DOI: 10.14260/jemds/2014/2186

ORIGINAL ARTICLE

A COMPARATIVE STUDY OF LUNG FUNCTIONS IN SWIMMERS AND NORMAL INDIVIDUALS IN AND AROUND HUBLI CITY

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HOW TO CITE THIS ARTICLE:
Basavaraj R, Satish M, Noor Jehan Begum, Arun Kumar S, Ramesh K. "A Comparative Study of Lung Functions in Swimmers and Normal Individuals In and Around Hubli City". Journal of Evolution of Medical and Dental Sciences 2014; Vol. 3, Issue 10, March 10; Page: 2639-2648, DOI: 10.14260/jemds/2014/2186

ABSTRACT: BACKGROUND: The thoracic and abdominal muscle strength plays an important role in pulmonary function and diffusing lung capacity. The purpose of this study is to observe chest and abdominal muscles following period of breath holding which is a part of training for swimmers. Aims and objectives: To compare the pulmonary function test among swimmers and non-swimmers. **MATERIALS AND METHODS:** In this study 30 Males aged between 18 and 30 years who were swimming regularly for at least 3days in a week for a period of 1yr and above were selected as subjects and 30 controls that were in the same age group. Spirolyser - SPL – 95 is used. **RESULTS:** Statistically parameters were analyzed by student 't' test. There was no significant difference in age, weight, height, BMI between swimmers and non-swimmers. There was a significant difference in mean and standard deviation of pulmonary parameters with the p-value <0.05 in swimmers which shows that they have greater ventilator drive. **CONCLUSION**: Regular swimming produces a positive effect on the lung by increasing pulmonary capacity.
KEYWORDS: Pulmonary function tests, Swimmers, Spirolyser.

INTRODUCTION: The respiratory response to swimming may be expected to be different from the response to many other types of man's activities for the following reasons; 1. Swimming is performed in horizontal position. 2. Ventilation is restricted. 3. External pressure is increased. 4. Heat conductance of water is higher than that of air. The above mentioned factors in swimming can be anticipated to produce pulmonary function changes quite different than those observed in other sports activities.[1]

There are a number of factors on which pulmonary functions depend in normal individuals. Besides the balance between lung recoil and chest elasticity that determine the mid-position at the end of spontaneous expiration and the coordinated neuro-muscular function of maintenance of effort; the thoracic and abdominal muscle strength play an important role in most of the pulmonary functions. Swimming involves both the total body muscular activity and excessive use of chest and abdominal muscles following period of breath holding which is a part of training for competitive swimmers.[2]

Pulmonary ventilation describes the process in which ambient air moves into and exchanges with air in the lungs. Air entering the lungs is adjusted to body temperature, filtered and almost completely humidified as it passes through trachea. The lungs provide the gas exchange surface separating blood from the surrounding alveolar air into capillary blood, simultaneously CO_2 moves into alveolar chambers. An average adult lung weighs around 1kg and volume varies between 4 to 6 liters. If spread out, the lung tissue would cover an area of 50 to 100m.[2,3]

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Each minute at rest 250ml of oxygen and 200ml of CO_2 diffuses in opposite direction. When athletes exercise intensely, nearly 25 times this oxygen readily transfers across the respiratory membrane. Pulmonary ventilation functions to maintain a fairly constant and favorable concentration of O_2 and CO_2 in the blood during rest and exercise.[3]

According to the respiratory physiologist John B. West man and other higher animals remove oxygen from the air and add carbon dioxide to it in the course of satisfying the metabolic demands of their tissues. The business of getting O_2 and letting out CO_2 is the essence of respiratory physiology.[4]

The highly vascularized moist surface of the lungs fits within the confines of the chest cavity with numerous infoldings, the lung tissues actually fold on themselves. At rest a single RBC remains in the pulmonary capillary of 0.5 to 1.0 second. The lung contains more than 300 million alveoli. These elastic thin walled membranous sacs are approximately 0.3mm in diameter. Millions of short thin walled capillaries lie side by side. Gases diffuse across the extremely thin barrier of 0.3 microns.[3]

The aims of the study are:

1. To study various spirometric measurements like static and dynamic lung volumes in the swimmers.
2. To study the pulmonary function measurements in controls.
3. To compare the data of swimmers and controls.

The objective of the study: To know whether swimming brings any changes in the pulmonary function tests.

METHODOLOGY: This study was conducted under the auspices of the laboratory set up of the Department of Physiology, Karnataka Institute of Medical Sciences, Hubli.

