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RESEARCH ARTICLE

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

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ABSTRACT

Background: Children and sports go hand in hand. When it comes to water sports and especially swimming, they are the favourite forms of exercise for children. As per the study by Nilesh Netaji Kate *et al*., 2012, exercise in the form of swimming for more than two years produces a significant improvement in the pulmonary functions. This improvement 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:** To assess and compare the basal anthropometric parameters and pulmonary ventilation among swimming and non- swimming children. Forced Vital Capacity (FVC), Forced Expiratory Volume in first second (FEV_1), Forced Expiratory Volume percentage ($FEV_1\%$) and Peak Expiratory Flow Rate (PEFR) are recorded using a spirometer. **Methodology:** A total of 120 subjects were included for the study. Study group consisted of 60 male & female children of age 8 to 12 years, from Dr.MGR 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. Basal anthropometric parameters were recorded. Basal cardiovascular parameters were recorded. The pulmonary functions of the subjects were measured using portable computerised spirometer (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 best of three consistent trials was recorded. **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 with a 'p' value > 0.05. 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 ($p < 0.05$). **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. This improvement 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.

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INTRODUCTION

Children and sports go hand in hand. The importance of sports in the development of a child is a massive one. Active children are more likely to mature into physically active adults. Benefits of sport and physical activity for children include reduced risk of obesity, increased cardiovascular fitness, improved coordination and balance, better sleep and improved social skills. Reducing sedentary time may be as important for health as increasing exercise time. These days, physical fitness is considered as a measure of the body's ability to function efficiently and effectively in work and leisure activities to be healthy, to resist diseases and to meet emergency situations. Physical fitness is generally achieved through exercise, correct nutrition and enough rest. Children gain many benefits by being exposed to sports at a young age. They get physical exercise, they become stronger and competitive, they understand the importance of team work and coordination, they learn to respect other people, their self-esteem gets boosted and they realize the importance of hard work. There are plenty of choices when it comes to picking up a sport that a child enjoys. Many of the children do not like the idea of exercising. When it comes to water sports and especially swimming, they are the favourite forms of exercise for children.

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Most children enjoy being in water. Swimming is never considered as an exercise to children because it is fun for them. Swimming is a low cost activity that can be continued throughout the life. Swimming is an aerobic exercise that burns lots of calories. The fun of messing around in the water allows them to exercise without even knowing it. It can provide toning and stretching exercises. Studies show that swimming is an excellent activity for children with a lot of health benefits.

- Children who swim have a physical advantage than those who do not swim, with increased joint mobility, stamina and strength. 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 that the children make during swimming is found to stimulate the nerves of their brain thereby the nerves in the brain become more active. Thus it is expected to increase their intelligence as well.
- Cognitive and social skills are improved. The cardio respiratory system is also strengthened.
- Swimming helps in cooling the body temperature and increases hunger.

According to the Centers for Disease Control and Prevention, swimming can improve the mood and decrease anxiety. For children, swimming is a brilliant way to burn off their energy. Not only is swimming great for their health, it could 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 India, swimming is popular in all the three aspects- as a general activity, sporting event and as occupation. Previous studies by Lakera SC *et al*., in 1984 have shown that 'swimming produces maximum effect on lungs compared to any other sport'. During childhood and adolescence, there is a correlation between anatomical and physiological growth of lung, chest cage and airway. During childhood, the lungs grow in proportion to the increase in height. This growth results in an exponential increase in lung volumes (and maximal flows) with each year from preschool age through adolescence. On an average, girls reach both their maximal height and their maximal lung volume earlier than boys, but boys achieve larger lung volumes. As per the study by Nilesh Netaji Kate *et al*., 2012, exercise in the form of swimming for more than two years produces a significant improvement in the pulmonary functions. This improvement 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

- To compare the basal anthropometric parameters of swimmers and non- swimmers.
- To assess the pulmonary ventilation of the swimming and non- swimming children by recording the dynamic lung volumes like 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.
- To compare the spirometric measurements of swimmers and non- swimmers.

MATERIALS AND METHODS

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 & female children of age 8 to 12 years, from Dr.MGR 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 & female children of age 8 to 12 years fromDr.MGR 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

- Upper respiratory tract infection.
- Lower respiratory tract infection.
- Bronchial asthma.
- Tuberculosis.
- Thoracic cage and spine deformities.
- Cor-pulmonale on clinical examination.

