 1963; Magel JR et al., 1969; Andrew GM et al., 1972; Ness GW et al., 1974; Ericksson BO et al.,**

1978; Vaccaro P et al., 1980; Zinman R, Gaultier et al., 1986; Jones ADG et al., 1989.

All the studies were done after a training period of more than 1 year. The youngest group included girls of age 7–8 years. The Total Lung Capacity, Functional Residual Capacity and Vital Capacity were higher than the age-matched control groups. The lungvolumes increased depending on the duration of training **Zinman R et al., 1986**.

Three longitudinal studies were conducted for a period of over 1 year **Zinman R et al., 1987**, 3 years **Andrew GM et al., 1972** and 5 years **Engstrom I et al., 1977**. In study involving girl swimmers for a period of 1 year, the heights were normal both initially and after 1 year. But after 1year, 11 out of 17 subjects had more than normal values for TLC and VC. The 3 year study included young swimmers of both gender. Anthropometric examination revealed an increase in their height for their age. The difference was higher in older children. The increased values for VC lead to a rise in TLC.

In the study involving duration of 5 years, girls were in a mean age of eleven and a half years when the study commenced. The vital capacity increased all through the training period to a remarkable extent than the researchers expected. Thus they came to the conclusion that the degree of training and duration influence the increase in vital capacity.

The young female swimmers who were trained intensively for 2.5 years were followed-up for 10 years **Eriksson et al., 1978**. After 7 and 10 years of the initial study, swimming training was discontinued by many of them. Fascinatingly, on examination the vital capacity values remained unchanged. Thus the increased values were retained even after discontinuation of training.

Other parameters for lung function have also been studied in swimmers of younger age group. In prepubertal girl swimmers, though there was no increase in maximal static pressures chest wall measurements were higher **Zinman R et al., 1986, 1987**.

Maximum mid-expiratory flow rates (MMEFR) and maximal expiratory flow rates were noticeably raised in swimmers- both boys and girls compared to the control groups similar to VC and TLC **Astrand PO et al., 1963; Andrew GM et al., 1972; Vaccaro P et al., 1980**.

There is no study measuring the alveolar distensibility in swimming children. Normal alveolar distensibility was reported in a study on young adult swimmers **Armour J et al., 1993**. The finding of a normal alveolar distensibility in young adult swimmers suggests that large lungs might be due to an increase in the alveolar number.

In **2005, Kubiak- Janczaruk E** observed the parameters defining inspiratory airflows in swimmers and found a higher value in those who were trained regularly for 7- 8 years. They concluded that it may be due to the effect of training on the respiratory muscles especially the inspiratory muscles.

Armour J et al., 1993 reported that swimmers had increased total lung capacity, vital capacity and inspiratory capacity than the elite long distance athletes and control subjects. This study showed larger FEV_1 in swimmers. They proposed that the swimmers might have achieved greater values of lung function parameters than runners by the development of chests with greater diameters and their lungs having many alveoli, rather than the increase in the size of the alveoli.

Ekblom B and **Hearmansen L 1968** conducted a study on athletes of the Swedish National team. They measured the lung volumes and found lower values. This may be due to increase in the vital capacity caused by increased strength of the accessory muscles of inspiration which may further be due to training of the shoulder girdle muscles. Though these changes take place, they are not accompanied by a simultaneous increase in forced expiratory volume. Hence FEV_1 tends to be comparatively low.

Baxter-Jones and **Helms 1993** studied a sample of 231 highly trained male swimmers, gymnasts, tennis players and soccer players. Of the four sports, the swimmers had the highest initial lung volume in each of five age cohorts (8, 10, 12, 14, 16 years).

Asha.V.Pherwani et al., 1989 in their study on the pulmonary function of competitive swimmers analyzed the effect of period of training on pulmonary function tests. They found that inspiratory capacity was the first pulmonary function to improve after 6-12 months of regular swimming. They concluded that greater increase in the pulmonary function tests after 5 years of swimming may be due to hypertrophy of the diaphragm.

Though swimming and yoga improve the pulmonary functions appreciably within 12 weeks, FVC, FEF_{25-75}, MVV are greatly improved in swimming than yogic exercises **Shilpa S Gupta et al., 2012.** Thus swimming practice done regularly may change the elasticity of the chest wall and lungs thereby leading to improvement in the lung function.

A study was done in **1997** to compare the lung volumes in swimmers, land based athletes and sedentary controls by **M Doherty** and **L Dimitriou.** They observed that swimmers had high FEV_1 independent of stature and age. In competitive swimmers the maximal aerobic capacity reaches its peak in males and females between 18 to 20 years of age **Elizabeth E Mc Kay et al., 1983.**

Amid a range of investigation modalities available, pulmonary function test (PFT) is an important means for the evaluation of lung function. It can be compared to the ECG for heart. Spirometry is the investigation of choice for the overall assessment of pulmonary function in clinical practice. Pulmonary functions are determined by airway resistance, elastic recoil of lungs, compliance of the thoracic cavity and respiratory muscle strength **Cotes JE 1979**.

Predictive normal values are necessary for clinical interpretation of these tests. Studies in children had estimated the equations for predicting various lung functions using age, height and weight as independent variables. These studies also showed differences in India and other countries as well as regional differences for spirometric parameters. Therefore it is obvious that there are differences in spirometric parameters between Indian and Western countries as well as regional differences **R HariKumaran Nair et al., 1997**.

RESPIRATORY SYSTEM- FUNCTIONAL ANATOMY:

EMBRYOLOGY:

Development of trachea:

Tracheal epithelium and glands develop from the endoderm. The smooth muscles, connective tissue and cartilage develop from the mesoderm.

Development of lungs:

Thurlbeck and Zeltner and Burri described the anatomical development of lungs. Lungs develop from epidermal and mesodermal cells. Lung development is divided into five overlapping stages based on the histological appearance.

- Embryonic (1 month to 1 month 3 weeks),

- Pseudoglandular (1 month 7 days to 4 months 7 days),

- Canalicular (4 months to 6 months 2 weeks),

- Saccular (6 months to 9 months) and

- Alveolar (9 months to childhood).

26 days of life-

Evaginations from the primitive gut invade the adjacent mesenchyme thereby forming the initial human lung. Laryngotracheal groove is formed in the endodermal tube. Lung bud forms at once and divides progressively. From the lung bud, two bronchial buds are formed- the primary bronchi. The primary bronchi branch into secondary bronchi- three buds on the right and two buds on the left. Tertiary bronchi are formed by the branching of the secondary bronchi- 10 on the right side and 8-9 on the left side, which becomes the bronchopulmonary segments.

16th week-

Bronchial structure of lung is complete. The epithelial lining of the bronchi is of columnar type. Bronchi give a pseudoglandular appearance to the lung. Bronchi are separated by the blood vessels.

16th – 24th week-

There is further differentiation of the mesenchyme as the capillaries grow. Branching network of pulmonary vessels is complete at birth.

21st week-

Epithelium of peripheral airways become flattened and airways become conspicuous- canalicular stage of fetal development. During this period alveolar cells- type I and type II are recognizable. Type II Clara cells contains osmophilic bodies representing the appearance of surfactant which lowers the surface tension. Surfactant secreted by these Type II cells also contains proteins which have antimicrobial activity.

28th week-

Respiratory bronchioles appear. During this period of gestation, first true alveoli appear on the walls of peripheral airways. Transitional ducts grow out which produces peripheral saccules. This is the saccular stage. Saccules are present in the baby after birth. Numerous cells and capillary network are seen in the interstitium. The saccules and the transitional ducts develop further into atria, alveolar ducts and alveoli. Thyroxine enhances septation of the air spaces. Steroids inhibit septation and accelerate thinning of the walls of the airways.

At birth-

Lung is converted into an organ that absorbs fluid. In a full term infant there are 50 million alveoli which provide sufficient gas exchange for the beginning of extrauterine life.

Till 4 years-

The ducts and alveoli keep on increasing after birth for the first 4 years of life. Capillaries which were double layered merge to form a single layer. Formation of new alveoli ceases at this point. Holes appear in inter alveolar septa called pores of Kohn.

Upto puberty-

Lungs continue to grow. Growth of all the structures causes an increase in lung volume. Increases in size are not homogeneous. The increase in diameter of the peripheral airways is more than that of the airways present proximally thereby resulting in fall of airflow resistance.

In children, the growth of lungs is proportionate to the increase in height. Thus with each birthday the volumes of the lungs and the maximal flow rates also increases. Girls obtain maximum lung volumes at an early age when compared to boys. Even then boys have lung volumes more than girls.

Development of the pleura:

Visceral pleura develop from the visceral mesoderm. Parietal pleura develop from the somatic mesoderm.

Morphogenesis of lungs- Signalling mechanisms:

For the lung to grow there should be an interaction between the endoderm of the gut and the mesenchyme. The septal fibrous network, vessels of the pulmonary system, cartilage and smooth muscle are all derivatives of the mesenchyme. Mesenchymal cells secrete growth factors which drive the development of airways and air spaces. These factors play a vital role in the budding of the airways.

The proteins governing lung growth are given below:

- The fibroblast growth factors (**FGFs**) consist of 24 proteins, of which 6 are needed for growth of lung. Of these six FGF proteins, **FGF 10** is very essential which helps in growth and differentiation of nearby epithelium. There are 4 receptors in the respiratory epithelium specific for these FGF molecules. Lung formation is retarded when these receptors are absent.

- The **sonic hedgehog protein** (described first in fruit flies) which directs the formation of brain, various organs, limbs and regulates the branching of airways.

- Bone morphogenetic protein 4 regulates lung development.

- The protein **‘sprouty’** and **"WNT” growth factors** regulate the branching of airways.

Formation of blood vessels in the lungs depends on the following growth factors:

- vascular endothelial growth factor (VEGF),

- transforming growth factor-β (TGF- β),

- integrins,

- fork head box (FOX) transcription factors and

- caveolin.

Alveolar formation is a late process. The local tissue factors and glucocorticoids determine their growth.

From the C_3-C_5 levels to the lower thoracic vertebrae, the diaphragm descends with the phrenic nerve during the period of embryogenesis. This explains the radiation of pain to the shoulders when the sensory fibers of the oesophagus are stimulated.

Children- effects of somatic growth on lung function:

Aspect of growth	Response	Effect on lung function
Thoracic rib cage- increase in length, width and depth.	Thoracic cavity expands.	Lung volumes increase, ventilatory capacity increases.
Quantity of lung tissue increases.	Elastic recoil increases.	Closing capacity decreases, maximal expiratory flow increases.
Alteration in the shape of chest wall.	Outward recoiling of chest wall increases.	Total Lung Capacity increases.
Muscles including respiratory muscles enlarge.	Muscle strength increases.	Inspiratory Capacity increases and this affects TLC, VC and FEV_1.
Increase in the quantity of fat.	Fat accumulates in thorax and abdomen.	Lung volumes and exercise tidal volumes can be diminished.

HISTOLOGY:

The respiratory tract is lined by mucosa, lamina propria, sub mucosa, airway smooth muscle, glands, cartilage, vessel, lymphoid tissue and nerves. The larger intrapulmonary and extrapulmonary passages are lined with respiratory epithelium which is pseudo-stratified ciliated columnar epithelium interspersed with mucus secreting goblet cells. The respiratory bronchiole is lined with cuboidal epithelium. The alveolar ducts and alveoli have squamous lining. Alveoli are devoid of cilia.

Cartilage is present in the form of C- shaped rings in the walls of trachea and primary bronchi and as flakes in other bronchi. It is absent in the bronchioles. The presence of cartilage keeps the trachea and bronchi patent.

Smooth muscles are present throughout the tracheobronchial tree. They are most abundant in the bronchioles and found as thin bands in the alveolar ducts. Elastic tissue is abundant throughout the respiratory passage and plays a role in mechanics of respiration. Collagen fibres are also present in the lungs.

Types of cells found in the respiratory tract:

1. Ciliated columnar cells:

These cells are responsible for the mucociliary rejection current in the bronchial tree.

2. Goblet cells:

These cells are filled with mucinogen.

3. Type I alveolar epithelial cells:

These are flat cells with large cytoplasmic extensions covering 95% of the alveolar surface area and are agranular.

4. Type II alveolar epithelial cells (Clara cells/ granular pneumocytes):

These are non-ciliated cuboidal cells. They regulate ion transport as well as surfactant production.

5. Basal cells:

These are mitotic stem cells for other epithelial cell types.

6. Brush cells:

Present throughout the conducting airway passages. These cells are also present in the respiratory epithelium of nasopharynx. They are in contact with the afferent nerve fibres basally and hence are considered to have a sensory receptor function.

7. Neuro endocrine cells/ Amine Precursor Uptake and Decarboxylation (APUD) cells:

Secrete various amines and polypeptides like Vasoactive Intestinal Polypeptide (VIP) and Substance P.

8. Lymphocytes:

Lymphocytes are concerned with inflammatory functions.

9. Mast cells:

These cells are present on the basal regions of epithelium. Histamine containing granules are released from the mast cells in response to irritants and inhaled allergens.

FUNCTIONAL ANATOMY:

The organs of respiration consist of the respiratory passages and lungs. The respiratory passages consist of upper respiratory tract and lower respiratory tract. The walls of the tract have a skeletal basis made up of bone, cartilage and connective tissue. The bone and cartilage of respiratory tract keeps the passages always patent.

The upper respiratory tract is made up of nose, nasopharynx, oropharynx and larynx. This is concerned with warming and humidification of inspired air, cleaning the inspired air of dust particles and voice production.

The lower respiratory tract is made up of trachea, bronchi, bronchioles and alveoli. Smooth muscles present in the walls of the trachea and bronchi enables some alterations in the size of the lumen. The trachea divides 23 times to form 23 generations of the tracheobronchial tree. Swiss anatomist **Weibel** divided the tracheobronchial tree into 23 divisions.

Generation 0 is the trachea. The two main bronchi are designated as first generation. Segmental bronchi form the third generation.Segmental bronchus further divides into many branches and the terminal bronchiole forms the 16^{th} generation. Respiratory bronchiole is from 17^{th} to 19^{th} generation. Alveolar duct, the alveolar sac and the alveoli constitute the 20^{th} to 23^{rd} generation. These divisions raise the surface area available for gas exchange and decrease the velocity of air flow.

According to the function, the tracheobronchial tree is classified into

- conducting zone,

- transitional zone and

- exchange zone.

Conducting zone is from trachea to terminal bronchiole (generation 0 to generation 16). This is concerned with conduction of air. There is no gas exchange and hence it is called as anatomical dead space (150 ml).

Transitional zone is formed by the respiratory bronchioles (generation 17 to generation 19). Generation 20 to 23 forms the exchange zone and includes alveolar ducts and alveolar sacs.

The respiratory unit, also called as respiratory lobule is formed by the respiratory bronchiole, alveolar ducts and the alveoli. The respiratory unit is the functional unit of the lung. There are two million alveoli in the two lungs.

Gas exchange takes place through the respiratory membrane. This layer is constituted by alveolar fluid and surfactant lining the alveoli, epithelial cells with their basement membrane, a minimal interstitial space and the basement membrane of the capillary endothelium. The overall thickness is about 0.6 μm and the total surface area is 70 square meters. This increases the rapidity of gas exchange.

Blood supply:

Lungs receive blood from pulmonary vessels and bronchial vessels.

Pulmonary (lesser) circulation:

The pulmonary artery carries impure blood from the right ventricle to the lungs. It divides continuously to form a dense network of capillaries around the alveoli. These capillaries form venules and veins finally forming the four pulmonary veins. They carry pure blood to the left atrium. The structural characteristics of the air passages are such that the nutrition for respiratory bronchioles, alveolar ducts and alveolar sac is by pulmonary circulation.

Bronchial circulation:

Bronchial artery carries pure blood and is a branch of descending aorta. It nourishes the tracheobronchial tree and parietal pleura. Impure blood is carried by bronchial veins which drain into azygos vein which in turn opens into right atrium.

Lymphatic drainage:

The lymphatics drain into broncho-pulmonary nodes. The superficial lymphatic vessels drain the lung tissue lying underneath the pleura of the lung. Deep lymphatics drain the bronchial tree, pulmonary vessels and the connective tissue septa. Particulate matter reaching the alveoli and plasma proteins leaking from lung capillaries are removed from the lung tissues by the lymphatics thereby preventing pulmonary edema.

Innervation:

Rhythmical breathing is controlled by specific group of neurons situated in the brainstem. Parasympathetic innervations to lungs are derived from the vagus and sympathetic innervations from the second to fifth thoracic spinal segments. The large airways are innervated by the parasympathetic nervous system. Activation of the parasympathetic nervous system causes bronchoconstriction. The neurotransmitter released is acetyl choline. The only bronchodilator nervous innervation to airways is by non-adrenergic, non- cholinergic nerves. These bronchodilator nerves extend from the larynx to the terminal bronchioles. The neurotransmitter is vasoactive intestinal peptide (VIP).

Control of respiration:

Control of respiration is by the respiratory centres in brain which have intrinsic rhythmicity. Respiratory centres are situated in the pons and the medulla. The medullary respiratory centres include the dorsal (entirely inspiratory) and ventral (both inspiratory and expiratory) respiratory group of nerve cells situated in the medullary reticular formation. The pontine centres include the pneumotaxic centre and the apneustic centre. These centres are responsible for the automatic rhythmic breathing.

PHYSIOLOGY OF RESPIRATION:

Respiration is defined as the exchange of gases between an organism and its environment. Lungs are safely encased in and protected by rib cage. The lungs deliver oxygen to tissues and remove carbondioxide from tissues. This is the major function of lungs.

The entire respiration is divided into

1. External Respiration

This consists of

a. Ventilation,

b. Gaseous exchange at alveolar level,

c. Carriage of oxygen and carbondioxide by the blood and

d. Exchange of gases at tissue level.

2. Internal or Tissue Respiration

This is concerned with consumption of oxygen and production of carbondioxide by the tissues. The respiratory system is made up of a pump that helps in ventilation of the lungs. The chest wall, respiratory muscles, control centres in the brain and the tracts connecting the brain and the muscles together constitute the pump. The respiratory muscles alter the size of the thoracic cavity.

LUNG VOLUMES AND CAPACITIES:

1. Tidal volume (TV):

It is the amount of air moving into or out of the lungs during quiet breathing. It is about 500 ml.

2. Inspiratory reserve volume (IRV):

It is the amount of air above the tidal volume that can be inspired by maximum effort. It is about 2500 ml.

3. Expiratory reserve volume (ERV):

It is the amount of air that can be forcefully expired above the normal tidal expiration. It is about 1100 ml.

4. Residual volume (RV):

It is the amount of air left behind in the lungs even after maximal voluntary expiration. The lungs are not completely emptied of air because the distal airways collapse with air trapped inside due to increase in external pressure. Residual volume can be expelled only by opening the thoracic cage and causing collapse of the lungs. It is about 1200 ml.

The lungs are not completely emptied of air even after complete collapse because of the air trapped inside the alveoli. This is the minimal volume or minimal air. This air makes the lung tissues to float in water **(Swammeredam 1664).**

5. Closing volume:

This is the volume at which the peripheral small airways begin to close during a forced expiration. This occurs when 10% of the vital capacity is left in the lungs. Closing volume is increased in obstructive lung disease.

6. Respiratory minute volume (Pulmonary Ventilation):

This is the amount of air inspired or expired during 60 seconds. It is about 6 liters at rest.

