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ORIGINAL ARTICLE

Superior lung capacity in swimmers: Some questions, more answers!

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Abstract
Background: Physical activity has a positive effect on the function of the whole human body system. The influence of physical activity on the development of the respiratory system is still a matter for debate. Swimming is considered the sport with the most profound effect on the lungs.
Aim: The first aim was to determine pulmonary function and to correlate it with anthropometric features of sportsmen, represented by land- and the water-based elite athletes comparing with their sedentary counterparts; the second aim was to examine whether the training factors (frequency and amount) influence pulmonary function in swimmers, when controlled for anthropometric features.
Methods: Thirty-eight elite male swimmers were matched for age and sex with two hundred and seventy-one elite football players and one hundred controls who were not involved in any routine exercise. Lung volumes were recorded by Pulmonary Function test and analyzed statistically.
Results and conclusion: Swimmers had statistically higher values of VC, FVC, FEV1 and FEV1/FVC when compared to both the football players and the controls, as the latter two showed no in-between differences. There was significant positive correlation between age, body weight and body height and each of the above named pulmonary parameters, when presented separately for swimmers, football players and the control group. When controlled for

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the anthropometric features, larger lung volumes in swimmers were not influenced by training period, age at the beginning of training and weekly extent of personal training. Further comprehensive longitudinal studies are needed to confirm these observations.

Introduction

Better function of every system in the human body is achieved by regular exercise. Muscular strength in general (including respiratory muscles) is developed by systematic training, so it is assumed that it has a positive effect on the lung function. Recent studies have shown that athletes have larger capacity of the respiratory system when compared to their age-matched sedentary controls.[1] It was also observed that some particular sport disciplines improve the lung function better than others, these include swimming, and, as recently reported, basketball, water polo and rowing.[2–4] Swimmers also achieve larger lung volumes and higher functional cardiorespiratory system capacity compared to other athletes.[5,6] However, the impact of swimming (as a specific type of sport) on the development of the lung function has not yet been clearly established.

Aerobic exercise enables efficientt lung oxygen uptake, making the lungs work effectively by activating large muscle groups and raising the heart rate. In addition, swimmers perform strenuous underwater exercise holding their breath for prolonged periods.[3] Respiratory muscles, including swimmer's diaphragm, are required to develop higher pressure, resulting from water immersion during the respiratory cycle, leading to functional strengthening of the muscles, as well as improvement in the chest wall elasticity, resulting in higher level of the lung function.[3,6] However, the possibility that hereditary factors may have an influence on the larger lung volumes in swimmers cannot be ruled out. Recent studies have shown that swimmers present larger lungs, which could not be attributed to changes in height, fat free mass, maximal respiratory mouth pressures, alveolar distensibility, age at start of training, years of training, training time per week, distance per session, sternal length, or chest depth at total lung capacity.[7]

In the land-based sport activities, respiratory system is not usually considered to be a limitation factor for physical activity, but no extensive studies have been conducted to approve or rebut this statement in general.[1,8]

Spirometry is the crucial respiratory function assessment test, as a standardized and reproducible method for estimating the respiratory mechanism and pulmonary ventilation. Spirometric values determined in athletes usually refer to standards (i.e. standardized predicted values) for the average population of healthy subjects, as recommended by international organizations, such as the European Respiration Society (ERS), European Commonwealth of Coal and Steel (ECCS) or the American Thoracic Society (ATS).[9,10,11]

The first aim of this study was to compare lung volumes in elite athletes, e.g. swimmers (representing water-based sport activity) and football players (representing land-based sport activity) and their age- and sex-matched sedentary controls; the second aim was to examine whether the training factors have an influence on the pulmonary function in swimmers in controlling anthropometric features.

Materials and methods

Participants

Three hundred and nine elite athletes (thirty eight swimmers) and one hundred age- and sex- matched sedentary controls were included in the study. An elite athlete was defined as a male athlete participating in international competitive tournaments, with at least a five year history of active playing and with at least 15 h of training per week. Sedentary controls were medical students, conditioned to not being connected with any particular sport activity and with no regular exercise program.

Data concerning age at the beginning of training, training period (years) and weekly amount of personal training (hours) were recorded. Each athlete's personal training was assessed as the number of training sessions per week and hours per session, as obtained by questionnaire and interview and presented as total hours of weekly personal training.

The exclusion criterion was any kind of pulmonary disease. All tests were performed in laboratory settings with the same instruments and techniques.

Measurement

Spirometry was performed using the (Turninac, Pneumotah) Pony FX (Cosmed Pulmonary Function Equipment, Italy). Subjects underwent the test in a sitting position, wearing a nose clip. After a maximal inhalation, they sealed their lips around the mouthpiece and exhaled as hard and as fast as possible. They were encouraged to continue exhaling for at least six seconds so that forced expiratory volume for one second (FEV1) and FVC could be measured. Tests were repeated three to five times until the two highest recorded values-forced vital capacity (FVC) and FEV1-varied by less than 3%. Direct measurements included FVC (liters), FEV1 (liters), and peak expiratory flow-PEF (liters/second). The forced expiratory ratio (FEV1/FVC $\times$ 100) was also calculated (%).[10] All of the above measurements were carried out under standard environmental conditions, by continuously measuring the temperature, humidity and atmospheric pressure which enabled comfort temperature (between 18 °C and 22 °C), the atmospheric pressure of 760 mmHg, and a relative atmospheric humidity of 30 to 60%.

Body mass (kg; Seca 761 scales, ±0.5 kg; Seca Co., Germany) and body height (m; Cranlea JP60 portable stadiometer, +0.001 m; Cranlea & Co) were measured using standardized anthropometric techniques. Body mass index