All the subjects were clinically examined to rule out any cardio respiratory illness and the 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:

FVC: It is the maximum volume of air that can be expelled rapidly by a maximal effort following deep inspiration. (It is equal to inspiratory reserve volume + tidal 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.

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

[Young Men, Age upto 24]

FVC = 0.1651 x Height (inches) - 0.0290 x Age (years) - 5.459 [Men, Age Greater Than 24]

FVC = 0.0838 x Height (inches) + 0.0920 x Age (years) - 3.469
[Young Women, Age upto 19]

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

[Young Women, Age Greater Than 19]

FEV_1: It is the forced expiratory volume in the first second. This is the fraction of the FVC expelled in the first second during a forced expiration. In a normal individual 80- 85% of the FVC is expired in 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.

FEV_1 = 0.1168 x Height (inches) + 0.0450 x Age (years) - 4.808 [Young Men, Age upto 24]
FEV_1 = 0.1321 x Height (inches) - 0.0270 x Age (years) - 4.203[Men, Age Greater Than 24]
FEV_1 = 0.0686 x Height (inches) + 0.0850 x Age (years) - 2.703 [Young Women, Age upto 19]
FEV_1 = 0.0686 x Height (inches) - 0.0210 x Age (years) - 0.794 [Young Women, Age Greater Than 19]

FEV_1%: FEV_1 expressed as a percentage of FVC gives FEV_1%. FEV_1% = Predicted FEV_1 / Predicted FVC

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.

Children: (Height in cm - 100) x 5 + 100
Adult Men: (Height x 5.48) + 1.58 - (Age x 0.041) x 60
Adult Women: (Height x 3.72) + 2.24 - (Age x 0.03) x 60

Indications for spirometry:

- Evaluation of respiratory disorders.
- Assessment of response to therapy.
- Preoperative assessment.
- 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 asthma control and disease activity in cystic fibrosis.
- To measure lung function in a number of diseases that affect the lungs including haematological disorders.
- To assess the preoperative lung function in flaccid neuromuscular scoliosis (e.g. muscular dystrophy, spinal muscular atrophy and cerebral palsy).

Contraindications

- Recent myocardial infarction.
- Chest or abdominal diseases.
- Oral or facial pain aggravated by mouth piece.
- Stress incontinence.
- Dementia or confused state.

Activities to be avoided prior to spirometry:

- Smoking within one hour of testing.
- Consuming alcohol within 4 hours of testing.
- Exercise within 30 minutes of testing.
- Clothing that restricts full chest and abdominal expansion.
- A large meal within two hours of 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 with the subject in the sitting position, 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:

- The turbine sensor was sterilized before each spirometric test.
- Disposable mouth pieces were used for each subject.
- The subjects were well instructed and encouraged to make maximum possible effort.
- The time interval between each trial was 3minutes.

RESULTS AND OBSERVATION

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 .

Table 1

- 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 and16.68 ± 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 of Hg and 104.63 ± 5.63 mm of Hg respectively.
- The mean ± SD for diastolic blood pressure for study and control group were 63.53 ± 5.76 mm of Hg and 63.90 ± 4.78 mm of Hg respectively.

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 with a 'p' value > 0.05.

Table 2 Results are expressed as Mean ± SD. 'p' value <0.05 is significant and 'p' value < 0.001 is very significant

- The mean ± SD of FEV_1 for study and control group were 2.57 ± 0.89 Litres and 1.71 ± 0.59 Litres respectively.
- The mean ± SD of FVC for study and control group were 2.33 ± 0.84 Litres and 1.47 ± 0.54 Litres respectively.
- The mean ± SD of FEV_1% for study and control group were 90.26 ± 6.23 % and 86.37 ± 10.09 % respectively.
- The mean ± SD for PEFR for study and control group were 4.82 ± 0.78 Litres/ second and 3.99 ±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 in swimmer group was observed which was highly significant. Increase in vital capacity 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 the increase in vital capacity was explained by increased inspiratory muscle strength, since during immersion in water these swimmers experience negative pressure breathing. The results discussed above clearly indicate that swimmers had higher values of lung functions compared to the controls thereby confirming that regular swimming has a facilitating effect on the lungs. The large metabolic demand of sternuous exercise requires an efficient oxygen transport system from the atmosphere to the active tissues. Lung inflation near to total lung capacity is a major physiological stimulus for the release of lung surfactant and prostaglandins into alveolar space which increases lung compliance and decreases bronchiolar smooth muscle tone respectively. The ability of the individual to inflate and deflate the lungs depends upon the strength of the thoracic and abdominal muscles, posture of the individual and the elasticity of lungs. Swimming increases this ability because it is performed in horizontal position compared to the vertical position in other sports. Swimming involves keeping the head extended which is a constant exercise of the Erector Spinae muscle which increases the vertical and antero-posterior diameter of the lungs and the supraspinatus which increases the antero-posterior diameter of the lungs. The sternomastoid, trapezius and the diaphragm are also being constantly exercised. Ventilation is limited during swimming and this leads to intermittent hypoxia in every respiratory cycle. Due to this intermittent hypoxia, lactic acid starts accumulating in the blood causing "lactic oxygen deficit". This leads to the stimulation of respiratory center in the medulla therefore increasing respiration. The resultant alveolar hyperplasia may be responsible for increase in FVC, VC and the number of alveoli. FVC and FEV_1 depend on the strength of abdominal muscles which require prolonged exercise to hypertrophy. The diaphragm and accessory muscles respond to physical training in the same way. The higher values of FVC and FEV_1 depend on the muscle power Stuart *et al*., 1959.