7. Maximum voluntary ventilation (MVV):

It is the maximum amount of air flowing into or out of the lungs by voluntary effort. It is about 125-170 L/ min.

Lung Capacities:

1. Vital capacity (VC):

It is the maximum volume of air that can be expelled rapidly by a maximal effort following deep inspiration. (Vital capacity = Tidal Volume + Inspiratory Reserve Volume + Expiratory Reserve Volume). It is about 3.5 – 5.5 liters. It is a good index to assess pulmonary function and strength of the muscles of respiration.

2. Inspiratory capacity (IC):

It is the maximum volume of air that an individual can breathe in by forced inspiration after a normal expiration. It is about 3000 ml.

3. Functional Residual capacity (FRC):

It is the amount of air left behind in the lungs after quiet expiration. It is about 2500 ml. FRC acts as a buffer against fluctuations in pO_2 and pCO_2 in the respiratory cycle which enables continuous gas exchange and reduces the load on the respiratory system and the left ventricle.

4. Total Lung Capacity (TLC):

It is the volume of air that is present in the lungs after a maximal deep inspiration. It is about 4500 – 6000 ml.

Types of lung volumes and capacities:

I. Static volumes and capacities.

II. Dynamic volumes and capacities.

I. Static volumes and capacities:

In these, time factor is not considered and are expressed in millilitres or litres. They include

a. Static volumes:

- Tidal Volume
- Residual Volume
- Inspiratory Reserve Volume
- Expiratory Reserve Volume

b. Static capacities:

- Inspiratory Capacity
- Vital Capacity

-Functional Residual Capacity

- Total Lung Capacity

II. Dynamic volumes and capacities:

These measurements are time dependent and are expressed in millilitre/ second or litre/ minute. They include

Dynamic Volumes:

- Minute volume

- Maximum voluntary ventilation (MVV)

Dynamic capacities:

-Timed vital capacity (FEV_1)

-FEV_1 %

- Maximum Mid Expiratory Flow Rate (MMEFR) or Mean Forced Expiratory Flow $_{25\text{-}75\%}$ (FEF $_{25\text{-}75\%}$)

- Maximal Expiratory Flow Volume (MEFV) Curves and Maximal Forced Expiratory Flow Rates

- Peak Expiratory Flow Rate (PEFR)

- Inspiratory Volumes and Flow rates

- Breathing Reserve or Dyspnoeic Index

a. Timed vital capacity- FEV_1:

It is the amount of air expelled in the first second after forceful expiration. This is the fraction of the forced vital capacity expelled in the first second during a forced expiration. In a normal individual 80-85% of the FVC is expired during the first second (FEV_1), 95% in two seconds (FEV_2) and 97-100% in three seconds (FEV_3). It is reported as volume in litres even though it denotes volume over a specific time.

b. FEV_1%:

FEV_1 expressed as a percentage of FVC gives FEV_1%.

$FEV_1\% = FEV_1 / FVC \times 100$.

Normal Values:

Young Adults : 80-85%.

Elderly people : 70-80%.

Children : > 90%.

In restrictive lung disorders FVC and FEV_1 are reduced. $FEV_1\%$ is normal or even above normal.

In obstructive lung disorders FEV_1 is reduced and FVC is very much reduced. So $FEV_1\%$ is also reduced.

c. Maximum Mid Expiratory Flow Rate (MMEFR) or Forced Expiratory Flow $_{25\text{-}75\%}$ (FEF $_{25\text{-}75\%}$):

This is the mean flow rate achieved during the mid 50% of FVC. This indicates the patency of small airways.

d. Maximal Expiratory Flow Volume (MEFV) Curves and Maximal Forced Expiratory Flow Rates:

It is a graphical representation of maximum flow rate against lung volume during FVC performance. The values derived are FEF_{25}, FEF_{50} and FEF_{75}. It is helpful to differentiate between central and peripheral airway disease.

e. Peak Expiratory Flow Rate (PEFR):

This is the rate of maximum airflow out of the lungs which is sustained for 10 milliseconds during a forceful sudden expiration following a maximum inspiration. It is expressed in litres per minute or litres per second. This is decreased in obstructive and restrictive lung disorders.

Normal values:

Age group	PEFR (L/ min)	
	Male	Female
< 40 years	400-650	250-450
> 40years	300-500	200-400

f. Inspiratory Volumes and Flow rates:

Forced Inspiratory Volumes (FIV), Forced Inspiratory Flow Rates (FIF), Forced Inspiratory Vital Capacity (FIVC) and Maximum Inspiratory Flow Volume (MIFV) Curves can also be derived. They are useful in detecting extra thoracic airway obstruction.

g. Breathing Reserve or Dyspnoeic Index:

BR% = MVV – RMV/ MVV x 100.

Normal breathing reserve is > 90%.

SPIROMETRY:

Historical Aspects:

Galen, 129-200 AD, did a volumetric experiment on human ventilation. He recognized the need for fresh air. In **1681, Borelli** first measured the volume of air that a man can inhale during a single deep breath. In **1749, Bernoulli** described a method of measuring an expired volume. In **1793, Menezies R** determined the tidal volume using body plethysmograph. In **1845, Vierordts'** main interest was the determination of exhaled gases and he used an expirator. He described parameters that are still used today in spirometry- 'Residual volume' and 'Vital capacity'.

In **1844, John Hutchinson,** a surgeon pointed out that the volume of air exhaled after a full inflation is an indicator of longevity of life. He invented the water-sealed volume-displacement spirometer to measure the vital capacity. He showed that vital capacity is related to height. He also showed that vital capacity decreases with age, excess weight and diseases of the lung. His water spirometer is used even now with little alterations.

In **1854, Wintrich** by using a modified spirometer found that height, weight and age determine the vital capacity. In **1866, Smith.E** developed a portable spirometer to measure gas metabolism. In **1866, Salter** used spirometer with kymograph to record the time and volume obtained. In **1902, BrodieT.G.** used a dry bellow wedge spirometer. In **1959, Wright** developed the Peak flow meter.

Spirometry:

Spirometry is the most simple and useful method available to evaluate the pulmonary function. Spirometry is the measure of airflow during inspiration and expiration. Spirometry is an essential tool which helps in the diagnosis, management and to evaluate the beneficial effect of bronchodilators in bronchial asthma.

Spirometric measurements are recorded in graphic forms and as absolute values. Graphical recording of spirometry is in the form of volume versus time (spirogram or timed vitalograph) and flow rate versus volume (flow volume curve/loop). Several parameters are available for interpretation of spirometric data in terms of absolute values. These parameters include FVC in litres, FEV_1 in litres, MEFR (25- 75%) in litre/ sec or litre/ min, PEFR in litre/ sec or litre/ min. From these, the two basic types of pulmonary function abnormalities are described- obstructive and restrictive.

Indications for Spirometry:

Monitoring:

- To monitor people exposed to injurious agents

- For monitoring the course of diseases affecting lung function
- To assess therapeutic intervention
- For monitoring adverse reactions to drugs that are toxic to the lungs

Diagnostic:

- Evaluation of respiratory symptoms
- Diagnosis of respiratory diseases
- To correlate with abnormal tests and X rays
- To assess progression of respiratory disease
- To measure the disease effect on lung function
- To screen individuals at risk of having respiratory disease
- To assess the risk prior to surgery

Disability/ impairment evaluations:

- For insurance evaluations
- For legal issues
- For rehabilitation programmes

Public Health:

- Clinical research
- Epidemiological surveys
- Derivation of reference equations

Indications for spirometry in children:

- Children with chronic cough and persistent wheezing.
- Diagnosis and monitoring of asthma, cystic fibrosis. Is used to review disease activity in cystic fibrosis and asthma control.
- To measure lung function in diseases affecting the lungs such as
    a) haemato-oncology conditions,
    b) transfusion-dependent thalassaemia major and sickle cell anaemia,
    c) connective tissue disorders and
    d) ataxia telangiectasia.
- Measurement of lung function in chest deformities such as pectus excavatum.
- To assess the lung function in flaccid neuromuscular scoliosis like muscular dystrophy, spinal muscular atrophy and cerebral palsy as a preoperative procedure.

Contraindications to Spirometry:

Forced breathing maneouver during spirometry may elevate the pressures within the cranial cavity, thorax and abdomen. Relative contraindications as per ATS 2005 are:

- Presence of respiratory tract infection (e.g. influenza)
- Pneumothorax

- Recent eye, thoracic or abdominal surgery

- Hemoptysis of unknown origin

- Past history of MI or uncontrolled hypertension

- History of stroke

- Known history of abdominal or cerebral aneurysm

- Acute disorders affecting the performance of the test like nausea, vomiting, vertigo etc.

SPIROMETER:

Instrument used to measure volumes of respired gases is the spirometer.

Types of spirometer:

Volume-Displacement spirometers:

These spirometers collect exhaled air and act as a reservoir for inhaled air. Generally before the testing starts, these spirometers are empty. Various types include the following:

a. The wet/ water-seal spirometer.

b. Stead-Wells water / dry-seal spirometer.

c. Dry Rolling-seal spirometer.

d. Bellows-type dry spirometer.

e. Tissot’s open circuit spirometer.

Advantages of volume displacement spirometers:

1. They directly measure the volume.

2. Low cost.

3. Ease of operation.

Disadvantages:

1. Less portable.

2. Some are very large and bulky.

3. Water must be changed.

4. Leaks.

5. Manual calculation is required if there is no microprocessor.

Flow sensing spirometers or Pneumotachometer:

a. Turbine-type flow sensing spirometer (respirometer).

b. Pressure-differential flow sensing spirometer.

c. Heated-wire flow sensing spirometer.

d. Pitot tube flow sensing spirometer.

e. Infrared interruption based flow sensing spirometer.

f. Ultrasonic flow sensing spirometer (Portable or Office spirometer).

g. Computerised spirometer.

h. Microprocessor based spirometer.

Flow-Sensing Spirometers:

The sensor present in these instruments measures flow which is sensed as the primary signal. By integration of the electronic or numerical flow signal it calculates the volume of air flow. Most commonly used flow sensors are

• turbine flow meter;

• anemometer;

• pneumotachometer and

• ultrasonic sensor.

Advantages:

The reason why they are popular than volume displacing spirometer is because:

- these devices are easy to carry,

- automatic calculation of ventilatory indices,

- give immediate opinion on the quality of every blow,

- select the best of the results among the trials,

- calculate the reference values,

- store the patient’s results and

- it is possible to take a printout of the recorded graphs- spirogram and flow-volume loop.

The flow and volume measurement sensor is a digital turbine. This infrared interruption principle ensures the accuracy and the reproducibility of the measurements without requiring a periodic calibration.

There is a vane inside the turbine flow meter which turns when air is blowed. When the vane turns light is directed to a photocell which generates electrical impulses. The number of revolutions is measured from the electrical impulses. RPM per minute is directly proportional to the flow. The turbine flow meter is insensitive to gas composition, turbulent flow, temperature of the gas.

Portable flow sensing spirometer working on the infrared interruption principle was used in the present study.

Recommendations for choosing a Spirometer:

Recommendations for choosing a spirometer are published by the American Thoracic Society in 1979, 1987 and 1995. American Thoracic Society (ATS) recommends that spirometric equipment should be such that it meets the minimum standards:

- Should record 7 litres volume and 12 litres/ second flow rate.
- Should be calibrated with 3 litre syringe.
- Should record minimum FVC and FEV_1.
- Should record flow volume curve or flow volume loop or both.

Calibration of Pulmonary Function Instrumentation:

Calibration of volume collecting and flow sensing spirometers require the use of a calibration syringe (3 Litre syringe).

Calibration of volume collecting spirometers:

Patient testing tubing should be attached and the entire calibration syringe volume is injected. The pen or graphic display is observed. The indicated volume should be equal to the volume of the calibration syringe within ± 3%. If the display or line does not travel in a straight line, it implies that there is a leak.

Calibration of flow- sensing spirometers:

These types of spirometers often have a menu option for calibration. Periodical calibration of these spirometers should be done with a certified 3 litre syringe. At least one injection from the calibration syringe should be with a reported value within ± 3%. Similarly, the calibration syringe is usually stored near the spirometer as it should be at a temperature similar to the spirometer.

American Thoracic Society (ATS) standards are required for the documentation of the calibration.

Standards for performing Spirometry:

American Thoracic Society (ATS) also recommends standards for performing the spirometry which includes the following

- Spirometry should be performed in sitting position.

- Effort should be maximal, smooth and cough free with exhalation time of minimum 6 seconds or preferably 12 seconds.

- A 2 second volume plateau indicates end of test and reproducibility should be a FVC value within 5% or 100 ml in 3 acceptable tests.

- Selection of best curve should be the largest sum of FEV_1 and FVC.

Assessment of lung function in children above 6 years can be assessed by the methods used for adults.

Interpretation of Spirometric data:

To interpret the spirometric values in an individual, results are compared with the standards. These values are obtained from studies involving the normal population where the subjects are matched for age, gender, height and ethnic origin. Weight is occasionally taken into consideration because variations in weight make little difference in the predicted normal value.

Normal variations in the predicted values:

1. **Sex:** Males- larger FEF_{25-75}%, FEV_1, PEFR and FVC; lower FEV_1%.

2. **Age:** FEF_{25-75}%, FEV_1, PEFR and FVC values are lower in children and increases with age. At the same time FEV_1/FVC decrease with age. This decrease occurs earlier in females (20 years) than males (25 years). As the person grows, all the indices gradually become reduced. In adults the decrease in FEV_1 is greater than FVC. This is the cause for reduced FEV_1% in adults.

3. **Height:** All indices except FEV_1% increase with standing height.

4. **Ethnic Origin:** Polynesians- lowest FEV_1 and FVC. Caucasians- largest FEV_1 and FVC. Indians- 10% lower FVC than matched Caucasians. Chinese- 20% lower FVC; Negroes- 10 to 15% lower than Caucasians. No difference exists between the ethnic groups for PEFR.

Values > 75% of predicted is considered as normal for all parameters.

The sets of normal predicted values used commonly are:

- Morris/ Polgar
- NHANES III (The Third National Health and Nutrition Examination Survey)
- Knudson (1983)
- Crapo/ Hsu

In this study, spirobank-G manufactured by MIR- Medical International research- Roma - Italy was used. The predicted values set in this spirometer are European Respiratory Society (ERS) predicted values; USA Capro; Bass, Morris predicted values and Knudson predicted values. In case of a child or young person the predicted values used are always Knudson. Hence Knudson's predicted values are used in this study for comparison.

PULMONARY FUNCTION TESTS:

Various pulmonary function tests are being carried out to make proper assessment of lung function by non invasive method. Pulmonary function tests aim at assessing the various aspects of pulmonary function like ventilation, diffusion, perfusion etc.

I. Tests for ventilation:

These tests are done with Helium dilution technique or body plethysmography. Ventilation related parameters are the following lung volumes and capacities:

a. Forced Vital Capacity (FVC).

b. Timed Vital Capacity (FEV_1).

c. FEV_1%.

d. Forced Expiratory Flow rate (FEF_{25-75}).

e. Maximum Voluntary Ventilation (MVV).

f. Peak Expiratory Flow Rate (PEFR).

g. Breathing Reserve.

h. Maximal Forced Expiratory Flow Rates.

i. Mean Expiratory Flow Volume Curves.

j. Closing volume.

II. Tests for Ventilation–Perfusion:

This is assessed by ventilation- perfusion scanning and nitrogen wash out test. The ventilation- perfusion related parameters are:

a. Pulmonary blood flow.

b. Ventilation/ perfusion ratio.

III. Tests for diffusion:

These tests are done by estimating the diffusion capacity of lung for the gases oxygen and carbon-monoxide. Diffusion related parameters are:

a. Diffusing capacity of lung for oxygen (DLO_2).

b. Diffusing capacity of lung for carbon-monoxide (DLCO).

IV. Tests for Mechanics of Breathing:

a. Elastic resistance (Compliance and Elastance).

b. Non-elastic tissue resistance.

c. Airway resistance.

V. Exercise testing:

Useful when patients complain of exertional dyspnea.

VI. Arterial blood gas analysis:

This test estimates the overall gas exchange.

VII. Bed side tests:

Simple bed side measures of lung function include Peak Expiratory Flow, transcutaneous O_2 (SpO_2) and transcutaneous CO_2 (tCO_2).

VIII. Tests for respiratory muscle function:

The useful indicators of respiratory muscle function are the measurement of maximum inspiratory (PI max) and maximum expiratory (PE max) pressures.

IX. Tests for respiratory centre function:

This is studied by carbondioxide stimulation tests.

X. Tests for sleep related disorders:

This is assessed by polysomnography.

The present study is concerned with measurement of Ventilation related parameters.

SWIMMING:

History of Swimming:

The earliest records of swimming were found as Stone Age paintings in ‘The cave of swimmers’ near WadiSora in Egypt- SouthWestern part 14,000 years ago. Mohenjo Daro (2800 B.C.) had a swimming pool sized 30 meters by 60 meters.

‘The Swimmer or A Dialogue on the Art of Swimming’ was the first swimming book written by **Nikolaus Wynmann**, a German professor in 1538. From 1800 competitive swimming was started in the United States. They mostly used breaststroke. At that period many Americans used this sport as a competition for property settlements.

Later in 1873, the trudgen was introduced in these competitions by **John Arthur Trudgen**. He copied and modified the front crawl practiced by Americans. The modification is scissor kick instead of the flutter kick.

Australia was the first country to standardize front crawl which was later made perfect by the Americans. Modern history of swimming begins from the time swimming was introduced in the Olympic Games first in 1896 conducted at Athens.

In 1902, **Richmond Cavill** was the first to introduce the front crawl to this game. **Federation Internationale de Natation (FINA)** was formed in 1908. It is the international association for swimming.The butterfly stroke was developed in the 1930s. It was accepted as a separate style in 1952. This stroke was the variant of breast stroke.

Similar association is also found in India- the **Swimming Federation of India (SFI)** which manages the competitive swimming. It is allied to FINA. National Swimming Association (NSA) and the Indian Swimming Federation (ISF) constitute the SFI.

Swimming Stroke:

Swimming consists of repeating a specific body movement to move the body forward. There are many kinds of strokes, each having a different **swimming style** or **crawl**.

The majority of strokes involves movements which are rhythmic and leads to the coordination of the upper limbs, lower limbs, body and head. With each stroke, breathing must also be synchronized. It is however possible to swim by moving either the upper limbs or the lower limbs alone. Such strokes may be useful for teaching the amputees and paralytics.

Swimming Styles:

There are various types of swimming styles. They include the following.

1. Front Crawl:

This is the fastest swimming style. Strokes similar to front crawl include

- Dolphin crawl: Similar to front crawl but with a dolphin kick. This style uses either one kick or two kicks in one cycle and is frequently used for training purposes.

- Catch up stroke: Here, one arm always rests at the front while the other arm performs one cycle.

- Water polo stroke: This stroke is used for water polo.

2. Trudgen:

The trudgen is swum with a scissors kick and is analogous partly to front crawl and the breaststroke. Strokes similar to trudgen include

- Trudgen crawl: use of a flutter kick (up and down leg kick) between the scissors kicks.

- Double trudgen: Here the sides of the scissors kick alternate.

- Double trudgen crawl: Similar to the double trudgen but with alternating flutter kick and scissors kick.

