ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 08, Issue, 12, pp.24473-24479, December, 2018

ORIGINAL RESEARCH ARTICLE **OPEN ACCESS**

PREVALENCE OF EXERCISE-INDUCED BRONCHOSPASM AMONG ATHLETES IN THE HOT AND HUMID CLIMATE OF BRAZZAVILLE, CONGO

[1]Florent NSOMPI, [1]Folly MESSAN, [1]Albérick TITO and [2]Mohamed Mansourou LAWANI

[1]Laboratory of Respiratory and Hormonal Explorations of Sportsman., University of Abomey-Calavi (Benin), National Institute of youth, Physical Education and Sport, 01 PO Box 169 Porto-Novo.
[2]Laboratory of Biomechanics and Performances (LABIOP)., University of Abomey-Calavi (Benin), National Institute of Youth, Physical Education and Sport, 01 PO Box 169 Porto-Novo.

ARTICLE INFO

Article History:
Received 17th September, 2018
Received in revised form
20th October, 2018
Accepted 22nd November, 2018
Published online 26th December, 2018

Key Words:
Prevalence; Bronchospasm; Athlete; Hot and Humid Climate; Brazzaville; Congo.

ABSTRACT

Background: This study aims to determine the prevalence of EIB in high-level Congolese athletes acclimated to hot and humid air conditions. **Materials and Methods:** The study involved 18 high-level athletes training in an environment relatively polluted. The stress test consisted of a continuous running treadmill warm-up set at 7.5 km.h-1, followed by an endurance race incremented by 1.5 km.h-1 every 3 minutes until exhaustion. Respiratory function examinations were performed at rest, at the end of the exercise test and at 5-minute increments for 25 minutes. For each modality, the EIB diagnosis was based on an average reduction of at least 10 % in the first-second forced expiratory volume (FEV1). The subjects who presented this criterion were declared sensitive to bronchospasm and constituted the EIB (+) subgroup, while those that were not identified as such were considered non-susceptible and constituted the EIB (-) subgroup. **Results:** A prevalence of 33 % EIB was observed among athletes. A significant mean post-exercise FEV1 decrease of 18.37 % was observed in EIB (+) compared with EIB (-) individuals. **Conclusion:** The hyperventilation associated with particulate matter may play a greater role in the initiation and exacerbation of post-exercise bronchospasm in hot, humid climates.

Citation: Florent NSOMPI, Folly MESSAN, Albérick TITO and Mohamed Mansourou LAWANI. 2018. "Prevalence of exercise-induced bronchospasm among athletes in the hot and humid climate of Brazzaville, Congo", *International Journal of Development Research*, 8, (12), 24473-24479.

INTRODUCTION

Asthma is a chronic respiratory airway disease that affects more than 300 million people worldwide (Cruz, 2007), with a marked increase in recent decades (Asher, M.I., Montefort, S., Björkstén, 2006); (Anandan, C., Nurmatov, U., Van Schayck, O., and Sheikh, 2010). Exercise-induced asthma and bronchospasm are two terms used to describe the same path physiological phenomenon. Asthma is manifested by attacks of respiratory difficulty occurring in crises that are variable in time and reversible spontaneously or under the effect of appropriate treatment. Several tests have been used to diagnose this condition, and the stress test can be indicative of patent or latent asthma. Latent asthma highlighted by physical exercise is called exercise-induced bronchospasm (EIB). Currently, bronchospasm is a serious public health problem whose risk factors are still well under control in both the general population and the sport population. Indeed, studies continue to reveal increasing prevalence values for EIB in the sport population compared to those observed in the general population (Bussotti, M., Di Marco, S., and Marchese, 2014); (Burnett DM, Burns S, Merritt S, Wick J, 2016) (Becerril-Ángeles, M., Vargas, M., Hernández-Pérez, L., Rivera-Istepan, NJ., Pérez-Hidalgo, R., Ortega-González, AG., Rubio-Domínguez, S., Rodríguez-Gutiérrez, MC., Gaxiola-Cortés, R., Dosal-Ulloa, R., Gochicoa-Rangel, 2017); (Messan F, Tito A, Gouthon P, Nouatin K, Nigan I, Blagbo A, Lounana J, 2017). The prevalence of EIB varies from 11 to 59 % and is even higher in the sport population (Messan F, Tito A, Gouthon P, Nouatin K, Nigan I, Blagbo A, Lounana J, 2017); (Medelli J, Lounana J., Messan F., Menuet JJ., 2006); (Pohjantähti H., Laitinen J., 2005); (Rundell KW., Spiering BA., Evans TM., 2004); (Storms WW, 2003) . In addition, the prevalence values for asthma in the athlete population (11-59 %) are sometimes more than double those of the general population (4-20 %).