Spirometric measurements were attained from swimmers from Corporation swimming pool, Hubli.

80 people were screened for our study and 30 people were selected as subjects. Some of the measurements were done in our lab while most were done at swimming pool, as most of the subjects were busy in the working hours of our department.

All the subjects and controls selected were males only, A similar number of age and sex matched persons were selected as controls, they were similar in all respects except that they were not involved in swimming or any other athletic activity.

Inclusion criteria for subjects: Males aged between 18 and 30 years who were swimming regularly for at least 3days in a week for a period of 1yr and above were selected as subjects.

Exclusion criteria: Persons who had history of chronic respiratory disease, hypertension and any congenital cardiorespiratory disease were excluded after studying their history and thorough clinical examination. Swimmers involved in other athletic activities were excluded.

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The following vital data was collected from both controls and subjects:

- Name, Age, Sex.
- Height-standing height was measured without footwear with the subject's body in contact with the wall.
- Weight-was recorded in shorts and Banians with a digital weighing machine. A thorough Clinical examination to rule out any cardio-respiratory illness was carried out and the vital data was recorded.
- Blood Pressure - right arm, sitting position, auscultatory method.
- Pulse rate - was measured for 1 min. during rest.
  Ethical clearance for this study was obtained from ethical clearance committee KIMS, Hubli.

Spirolyser - SPL - 95: is a portable spirolyser manufactured in France by French International Medical (FIM). This is a computerized instrument with RS-232 connectivity for PC. It has a built in thermal printer and also an option for external printing (through PC).

The sensor used for this instrument is a pneumotachograph - This is a tube which has a mesh of corrugated metal sheet, which provides some minor degree of resistance to airflow. On either side of the meshwork is placed tubes which in turn are connected to a high quality differential pressure transducer. So in effect in the pneumotach senses the pressure difference, proximal and distal to the mesh work, when no flow of air (or breath) is occurring there is no pressure difference, as the flow starts, the mesh work offers a mild degree of resistance to flow, which in turn leads to a mild rise in pressure on the proximal side of mesh work, so a pneumotach converts flow into pressure differential and measures it accordingly, the volume obtained is computed by the microprocessor by plotting flow over time.

There are 3 types of tests that can be done with spirolyser.

1) Static lung volumes
2) Dynamic lung volumes & flow rates and flow volume loops.
3) MVV or ventilation over a period of 1 min.

Following measurements are obtained:

1) Static or slow VC (or VC on instrument)
   a) VC
   b) TV
   c) ERV
   d) IRV
   e) IC

2) Dynamic of forced VC (FVC button on instruments)

a) FVC	d) MMEF	g) MEF 50	j) FEV_1/VC
b) FEV_1	e) PEFR	h) MEF 25	k) MEF/VC
c) Ex.t	f) MEF	I) FEV_l/FVC	

3) Maximum Voluntary Ventilation: (MVV button on instrument).

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PROCEDURE: All the maneuvers were performed in sitting position and at rest. A thorough instruction was given to each subject about the performance of the maneuvers, most of the times we demonstrated to them by doing the maneuvers ourselves on the machine. Every subject was given ample time to understand carefully, every part of the procedure and was asked to perform it number of times before we selected the best one. A soft nose chip was put over the nose to occlude the nostrils, disposable mouthpieces were used to minimize cross infection.

Slow VC maneuver: Press the VC Button, then press start button and let the instrument record normal respiration for 2 or 3 cycles (to record TV) and then ask the subject to inhale and exhale as deeply as possibly (to record the VC). Then press the start button again to stop the recording.

Forced VC maneuver: Press the FVC button and then start, the subject is asked to take in air as deep as possible and to exhale as forcefully as possible as fast as possible in one blast and as completely as possible after that to inhale as deeply as possible again.

MVV Maneuver: The subject is asked to breath as deeply as possible and as rapidly as possible for a period of 12 sec.

Statistical Analysis: Was done by comparing the results of the groups using student 't' test and was made easy and accurate with the MS Excel software and the graph pad software.

RESULTS:

Parameter	Swimmers Mean + SD	Controls Mean + SD	't' value	'p' value	Significance
Age (yrs.)	22.63 + 3.38	22.53 + 2.99	0.121	>0.05	NS
Height (cms)	165.93 + 6.64	168.43 + 4.88	1.661	>0.05	NS
Weight (kgs)	61.53 + 7.51	62.73 + 7.23	0.630	>0.05	NS
Body surface area (sqm)	1.69 + 0.12	1.71 + 0.11	0.672	>0.05	NS
Body mass index (wt./ ht^2)	22.34 + 2.05	22.27 + 2.46	0.119	>0.05	NS

Table No. 1: Anthropometric data of swimmers and controls

NS – Nothing Significant

Age: The mean age in swimmers was 22.63+3.38 years and in controls was 22.53+2.99 years. There was no statistically significant difference between the two groups.