3. Butterfly stroke:

This stroke is performed with face down in the water. There is simultaneous movement of arms in a forward circle and the legs performing the dolphin kick. Strokes similar to this stroke include

- Slow butterfly (also known as "moth stroke"): Similar to butterfly but with an extended gliding phase. The swimmer breathes during the phase of pull/ push and during recovery returns his head into water.

4. Breast stroke:

This is performed without rotating the body. The arms and legs move synchronously and the legs execute a whip kick. Though the head usually dips in and out, the head can be kept elevated above the level of water.

5. Back stroke:

This stroke is done by lying supine.

- Elementary backstroke: Both the upper limbs move synchronized with a whip kick. The steps involved: arms begin out; arms go beside the body; the arms run up laterally and finally back out to the initial position.

- Inverted butterfly: Similar to elementary backstroke but with a dolphin kick. This is often used for training.

- Back double trudgen: Similar to the backstroke but the difference is that it is performed with a scissors kick to alternating sides.

6. Side stroke:

This stroke involves pushing most water when moving away from that place and pulling the water with arms when moving towards the destination. The legs perform sideways scissors kick.

- Lifesaving stroke: Similar to the side stroke but only the bottom arm moves while the other arm catches hold of a distressed swimmer.

7. Combat side stroke:

This stroke was performed by the Navy of United States.

8. Dog paddle:

This style is swum by paddling with alternate hands often with face above the water.

- Human stroke: Similar to the dog paddle but the arms reach out more and pull farther down.

9. **Snorkeling**:

This includes swimming on the breast using a snorkel, masks and fins. Here the head need not be moved for the purpose of breathing.

10. Fin swimming:

Here the swimmer uses fins.

11. Feet first swimming:

This is a very slow stroke done in supine position with the arms and a breaststroke movement that moves the body to the front with feet first. The arms are pulled backwards together producing a scooping movement or pushing with the hands or brought together in a clapping action propelling the body forwards. This is also repeatedly used for the purpose of training.

12. Corkscrew swimming:

In this type the swimmer alternates between front crawl and backstroke leading to a constant rotation of his body. 'Waltz crawl' is the name given for each 3^{rd} stroke.

13. Underwater swimming:

Any type of swimming style can be used for swimming certain distances under water. The duration of swimming depends on the need for air.

14. **Gliding**:

Here the swimmer lies stretched in prone position with the upper limbs to the front, head between the arms, the lower limbs held together and feet to the back. This posture helps to minimize resistance and thus the swimmer can glide in the water.

15. Turtle stroke:

On the breast, the swimmer extends one arm and then pulls after pushing with the opposite leg. Then the process repeats in an alternative manner. This stroke uses the muscles of the waist. This is a slow but sustainable stroke.

16. Moth Stroke:

This stroke was developed for recreational purpose. This stroke consists of motions opposite to that of the butterfly stroke. But here the swimmer moves in a backward direction.

Special Purpose Styles:

Some strokes are used only for special purposes like saving lives, water sports etc.

Lifesaving strokes:

1. Lifesaving stroke:

In this stroke only the bottom arm moves. The other arm holds a swimmer in distress.

2. Head-up front crawl or **Lifesaving approach stroke:**

This stroke is swum with the head to the front above the water level so as to watch the surroundings. It is similar to the front crawl and is used to save a swimmer in distress.

3. Pushing rescue stroke:

This stroke helps assisting a tired swimmer. The tired swimmer lies on the back. The rescuer swims a breaststroke kick and pushes against the soles of the tired swimmer.

4. Pulling rescue stroke:

This stroke is used to assist a swimmer in distress. Both swimmers lie on the back and the rescuer performs a breaststroke kick on the back for forward motion. The rescuer grabs the armpits of the swimmer in distress.

5. Extended Arm Tow:

This style is used for rescuing an unconscious victim.

6. Arm Tow:

Here the rescuer swims sidestroke holding the upper right arm of the casualty with his left hand and lifts the casualty out of the water.

7. Vice Grip turn and Trawl:

This type is used on a victim in whom spinal injury is suspected. This is one of the difficult lifesaving maneouvers because the grip must be ideal on the first attempt; or else the victim may be given additional spinal damage leading to paralysis.

8. Clothes swimming:

This is done to practice situations where the swimmer fell in the water dressed. Due to the restricted movement and the weight of wet clothes out of the water, an over arm recovery is not possible. Here the swimming style used is breaststroke.

9. Rescue tube swimming:

The lifeguard pulls a floatation device, which is pushed forward when approaching the victim.

Without forward motion:

1. Survival floating:

This is also called as ‘dead man float’. Here the swimmer lies prone with minimal leg movement and stay afloat with the natural buoyancy. This style is used only to rest.

2. Back floating:

Similar to the dead man float but here the swimmer lies on his back.

3. Treading water:

The swimmer is in the water head up and feet down. This is used in water polo.

4. Sculling:

This is a figure of 8 movement of the hands for forward motion or upward lift. This is used in life saving, water polo and treading water.

5. Turtle float:

The knees are raised to the chest and encircled by the arms.

6. Jellyfish float:

This is done by holding the ankles with the hands.

Competitive Swimming:

Four major styles have been established in competitive swimming. The four main strokes are:

- Freestyle
- Backstroke
- Breaststroke
- Butterfly

a. Freestyle:

This is a pretty simple technique. In this technique, the swimmer floats on his abdomen in the water and propels forward by rotating his arms in a windmill movement and kicks his legs in a fluttering motion. The hardest part of this technique is the synchronization of the breathing while performing the strokes.

b. Backstroke:

In this stroke, the swimmer floats on his back in the water. The arms and the legs are moved similar to freestyle. The two basic techniques include:

1. The arms should be moved with equal force.

2. The body should be rolled from one side to the other.

c. Breaststroke:

This swimming technique involves a pattern wherein the body bobs upwards and downwards as the swimmer propels forward in the water. The breaststroke is also a difficult swimming technique. The arm pulling and the leg kicking are done alternatively.

d. Butterfly Stroke:

This is also a difficult swimming technique and involves strength as well as precise timing. The legs should be moved together akin to the movements of a dolphin's tail, the arms should also be moved together pushing the water downwards and then backwards while the torso moves forward in an undulating manner.

Basic Training Principles for Swimming in Children:

The coaching of children is sufficiently different to the coaching of adults. It is essential that children be allowed to follow childhood development in accordance with natural and inherited forces. An intrusion or disruption to those processes will result in later detrimental effects. Since pre-pubertal growth occurs at individual rates, sensory awareness and motor control in children continually change. The biological needs of growing children are coupled with growth.

Swimming instruction for children should focus on general factors of body alignment/ posture, appropriate anatomical positions for direct force production, resistance reduction and variety in skill experiences.

Physical conditioning:

The physiology and physiological reactions to exercise of children are distinctly different to those of adults. Children are primarily aerobic and respond to exercise stress in a non-differentiated manner.

When children enter swimming they have to first proceed with physical and life-style adjustments until a stage when they can perform more intense training. **Andrei Vorontsov 1997** defined two stages of children's development. These should influence programming.

1. Stage I- Preliminary stage of Sport Preparation:

This stage is initiated in 8-10 years old boys and 7-9 years old girls. Total duration is 12 months to 24 months.

Objectives are:

- Identification of the body type, proportions, anthropometry, buoyancy and motor talents for this sport of swimming.
- Creating a constant interest to this sport.
- Learning basic techniques in swimming.
- Acquiring an extensive range of motor skills.
- Improving their overall wellbeing.

This stage involves learning the basic swimming techniques and particular exercises with a chief emphasis on pleasure. The regularity of practices should increase gradually from 3 to 5-6 sessions in a week leading to an increase in the total training load and also increase in both swimming and general body fitness.

2. Stage II- Basic Training stage:

This stage should begin for boys at 10- 11 years and for girls at 9- 10 years. This stage extends from 36-48 months upto puberty.

Objectives of this stage are:

- Development of general motor abilities and a functional foundation for swimming.
- Identification of the gifted children based on morphological factors, endurance and pulling strength.
- Perfection of basic technical swimming skills in all strokes with gradual specialization in at least two strokes.
- Formation of a positive attitude towards regular training.

This is the most essential stage for the development of aerobic capabilities. There is a progressive annual increase in total swimming volume. In the last year of this stage the total swimming volume may reach 1000-1200 km for boys and 1200-1400 km for girls. An analysis reveals that the total training volume includes 70-75% aerobic exercises, 25-30% of "mixed" aerobic-anaerobic activities and 2-3% of anaerobic glycolytic and alactic work.

As the swimming children grow, pulling power and speed of swimming during workouts should increase. This should be assisted by using additional resistance like belts, paddles and stretch cords. There is a remarkable increase in aerobic capacity and efficiency. The development of anaerobic abilities is achieved by periodic use of glycolytic and alactic training exercises and an increase in the number of competitions per year.

Near the end of this stage of MYT it is important to introduce land training exercises with both submaximal and high resistances.

The development of specific pulling force in the water in young swimmers is a very powerful factor for forming effective swimming techniques. This is achieved by teaching conscious control of the stroke rate and stroke distance.

Benefits for children due to swimming lessons:

Swimming is an important talent in life that all children should learn early. Children get pleasure despite many acquired benefits. One day it can save their life too.

a. Health and Fitness:

Swimming is the best form of exercise as it works each and every muscle group in the body. It does not put stress on the bones and joints. It is a brilliant way to burn off their constrained energy. The swimming pools are usually supervised by trained lifeguards. Parents are also allowed to stay beside the pools. Hence it is a safe environment for children. Instilling the value of leading a healthy, active lifestyle at an early age is important as any behaviour inculcated in children will in later years be converted into a habit.

b. Competitiveness:

Swimming classes instill a competitive thought in children as they try hard to achieve more and compete among their friends. This character will help them in a variety of environments as in school or at work.

c. Social Skills:

Swimming classes are taken in groups of children of a similar age and ability. Hence children will be able to learn many valuable social skills. They will make friends and have fun in an environment different from home, school or classroom.

d. Safety:

Learning to swim is important to ensure that children are safe around water. Many situations are there where children might come into contact with water. Swimming may help in danger.

e. Life skill:

Swimming will bring a lifetime of pleasurable experiences like boat trips, beach or resort holidays, pool parties, water sports, SCUBA diving etc. As children get older they could find themselves excluded from such activities if they cannot swim.

Swimming for 'Health Concern' kids:

In contrast to some sports which require participants to be in good health, swimming can offer benefits for kids at varying levels of fitness and even children with health concerns that may exempt them from participation in other sports. These children need supervision and proper guidance.

a. Childhood Obesity:

Overweight kids may find swimming to be a pleasure. Movement in the water may be easier, making fitness fun for even those who have avoided other forms of exercise.

b. Bronchial Asthma:

When asthmatic kids exercise it can bring on attacks of asthma. This makes them reliant on the use of inhalers. Thus they avoid sports activities. Most of these kids can swim without experiencing any difficulties. Indoor swimming is especially favoured because the environment will be warm. This warm environment makes breathing easier. Care should be taken not to over-chlorinate the pool.

c. Autism:

Swimming lessons for these children gives them a social and physical outlet to build confidence, relieve stress and have fun. They get an opportunity to keep fit, stretch their muscles and also avoid massive injuries- the main reason why most parents would not let them out.

d. Juvenile Arthritis:

Juvenile Arthritis children are usually left out of physical education classes and may have difficulty with even the simplest movements. Water provides a weightless feeling that makes it much easier for these kids to get little exercise daily. Exercise can help alleviate the stiffness associated with this disease and is considered necessary for their overall health benefits and also prevention of joint deformity which can occur with inactivity.

Swimming pool:

A swimming pool is a water filled container. It is used for water-based recreational activities and swimming. They are of various sizes. The Olympic- size swimming pool has the maximum size. These pools can be built on land or in the terrace of a building. It can be constructed from materials such as concrete, plastic, metal or fiberglass. For continuous cleaning of the large volume of water, swimming pools use the processes of filtration and treatment with chemical agents.

The major components of a typical swimming pool are:

- A sink
- A chemical feeder
- A pump with a motor
- A water filter
- Pipes for draining water
- Pipes for return of recycled water

The water is constantly recycled so that the waste products and the infecting organisms are removed. Nowadays pools are also provided with heaters to maintain water at a certain temperature.

Types:

a. Residential/ Private Pool:

These pools are made for personal use and for recreational activity. The volume of these pools is 15,000 to 1,50,000 litres. These are very common for bungalows and terrace. These pools are used by only one family and occasionally by relatives and friends.

b. Public/ Commercial Pool:

Commercial pools are regularly used by many swimmers in society, clubs, hotels and municipalities. These pools have volume of 2,00,000 litres and above.

c. Competition/ Diving Pool:

These pools are used by professional swimmers. They have pool volumes above 12,00,000 liters. These pools are also called Olympic or

Semi Olympic size and are used to conduct national and international level practice and competition.

d. Hot tubs and spas:

These pools are used in hotels, clubs and massage parlours. Hot water is used for relaxation or therapy.

Water treatment-Swimming pool:

Swimming pool water gets impure by environmental pollutants and swimmers. These pollutants may be in suspended or dissolved state. Water treatment of swimming pools is important to maintain the hygiene of swimmers. There are various methods of water treatment which include the following:

1. Physical Methods:

a. Screens – Used at the initial stages of purification. They come in various shapes depending on the particles they should filter. They remove solid particles from the water.

b. Sand Filtration – The filter is made of multiple layers of sand. The sand grains vary in their size. When the water flows through, the solid particles are filtered.

2. Cross Flow Filtration:

This method uses a permeable membrane. It filters out salts and dissolved matter. Several membrane filtration methods are available in the market depending on the contaminant that is to be removed from the water:

a. Microfiltration –

Microfiltration removes very small particles of size 0.1 to 1.5 µ. It filters out suspended matter and microorganisms.

b. Ultrafiltration –

Ultrafiltration removes particles that range in size from 0.005 to 0.1 µ. It removes suspended particles, proteins and salts.

c. Nanofiltration –

Particles that range in size from 0.0001 to 0.005 µ are filtered. It also filters pesticides, herbicides and viruses from the water.

d. Reverse Osmosis –

Remove the particles with a size of upto 0.001 µ. It removes metal, ion particles and dissolved salt.

3. Chemical Methods:

a. Chemical Addition-

- addition of chelating agents prevent the problems of water becoming hard.
- oxidising agents kill certain microorganisms.
- reducing agents neutralize the oxidising agents. They prevent erosion of the membranes used for purification and neutralize substances (chlorine and ozone).

b. Clarification-

This process removes suspended solids. This involves the following steps: addition of coagulants to reduce ion charges; this causes smaller particles to stick together. This creates a bigger particle. These bigger particles are finally removed through a filter. Thus this method is effective at removing large particles.

c. Deionisation and softening-

Ion exchange systems absorb certain anions and cations in order to deionise the water. The cations and anions are replaced by counter-ions until the tank is saturated with ions. The ion-exchanging device then needs to be regenerated with the use of certain chemicals. Water softeners are often used as ion exchangers; they work by removing calcium and magnesium ions from the water and then replace them with positively charged ions. This reduces the hardness of the water.

4. Disinfection:

Disinfectants are used to kill any remaining microorganisms in the water; it can prevent pathogenic microorganisms from causing human disease. There are many ways to disinfect the pool water:

a. Chlorine disinfection-

Chlorine though capable of killing many microorganisms, when it reacts with organic substances present in the water, it causes liberation of dangerous carcinogenic chemicals trihalomethane and chloroform. This is prevented by using chlorine-dioxide. This chlorine-dioxide is effective at low concentrations.

b. Ozone disinfection –

Ozone is a gas composed of three atoms of oxygen joined to form an odourless, colourless vapour. Ozone is a reliable disinfectant that eliminates bacteria and neutralizes organic compounds. There are two types of ozone-producing systems for pool water treatment- the corona discharge system and the ultraviolet method.

- **Corona discharge units** create ozone by placing high-voltage electricity into pressurized dry air. This provides ozone gas that is pumped into the bottom of a pool where it rises to the surface in the form of small bubbles.

- The **ultraviolet method** forces pressurized dry air into a chamber, where it passes by an ultraviolet light bulb. The rays from the light interact with the oxygen and produce ozone.

c. UltraViolet radiation-

This type of disinfection is popular nowadays. The application of UV radiation in the treatment of water in swimming pools makes it possible to reduce the concentration of chlorine to 0.1- 0.3 milligram/ litre.

UV works in two ways

- as a photo-oxidant - the process by which it breaks down chloramines and other organic pollutants,

- as a biocide - effective against bacteria as well as the chlorine-resistant parasites Cryptosporidium and Giardia.

5. Biological Methods

Water purification can also be done using microorganisms such as bacteria. These microorganisms decompose organic matter. In this way they help to reduce the amount of organic suspended matter. Both anaerobic and aerobic bacteria can be used.

Swimming pool Safety:

Pools present a considerable risk of child death due to drowning. Municipalities have legislation by order that require the residential pools to be enclosed with fencing thereby restricting unauthorized entry.

There is an act to regulate pools to reduce the risk of entrapment- **Virginia Graeme Baker Pool and Spa Safety Act**. Head-first diving should be done in the deepest part of the pool. This should be done at a minimal depth of 96 inches but desirably at 144 inches depth. Diving unknowingly in the shallow end can lead to morbidity like head and neck injuries and mortality.

Nowadays many products are available in the market like floating alarms, removable baby fences etc. Modern pools also have the latest technology- electronic security systems and computers for regular monitoring thereby preventing mortality due to drowning .

Suspended ceilings in indoor swimming pools are safety-relevant components. Care should also be taken while selecting the materials for construction. When stainless steels are used, they can cause corrosion cracking.

MATERIALS AND METHODOLOGY

This study was conducted in our Institute of Physiology, Madurai Medical College, Madurai. Ethical committee of Madurai Medical College, Madurai granted approval for the study.

Total of 120 subjects were included for the study. Study group consisted of 60 male and female children of age 8 to 12 years, from Dr. M.G.R. Stadium, Race Course, Madurai who has been swimming regularly for at least 3 days a week for the past two to three years. Age, Sex and BMI matched 60 children who have not indulged in any sports activity were allocated as the control group.

An informed written consent was obtained from all the subjects and their parents before undertaking the study. The procedure of pulmonary function test was explained in detail to all the subjects. All the subjects were healthy and medication free.

Type of study:

Cross sectional study.

Inclusion criteria:

- Study Group:

A random sample of 60 male and female children of age 8 to 12 years from Dr. M.G.R. Stadium, Race Course, Madurai who has been swimming regularly for at least 3 days a week for the past two to three years.

- Control Group:

Age, Sex and BMI matched 60 children who have not indulged in any sports activity.

Exclusion criteria:

- Respiratory infections.
- Bronchial asthma.
- Tuberculosis.
- Thoracic cage and spine deformities.
- Cor-pulmonale on clinical examination.

A detailed history was taken. Thorough clinical examination was done. Vital data was recorded.

Matching for age, sex and BMI was necessary since these parameters are known to influence pulmonary function. The body weight of the study and control group was recorded by weighing machine in kilogram scale.

Height of the study and control group in meters was recorded by meter scale. Body mass index was calculated by Quetelet's Index (body weight in kilogram divided by height in meter square).

Blood pressure of the subjects was measured in the left arm with a mercury sphygmomanometer in sitting position by auscultatory method. Pulse rate was determined by counting the radial pulse for one minute during rest.