***Corresponding author:* Florent NSOMPI**
Laboratory of Respiratory and Hormonal Explorations of Sportsman., University of Abomey-Calavi (Benin), National Institute of youth, Physical Education and Sport, 01 PO Box 169 Porto-Novo

This finding could be explained by various diagnostic methods, different training modalities and the environmental conditions of sports practices (Bonini M., 2015). Indeed, the diagnosis of EIB in athletes is made either under laboratory conditions by means of incremental tests or in the field using specific exercises in relation to the requirements of the sport in question. These difficulties are related to the sensitivity and specificity of the diagnostic methods. Similarly, within the sports population, a great disparity in prevalence rates is observed due to the specific characteristics of sports activities (Messan F, Marqueste T, Akplogan B, Decherchi P, 2012); (Gomes RLM, Filho EAR, Júnior MAVC, Batista GR, Almeida AHS, 2018), i.e., whether the sports activities depend on "resistance" or "endurance". In fact, athletes who engage in "long-endurance" sporting activities have significantly higher EIB prevalence values than those who engage in "resistance" sports activities (Weiler JM, Layton T, 1998) (Turcotte H, Langdeau JB, Thibault G, 2003); (Helenius I, Lumme A, 2005); (Pedersen L1, Lund TK, Barnes PJ, Kharitonov SA, 2008); (Lund TK, 2009). A prevalence of 9 % was conditions in which these various sports are practiced are deleterious and exacerbate the bronchospasms induced by exercise, resulting in high asthma prevalence values. Previous studies (Provost-Craig MA, Arbour KS, Sestili DC, Chabalko JJ, 1996); (Mannix ET, Farber MO, Palange P, Galassetti P, 1996); (Rundell KW, Wilber RL, Szmedra L, 2000); (Rundell KW., 2003) have observed a prevalence of asthma ranging from 30 to 50 % in athletes in cold and dry climates. Indeed, winter sports practitioners in cooler and / or drier air environments would be more sensitive to and have a higher prevalence of bronchospasms (Wilber RL, Rundell KW, Szmedra L, Jenkinson DM, IM J, 2000).

These same authors observed a prevalence of 57 % in women and 43 % in men in a group of 14 American skiers at the 1998 Olympic Games under a temperature that varied from -18 °C to 0 °C and a relative humidity of 30-50 %. Among a team of 26 Olympic level ice hockey players, a prevalence of 15 % was observed only in women performing at an ambient temperature ranging from 10 to 13 °C and a relative humidity of 40-45 %. In a group of 60 ice sprinters, a prevalence of 50 % in women and 33 % in men was observed at a temperature ranging from 8 to 10 °C and a relative humidity of 30-35 %. From this study, the highest prevalence (50 %) was recorded under the coldest temperatures, and the lowest prevalence (15 %) was obtained under the highest temperatures. Similarly, Gomes *et al*. (2018) found a low prevalence of EIB (7 %) among 54 semi-professional Brazilian footballers who usually train in a hot climate ranging from 23 °C to 32 °C and a mean relative humidity between 70 % and 85 %. From these results, the authors concluded that the hyperventilation of hot, humid air, to which high-level athletes are subjected, can reduce the induction of bronchospasm. Moreover, based on a hypothesis of the physiological adaptation of athletes acclimatized to hot and humid air conditions, (Messan F, Dansou P, Lawani M, Falola J, 2011) found a prevalence of 26 % in asymptomatic basketball players. Therefore, the objective of this study, the first of its kind to examine Congolese athletes from Brazzaville, is to test exercise-induced bronchospasm in 5000 m, 10000 m and half marathon runners by 1) determining the prevalence of EIB in a controlled hot and humid environment; 2) observing the kinetics of EIB occurrence in steps of 5 to 25 minutes; and 3) determining the effect of ambient temperature, relative humidity and their interaction on the occurrence of EIB.