Height: The mean height in swimmers was 165.93+6.64 cm and in controls was 168.43+4.48 cm. There was no statistically significant difference between the two groups.

Weight: The mean weight in swimmers was 61.53+7.51 kg and in controls was 62.73+7.23 Kg. There was no statistically significant difference between the two groups.

Body surface area: The mean body surface area in sq.m in swimmers was 1.69 + 0.12 and in controls was 1.71+0.11. There was no statistically significant difference between the two groups.

Body mass index: The mean body mass index (kg/mt^2) in swimmers was 22.34+2.05 and in controls was 22.27+2.46. There was no statistically significant difference between the two groups.

Parameter	Swimmers Mean + SD	Controls Mean + SD	't' value	'p' value	Significance
Pulse rate (beats/min)	74.16 + 7.66	76.43 + 9.35	1.028	>0.05	NS
Blood pressure systolic/ diastolic (mm Hg)	114 ± 7.50 69.86 + 5.63	115.53 ± 7.83 72.33 + 5.53	0.772 1.714	>0.05	NS

Table No. 2: Vital data for swimmers and controls

NS – Nothing Significant

Resting pulse rate: The mean pulse rate at rest in swimmers was 74.16 + 7.66 beats/min and in controls was 76.43 + 9.35 beats/min. There was no statistically significant difference between the two groups.

Blood pressure: The mean of blood pressure in mmHg at rest in swimmers was 114+7.50 systolic and 69.86+5.63 diastolic and in controls was 115.53+7.83 systolic and 72.33+5.53 diastolic. There was no statistically significant difference between the two groups.

Parameter	Swimmers Mean + SD	Controls Mean + SD	't' value	'p' value	Significance
Vital capacity (L)	3.97 + 0.30	3.70 + 0.41	2.809	<0.01	HS
Expiratory reserve volume (L)	1.25 + 0.30	1.30 + 0.38	0.565	>0.05	NS
Inspiratory reserve volume (L)	1.68 + 0.32	1.85 + 0.37	1.903	>0.05	NS
Inspiratory capacity(L)	2.42 + 0.30	2.41 + 0.34	0.120	>0.05	NS
Tidal volume (L)	0.69 + 0.11	0.64 + 0.16	1.410	>0.05	NS

Table No. 3: Slow vital capacity parameter for swimmers and controls

NS – Nothing Significant

Vital Capacity: The mean vital capacity at rest in swimmers was 3.97+0.33 liters and in controls was 3.70+0.41 liters. There was statistically highly significant difference between the two groups.

Expiratory Reserve Volume: The mean expiratory reserve volume at rest in swimmers was 1.25+0.30 liters and in controls was 1.30+0.38 liters. There was no statistically significant difference between the two groups.

Inspiratory Reserve Volume: The mean inspiratory reserve volume at rest in swimmers was 1.68+0.32 liters and in controls was 1.85+0.37 liters. There was no statistically significant difference between the two groups.

Inspiratory capacity: The mean inspiratory capacity at rest in swimmers was 2.42+0.30 liters and in controls was 2.41+0.34 liters. There was no statistically significant difference between the two groups.

Tidal volume: The mean tidal volume at rest in swimmers was 0.69+0.11 liters and in controls was 0.64+0.16 liters. There was no statistically significant difference between the two groups.

Parameter	Swimmers Mean + SD	Controls Mean + SD	't' value	'p' value	Significance
Forced vital capacity (L)	3.33 + 0.40	3.07 + 0.39	2.549	<0.05	S
FEV_1(L)	3.06 + 0.34	2.84 + 0.39	2.328	<0.05	S
Expiratory time (sec)	1.46 + 0.55	1.62 + 0.77	0.926	>0.05	NS
FEV_1/VC	0.79 + 0.06	0.79 + 0.09	0	>0.05	NS
FEV_1/ FVC	0.95 + 0.05	0.95 + 0.05	0.009	>0.05	NS
MMEF(L/sec)	4.25 + 0.80	4.19 + 1.02	0.253	>0.05	NS

Table no. 4: Forced Vital capacity parameters for swimmers and controls

NS – Nothing Significant

Forced vital capacity: The mean forced vital capacity at rest in swimmers 3.33+0.40 liters and in controls was 3.07+0.39 liters. There was statistically significant difference between the two groups.