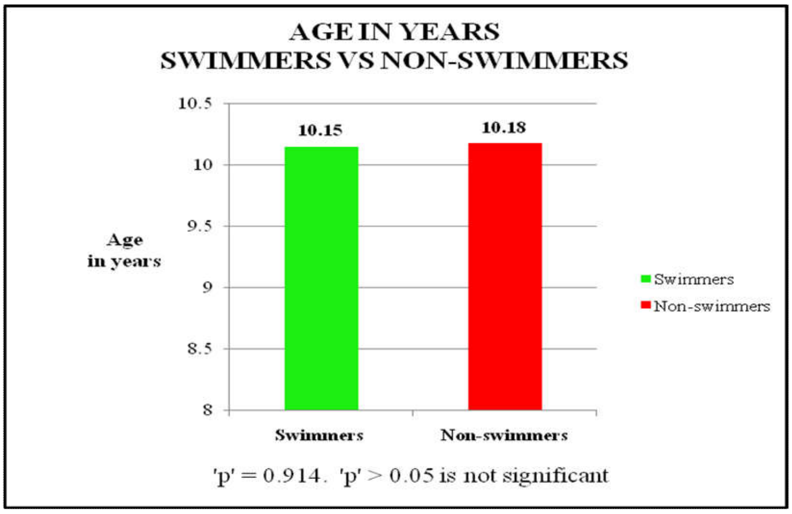
Swimming involves high pressure on the thorax from outside. So the respiratory muscles and the diaphragm are required to develop greater pressure as a consequence of immersion in water during the respiratory cycle thus leading to functionally better respiratory muscles. Also the heat conductance of water is more than that of air. Regular swimming practice may tend to alter the elasticity of the lungs and the chest wall which leads to improvement in lung functions in swimmers. These factors when combined together play an important role in developing better lung functions in swimmers compared to other sportsmen. Swimming takes place in a medium that presents different gravitational and resistive forces, respiratory conditions and thermal stress compared to air. The energy cost of propulsion in swimming is high but a considerable reduction occurs at a given velocity as a result of regular swim training. In swimmers the energy cost 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 of the power production capacity and emphasize the role of swim specific training movements. Improved swimming technique and efficiency are likely to explain the continuous progress in performance.

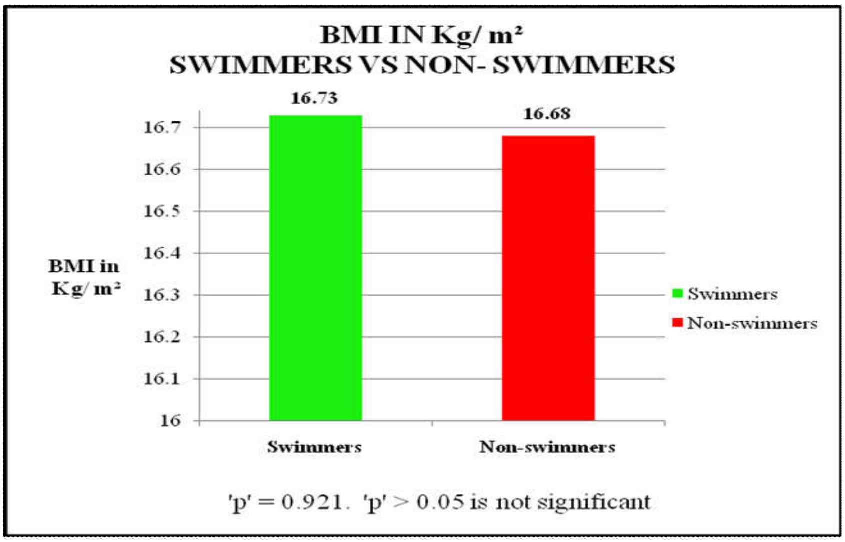
Swimmers are in a liquid medium i.e. water which has an increased density compared to air. This increase in density causes a swimmer's chest to perform millions of breaths against a small resistance throughout a swimming career. This minimal chest workout could develop the lung and inspiratory muscles Varsha Akhade *et al*., 2014. Pulmonary function tests denote how well the lungs take in and exhale air and how efficiently they transfer oxygen into the blood. Spirometry measures how well the lungs are functioning. Swimming by increasing the airway calibre and muscular efficiency brings about enhanced pulmonary function. Previous research comparing prepubescent swimmers and controls has shown that swim training improves the conductive properties of the airways independent of growth Courteix *et al*., 1997. Respiratory responses to swimming is different from other types of activities because