Pulmonary function test:

The pulmonary function of the subjects were measured using portable computerised spirometer (spirobank-G) manufactured by MIR-Medical International research- Roma– Italy. The instrument is based on a turbine sensor working on the infrared interruption principle. This is a small hand held instrument displaying the results and interpretation.

The predicted values set in this spirometer are European Respiratory Society (ERS) predicted values, USA Capro, Bass, Morris predicted values and Knudson predicted values. In case of a child or young person, the predicted values used are Knudson. Hence Knudson's predicted values are used in this study for comparison.

- **Knudson Predicted Equations:**

Knudson's prediction equations for pulmonary function tests are the following:

1. FVC:

Men- upto 24 years of age:

FVC = (Height in inches + 0.0780) x 0.1270 x Age in years - 5.508

Men- more than 24 years of age:

FVC = (Height in inches - 0.0290) x 0.1651 x Age in years - 5.459

Women- upto 19 years of age:

FVC = (Height in inches + 0.0920) x 0.0838 x Age in years - 3.469

Women- more than 19 years of age:

FVC = (Height in inches - 0.0220) x 0.0940 x Age in years - 1.774

2. FEV_1:

Men- upto 24 years of age:

FEV_1 = (Height in inches + 0.0450) x 0.1168 x Age in years - 4.808

Men- more than 24 years of age:

FEV_1 = (Height in inches - 0.0270) x 0.1321 x Age in years - 4.203

Women- upto 19 years of age:

FEV_1 = (Height in inches + 0.0850) x 0.0686 x Age in years - 2.703

Women- more than 19 years of age:

FEV_1 = (Height in inches - 0.0210) x 0.0686 x Age in years - 0.794

3. FEV_1% = Predicted FEV_1 / Predicted FVC

4. PEFR:

Children:

(Height in cm - 100) x 5 + 100

Adult Men:

1.58 + (Height in cm x 5.48) - (Age in years x 0.041) x 60

Adult Women:

2.24 + (Height in cm x 3.72) - (Age in years x 0.03) x 60

Indications for spirometry:

1. Evaluation of respiratory disorders.
2. Assessment of response to therapy.
3. Preoperative assessment.
4. Detection of pulmonary function abnormality in persons predisposed to lung diseases due to occupational exposure.

Indications for spirometry in children:

- Children with chronic cough and persistent wheezing.
- Diagnosis and monitoring of asthma and cystic fibrosis. Is used to review the disease activity in cystic fibrosis and in the control of asthma.
- To measure lung function in diseases affecting the lungs including haematological disorders.
- To assess the preoperative lung function in flaccid neuromuscular scoliosis.

Contraindications:

1. Recent myocardial infarction.

2. Chest or abdominal diseases.

3. Oral or facial pain aggravated by mouth piece.

4. Stress incontinence.

5. Dementia or confused state.

Activities to be avoided prior to spirometry:

1. Having performed any exercise half an hour before testing.

2. Clothing that restricts full expansion of the abdomen and the chest.

3. Have taken food within two hours before testing.

After calibrating the spirometer according to the procedure given in the manual, three trials of ventilatory function of each subject was carried out. **Indian Journal of Physiology and Pharmacology 2004; 8 (3).**

Spirometry was performed in the sitting position, with head slightly elevated and nose clips applied. The mouth piece is held between the lips to create a good seal. After taking a deep breath the subjects were asked to expire as fast and forcibly as possible into the mouth piece.

The readings with the highest value were included for the study. The spirometer used was the same throughout the study. All the subjects were asked to make forced maximal expiration following maximal inspiration. The best of three consistent trials was recorded.

Precautions undertaken:

1. The turbine sensor was sterilized before each spirometric test.

2. Disposable mouth pieces were used for each subject.

3. The subjects were well instructed and encouraged to make maximum possible effort.

4. The time interval between each trial was 3 minutes.

RESULTS AND OBSERVATIONS

Table-1: Comparison of anthropometric and cardiovascular parameters between the study and control group.

S.No	Parameters		Study group (n=60)	Control group (n=60)	‘p’ value
1	Age (years)		10.15 ± 1.52	10.18 ± 1.52	0.914
2	BMI (kg/m^2)		16.73 ± 2.41	16.68 ± 2.39	0.921
3	Pulse rate/ minute		74.33 ± 6.06	73.23 ± 4.42	0.258
4	Blood Pressure (mmHg)	Systolic	105.33 ± 6.67	104.63 ± 5.63	0.539
		Diastolic	63.53 ± 5.76	63.90 ± 4.78	0.705

Results are expressed as Mean ± SD. ‘p’ value > 0.05 is not significant.

STATISTICAL ANALYSIS

The comparison between the study group (swimmers) and control group (non swimmers) was done by **student’s t- test** using **SPSS 20 (Statistical Package for Social Sciences) software, Sigma stat version 3.5.** The **statistical significance** was drawn at ‘**p’ value < 0.05.**

- The mean ± SD for **age** for study and control group were **10.15 ± 1.52** years and **10.18 ± 1.52** years respectively.

- The mean ± SD for **BMI** for study and control group were **16.73 ± 2.41** kg/m^2 and **16.68 ± 2.39** kg/m^2 respectively.

- The mean ± SD for **pulse rate** for study and control group were **74.33 ± 6.06/** minute and **73.23 ± 4.42/** minute respectively.

- The mean ± SD for **systolic blood pressure** for study and control group were **105.33 ± 6.67** mm Hg and **104.63 ± 5.63** mm Hg respectively.

- The mean ± SD for **diastolic blood pressure** for study and control group were **63.53 ± 5.76** mm Hg and **63.90 ± 4.78**mm Hg respectively.

Statistical analysis was done by student's t- test which revealed that the anthropometric and basal cardiovascular parameters did not vary significantly between the study and control group with a **'p' value > 0.05.**

Table-2: Comparison of the parameters of the pulmonary function test between the study and control group.

S.No	Parameters	Study group (n=60)	Control group (n=60)	'p' value
1	**FEV_1 (L)**	2.57 $\pm$ 0.89	1.71 $\pm$ 0.59	< 0.001
2	**FVC (L)**	2.33 $\pm$ 0.84	1.47 $\pm$ 0.54	< 0.001
3	**FEV_1 %**	90.26 $\pm$ 6.23	86.37 $\pm$10.09	0.012
4	**PEFR (L/sec)**	4.82 $\pm$ 0.78	3.99 $\pm$ 0.76	< 0.001

Results are expressed as Mean $\pm$ SD. 'p' value < 0.05 is significant and 'p' value < 0.001 is highly significant.

- The **mean $\pm$ SD** of **FEV_1** for study and control group were **2.57 $\pm$ 0.89** Litres and **1.71 $\pm$ 0.59** Litres respectively.

- The **mean $\pm$ SD** of **FVC** for study and control group were **2.33 $\pm$ 0.84** Litres and **1.47 $\pm$ 0.54** Litres respectively.

- The **mean $\pm$ SD** of **FEV_1%** for study and control group were **90.26 $\pm$ 6.23**% and **86.37 $\pm$ 10.09**% respectively.

- The **mean** $\pm$ **SD** for **PEFR** for study and control group were **4.82** $\pm$ **0.78** Litres/ second and **3.99** $\pm$ **0.76** Litres/ second respectively.

The pulmonary function tests show an increase in swimmers when compared with normal individuals. Results analysed using student's t- test revealed a statistically **significant 'p' value ($p < 0.05$).**

DISCUSSION

Like in most studies an increase in value of vital capacity (VC) in swimmer group was observed which was highly significant. Increase in VC observed in swimmers may be the result of changes in the inspiratory muscle strength induced by swim training. Load comprised of the water pressure against the chest wall and elevated airway resistance due to submersion could comprise conditioning stimulus for increase in inspiratory muscle strength **Andrew GM et al., 1972.**

In a study conducted by **Bjurstrom RL** and **Shoene RB** in **1987,** the increase in VC was explained by increased inspiratory muscle strength, since during immersion in water these swimmers experience negative pressure breathing.

From the above results it is clear cut that swimming children have higher values of pulmonary functions when compared to the non swimming children. This study confirms that swimming practices performed regularly have a beneficial effect on the lungs. Similar such results have been obtained by other researchers in this field **Cotes JE et al., 1975; Das SK, Ray A, 1989; Kamat SR et al., 1977; Miller GJ et al., 1977.**

During sternuous exercise the metabolic demand of the body is enormous. This requires an effective oxygen transport system from air to the active tissues. From the results obtained in the present study it is concluded that physical training has a significant facilitatory effect on ventilatory function and that physically active persons have greater lung function values when compared to individuals leading a sedentary life **Andrew GM et al., 1972; Holmer I et al., 1974; Kaufmann DA et al., 1974; Leith DE et al., 1976; Sinning W et al., 1968.**

When the lungs are inflated to the maximum extent surfactant and prostaglandins are released into the alveolar space. Surfactant increases the ability of the lung to expand and PGs decreases the tone of the bronchiolar smooth muscle.

The ability of the individual to inspire and expire depends upon the posture, power of the thoracic and abdominal muscles and the ability of the lungs to expand. Swimmers can acquire this ability because swimming is performed in a position (horizontal) different from other sports (vertical).

Swimming gives a constant exercise to the erector spinae muscle as this sport involves keeping the head extended. This increases the antero-posterior diameter and vertical diameter of the lungs. Exercise to the supraspinatus muscle increases the antero-posterior diameter of the lungs. The other muscles that are also exercised are: the diaphragm, sternocleidomastoid and trapezius.

Limited ventilation during swimming leads to intermittent hypoxia. Due to this intermittent hypoxia, lactic acid accumulates in the blood causing “lactic oxygen deficit”. Excess accumulation of lactic acid causes metabolic acidosis which in turn stimulates the respiratory center and subsequently increases the rate and depth of respiration.

FVC and FEV_1 depend on the strength of abdominal muscles. These muscles undergo hypertrophy with prolonged exercise. The diaphragm and accessory muscles of respiration also respond in the same manner. The higher values of FVC and FEV_1 depend on the muscle power **Stuart et al., 1959.** The resultant alveolar hyperplasia may be the cause for increase in FVC, VC and the number of alveoli.

Swimming involves high pressure on the thorax from outside. So the respiratory muscles and the diaphragm develop greater pressure during the respiratory cycle to overcome this high external pressure. This ultimately leads to functionally better respiratory muscles. Also the conductance of water for heat is more than that of air.

Regular swimming practices alter the elasticity of the lungs and the chest wall which leads to improvement in lung functions in these people. These factors play an important role in developing better lung functions in swimmers compared to any other sportsmen.

Swimming takes place in a medium that presents different forces of gravity and resistance. The respiratory conditions and thermal stress are also different. The energy utilized for moving forward during swimming is high. But regular swim training causes a considerable reduction of energy at a given velocity. The energy cost during swimming is also different for each type of swimming style. It is lowest for front crawl, followed by backstroke, butterfly and breast-stroke.

Local factors such as peripheral circulation, capillary density, perfusion pressure and metabolic capacity of active muscles are important determinants to enhance the person to swim. Improved swimming techniques explain the continuous advancement in performance.

Swimmers are in a liquid medium i.e. water. It has an increased density when compared to air. This increase in density causes a swimmer's chest to perform millions of breaths against a small resistance throughout his swimming career. This chest workout could develop the lung and inspiratory muscles **Varsha Akhade et al., 2014.**

Pulmonary function tests denote how well the lungs ventilate and how powerfully they transfer oxygen into the blood. Spirometry in general, measure how well the lungs are functioning. Swimming by increasing the airway calibre and muscular efficiency brings about enhanced pulmonary function. Previous research done in swimmers of prepubescent age groups has shown that swim training improves the conductive properties of the airways independent of growth **Courteix et al., 1997.**

Regular swimming produces a positive effect on the lungs by increasing pulmonary capacity and thereby improving the lung functioning. Good swimmers tend to be above average for lung capacity.

Training during the younger age increases vital capacity and total lung capacity due to the development of a broad chest and long trunk. This increased vital capacity helps swimmers maintain their buoyancy **Shephard, 1978.**

Maximal aerobic capacity reaches its peak in both males and females between the ages of 18 to 20 years **Astrand and Rodahl, 1977.**

This study shows that $FEV_{1,}$ FVC, FEV1% and PEFR were significantly higher in swimmers than controls ('p' value < 0.05). The higher values may be due to the beneficial effect of swim training on the pulmonary efficiency.

Hence a regular practice of swimming increases the pulmonary function and this may help a regular swimmer to be less likely to develop chronic obstructive pulmonary diseases.

CONCLUSION

Previous studies have shown that children swimming at an early age developed physically, intellectually and emotionally. They reached developmental milestones earlier than the normal in areas of cognitive, physical and language development. These children are found to have higher learning skills, better visual- motor skills and mathematically related tasks. They became more creative and observant. Their ability to speak and explain things was also found to be better in areas of literacy and numeracy.

Swimming helps the children to become more confident. It also provides them a sense of relaxation. Swimming can also improve the mental health and thus help the individual to combat depression in this competitive world. Their bonds with parents grows stronger as together they share new experiences. Their experience also contributes to their socialization in this society.

Another benefit is that it helps to keep them fit. Even children who dislike exercise enjoy being in water. In water, children can move more freely than on land with a sense of weightlessness.

Moreover swimming is a great calorie burner. Swimming burns three calories a mile per pound of body weight. With advancements in technology and unhealthy eating practices many children are obese today. Many children spend less than 1 hour for physical activity. Rising childhood obesity is of great concern as these children are more prone for early onset of diabetes, heart diseases, osteoarthritis, stroke and cancer. Hence physical activity in the form of swimming can be recommended for these children.

Swimming also benefits children with learning difficulties. The gentle pressure against the child’s body is also calming and can assist children who are autistic. Swimming also puts less strain on joints and connective tissues than other forms of exercise. Even children with chronic lung disorders like bronchial asthma get benefitted by swimming. However, they need keen supervision and guidance.

The present study concludes that physical activity in the form of swimming for more than two years produces a major improvement in the pulmonary functions. This improvement is directly proportional to the duration of swimming. Hence swimming can be recommended to improve the lung function of an individual. Improvement in the lung function at an early age may prevent respiratory diseases in the adult life.

Hence swimming inculcated at an early age makes the children grow into a healthy, confident and self- esteemed adults.

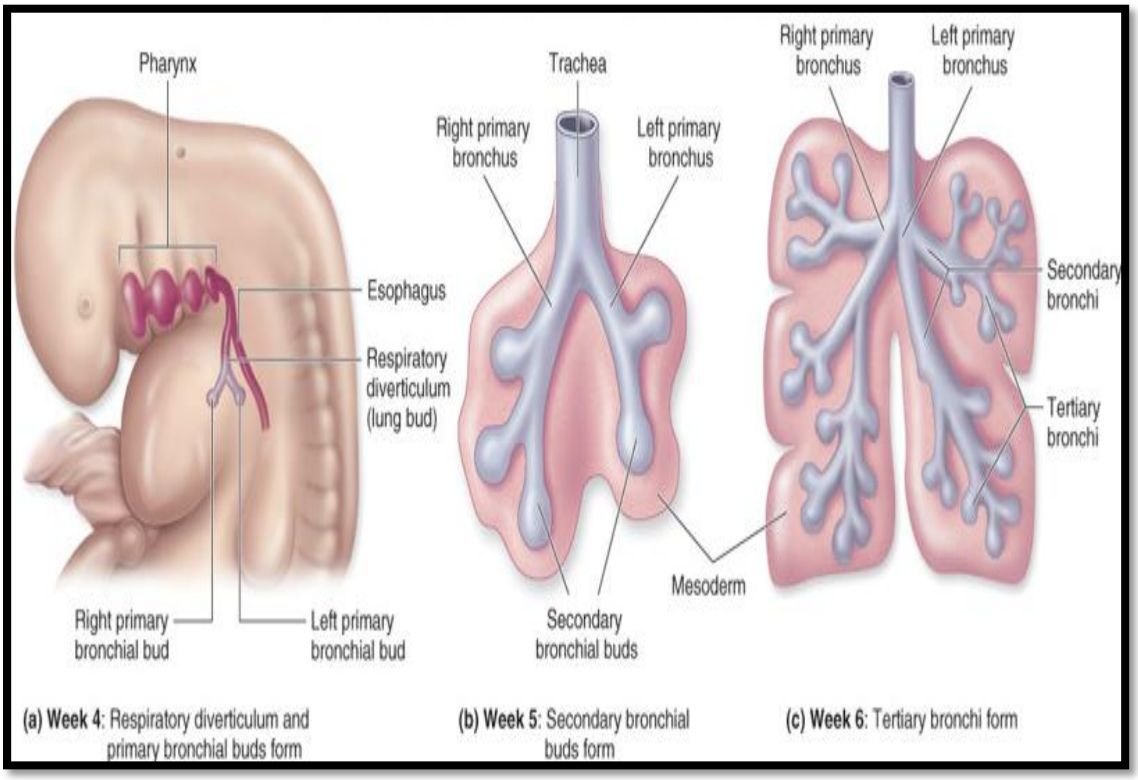
MASTER CHART- SWIMMERS																	
S. No.	Name	Age	Sex	Duration-swimming	H/oLung disorders	Medica-tions	PR/ min	BP mmHg		Height (m)	Weight (Kg)	BMI (Kg/m^2)	FVC (L)	FEV_1 (L)	FEV_1 %	PEFR (L/sec)
								SBP	DBP							
1	Sakthivel	8	M	3 years	-	-	80	100	60	1.26	24	15.1	1.90	1.85	97.4	4.10
2	Gunabalan	10	M	3 years	-	-	78	100	70	1.37	32	17.1	2.30	2.10	91.3	4.70
3	Harsha	10	F	3 years	-	-	88	96	60	1.43	34	16.7	3.17	2.95	93.1	5.40
4	Tarun	12	M	3 years	-	-	68	102	60	1.50	39	17.3	3.01	2.90	96.3	5.60
5	Krithik	10	M	3 years	-	-	80	102	62	1.36	32	17.4	2.28	1.90	83.3	4.30
6	Darshin	9	M	3 years	-	-	68	100	70	1.39	33	17.1	2.67	2.51	94.0	5.10
7	Bharathithasan	9	M	2.5 years	-	-	76	106	68	1.33	30	17.0	1.80	1.70	94.4	4.90
8	Harshath	8	M	3 years	-	-	78	100	60	1.32	29	16.7	1.80	1.60	88.8	4.50
9	Rakesh Kumar	8	M	3 years	-	-	88	110	66	1.27	24	14.9	1.80	1.50	83.3	3.50
10	MeenakshiSundaram	9	M	3 years	-	-	78	100	60	1.35	25	13.7	2.31	1.90	82.2	4.80
11	Ashwin	10	M	3 years	-	-	78	100	56	1.39	34	17.6	2.60	2.41	92.6	4.90
12	Srinithi Krishna	11	F	3 years	-	-	70	100	60	1.43	40	19.6	2.75	2.62	95.2	5.80
13	Asmita	8	F	3 years	-	-	70	100	56	1.23	24	15.9	1.50	1.30	86.6	3.90
14	Surya	9	M	2.5 years	-	-	70	100	60	1.30	23	13.6	1.90	1.60	84.2	4.00
15	Prasanna	10	M	3 years	-	-	68	110	70	1.32	24	13.8	2.01	1.98	98.5	4.50
16	Divya Bharathi	10	F	3 years	-	-	74	100	60	1.30	25	15.0	1.90	1.65	86.8	4.40
17	Lalitha	9	F	3 years	-	-	78	100	60	1.27	28	17.4	1.60	1.48	92.5	3.80
18	Prakash Daniel	11	M	3 years	-	-	70	106	74	1.42	40	19.9	2.50	2.31	92.2	5.00
19	Neha	9	F	3 years	-	-	78	110	60	1.28	30	18.4	2.45	2.00	81.6	3.90
20	Pratapvatsav	11	M	3 years	-	-	68	120	70	1.32	26	14.9	2.76	2.44	88.4	4.39
21	Pragathi	12	F	3 years	-	-	70	110	60	1.45	49	23.3	3.45	2.76	80.0	5.08
22	Seeman Madesh	8	M	2.5 years	-	-	80	108	60	1.32	28	16.1	1.60	1.30	81.2	4.43
23	Mugilavanika	9	F	3 years	-	-	68	110	58	1.30	27	16.0	1.90	1.55	81.5	4.01
24	Bhuvannath	10	M	3 years	-	-	86	100	56	1.34	26	14.5	2.69	2.67	99.2	5.00
25	Rahul Gupta	12	M	3 years	-	-	68	120	68	1.49	39	17.6	2.82	2.77	98.2	5.60
26	Kavya	10	F	2.5 years	-	-	74	100	60	1.27	28	17.4	2.01	1.90	94.5	3.90
27	Sanjana Lakshmi	10	F	3 years	-	-	88	108	60	1.42	31	15.4	3.70	3.04	82.1	5.50
28	Shasmi	9	F	3 years	-	-	80	108	66	1.33	24	13.6	1.83	1.65	90.1	4.50
29	Kavin Raj	11	M	3 years	-	-	78	106	66	1.42	30	14.9	2.25	2.17	96.4	5.00
30	Prabhakaran	12	M	3 years	-	-	72	110	70	1.49	44	19.8	2.90	2.60	89.6	5.50

