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Ventilatory Disorders in Elite Athletes: Comparative Study between High-Level Athletes and Sedentary Subjects in a Sub-Saharan African Country

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Abstract

Background/Objective: Very intense and repeated exercise, particularly when performed over many years, could cause respiratory health problems. The combination of a sustained high ventilation and provocative training environments may impact the susceptibility of athletes to ventilatory disorders. Previous studies suggest that impaired ventilatory function in elite athletes can be detected in the absence of respiratory symptoms even after cessation of sports activity. The purpose of this study was to evaluate the ventilatory function of elite athletes compared to sedentary subjects. **Material and Methods:** This study included sedentary subjects and elite athletes, all male, aged 16 to 23 years. The athletes played regularly in the Senegalese league 1 championships (football and basketball) for at least two seasons with more than 10 hours of training per week during two years. For all participants, an interrogation was submitted and we conducted a clinic examination was performed following by a basic and post-bronchodilator spirometry. **Results:** The mean age of athletes (n = 66) and sedentary subjects (n = 61) was respectively 19.16 ± 2 years and 19.54 ± 2.12 years. The elite athletes presented significantly higher spirometry values ($p < 0.05$) than sedentary subjects for the following parameters: FVC, FEV1, $FEF_{50\%}$, $FEF_{25\%}$, $FEF_{25\%-75\%}$ and MVV. The prevalence of ventilatory disorders was 72.73% (n = 48) in athletes with a predominance of mixed ventilatory disorders (36.36%). Twelve athletes (18.62%) presented an asthma after carrying out the reversibility test. **Conclusion:** This study found a high prevalence (72.73%) of ventilatory disorders (VD) in Senegalese elite athletes. Many previously undiagnosed elite athletes had significant ventilatory problems. To prevent the respiratory risk, athletes should be encouraged to avoid certain environmental factors and to adapt the period of their training.

Keywords

Spirometry, Sport, Sedentary, Asthma, Senegal

1. Introduction

Physical exercise is a stressful condition that produces a marked change in major body functions. In the vast majority of athletes, exercise tolerance is limited by cardiovascular and muscular factors, and not by the lungs [1]. Even at exhaustion, the pulmonary reserve is considerable, and the capacity of the pulmonary system is generally believed to be sufficient to meet the higher demands for ventilation and gas exchange [2]. However, it has been described that elite athletes can develop maladaptive changes in the respiratory system, such as intra and extrathoracic obstructions, expiratory flow limitation, respiratory muscle fatigue, and exercise-induced hypoxemia, which can influence their performance [3]. Environmental conditions can significantly affect athlete's health and how they perform. Previous studies suggest that impaired ventilatory function in elite athletes can be detected in the absence of respiratory symptoms even after cessation of sports activity [4]. Despite these important considerations, limited information is currently available on the possible alteration of the basic ventilatory capacity of athletes in tropical environments. The aim of our study was to evaluate the ventilatory function of elite athletes compared to sedentary subjects.

2. Material and Methods

2.1. Study Design

We conducted a descriptive and comparative cross-sectional study over a six-month period (March 17, to September 30, 2019) in the functional exploration department of the Regional Hospital Center of Thies (Senegal). The study population consisted of sedentary subjects and elite athletes, all of male sex and aged 16 to 23 years. The elite athletes came from the National Center for Popular and Sports Education in Thies and played regularly in the Senegalese league 1 championships (football and basketball) for at least two seasons with more than 10 hours of training per week during two years. The sedentary subjects did not practice any sport or physical activity on a regular basis and were recruited from the general population. The non-inclusion criteria were voluntary refusal to participate, active smoking, the presence of a chronic respiratory pathology and the absence of competition during the study period for athletes. Exclusion criteria were the presence of a thoracic deformity and the poor cooperation on spirometry.

Participants were informed of the procedure and purpose of the study and all subjects had agreed to voluntarily participate in the study after signing a free and informed consent form before inclusion. A questionnaire was administered to all participants to collect information related to civil status, personal and family medical history. Moreover, anthropometric data such as weight, height, waist circumference were determined. Also, a complete physical examination was performed with emphasis on the respiratory system.