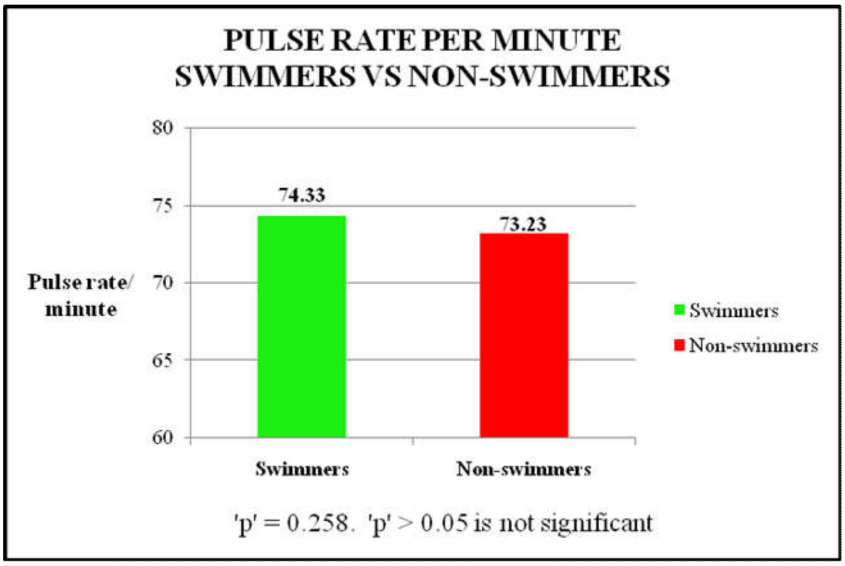
Table 1. Comparison of anthropometric and cardiovascular parameters between the study and control group.

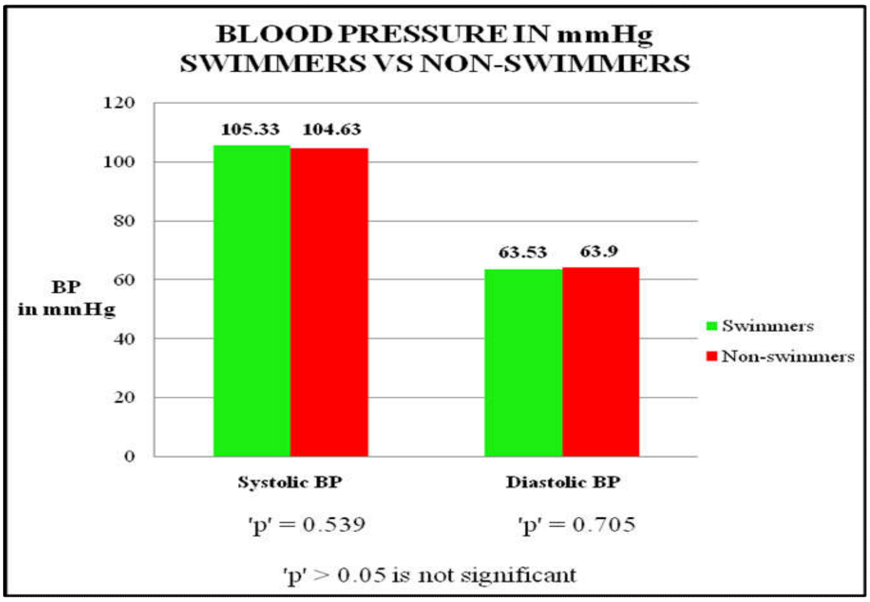
S.No	Parameters		Study group (n=60)	Control group (n=60)	'p' Value
1	Age (yrs)		10.15 ± 1.52	10.18 ± 1.52	0.914
2	BMI (kg/m^2)		16.73 ± 2.41	16.68 ± 2.39	0.921
3	Pulse rate/ minute		74.33 ± 6.06	73.23 ± 4.42	0.258
4	Blood Pressure (mmHg)	Systolic	105.33 ± 6.67	104.63 ± 5.63	0.539
		Diastolic	63.53 ±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