MASTER CHART- SWIMMERS																
S. No.	Name	Age	Sex	Duration-swimming	H/o Lung disorders	Medic-ations	PR/ min	BP mmHg		Height (m)	Weight (Kg)	BMI (Kg/m^2)	FVC (L)	FEV_1 (L)	FEV_1 %	PEFR (L/sec)
								SBP	DBP							
31	Nega	11	F	3 years	-	-	68	110	60	1.45	29	13.8	2.30	2.10	91.3	5.10
32	Naveen Sundar	10	M	3 years	-	-	68	100	60	1.36	27	14.7	2.10	2.00	95.23	4.70
33	Vikkas	11	M	2.5 years	-	-	70	110	60	1.43	34	16.7	2.52	2.35	93.2	5.30
34	Sreeman	11	M	3 years	-	-	76	124	74	1.52	43	18.6	2.95	2.68	90.8	5.60
35	Sanjai	12	M	3 years	-	-	82	110	80	1.52	50	23.4	2.94	2.71	92.1	5.50
36	Balaji	11	M	3 years	-	-	82	108	80	1.38	26	13.7	2.60	2.44	93.8	4.10
37	Siddarth	11	M	3 years	-	-	84	114	72	1.48	33	15.1	3.02	2.75	91.0	5.80
38	Dharun Kumar	10	M	3 years	-	-	86	104	62	1.46	36	16.9	2.80	2.60	92.8	5.70
39	Haajra Fathima	8	F	3 years	-	-	70	100	60	1.19	20	14.2	1.50	1.10	73.3	3.50
40	Sree Amuthavalli	12	F	3 years	-	-	76	110	60	1.49	33	14.9	3.11	3.11	100.0	5.60
41	Rochana	12	F	3 years	-	-	68	110	60	1.58	52	20.9	5.17	5.17	100.0	5.50
42	Gopika	8	F	2.5 years	-	-	68	100	60	1.18	19	13.7	1.32	1.08	81.8	3.20
43	Swetha	11	F	3 years	-	-	70	100	70	1.40	37	18.9	2.20	2.00	90.9	4.10
44	Prasothguhan	12	M	3 years	-	-	76	100	60	1.41	40	20.2	2.77	2.25	81.2	4.00
45	Radhika	12	F	3 years	-	-	80	120	60	1.52	48	20.8	4.71	4.10	87.0	5.70
46	Gogul	8	M	3 years	-	-	70	100	62	1.33	28	15.9	2.00	1.90	95.0	4.50
47	Sivaprakasam	12	M	3 years	-	-	76	106	60	1.47	40	18.5	2.98	2.61	87.5	5.80
48	Harish Pandiyan	12	M	2.5 years	-	-	72	120	70	1.50	40	17.8	3.01	2.96	98.3	5.97
49	Selva Presanna	12	M	3 years	-	-	70	100	60	1.52	30	13.0	3.98	3.68	92.4	5.50
50	Kishan	8	M	3 years	-	-	72	110	60	1.28	27	16.6	1.99	1.58	79.3	4.20
51	Poojasree	8	F	3 years	-	-	68	100	58	1.26	25	15.8	1.90	1.57	82.6	4.10
52	Sriram	12	M	3 years	-	-	72	100	60	1.42	42	21.0	2.98	2.46	82.5	5.30
53	Prince	8	M	3 years	-	-	68	100	60	1.29	22	13.3	1.90	1.75	92.1	4.50
54	Rishinikkesh	8	M	3 years	-	-	68	102	60	1.17	24	17.6	1.01	1.01	100.0	3.35
55	Visvesh	12	M	3 years	-	-	76	100	70	1.51	35	15.4	3.62	3.37	93.0	5.99
56	Chandru	12	M	3 years	-	-	74	110	70	1.52	37	16.0	3.90	3.67	94.1	5.89
57	Guruprasanth	9	M	3 years	-	-	68	110	60	1.35	30	16.5	2.01	1.85	92.0	4.90
58	Vignesh Raja	12	M	2.5 years	-	-	68	110	68	1.50	43	19.1	3.93	3.62	92.1	5.04
59	Annapoornima	8	F	3 years	-	-	68	90	60	1.26	24	15.2	1.48	1.44	97.2	4.10
60	Hari	12	M	3 years	-	-	76	100	70	1.60	46	17.9	5.33	4.68	87.8	6.80

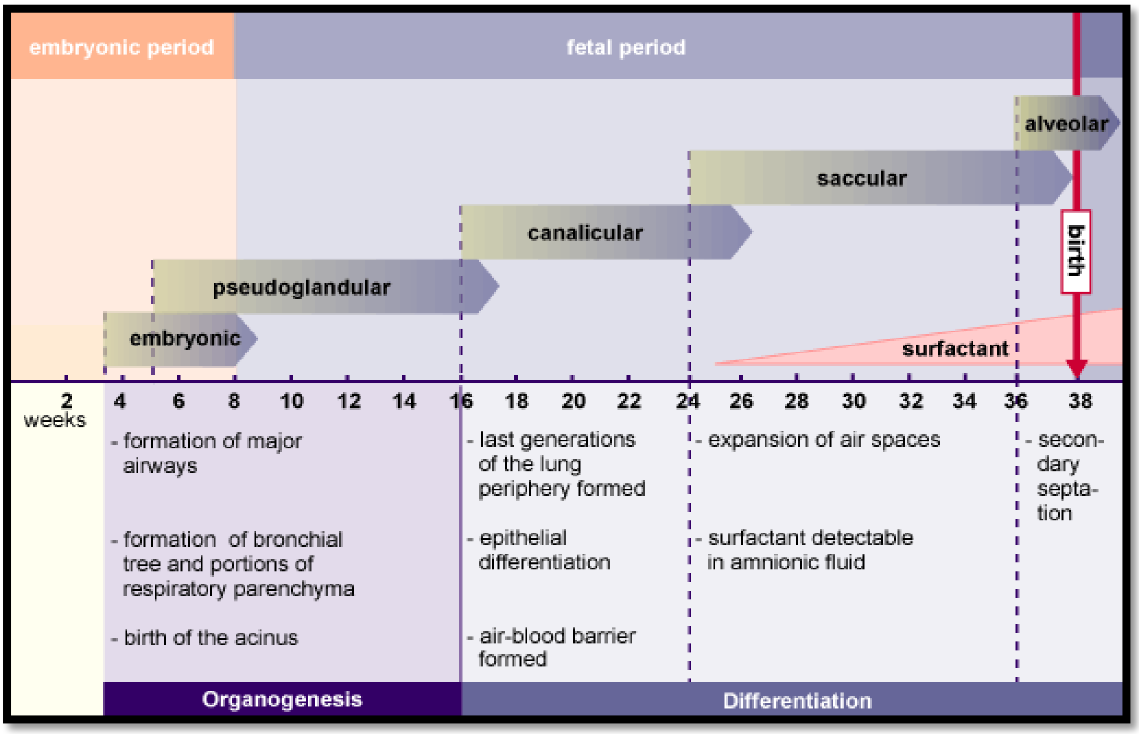
MASTER CHART- NON-SWIMMERS															
S. No.	Name	Age	Sex	H/o Lung disorders	Medica -tions	PR/ min	BP mmHg		Height (m)	Weight (Kg)	BMI (Kg/m^2)	FVC (L)	FEV_1 (L)	FEV_1 %	PEFR (L/sec)
							SBP	DBP							
1	Rajkumar	8	M	-	-	68	100	60	1.24	23	15.0	1.20	1.04	86.66	3.65
2	Praveen kumar	10	M	-	-	70	100	60	1.36	32	17.3	1.30	1.08	83.07	3.98
3	Sandhiya	10	F	-	-	80	102	60	1.42	33	16.4	2.01	1.83	91.04	4.99
4	Karthikeyan	12	M	-	-	76	108	66	1.50	40	17.7	1.89	1.70	89.94	4.91
5	Sabari	10	M	-	-	74	100	60	1.36	32	17.4	2.06	1.74	84.46	4.50
6	Pandian	9	M	-	-	72	100	64	1.37	32	17.1	1.13	1.08	95.57	4.91
7	Maheswaran	9	M	-	-	80	100	60	1.32	30	17.2	1.10	0.88	80.00	3.90
8	Ajith Kumar	8	M	-	-	68	106	58	1.32	29	16.7	0.99	0.89	89.89	3.83
9	Hariharan	9	M	-	-	74	100	60	1.28	24	14.7	0.81	0.79	97.53	3.34
10	Damodaran	9	M	-	-	70	110	70	1.34	25	13.9	1.93	1.67	86.52	4.00
11	Ramachandran	10	M	-	-	68	100	58	1.38	33	17.3	1.39	1.09	78.41	3.04
12	Seethalakshmi	11	F	-	-	74	110	70	1.43	40	19.6	2.22	1.80	81.08	4.15
13	Bharathi	8	F	-	-	78	100	60	1.22	23	15.5	0.97	0.88	90.72	2.96
14	Sabarirajan	9	M	-	-	68	110	68	1.31	23	13.5	1.05	1.00	95.23	3.73
15	Santhosh Pandi	10	M	-	-	80	100	62	1.32	24	13.8	1.71	1.65	96.49	3.45
16	Rubini	10	F	-	-	72	100	60	1.29	25	15.1	1.49	1.20	80.53	3.88
17	Praveena	9	F	-	-	70	102	68	1.28	28	17.1	0.98	0.88	89.79	2.98
18	Muthukumar	11	M	-	-	80	100	60	1.41	39	19.7	1.78	1.74	97.75	4.33
19	Kumari	9	F	-	-	72	110	70	1.28	30	18.4	1.42	1.12	78.87	2.04
20	Surya	11	M	-	-	78	110	70	1.34	26	14.5	1.84	1.04	56.52	3.39
21	Sowmya	12	F	-	-	70	100	60	1.44	48	23.1	2.14	2.00	93.45	4.18
22	Vikash	8	M	-	-	68	120	70	1.32	29	16.6	1.16	1.03	88.79	3.43
23	Narmadha	9	F	-	-	72	100	60	1.30	28	16.5	1.53	1.40	91.50	3.90
24	Koodeeshwaran	10	M	-	-	70	110	70	1.33	26	14.7	1.90	1.81	95.26	3.60
25	Veeramanikandan	12	M	-	-	78	110	60	1.48	39	17.8	2.50	2.28	91.20	4.48
26	Sundari	10	F	-	-	72	100	58	1.27	28	17.4	1.50	1.10	73.33	2.29
27	Gayathri	10	F	-	-	80	102	60	1.42	31	15.4	2.13	1.97	92.48	4.91
28	Saranya	9	F	-	-	70	100	60	1.34	25	13.9	1.39	1.28	92.08	3.94
29	Bharath	11	M	-	-	72	102	58	1.42	29	14.4	2.25	1.95	86.66	4.18
30	Siva	12	M	-	-	68	120	70	1.48	44	20.0	1.66	1.60	96.38	4.46

MASTER CHART- NON-SWIMMERS															
S. No.	Name	Age	Sex	H/o Lung disorders	Medic-ations	PR/ min	BP mmHg		Height (m)	Weight (Kg)	BMI (Kg/m^2)	FVC (L)	FEV_1 (L)	FEV_1 %	PEFR (L/sec)
							SBP	DBP							
31	Gayathri	11	F	-	-	70	110	70	1.45	28	13.3	1.05	0.99	94.28	4.91
32	Adhikesavan	10	M	-	-	74	100	60	1.36	27	14.7	1.22	1.02	83.60	4.24
33	Gopiraj	11	M	-	-	80	110	70	1.42	33	16.4	1.52	1.35	88.81	3.96
34	Muthamizh	11	M	-	-	68	100	60	1.52	43	18.6	1.95	1.95	100.0	5.04
35	Mani	12	M	-	-	76	102	68	1.52	50	23.4	1.42	1.02	71.83	4.53
36	Rajamani	11	M	-	-	74	110	70	1.38	26	13.7	2.04	1.92	94.11	3.80
37	Kesavan	11	M	-	-	70	100	60	1.47	33	15.2	2.47	2.40	97.16	4.30
38	Jawahar	10	M	-	-	68	104	60	1.46	35	16.4	2.56	2.01	78.51	4.80
39	Devi	8	F	-	-	80	102	60	1.20	20	13.9	0.84	0.81	96.42	2.09
40	Karthiga	12	F	-	-	74	110	70	1.49	33	14.9	2.51	2.03	80.87	4.31
41	Lalitha	12	F	-	-	68	110	70	1.58	52	20.9	2.84	2.57	90.49	4.93
42	Chandra	8	F	-	-	74	100	60	1.20	20	13.9	0.91	0.87	95.60	2.62
43	Seetha	12	F	-	-	72	102	68	1.40	36	18.4	1.71	1.01	59.06	3.76
44	Gokul	12	M	-	-	70	110	70	1.40	39	19.9	1.77	1.05	59.32	4.50
45	Poornima	12	F	-	-	80	100	68	1.53	48	20.5	2.64	2.33	88.25	4.71
46	Sundaram	8	M	-	-	70	110	60	1.34	28	15.6	1.65	1.05	63.63	3.80
47	Gopi	12	M	-	-	68	120	60	1.47	40	18.5	2.76	2.61	94.56	4.80
48	Prabakaran	12	M	-	-	74	100	60	1.50	39	17.3	1.96	1.69	86.22	5.01
49	Karthik	12	M	-	-	80	110	70	1.51	31	13.5	2.98	2.42	81.20	4.82
50	Manikandan	8	M	-	-	78	100	60	1.28	27	16.6	1.10	0.87	79.09	2.79
51	ArchanaDevi	8	F	-	-	68	110	62	1.27	25	15.5	1.21	1.00	82.64	2.95
52	Surya Kumar	12	M	-	-	80	102	68	1.42	42	21.0	1.34	1.34	100.0	4.23
53	Raja	8	M	-	-	78	100	60	1.28	22	13.4	1.05	0.94	89.52	3.36
54	Ranjith	8	M	-	-	74	102	70	1.18	25	17.9	1.01	0.96	95.04	3.56
55	Alagarsamy	12	M	-	-	78	110	70	1.50	35	15.5	2.77	2.07	74.72	4.70
56	Tamilazaghan	12	M	-	-	68	100	60	1.52	37	16.0	1.98	1.86	93.93	4.04
57	Ajith Kumar	9	M	-	-	70	102	70	1.36	30	16.3	1.62	1.32	81.48	3.95
58	Prasanna	12	M	-	-	68	100	60	1.50	43	19.1	1.93	1.43	74.09	4.80
59	ShanmugaPriya	8	F	-	-	70	100	60	1.25	24	15.3	1.08	0.98	90.74	3.80
60	Balamurugan	12	M	-	-	80	110	70	1.60	46	17.9	3.12	2.68	85.89	5.26