2.2. Spirometry Parameters

Basic and post-bronchodilator spirometry were performed in all our subjects, using a regularly calibrated spirometer (Jaeger PNEUMO Vyntus M) coupled with a computer in which data analysis Care Fusion software was installed. Explanations and supporting illustrations were provided in advance regarding the conduct of the examination for better cooperation of the subjects. After the various tests were performed, lung volumes and bronchial flows were examined and the rates of variation of the different parameters were taken into account with respect to the reference standards (ERS/ATS 2005) [5]. The best test was selected taking into account the subject's degree of cooperation and the aspect of the flow rate/volume and volume/time curves. Volumes, lung capacities and bronchial flows were examined (basic and post-bronchodilator spirometric parameters). The rates of variation of the various parameters in relation to the reference standards were recorded. The parameters measured were the Forced Expiratory Volume at the first second (FEV1), the Vital Capacity (VC), the Tiffeneau ratio (FEV1/FVC), the Peak Expiratory Flow (PEF), the Forced Exporatory Time (FET), the Maximal Voluntary Ventilation (MVV), and the maximum expiratory flows (FEF) including $FEF_{75\%}$, $FEF_{50\%}$, $FEF_{25\%}$ and $FEF_{25\%-75\%}$. The ventilatory disorders (VD) detected were classified into obstructive ventilatory disorder (OVD), restrictive ventilatory disorder (RVD) and mixed ventilatory disorder (MVD). Obstructive syndrome was defined on the basis of a lower FEV1/FVC ratio (less than 70%) and FEV1 < 80% of the predicted value. Restrictive syndrome was retained ahead of a decrease in FVC < 80% of the predicted value and a normal CVF1/CVF ratio (>90%). The mixed syndrome was defined as forced vital capacity (FVC) < 80% and (FEV1/FVC) < 70% [6].

2.3. Statistical Analysis

Data collection and analysis were performed using Excel version 2013 and GraphPad version 5 softwares. Quantitative variables were expressed as mean and standard deviation. Ventilatory disorders were expressed as the number of times (n) they occur and as a percentage. Fisher's exact test and Chi^2 test were used to compare proportions. The Pearson test made it possible to search for possible correlations between variables. For the comparison of the means between the groups, we used the student's t-test. The significance threshold was a p-value < 0.05.

2.4. Ethical Consideration

Before carrying out this study, the protocol was approved by the Ethics Committee of Cheikh Anta DIOP University of Dakar (0381/2018/CER/UCAD). Patients were reassured about the anonymity and confidentiality of the information collected. The research is in accordance with ethical standards of the Declaration of Helsinki.

3. Results

3.1. Anthropometric Characteristics of Study Population

In total, we recruited 66 elite athletes and 61 sedentary subjects. The mean age of athletes and sedentary subjects was respectively 19.16 ± 2 and 19.54 ± 2.12 years (Table 1). The mean BMI for both athletes and sedentary subjects were 20.5 ± 2.31 kg/m^2 and 20.23 ± 2.46 kg/m^2 respectively (Table 1). Age, height, weight of elite athletes and sedentary subjects were comparable with no significant difference between the two groups (p > 0.05).

3.2. Spirometry Parameters

Table 2 illustrates that elite athletes presented significantly higher spirometry values (p < 0.05) for the following parameters: FVC, FEV1, $FEF_{50\%}$, $FEF_{25\%}$, $FEF_{25\%-75\%}$ and MVV compared to sedentary participants. The mean value of the Tiffeneau ratio (FEV1/FVC) was similar for both groups (p = 0.57).

3.3. Frequency of Ventilatory Disorders

Figure 1 shows the proportion of ventilatory disorders among elite athletes. It can be noted that, 72.73% of athletes presented ventilatory disorders (VD) (n = 48). Mixed ventilatory disorders was the most frequent (36.36%; n = 24), followed by isolated obstructive ventilatory disorders with 19.70% of cases.