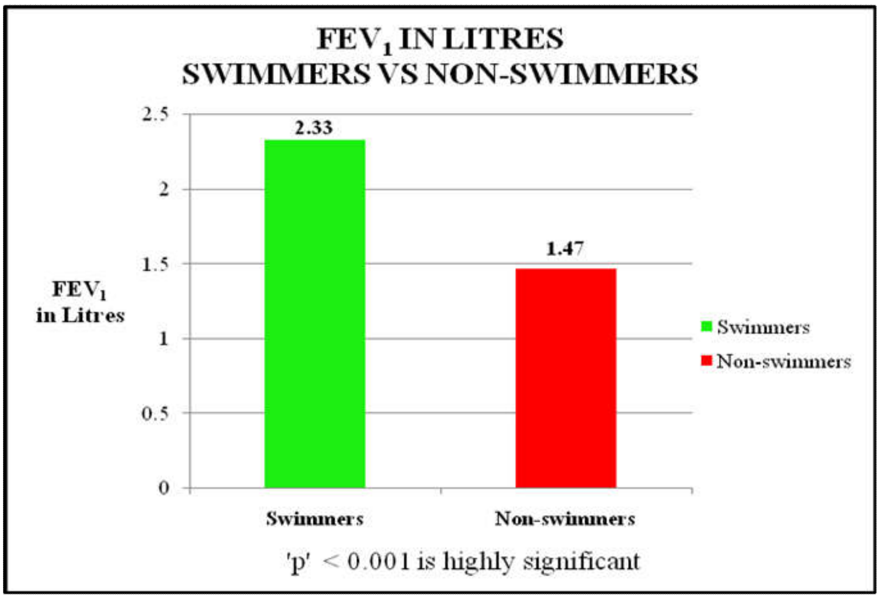
Results are expressed as Mean ± SD. 'p' value < 0.05 is significant.








BLOOD PRESSURE IN mmHg
SWIMMERS VS NON-SWIMMERS
BP in mmHg
120
100
80
60
40
20
0
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
FEV1 in Litres
2.5
2
1.5
1
0.5
0
2.33
1.47
Swimmers
Non-swimmers
Swimmers
Non-swimmers
'p' < 0.001 is highly significant