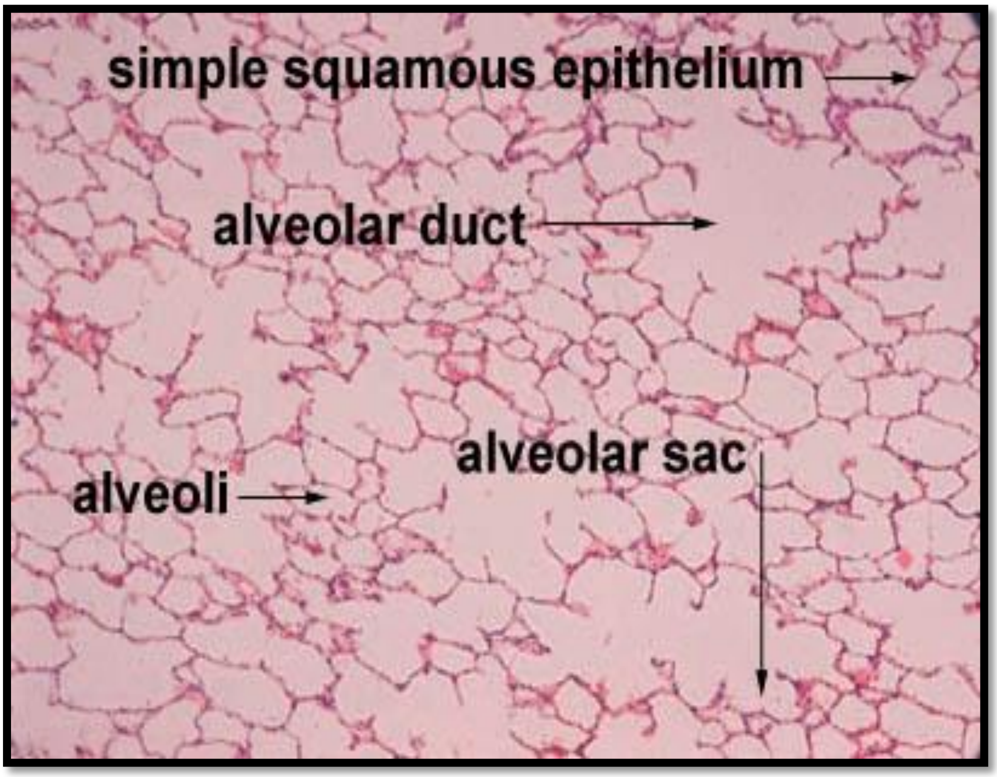
DEVELOPMENT OF THE LUNGS

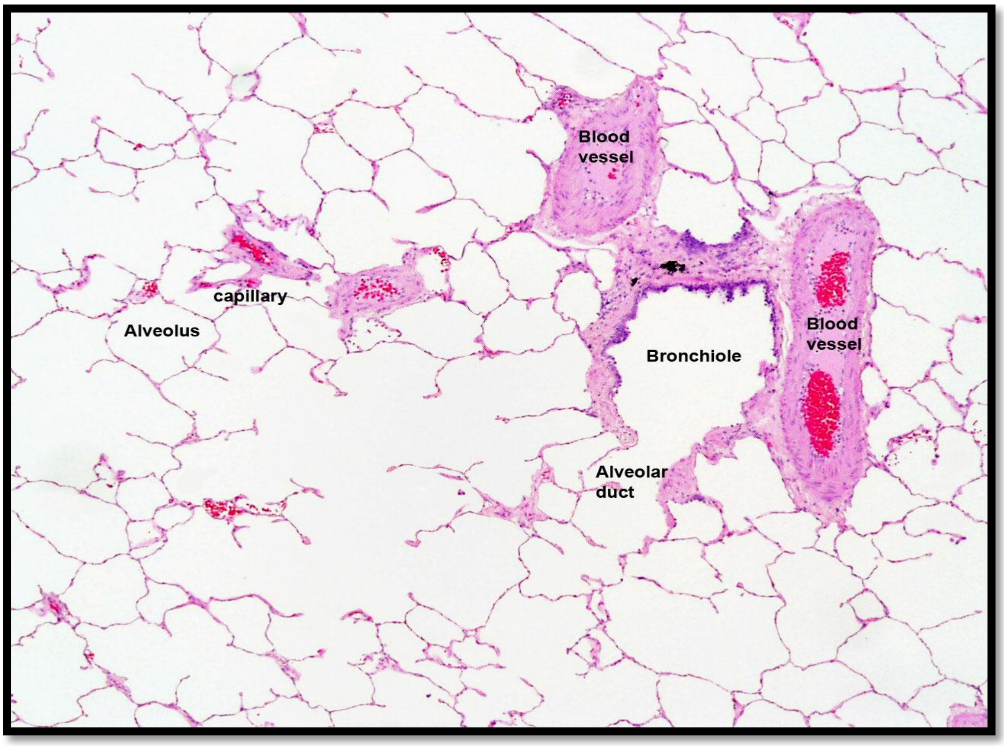


STAGES OF LUNG DEVELOPMENT

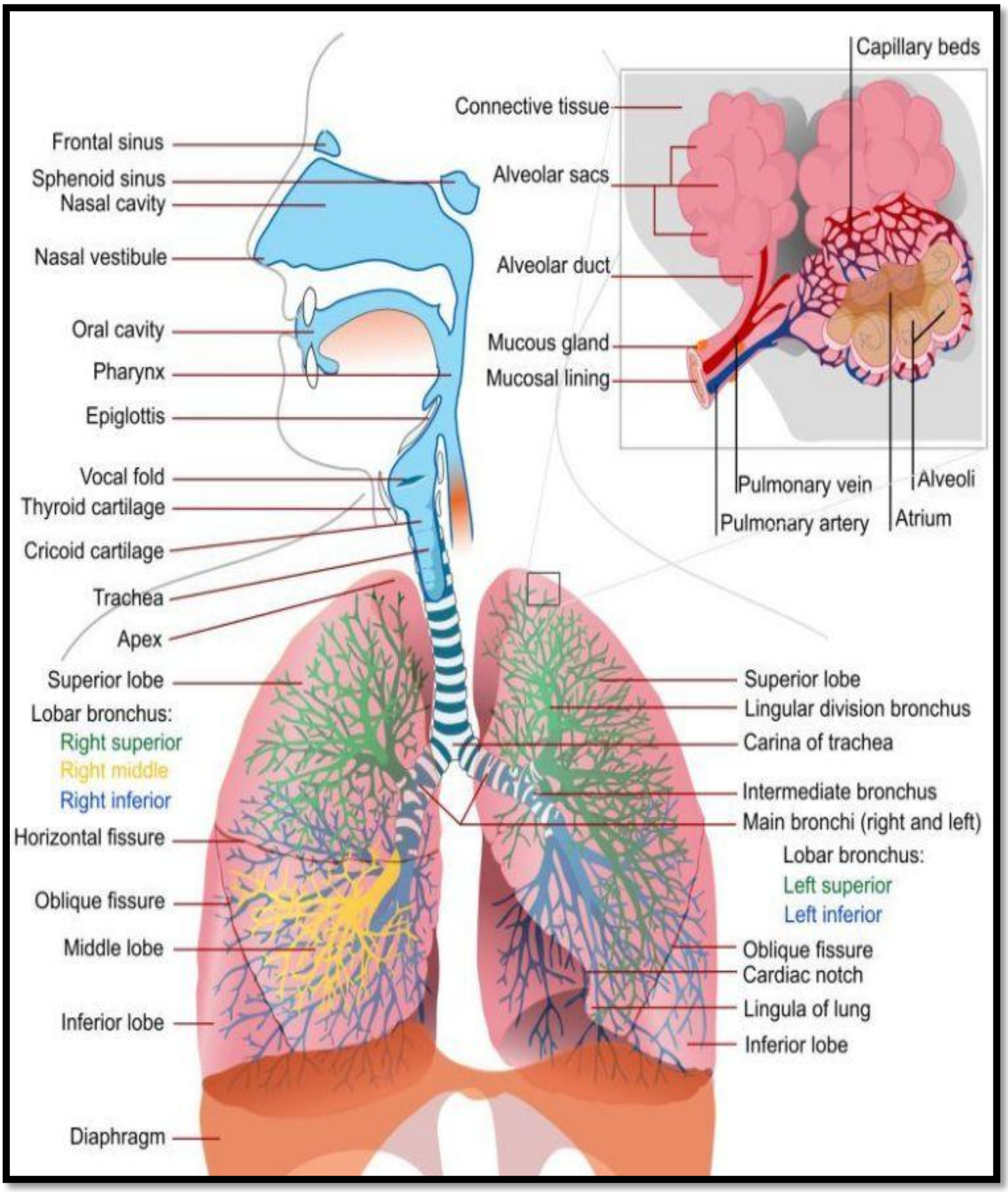


HISTOLOGY OF LUNGS

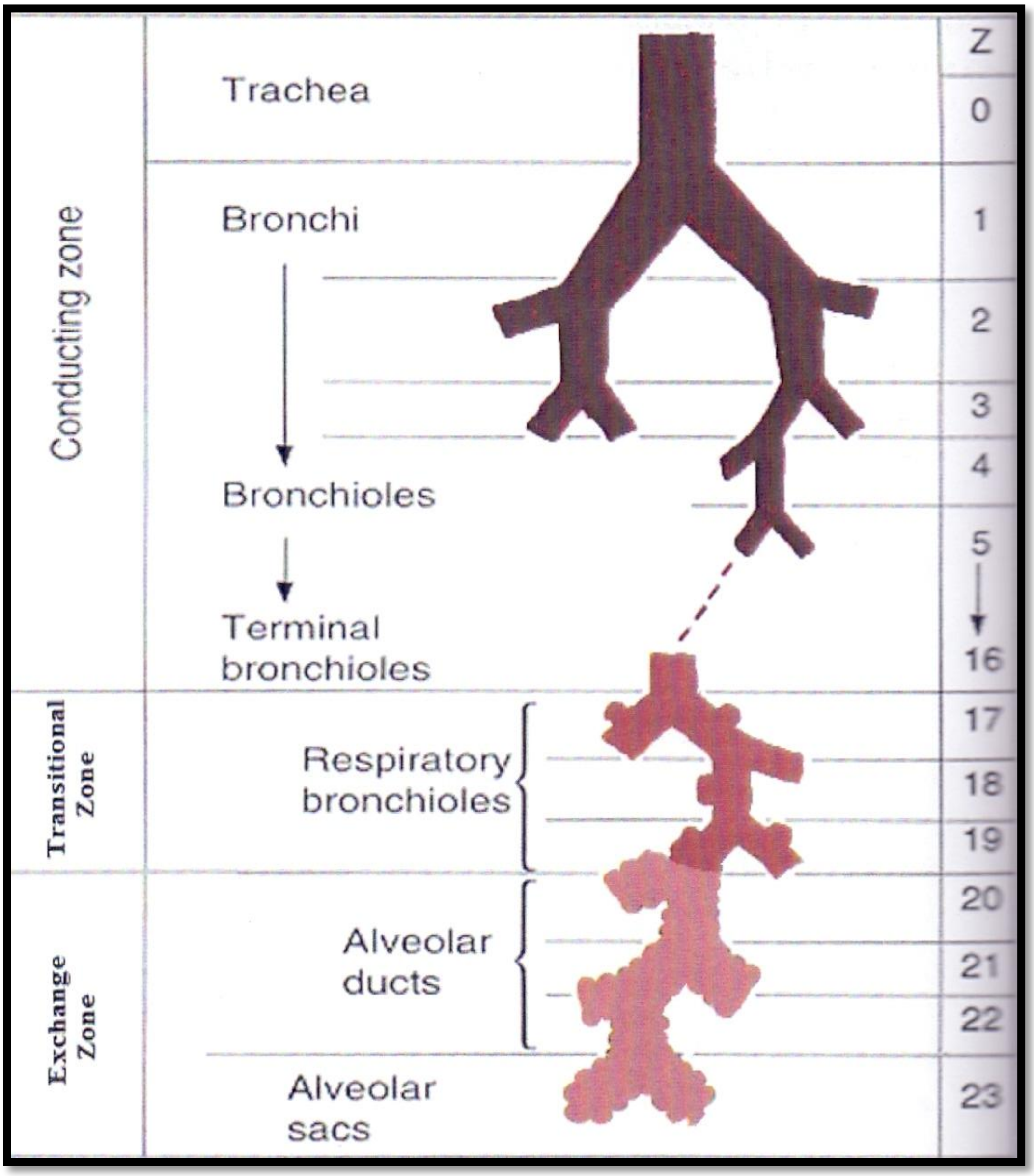




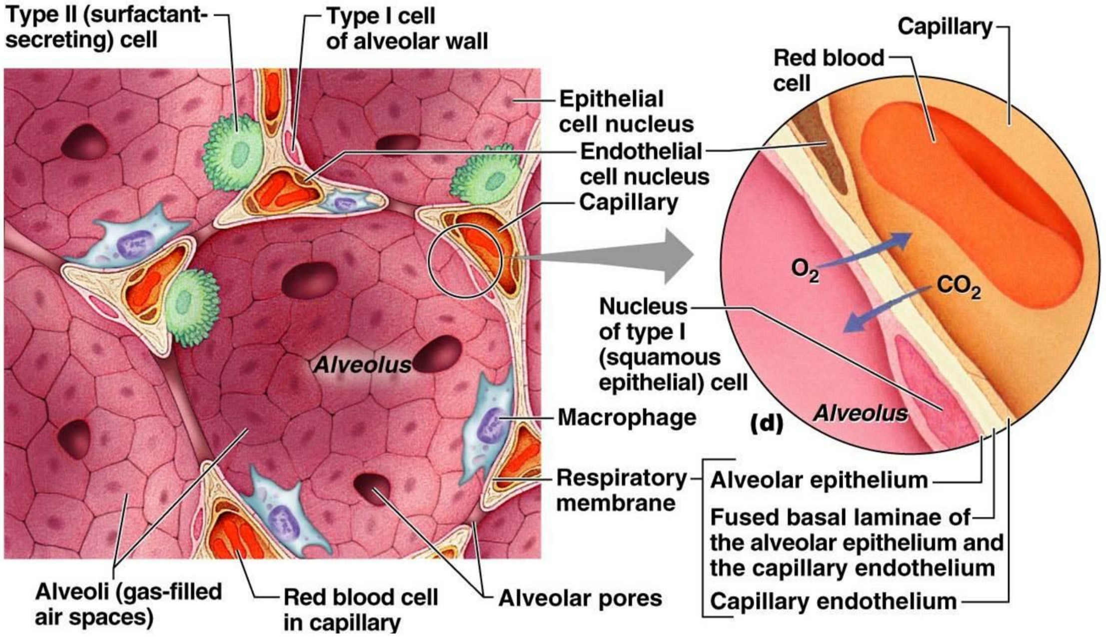
RESPIRATORY SYSTEM- FUNCTIONAL ANATOMY



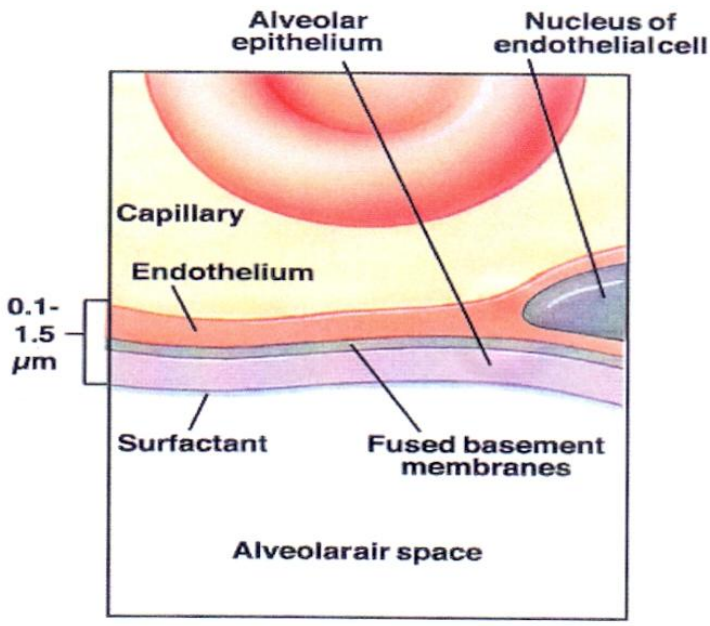
ORGANISATION OF TRACHEOBRONCHIAL TREE



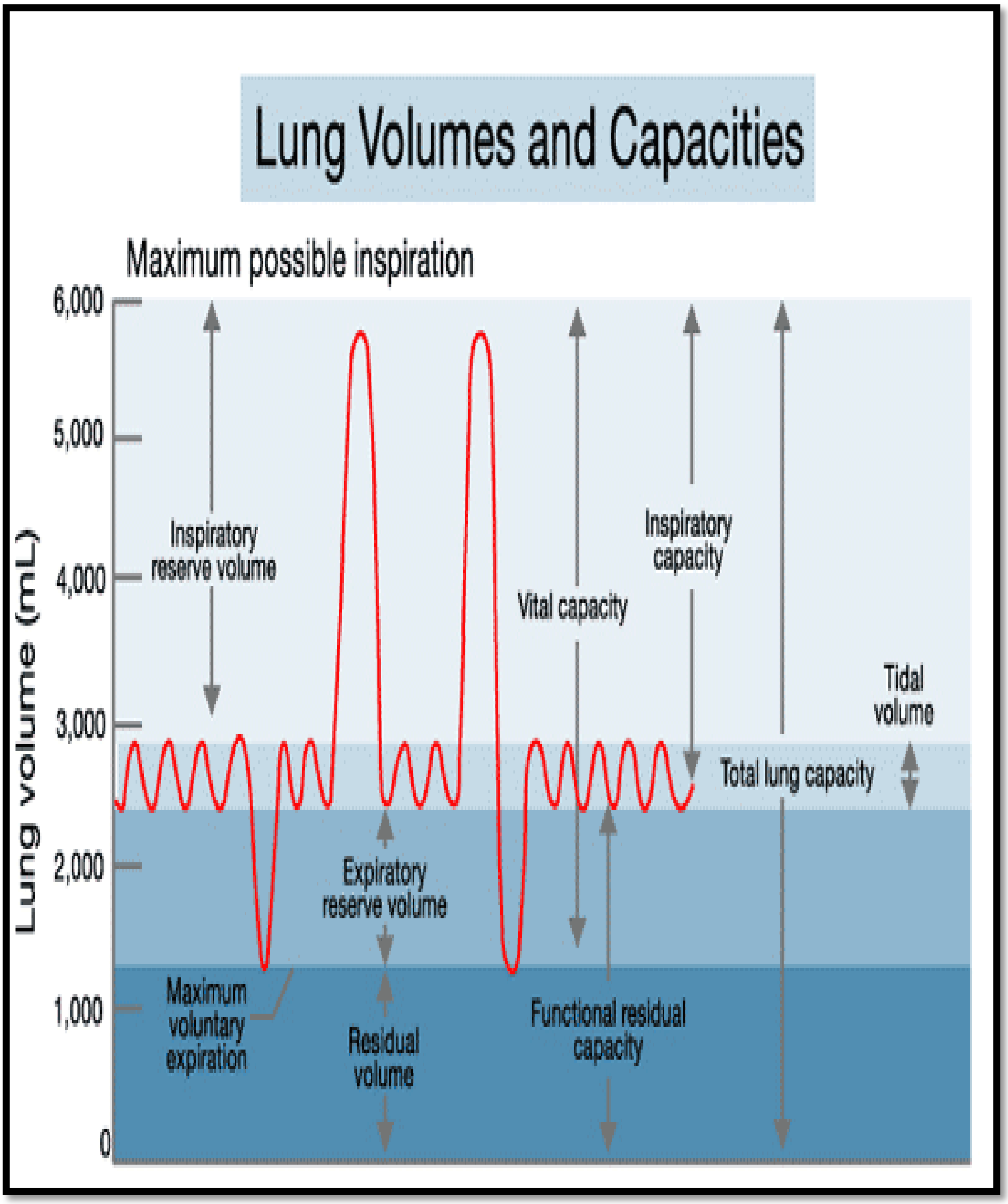
RESPIRATORY MEMBRANE



EXCHANGE SURFACE OF ALVEOLI



SPIROGRAM

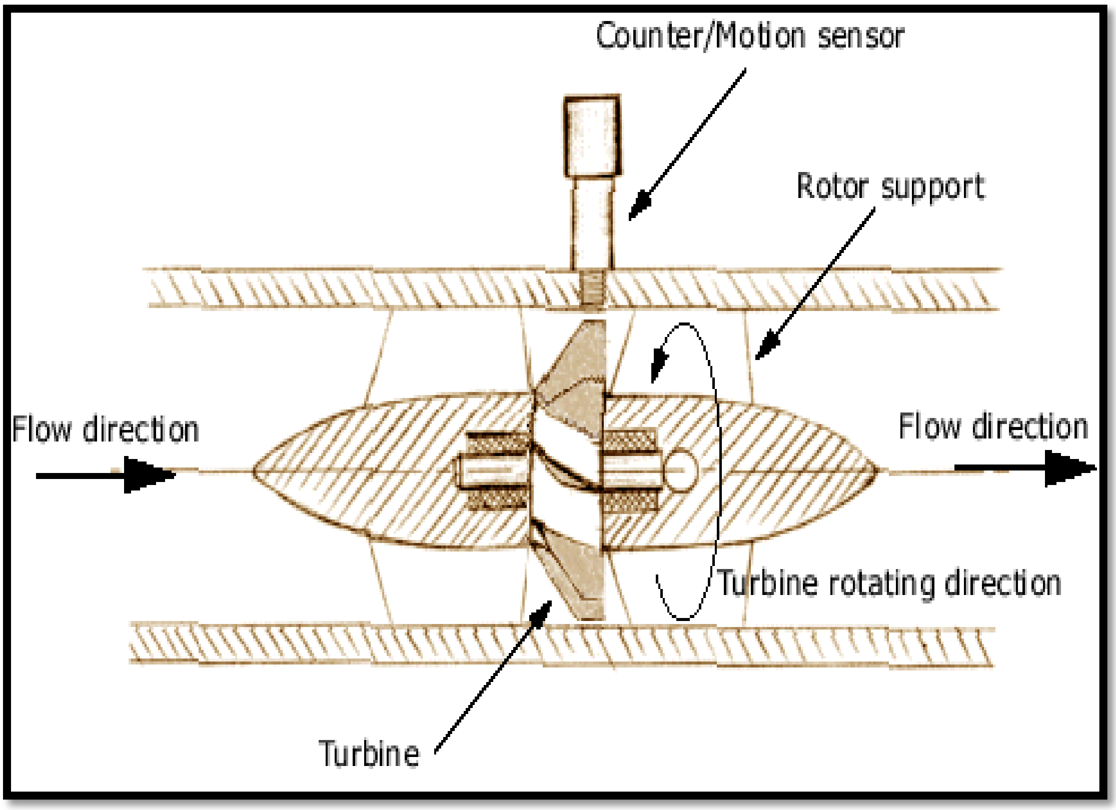


Lung Volumes and Capacities
Maximum possible inspiration
6,000
5,000
4,000
3,000
2,000
1,000
0
Lung volume (mL)
Inspiratory reserve volume
Inspiratory capacity
Vital capacity
Tidal volume
Total lung capacity
Expiratory reserve volume
Maximum voluntary expiration
Residual volume
Functional residual capacity