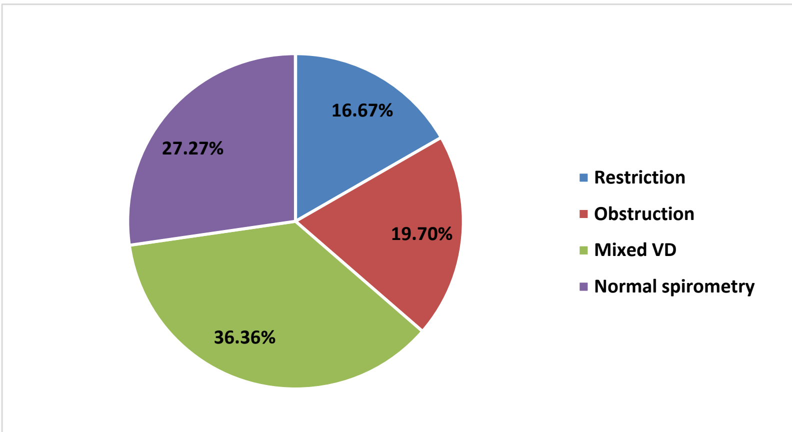

Figure 1. Frequency of ventilatory disorders in elite athletes. VD: Ventilatory disorders.

Table 1. Anthropometric data of the study population.

Parameters	Elite athletes	Sedentary subjects	p-value
Age (years)	19.16 ± 2.00	19.54 ± 2.12	0.34
Weight (kg)	71.28 ± 11.72	69.18 ± 9.90	0.14
Height (m)	1.86 ± 0.10	1.84 ± 0.06	0.08
BMI (kg/m^2)	20.50 ± 2.31	20.23 ± 2.46	0.51

BMI: Body Mass Index.

Table 2. Spirometry parameters in both groups.

Parameters	Elite athletes	Sedentary subjects	p-value
VC (L)	4.67 ± 0.76	4.50 ± 0.58	**0.046***
FEV1 (L)	3.98 ± 0.62	3.82 ± 0.54	**0.048***
FEV1/FVC (%)	86.38 ± 7.63	85.73 ± 8.20	0.57
PEF (L/s)	8.80 ± 1.86	9.27 ± 2.04	0.36
$FEF_{75\%}$ (L/s)	7.83 ± 1.70	8.37 ± 1.85	0.21
$FEF_{50\%}$ (L/s)	4.94 ± 1.32	5.75 ± 1.27	**0.006***
$FEF_{25-75\%}$ (L/s)	4.45 ± 1.22	5.15 ± 1.13	**0.01***
$FEF_{25\%}$ (L/s)	2.30 ± 0.77	2.80 ± 0.75	**0.008***
FET (s)	3.76 ± 1.80	3.45 ± 1.68	0.4
MVV (L/min)	158.75 ± 29.15	141.06 ± 26.71	**<0.001*****

VC: Vital capacity; FVC: Forced vital capacity; FEV1: Forced expiratory volume in 1 second; FEF: Forced expiratory flow; FET: Forced expiratory time; PEF: Peak expiratory flow; MVV: Maximal Voluntary Ventilation. *p < 0.05; ***p < 0.001.

3.4. Prevalence of Asthma in Elite Athletes

Figure 2 shows that twelve elite athletes (18.62%) presented an asthma after carrying out the reversibility test.

3.5. Correlation between Anthropometric and Spirometry Parameters

Figure 3 presents the correlation between anthropometric data and spirometry parameters. A positive correlation was found between the vital capacity (VC) and the body mass index (BMI) of athletes ($r = 0.42$ and $p = 0.0004$) (Figure 3).

4. Discussion

The present study found a high prevalence (72.73%) of ventilatory disorders (VD) in Senegalese elite athletes apparently in good health. Parameters of the ventilatory function are influenced by genetic factors, ethnic characteristics, environmental pollution, altitude, physical activity and to a lesser extent by nutritional factors [7]. High lung volume and flow have been observed in athletes