Forced Expiratory Volume in one second: The mean FEV_1 at rest in swimmers was 3.06+0.34 liters and in controls was 2.84+0.39 liters. There was statistically significant difference between the two groups.

Expiratory time: The mean expiratory time at rest in swimmers was 1.46+0.55 sec and in controls was 1.62+0.77 sec. There was no statistically significant difference between the two groups.

FEV_1/VC: The mean FEV_1/VC at rest in swimmers was 0.79+0.06 and in controls was 0.79+0.09. There was no statistically significant difference between the two groups.

DOI: 10.14260/jemds/2014/2186

FEV_1/FVC: The mean FEV_1/FVC at rest in swimmers was 0.95+0.05 and in controls was 0.95+0.05. There was no statistically significant difference between the two groups.

MMEF: The mean MMEF at rest in swimmers was 4.25+0.80 liters/sec and in controls was 4.19+1.02 liters/sec. There was no statistically significant difference between the two groups.

Parameter	Swimmers Mean+SD	Controls Mean+SD	't' value	'p' value	Significance
PEFR (L/Sec)	6.74+1.43	7.25+1.56	1.319	>0.05	NS
Mid expiratory flow rate$_{75}$ (MEF_{75})(L/Sec)	5.97+1.57	6.50+1.54	1.319	>0.05	NS
MEF_{50} (L/Sec)	4.69+0.94	4.69+1.16	0	>0.05	NS
MEF_{25} (L/Sec)	2.75+0.83	2.68+0.90	0.313	>0.05	NS
MEF/FVC	1.34+0.29	1.37+0.36	0.355	>0.05	NS
MVV(L/min)	124.54+12.78	118.45+14.94	1.696	>0.05	NS

Table No. 5: Forced Vital capacity and maximal voluntary ventilation for swimmers and controls

NS – Nothing Significant

Peak Expiratory Flow rate: The mean PEFR at rest in swimmers was 6.74+1.43 liters/sec and in controls was 7.25+1.56 liters/sec. There was no statistically significant difference between the two groups.

Mid Expiratory Flow Rate 75: The mean $MEFR_{75}$ at rest in swimmers was 5.97+1.57 liters/sec and in controls was 6.50+1.54 liters/sec. There was no statistically significant difference between the two groups.

Mid Expiratory Flow Rate 50: The mean $MEFR_{50}$ at rest in swimmers was 4.69+0.94 liters/sec and in controls was 4.69+1.16 liters/sec. There was no statistically significant difference between the two groups.

Mid Expiratory Flow Rate 25: The mean $MEFR_{25}$ at rest in swimmers was 2.75+0.83 liters/sec and in controls was 2.68+0.90 liters/sec. There was no statistically significant difference between the two groups.

MEF/FVC: The mean MEF/FVC at rest in swimmers was 1.34+0.29 and in controls was 1.37+0.36. There was no statistically significant difference between the two groups.

Maximum voluntary ventilation: The mean MVV at rest in swimmers was 124.54+12.78 liters/min and in controls was 118.45+14.94 liters/min. There was no statistically significant difference between the two groups.

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DISCUSSION: A number of studies have been conducted to compare the lung functions of persons involved in different sports activities and normal people. There is a paucity of studies conducted on pulmonary functions in swimmers. Therefore to enrich the information on pulmonary functions in swimmers and to throw light on the changes produced in lungs by swimming this present study was undertaken in the Department of Physiology of Karnataka Institute of Medical Sciences, Hubli.

The subjects for the study were taken from corporation swimming pool. The study group comprised of 30 swimmers in the age group of 18to 30 years who were involved in swimming for a period of more than 1 year and 30 subjects who were non swimmers were selected as controls from within the campus Both subjects and controls were not involved in any other athletic activity. Both groups were of similar age, sex, height and weight.

The two study groups were well matched in age, height, weight, body surface area and body mass index. This is important in our study as significant difference in anthropometric measurements may result in higher values of pulmonary function tests. This does not happen in our study as both groups were well matched in anthropometric measurements.

There was no significant difference between the two study groups with respect to resting pulse rate and blood pressure.

The mean vital capacity at rest in swimmers was 3.97+0.33 liters and in controls was 3.70+0.41 liters. There was statistically highly significant difference between the two groups. Similar results were found in studies conducted by other workers like Clanton TL, Bjurstrom RL, Armour J and Lekhara SC.