MATERIALS AND METHODS

Framework of the study: This study is an experimental study conducted from February to March 2018 among Congolese athletes residing in the city of Brazzaville, the political capital of the Republic of Congo in Central Africa. The study was conducted in the weight room of the football training centre of the "*STADE MASSAMBA DEBAT*".

Topics of the study: The study population consisted of male cross-country runners between 16 and 29 years old. The anthropometric characteristics of the subjects are presented in Table 1. These athletes regularly take part in national and international competitions for 5000 m, 10000 m and half marathon races organized every year by the Congolese Athletics Federation. The target population consists of athletes whose top performances are among the top 10 in each event category. The subjects of the study must be holders of a license of the Congolese Federation of Athletics and reside in the city for at least 5 years. Athletes who did not agree by signing informed consent and those whose spirometry results did not meet the criteria were excluded from the study. Similarly, athletes who are recognized as smokers or who have had symptoms of asthma and respiratory conditions indicated by a doctor in clinical examinations were also excluded.

Sampling: The top 10 performances in each long-distance race category (5000 and 10000 metres and half marathon) constituted 50 pre-selected athletes, 18 of whom were selected on the basis of the regularity of their best performances.

Equipment: A Stanley mark, graduated from 0 to 200 cm and placed against a support in a vertical plane, was used to measure the size of the subjects standing barefoot. A "*SECA*" brand bathroom scale with a flat dial scale calibrated in kilograms and placed in a perfectly horizontal plane was used to determine the body mass of the subjects. At the beginning of the evaluation, the scale was calibrated using a mass of one kilogram to ensure the reliability of measurements. The measurement range of the scale was from 0 to 150 kilograms, and the measurement accuracy was plus or minus 10 grams. The $PM_{2.5}$ and PM_{10} concentration levels were measured using a "*Temtop Airing 1000*" gas detector with a measurement range of 0-999 µg / m^3 and an accuracy of 0.1 µg / m^3. Respiratory function examinations were performed using the "*CE Spirobank G*" portable spirometer, a product of "*Medical International Research* (MIR)" (volume accuracy: ± 3 % or 50 ml and flow accuracy: ± 5 % or 200 ml / s), and single-use nozzles. The "*Spirobank G*" consists of a central unit, a monitor, and a turbine, with "*WinspiroPRO*" software installed on the central unit. The "RS232" cable transfers data in real time to the central unit, and the results of the respiratory examinations for each subject in terms of volume flow curve instantly appearing on the monitor. An electronic hygrometer of the "*SUNROAD*" type was used to simultaneously measure the ambient temperature in degrees Celsius and the relative humidity as a percentage of the environment. The "*On Rhythm 100*" heart rate monitor, comprising an elastic belt equipped with a heart rate transmitter unit placed around the chest and another receiver placed around the wrist, was used to continuously measure the heart rates of the subjects at rest and at the end of the effort while standing. Next, a Matrix treadmill (model: "*T-3X-04-C S / N: CTM 523140306138",* Taiwan) was used to submit the subjects to stress tests.

Table 1. Anthropometric and cardio respiratory characteristics observed in the total group and comparison between EIB(-) et EIB(+)

	Total Group (n = 18)			BIE(-) group (n = 12)			BIE(+) Group (n = 6)			(C) Test	(D) Delta %
	Mean	±	SD	Mean	±	SD	Mean	±	SD	P values	
Age (years)	23,88	±	3.48	24.00	±	3.75	23.67	±	3.20	P > 0.05	-1,38
Height (cm)	172.22	±	7.31	173.67	±	7.16	169.33	±	7.34	P > 0.05	-2,50
Weight (kg)	61.11	±	5.56	62.58	±	4.5	58.17	±	6.70	P > 0.05	-7,05
BMI (kg/m^2)	20.65	±	2.01	20.82	±	1.98	20.31	±	2.25	P > 0.05	-2,45
FEV_(A) (L)	3.69	±	0.51	3.75	±	0.51	3.57	±	0.55	P > 0.05	-4,80
FEV_(B) (L)	3.58	±	0.59	3.81	±	0.49	3.11	±	0.49*	P < 0.05	-18,37
HR_(A) (bpm)	56.00	±	4.49	54.58	±	4.52	58.83	±	3.06	P > 0.05	7,79
HR_(B) (bpm)	140.00	±	19.80	141.00	±	18.83	138.00	±	23.40	P > 0.05	-2,13
TMHR (bpm)	196.11	±	3.48	196.00	±	3.74	196.33	±	3.20	P > 0.05	0,17