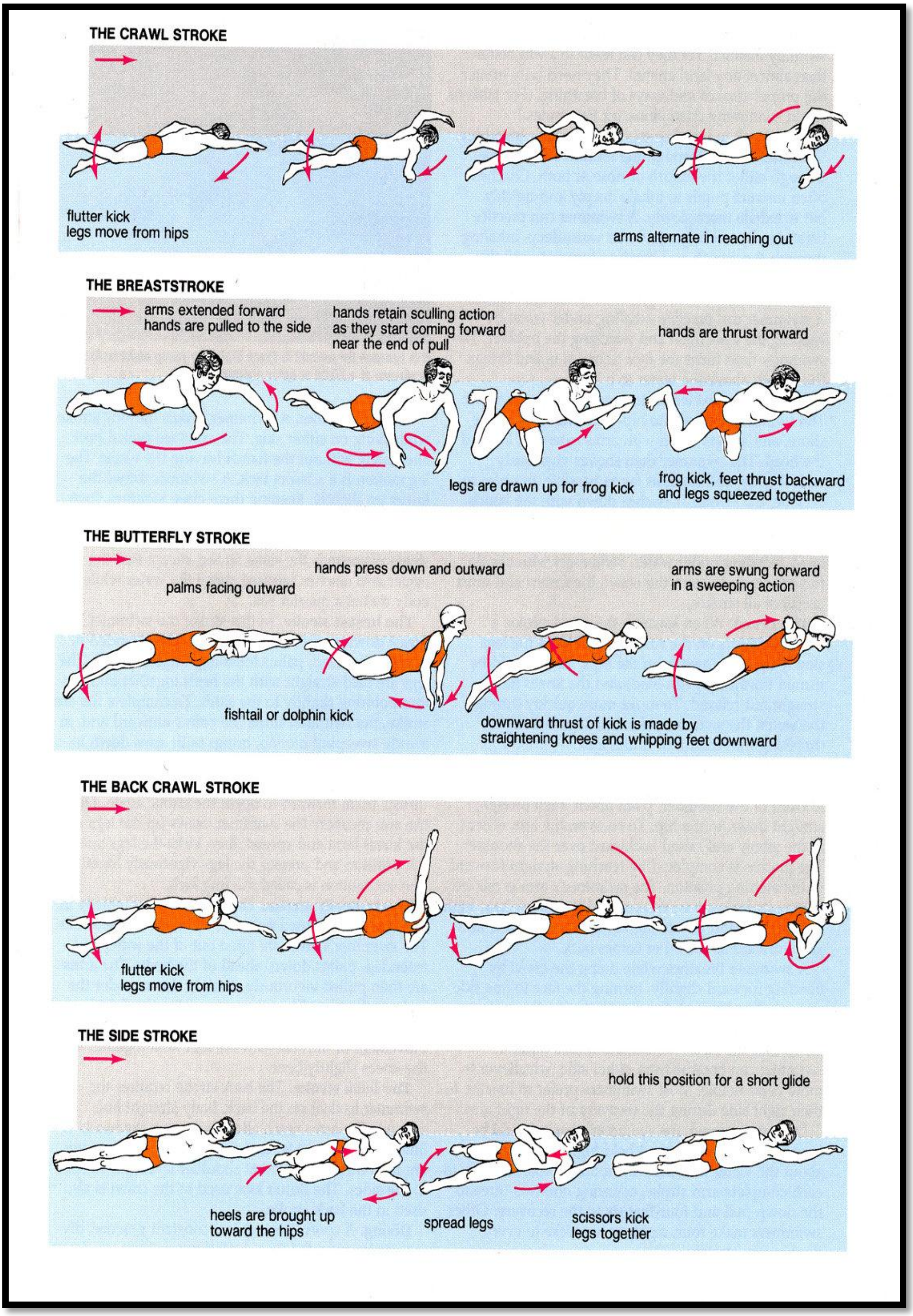
VOLUME DISPLACEMENT SPIROMETER

FLOW SENSING SPIROMETER

WORKING PRINCIPLE

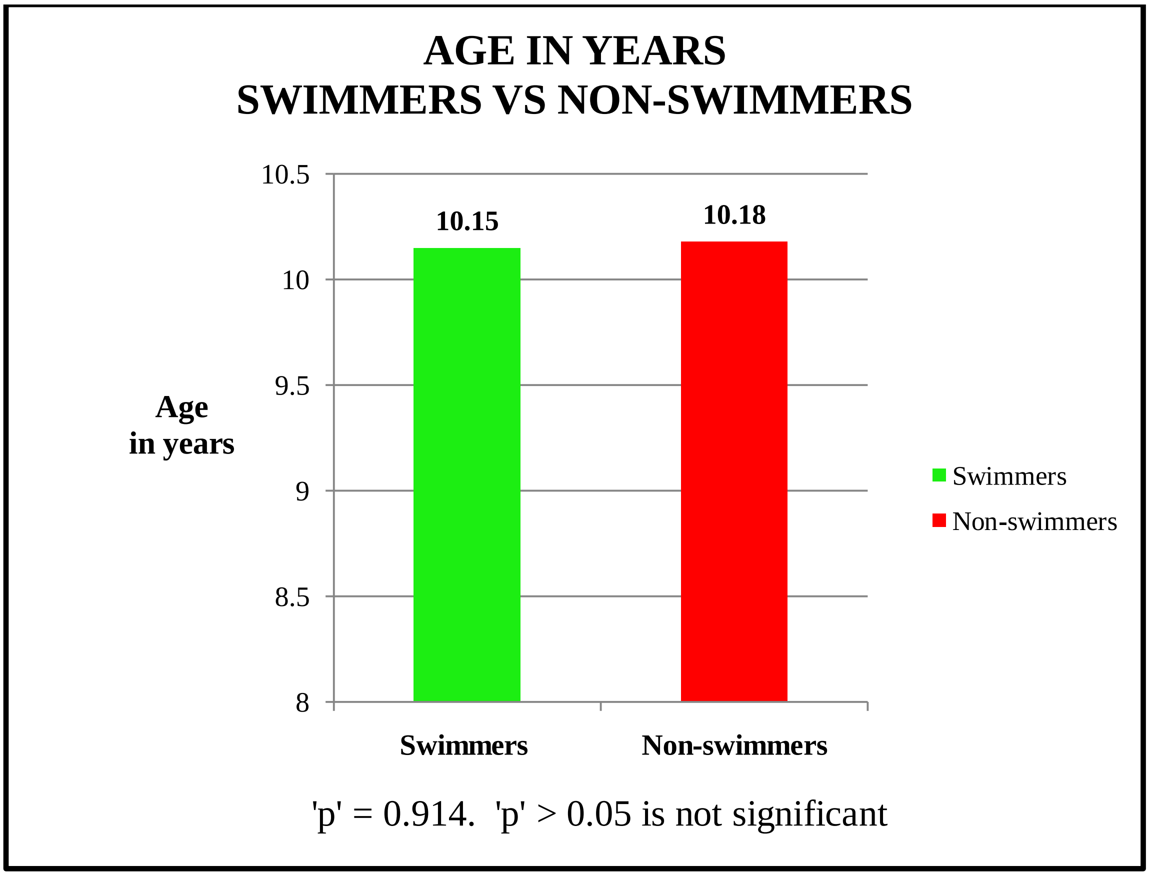


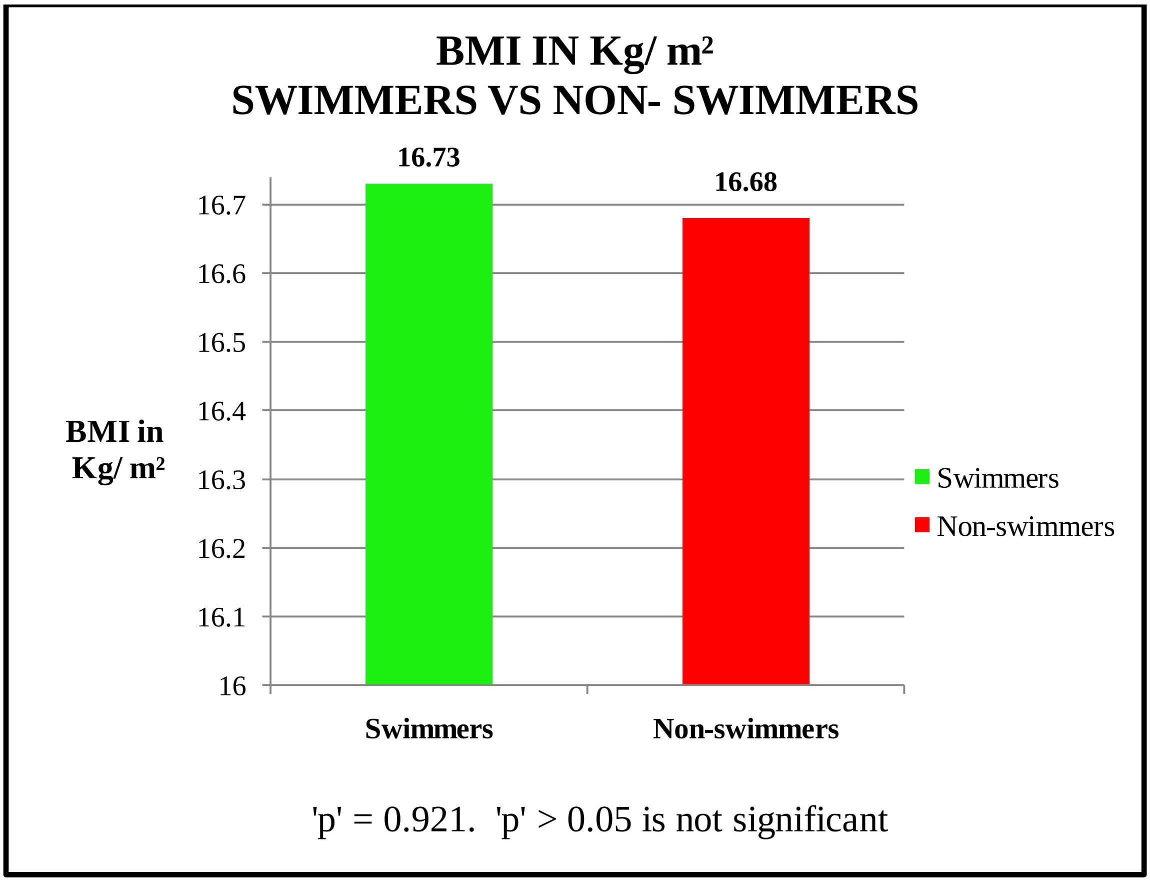
SWIMMING STROKES

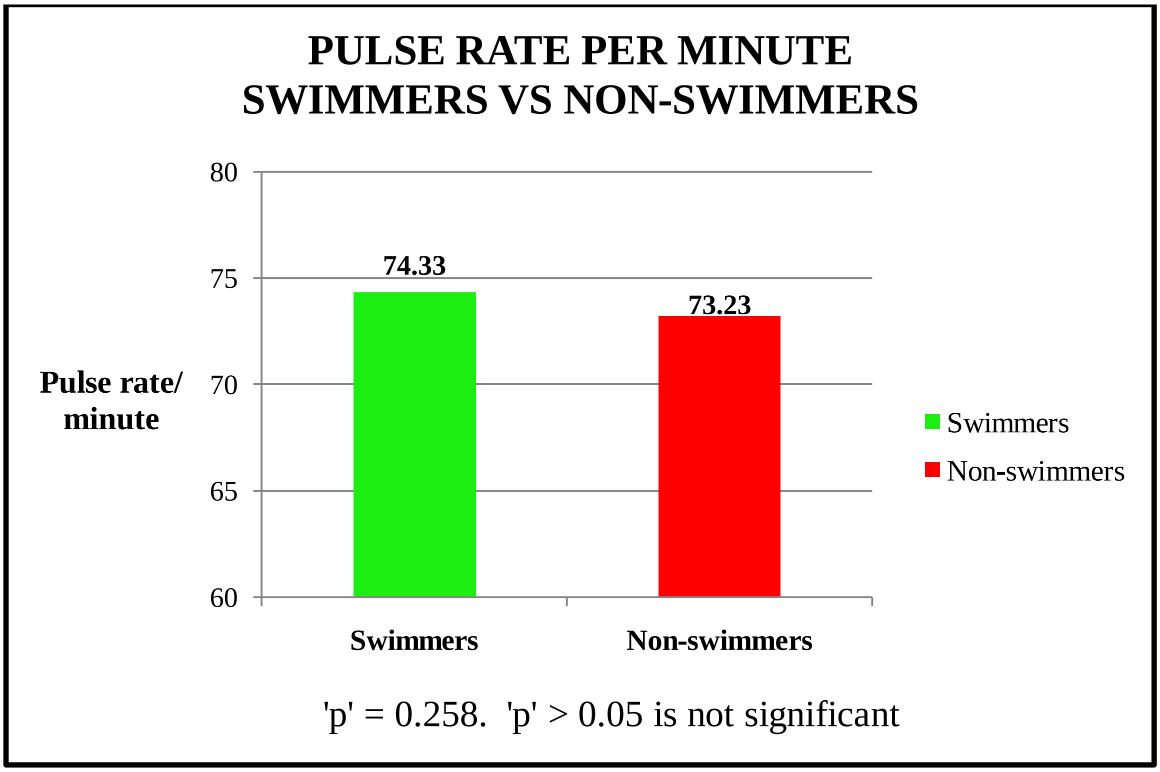


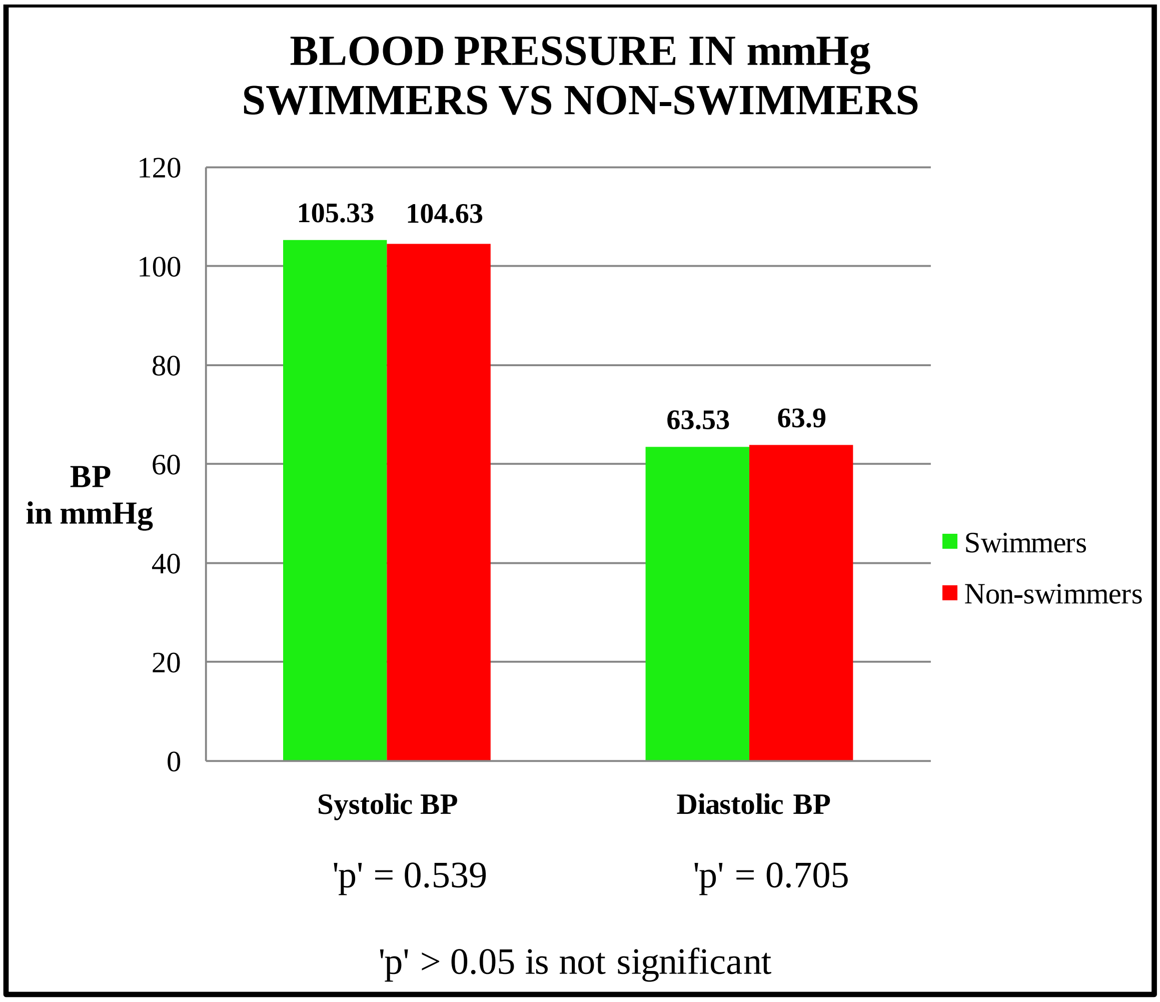
SPIROMETER

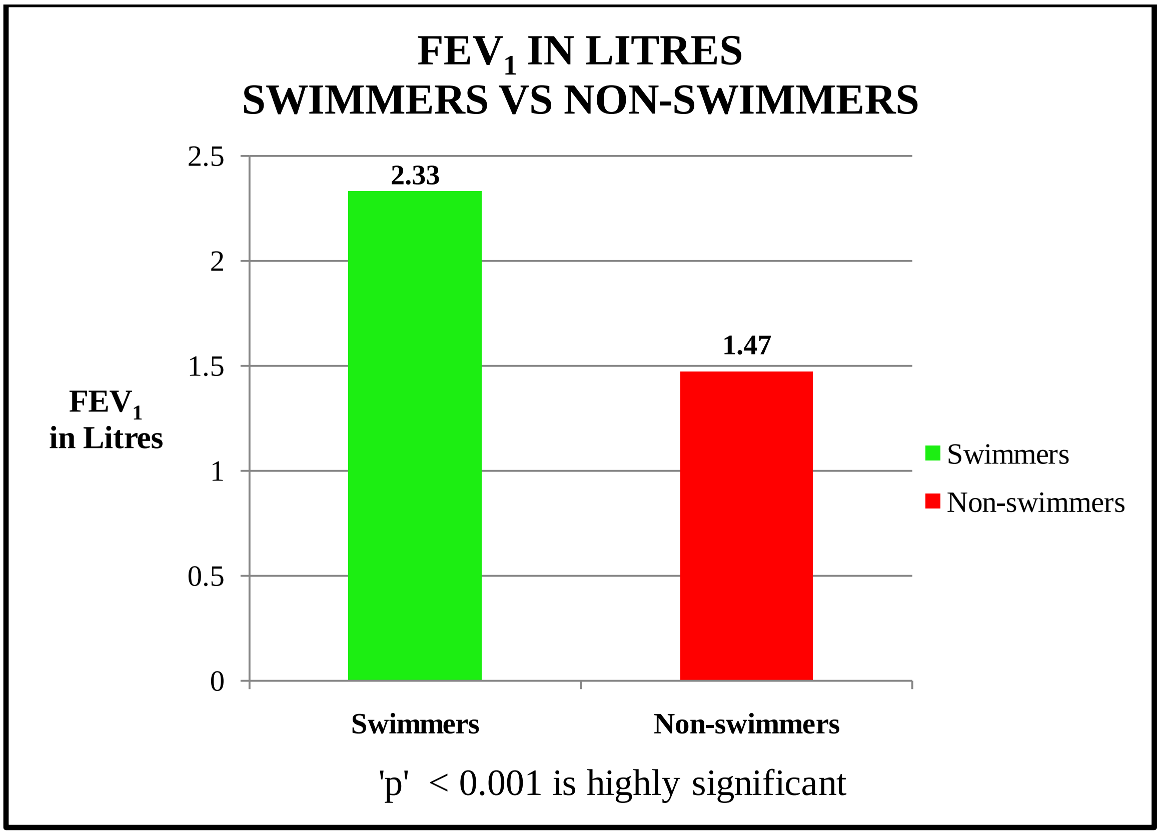
PULMONARY FUNCTION TEST

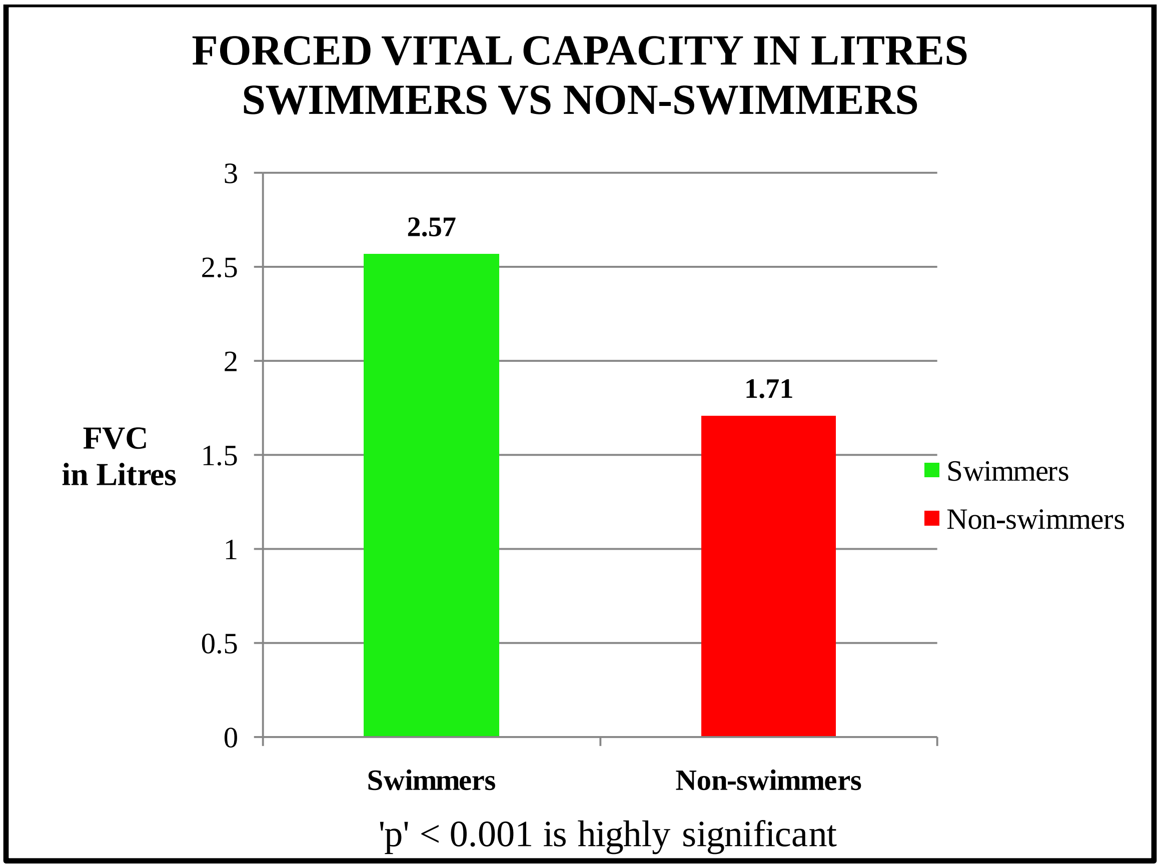

AGE IN YEARS
SWIMMERS VS NON-SWIMMERS
Age in years
10.5
10
9.5
9
8.5
8
10.15
10.18
Swimmers
Non-swimmers
Swimmers
Non-swimmers
'p' = 0.914. 'p' > 0.05 is not significant

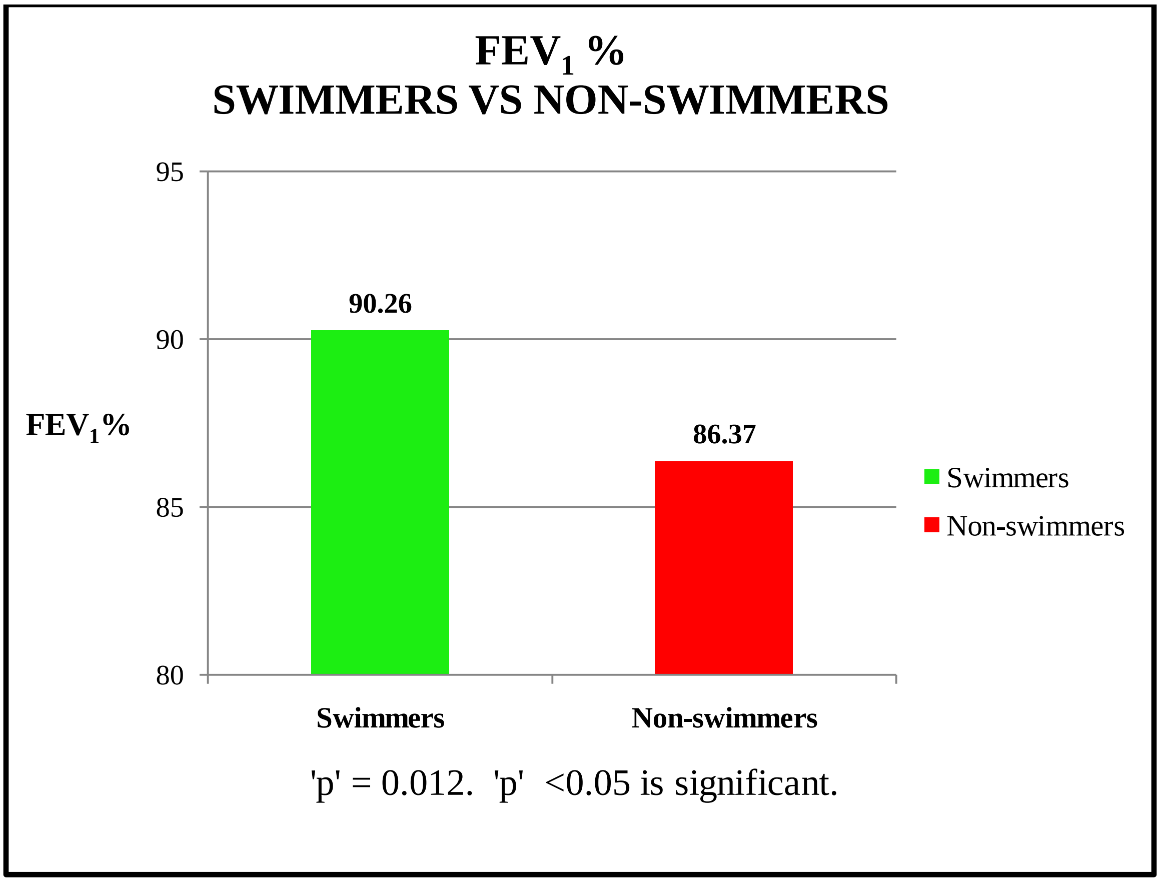

BMI IN Kg/ m²
SWIMMERS VS NON- SWIMMERS
BMI in Kg/ m²
16.7
16.6
16.5
16.4
16.3
16.2
16.1
16
16.73
16.68
Swimmers
Non-swimmers
Swimmers
Non-swimmers
'p' = 0.921. 'p' > 0.05 is not significant

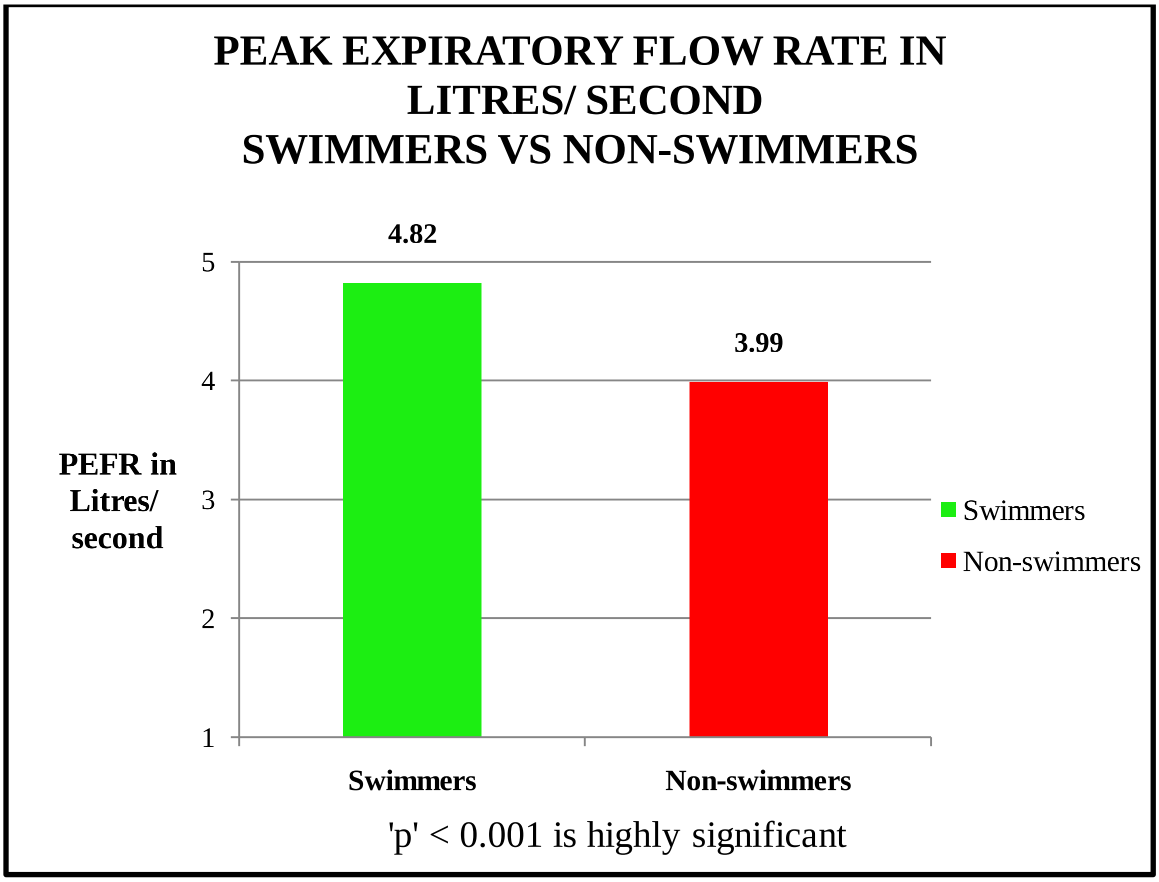

PULSE RATE PER MINUTE
SWIMMERS VS NON-SWIMMERS
80
75
70
65
60
Pulse rate/ minute
74.33
73.23
Swimmers
Non-swimmers
Swimmers
Non-swimmers
'p' = 0.258. 'p' > 0.05 is not significant


BLOOD PRESSURE IN mmHg
SWIMMERS VS NON-SWIMMERS
120
100
80
60
40
20
0
BP in mmHg
105.33
104.63
63.53
63.9
Systolic BP
Diastolic BP
Swimmers
Non-swimmers
'p' = 0.539
'p' = 0.705
'p' > 0.05 is not significant


FEV1 IN LITRES
SWIMMERS VS NON-SWIMMERS
2.5
2
1.5
1
0.5
0
2.33
1.47
FEV1
in Litres
Swimmers
Non-swimmers
Swimmers
Non-swimmers
'p' < 0.001 is highly significant


FORCED VITAL CAPACITY IN LITRES
SWIMMERS VS NON-SWIMMERS
3
2.5
2
1.5
1
0.5
0
2.57
1.71
FVC
in Litres
Swimmers
Non-swimmers
Swimmers
Non-swimmers
'p' < 0.001 is highly significant


FEV$_1$ %
SWIMMERS VS NON-SWIMMERS
95
90
85
80
FEV$_1$%
90.26
86.37
Swimmers
Non-swimmers
Swimmers
Non-swimmers
'p' = 0.012. 'p' <0.05 is significant.


PEAK EXPIRATORY FLOW RATE IN LITRES/ SECOND
SWIMMERS VS NON-SWIMMERS
5
4
3
2
1
PEFR in Litres/ second
4.82
3.99
Swimmers
Non-swimmers
Swimmers
Non-swimmers
'p' < 0.001 is highly significant

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PROFORMA

Name:

Age:

Sex:

Duration of swimming:

H/o Lung disorders/ Bronchial asthma:

H/o Tuberculosis:

H/o Heart disease:

Medications if any:

<u>Anthropometric measurements:</u>

Height (m): Weight (kg): BMI (kg/m^2):

<u>Chest measurements:</u>

Full inspiration (cm): Expiration (cm): Difference (cm):

<u>General Examination:</u>

Consciousness: Orientation:

Comfortable at rest: Pallor:

Cyanosis: Clubbing:

Jaundice: Pedal oedema:

Thoracic/ Spine deformity:

JVP:

Generalised Lymphadenopathy:

Temperature (^{0}C): Respiratory rate/ min:

Pulse rate/ min: Blood pressure (mmHg):

Systemic Examination:

Cardiovascular System:

Respiratory System:

Abdomen:

Central Nervous System:

Pulmonary Function Test:

FEV_1 (L)	
FVC (L)	
FEV_1 %	
PEFR (L/ sec)	

மருத்துவ பரிசோதனை முறைகளை பற்றி மருத்துவரிடம் தெரிந்து கொண்டேன். இதனை மேற்கொள்ள பெற்றோர் ஆகிய நானும், எனது மகனும்/ மகளும் முழுமனதுடன் சம்மதிக்கிறோம்.

ETHICAL COMMITTEE APPROVAL

Ref. No. 68/E4/2/2014

Govt. Rajaji Hospital,
Madurai.20. Dated:26.02.2014

Institutional Review Board / Independent Ethics Committee.
Captian. Dr. B. Santhakumar, M.D., (F.M.,)
Dean, Madurai Medical College &
Govt Rajaji Hospital, Madurai 625020. **Convenor**