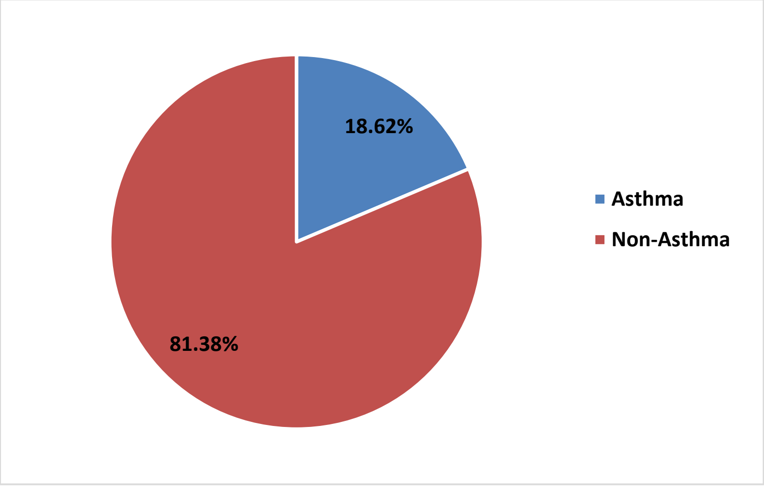

Figure 2. Prevalence of asthma in athletes.

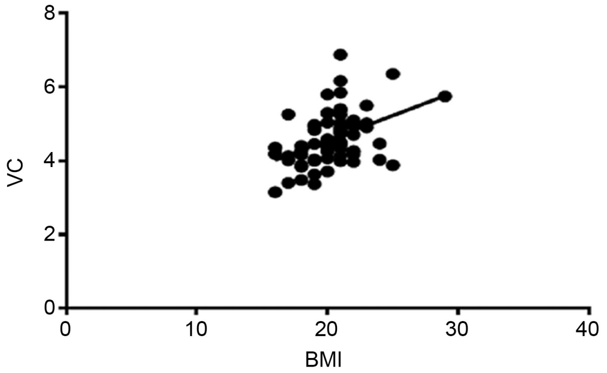

Figure 3. Correlation between VC and BMI in athletes ($r = 0.42$, $p = 0.0004$). VC: Vital capacity; BMI: Body Mass Index.

compared to their sedentary counterparts [8] [9]. The mean values of some spirometry parameters (FVC, FEV1, $FEF_{50\%}$, $FEF_{25\%}$, $FEF_{25\%-75\%}$ and MMV) were significantly higher in the elite athletes compared to sedentary subjects. Our results are similar to those of Mazic *et al.* and Durmic *et al.* [1] [10] who found significantly higher values of spirometry parameters (CV, FVC, FEV1, MMV) in athletes compared to sedentary controls. It has been proven that physical exercise can influence spirometric values leading to an increase in FEV1 and FVC [11]. These adaptive changes are even greater in elite athletes, with FEV1 values up to 20% higher than in a sedentary population [12]. This could be explained by the reduced airway resistance, increased alveolar expansion and improved total lung elasticity caused by continuous physical activity. In the Myrianthefs study [11], athletes also had higher lung capacities than age-matched controls. Muscular exercise increases the depth of respiration and thus improves FVC, oxygen consumption (VO_2) and diffusion rate [13]. This is explained by the fact that physical training not only improves the strength of skeletal and cardiac muscle but also improves the strength of inspiratory and expiratory accessory muscles [14]. The Maximal Voluntary Ventilation (MVV), which depends on both airway patency and respiratory musculature strength, was significantly higher in athletes than in sedentary people. The improvement in MVV could be due to a higher expiratory power and a lower overall resistance to the passage of air into the lungs.

A positive correlation was noted between FVC and BMI of athletes ($r = 0.42$ and $p = 0.0004$). Our results corroborate those of Durmic *et al.* [1] who found a positive correlation between BMI and all spirometry parameters including VC ($p < 0.0001$). However, these same studies [1] [10], found that body fat mass was negatively correlated to the spirometry parameters evaluated. This demonstrated that an increase in body fat mass could induce a decrease in lung function. These results are also highlighted by the work of Pekkarinen *et al.* [15] involving obese individuals, which demonstrated that lung function, expressed as diffusing capacity of the lungs for carbon monoxide (DLCO), is positively correlated with lean body mass. Moreover, about 36.36% of the athletes had an FEV1/FVC ratio lower than 70% and a VC lower than 80% of the predicted value, which is in favor of a mixed VD. The ventilatory function parameters of elite athletes could be influenced by structural changes, also called bronchial remodeling, which usually appear as a result of the chronic inflammatory process of the bronchi. The latter can be induced by an allergic reaction or by a variety of physical and chemical stimuli. These alterations are responsible for a progressive and irreversible decline in ventilatory function. In non-asthmatic endurance athletes, one observes at rest or after exercise bronchopulmonary alterations different from those usually encountered in asthma, and which are not linked to the existence of clinical signs or bronchial hyperreactivity [16].