BMI: Body Mass Index; FEV_(A): Forced expiratory volume in one second at remain (mean of remain values); FEV_(B): Forced expiratory volume in one second at post exercise (mean from 5 to 25 min); HR_(A): Heart Rate at remain (mean of remain values); HR_(B): Heart Rate at the end of exercise; TMHR: Theoretical Maximum Heart Rate (220-age); bpm: beat per minute. BIE (-): subjects whose FEV_1 do not meet this criterion; BIE(+): subjects whose FEV_1 decreased by at least 10 % from resting value; (C) Test : comparison between BIE(-) and BIE(+) values; (D) Delta %: percentage change in BIE(+) versus BIE(-) values. *: $P < 0.05$.

Experimental protocol: In the first phase of the experiment, the selected athletes completed individual information sheets and signed the informed consent forms. The body mass and height were measured. In the second phase, the standing subject wearing a heart monitor was observed for 3 minutes of passive rest, after which the following measurements were obtained: heart rate, volumes and pulmonary flow after blowing in a turbine. The subject then carried out the exercise test on a treadmill with a brisk walk at the beginning and then trotting along at a speed set at 7.5 km.h^{-1}, followed by an incremented stroke of 1.5 km.h^{-1} every 3 minutes until exhaustion. At the end of the test, the heart rate and the breath tests were immediately recorded and in steps of 5 minutes until the 25th minute.

Functional exploration tests procedures: Functional respiratory tests were performed under the supervision of a medical technician. After obtaining information for the height, body mass, age, sex and race, the Spirometer Central Unit was used to automatically calculate the theoretical values of each respiratory parameter. To assess the EFR, the subject, while standing, pinching their nose and holding the turbine between two hands, breathed naturally and calmly through the mouthpiece connected to the spirometer. The subject was then instructed to fill his lungs as much as possible by inhaling air and then empty the air into the turbine as quickly as possible in a continuous and complete manner for a maximum of 6 seconds. At the end of the test, the best test is selected from three reproducible tests that have been validated according to the spirometer algorithms. Peak volumes and flow rates were recorded.

Prerequisites for the stress test: The participants in this study were advised to abstain from all sports for 48 hours prior to testing and from all alcohol and coffee beverages or medications on the day of testing. Measurements of the heart rate, ambient temperature and relative humidity were made before and after the stress test.

Stress test: The stress test consisted of a continuous treadmill race at a speed of 7.5 km.h^{-}1 that was increased every 3 minutes 1.5 km.h^{-1} until exhaustion. Exhaustion was noted by the inability of the subject to maintain a speed consistent with that of the carpet. The race was conducted without prior warm-up. All subjects performed stress tests without encouragement and under the supervision of three teachers and a doctor and his assistants. A defibrillator was available in cases of cardiac malaise. Due to possible influences on the performance of the subject, all stress tests were performed in the mornings between 7:30 and 9:30 am, and food intake was not allowed before and during this time slot. The Resuscitation Unit of the hospital centre was informed of the experimentation as a precaution against any eventuality. This study was authorized by the Scientific Committee of "*Marien Ngouabi*" University of Congo-Brazzaville in accordance with the 1975 Helsinki Declaration on Ethics.

Measured variables: The maximum cardiac frequencies observed at the end of the stress test were expressed as a percentage of variation with respect to the Theoretical Maximal Heart Rate calculated according to the formula THR_{max} = 220-age. This percentage of variation was used to assess the intensity level of the stress test reached at the end of the exercise, which was calculated using the following formula: HR_{max} (%) = (HR_{max} x 100) / THR_{max}). The best variables recorded at the end of the stress test were considered post-exercise values. The diagnosis of bronchospasm was positive in a subject if his post-exercise $FEV_1$was at least 10 % lower than his resting value by applying the following formula: Delta FEV_1 (%) = [(FEV_1 post-exercise x 100) / (FEV_1 rest)] - 100. At the end of the exercise test, the mean post-exercise FEV_1 of the EIB (+) subgroup was compared with that of the EIB (-) subgroup. The ambient temperature and relative humidity observed at the beginning and at the end of the experiment were considered. Similarly, the post-exercise FEV_1values observed for 5 to 25 minutes in 5-minute increments were averaged.