13.3.14

Sub: Establishment-Govt. Rajaji Hospital, Madurai-20-
Ethics committee-Meeting Minutes- for January 2014
Approved list -regarding.

The Ethics Committee meeting of the Govt. Rajaji Hospital, Madurai was held on 20.1.2014, Monday at 10.00 am to 12.00.noon at the Anaesthesia Seminar Hall, Govt. Rajaji Hospital, Madurai. The following members of the committee have attended the meeting.

1.Dr. V. Nagarajan, M.D., D.M (Neuro) Ph: 0452-2629629 Cell.No 9843052029	Professor of Neurology (Retired) D.No.72, Vakkil New Street, Simmakkal, Madurai -1	Chairman
2. Dr.Mohan Prasad , M.S M.Ch Cell.No.9843050822 (Oncology)	Professor & H.O.D of Surgical Oncology(Retired) D.No.72, West Avani Moola Street, Madurai -1	Member Secretary
3. Dr. Parameswari M.D (Pharmacology) Cell.No.9994026056	Director of Pharmacology Madurai Medical College	Member
4. Dr.S. Vadivel Murugan, MD., (Gen.Medicine) Cell.No 9566543048	Professor of Medicine Madurai Medical College	Member
5. Dr.S. Meenakshi Sundaram, MS (Gen.Surgery) Cell.No 9842138031	Professor & H.O.D of Surgery Madurai Medical College	Member
6. Mrs. Mercy Immaculate Rubalatha, M.A., Med., Cell. No. 9367792650	50/5, Corporation Officer's quarters, Gandhi Museum Road, Thamukam, Madurai-20	Member
7. Thiru.Pala. Ramasamy , BA.,B.L., Cell.No 9842165127	Advocate, D.No.72.Palam Station Road, Sellur, Madurai -2	Member
8. Thiru. P.K.M. Chelliah ,B.A Cell.No 9894349599	Businessman, 21 Jawahar Street, Gandhi Nagar, Madurai-20	Member

The following Project was approved by the committee

Name of P.G.	Course	Name of the Project	Remarks
Dr.M. Vishnu Priya	PG in M.D., (Institute of Physiology) Madurai Medical College and Government Rajaji Hospital, Madurai.	Comparative study on Pulmonary Function Tests in children swimmers vs. Non swimmers.	Approved

Please note that the investigator should adhere the following: She/He should get a detailed informed consent from the patients/participants and maintain it Confidentially.

1. She/He should carry out the work without detrimental to regular activities as well as without extra expenditure to the institution or to Government.
2. She/He should inform the institution Ethical Committee, in case of any change of study procedure, site and investigation or guide.
3. She/He should not deviate the area of the work for which applied for Ethical clearance. She/He should inform the IEC immediately, in case of any adverse events or Serious adverse reactions.
4. She/He should abide to the rules and regulations of the institution.
5. She/He should complete the work within the specific period and if any Extension of time is required He/She should apply for permission again and do the work.
6. She/He should submit the summary of the work to the Ethical Committee on Completion of the work.
7. She/He should not claim any funds from the institution while doing the work or on completion.
8. She/He should understand that the members of IEC have the right to monitor the work with prior intimation.

Member Secretary Chairman
Ethical Committee

26.2.14
DEAN/Convenor
Govt. Rajaji Hospital,
Madurai- 20.

6/2/14

To
The above Applicant
-thro. Head of the Department concerned

ANTI PLAGIARISM CERTIFICATE