In our study, about 19.70% had an isolated obstructive VD. The obstructive syndrome noted in endurance athletes could also be explained by exercise-induced bronchospasm (EIB) independent of any underlying asthmatic disease. The EIB occurs in 10% to 35% of non-asthmatic subjects with intense sports practice. This increased airway hyperreactivity is due to a combination of the deleterious impact of environmental exposures in training and competition, coupled with the high and repeated respiratory demands necessary for participation in high-level competition [17]. In the athlete exposed to particularly aggressive environmental conditions together with his bronchial mucosa (cold and dry air, air polluted and/or loaded with allergens) and all the more so in the case of endurance sport, epithelial damage and the repairs that ensue will be repeated many times during the season [18]. The athletes we studied trained in environments with high temperature and humidity. According to certain authors [19], the inhalation of hot and humid air would reduce the degree of bronchospasm. The physiopathological mechanisms, showing the effect of cold and dry air inhalation in the occurrence of EIB, are not well documented by all the authors. Ben-Dov *et al.* [20] demonstrated through laboratory stress tests, the triggering of EIB regardless of the temperature and humidity of the inhaled air. In addition, increased parasympathetic activity due to systematic endurance exercise is suggested to influence bronchial tone and therefore EIB in top athletes [21].

Furthermore, our study showed isolated restrictive VD in 16.67% of subjects. Some athletes have been reported to exhibit hypoxemia during exercise and that there may be pulmonary subedema following intense and prolonged exercise [22]. The work of Dempsey and Wagner described many causes behind exercise-induced hypoxemia [23]. Among this long list of causes, special attention is focused on respiratory muscles fatigue [24] and the formation of interstitial edema [16]. Although we must recognize that overt pulmonary edema is a rare condition in healthy subjects. The most recent studies have begun to describe the formation of interstitial pulmonary edema in endurance athletes as a common phenomenon related to the physiological behavior of the lung, without a significant clinical impact. The incidence of pulmonary edema in apparently healthy people during physical exercise such as intercourse, emotional stress in a cold environment has been described in previous reports [25].

We equally found among athletes the prevalence of asthma to be 18.62%. Our data confirms the underdiagnosis of asthma among athletes as reported by other authors [26]. Additionally, symptoms such as dyspnea and cough are often considered as associated to intense physical training and in many cases are not considered potentially disease-related. Some studies suggest that asthma may be more common in elite athletes than in the general population with up to 10% of athletes affected. This makes it the most common chronic disease in elite athletes [27]. Recently, Alanta *et al.* [28] reported that 13.9% of Finnish elite athletes suffered from asthma. Exercise-induced asthma (EIA) or bronchial hyperactivity leads to bronchial remodeling which in the long term could explain the onset of asthma disease in elite athletes [29].

Limitations of our study include the lack of knowledge of the athlete's previous ventilatory status prior to sport practice and the absence of analysis of air pollutants present in the competition fields. Further research will be necessary to identify pollutants and determine their long-term effects on elite athlete's health.

5. Conclusion

The prevalence of ventilatory disorders remains high in the population of elite athletes. Many previously undiagnosed athletes had significant ventilatory problems. It seems that the adaptation of spirometry reference values and prediction equations for elite athletes could be useful. This high prevalence observed in this study also shows the importance of a frequent screening of these disorders in order to target subjects who need medical assistance adapted to their sport practice. To reduce the risk of developing these disorders, athletes should be encouraged to avoid certain environmental factors and to adapt the period, frequency and intensity of their training.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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