Statistical analysis: The variables were recorded and processed using StatView5 (version 5) software (Abacus Concepts Inc., Berkeley, CA, USA). Descriptive statistics were generated for the total group and the EIB (+) and EIB (-) subgroups. The normality of the distribution of the variables and the equivalence of their variances were verified by the Kolmogorov-Smirnov test and the F test, respectively. The anthropometric variables, the FEV_1, and the heart rate were compared between EIB (+) and EIB (-) by non-parametric tests (Mann-Whitney) when the normality of the distribution of variables (Kolmogorov-Smirnov test) and the homogeneity of the variances (F-Snedecor Test F) were not verified. To assess the potential effects of body mass index (BMI) and the relative humidity (RH) and room ambient temperature (TA) interaction on FEV_1, a one-way analysis of variance and then a two-way analysis of variance, respectively, were carried out. The level of significance was set at $p < 0.05$.

RESULTS

The anthropometric and cardio respiratory characteristics and comparisons of the whole group were compared between EIB

(-) and EIB (+). These comparisons did not show a significant difference ($p > 0.05$), except for the EIB (+) subgroup, which presented a mean FEV_1 significantly ($p < 0.05$) lower than that of the subgroup EIB (-), with a delta of -18.37 % (Table 1). A decrease of at least 10 % in FEV_1 post exercise was observed in 6 out of total of 18 athletes, indicating a prevalence of bronchospasm of 33 %. In these Congolese runner athletes, a total duration of 6 hours per week with an average resting heart rate of 56 bpm and a maximum average heart rate at the end of the stress test that corresponds to 71.40 % of the maximum theoretical heart rate was observed. The analysis of the variance tests performed to appreciate the possible effects of BMI (Table 2), relative humidity, ambient temperature and their interaction on FEV1 did not show any significant difference (Table 3).

The mean concentration of $PM_{2.5}$ observed for 24 hours was 100.33 ± 52.46 µg / m^3 [30.7; 205.6], which is more than double the average daily concentration recommended by the WHO at 25 µg / m^3. The mean PM_{10} concentration observed for 24 hours was 163.96 ± 120.67 µg / m3 [27.1; 400.8], which is more than three times that recommended by the WHO at 50 µg / m^3.

DISCUSSION

This study, carried out in a hot and humid atmosphere in Brazzaville, aimed to determine the prevalence of bronchospasm in Congolese athletes. To evaluate the possible influences of ambient polluted air on the respiratory function of the runners, the respiratory variables were measured at rest

Table 2. ANOVA Table to appreciate BMI effect on FEV

	DF	Sum of squares	Squares average	F values	P values	Lambda	Power
At remain before stress exercise							
BMI	1	0.171	0.171	0.630	0.4391	0.630	0.112
Residue	16	4.337	0.271				
At 5 minutes after stress exercise							
BMI	1	0.003	0.003	0.012	0.9140	0.12	0.051
Residue	16	3.666	0.229				
At 10 minutes after stress exercise							
BMI	1	0.002	0.002	0.006	0.9373	0.006	0.051
Residue	16	5.913	0.370				
At 15 minutes after stress exercise							
BMI	1	0.001	0.001	0.002	0.9684	0.002	0.050
Residue	16	7.429	0.464				
At 20 minutes after stress exercise							
BMI	1	0.042	0.042	0.099	0.7569	0.099	0.060
Residue	16	6.757	0.422				
At 25 minutes after stress exercise							
BMI	1	0.045	0.045	0.105	0.7500	0.105	0.061
Residue	16	6.838	0.427				

FEV: Forced expiratory volume in one second; DF: degree of freedom; BMI: Body Mass Index; ANOVA P values > 0.05 from remain to 25 minutes after stress exercise. BMI has no effect on FEV.

Table 3. ANOVA Table to appreciate interaction effect of ambient temperature and degree of humidity on FEV