Like in most studies we observed an increase in value of vital capacity (VC) in swimmer group, which was highly significant. Increase in VC observed in swimmers may be the result of changes in the inspiratory muscles 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.[5]

In a study conducted by Bjurstrom RL and Shoene RB the increase in VC was explained by increased inspiratory muscle strength, since during immersion in water these swimmers experience negative pressure breathing.[6]

In swimming, the stress of excessive upper body muscle contraction on the bones comprising the thoracic cavity may be stimulus for growth of chest wall resulting in increased chest surface area which has highly significant correlation with increase VC value.[7] Increase in the alveolar number because of hypoxia is also said to be reason for increased VC.[1]

The mean expiratory reserve volume at rest in swimmers was 1.25+0.30 liters and in controls was 1.30+0.38 liters. There was no statistically significant difference between the two groups. Similar result was found in a study conducted by Pherwani AV, Desai AG and Solepure AB.[2]

ERV depends on the strength of the abdominal muscles. The muscles of expiration probably required prolonged exercise to hypertrophy as a result ERV was not statistically significant.

The mean inspiratory reserve volume at rest in swimmers was 1.68+0.32 liters and in controls was 1.85+0.37 liters. There was no statistically significant difference between the two groups.

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The mean inspiratory capacity at rest in swimmers was 2.42+0.30 liters and in controls was 2.41+0.34 liters. There was no statistically significant difference between the two groups.

IC and IRV depends on the thoracic mobility, balance between lung and chest elasticity and muscle strength.[2] In our study IC and IRV were not found to be significant between the two groups, probably swimmers in this study were not long time swimmers.

The mean tidal volume at rest in swimmers was 0.69+0.11 liters and in controls was 0.64+0.16 liters. There was no statistically significant difference between the two groups. Similar result was obtained by Pherwani AV et al[2].

TV was slightly higher in both swimmer and control group probably due to apprehension caused by the testing procedure.[2]

The mean forced vital capacity at rest in swimmers 3.33+0.40 liters and in controls was 3.07+0.39 liters. There was statistically significant difference between the two groups.

The mean FEV_1 at rest in swimmers was 3.06+0.34 liters and in controls was 2.84+0.39 liters. There was statistically significant difference between the two groups.

FVC and FEV_1 are significantly increased in swimmer group compared to controls. Similar results were found in studies conducted by other workers like Pherwani AV, Mehrotra PK, Lakhera SC. Also, the mean values for VC and FEV_1 were found higher in swimmers of both sexes by Newman et al.[8]

Respiratory muscles including diaphragm of swimmers are required to develop greater pressures as a consequence of immersion during the respiratory cycle this may lead to functional improvement in these muscles. Alteration in elasticity of lungs and chest wall may also account for improvement in FVC and other lung functions of swimmers. Further, restricted ventilation during swimming may result in intermittent hypoxia and this may lead to alveolar hyperplasia and thus increased VC and FVC.[1] FVC, FEV_1 improve after 1 to 2 years of swimming practice.[2] Among various group of athletes swimmers have a higher value of VC and FEV_1.[10]

There was no significant change in various flow rates in the swimmers when compared to the controls probably suggesting significant increase in these flow rates requires more years of swimming practice. Similar results were found in studies conducted by Bjurstrom and Shoene[6], Armour[7] and Kubiak – Janczaruk.[9]

The value of MVV was higher in swimmers group compared to controls but the value was insignificant. MVV values depends on the patency of airways and tone of respiratory musculature.[1] probably this value of MVV also requires more number of years of swimming practice to become significant.[2]

Observations in our study show that swimming as an exercise is a good stimulant for increasing lung volumes and capacities. In our study VC, FVC and FEV_1 are significantly increased in swimmers compared to the control group. Thus observation of the present study are in accordance with many western and Indian studies in that the PFT values increase significantly in swimmers.

CONCLUSION: Swimming engages practically all muscle groups. Hence O2 utilization for the muscle is higher in swimmers. Regular swimming produces a positive effect on the lung by increasing pulmonary capacity and thereby improving the lung functioning. Swimmers have greater pulmonary efficiency than non-swimmers which acts as a predictor of performance.

ORIGINAL ARTICLE

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Date of Submission: 11/02/2014.
Date of Peer Review: 12/02/2014.
Date of Acceptance: 03/03/2014.
Date of Publishing: 07/03/2014.