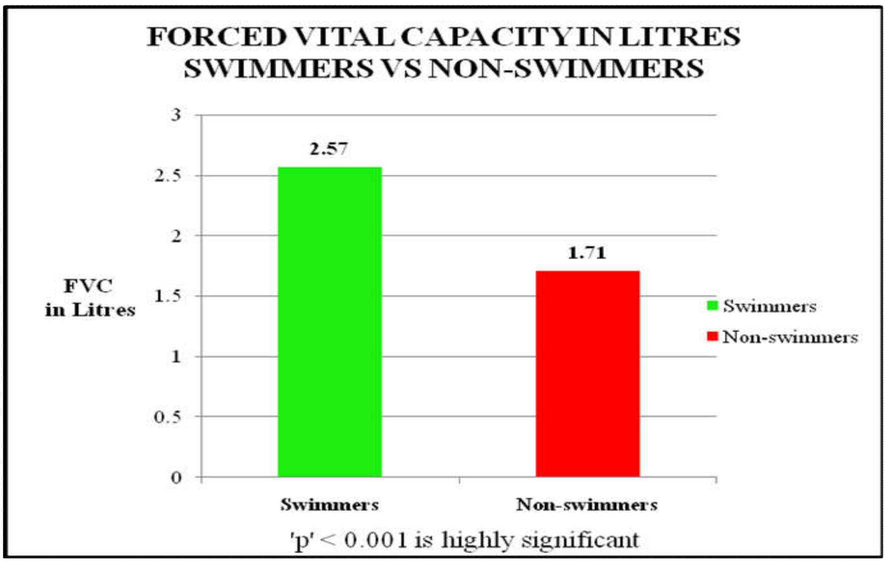
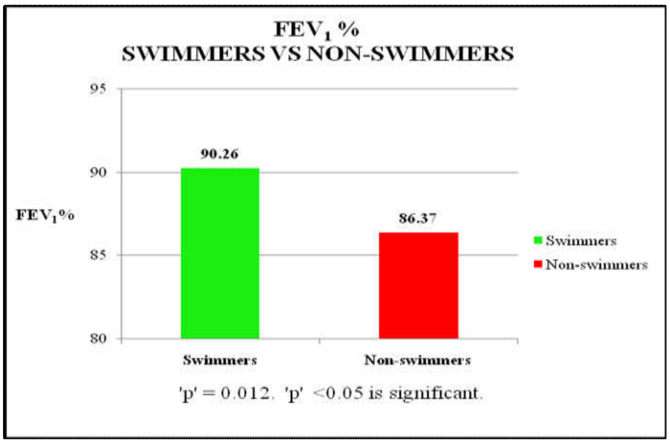
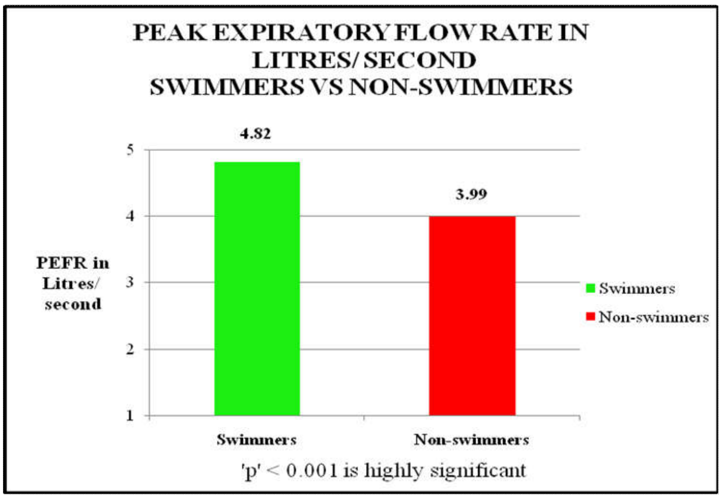

FORCED VITAL CAPACITY IN LITRES
SWIMMERS VS NON-SWIMMERS
FVC in Litres
3
2.5
2
1.5
1
0.5
0
2.57
1.71
Swimmers
Non-swimmers
Swimmers
Non-swimmers
'p' < 0.001 is highly significant

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

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

Results are expressed as Mean ± SD. 'p' value <0.05 is significant and 'p' value < 0.001 is very significant.





- swimming is performed in horizontal position;
- ventilation is restricted;
- external pressure is increased;
- heat conductance of water is higher than air and
- diaphragm is exposed to greater pressure during swimming than other sports.

During swimming, the breath is held in every respiratory cycle for a moment or other producing a condition of intermittent hypoxia. This intermittent hypoxia sets up the anaerobic process during swimming. The lactic acid levels in the blood go on rising resulting in lactic oxygen deficit. The restricted ventilation experienced during swimming leads the swimmers to face intermittent hypoxia. This may result in alveolar hyperplasia and thus increased 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 will slow down and the blood pressure improves. This makes breathing a much easier task. Swimming strengthens the body, helps relax the mind, regulates breathing, stimulates circulation and helps improve lung capacity. Unlike specific weight training exercises, swimming benefits the upper body, torso and legs together and it will improve general strength, lung capacity, stamina and cardiovascular fitness.

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 and this increased vital capacity helps swimmers maintain their buoyancy Shephard, 1978. 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. 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. 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 FVC, FEV_1 and PEFR were significantly higher in swimmers than controls ('p' value < 0.001). 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 in areas of cognitive, physical and language development earlier than the normal. 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. There are psychological benefits too. Swimming lessons help children become more confident and provide them a sense of relaxation. Swimming can also improve overall mood and help combat depression. Their experience also contributes to their socialization in an environment filled with people. Their bonds with parents grows stronger as together they share new and rewarding experiences. Another benefit is in terms of fitness development**.** Majority of the children who do not like the idea of exercising 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 benefited by swimming. However, they need keen supervision and guidance. The present study concludes that exercise in the form of swimming for more than two years produces a significant improvement in the pulmonary functions. This improvement is directly proportional to the duration of swimming. So swimming can be recommended to improve the lung function of an individual. Improvement in the lung function of an individual 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.

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