	DF	Sum of squares	Squares average	F values	P values	Lambda	Power
At remain before stress exercise							
AT	1	0.089	0.089	0.300	0.5926	0.300	0.079
RH	1	0.097	0.097	0.326	0.5772	0.326	0.082
AT* RH	1	0.092	0.092	0.310	0.5865	0.310	0.080
Residue	14	4.152	0.297				
At 5 minutes after stress exercise							
AT	1	0.097	0.097	0.441	0.5176	0.441	0.090
RH	1	0.113	0.113	0.510	0.4871	0.510	0.100
AT* RH	1	0.108	0.108	0.489	0.4957	0.489	0.98
Residue	14	3.094	0.221				
At 10 minutes after stress exercise							
AT	1	0.042	0.042	0.110	0.7450	0.110	0.061
RH	1	0.052	0.052	0.135	0.7188	0.135	0.63
AT* RH	1	0.051	0.051	0.131	0.7227	0.131	0.63
Residue	14	5.402	0.386				
At 15 minutes after stress exercise							
AT	1	0.006	0.006	0.013	0.9120	0.013	0.051
RH	1	0.012	0.012	0.026	0.8740	0.026	0.053
AT* RH	1	0.011	0.011	0.023	0.8810	0.023	0.052
Residue	14	6.429	0.459				
At 20 minutes after stress exercise							
AT	1	0.002	0.002	0.004	0.9535	0.004	0.050
RH	1	3.352E-4	3.352E-4	0.001	0.9786	0.001	0.050
AT* RH	1	4.248E-4	4.248E-4	0.001	0.9760	0.001	0.050
Residue	14	6.316	0.451				
At 25 minutes after stress exercise							
AT	1	0.001	0.001	0.003	0.9557	0.003	0.050
RH	1	0.005	0.005	0.011	0.9191	0.011	0.051
AT* RH	1	0.003	0.003	0.008	0.9301	0.008	0.051
Residue	14	6.066	0.433				

FEV: Forced expiratory volume in one second; DF: degree of freedom; AT: Ambient Temperature; RH: Relative Humidity; AT* RH: interaction on FEV; ANOVA P values > 0.05 from remain to 25 minutes after stress exercise. AT, RH and AT* RH do not have effect on FEV.

during a respiratory function examination. The physical characteristics of the subjects likely to influence the ventilatory variables were compared between the EIB (+) and EIB (-) groups. These comparisons showed no significant difference ($p > 0.05$) and thus show the equivalence of the two study groups. The variables observed in the EIB (+) group were assessed with reference to those of the EIB group (-). The major findings in this study were 1) the prevalence of exercise-induced bronchospasm among athletes was 33 %; 2) the mean post-exercise FEV_1 fall was 18.37 % in EIB (+) athletes; and 3) body mass and the interaction of DH and room temperature did not have a significant effect on bronchospasm. However, the observed $PM_{2.5}$ and PM_{10} concentrations were double and triple those recommended by the WHO. In addition, the WHO strongly recommends regular physical activity as one of the most effective means of preventing chronic diseases and ensuring better health (Latimer-Cheung AE, Toll BA, 2013). However, although beneficial, physical workouts with high demands and deleterious environmental conditions are likely to cause respiratory distress and exercise-induced bronchospasm (EIB) (Parsons JP, Hallstrand TS, Mastronarde JG, 2013). Indeed, the prevalence of EIB varies from 4 to 20 % in the general population but is 90 % in asthmatic subjects (ginasthma.org, 2018). From a terminology point of view, EIBa is observed in already asthmatic subjects, while EIB_{wa} is often recorded in sportsmen who are not initially asthmatic (Carlsen KH, Anderson SD, Bjermer L, 2008). In this study, the athletes were not asthmatic but sensitive to EIB, and a prevalence of 33 % was observed among these individuals. This prevalence is higher than that of the general population (4 to 20 %) but higher or lower than the EIB prevalence values reported in the literature.

Thus, on the basis of a questionnaire and/or specific provocative tests carried out by athletes of the summer and winter games, (Messan F, Tito A, Gouthon P, Nouatin K, Nigan I, Blagbo A, Lounana J, 2017); (Burnett DM, Burns S, Merritt S, Wick J, 2016); (Bonini M., 2015); (Robson-Ansley P, Howatson G, Tallent J, 2012); and (Larsson K, Ohlse´n P, Larsson L, 1993) found prevalence values of 59 %, 42.5 %, 14.7 %, 32 %, 54.8 %, respectively. Similarly, (Bonini M., 2015) reveal that, starting in the 2000s, the prevalence of exercise-induced asthma and bronchospasm increased steadily and significantly in the population of high-level athletes, particularly among long-distance athletes. Indeed, the prevalence of 33 % observed among Congolese athletes is compatible with those reported in the literature and can be explained by the fact that these athletes train three times a week over distances of 5,000 and 10,000 m. Indeed, because of the long distances at which these individuals practice and compete, the runners develop a hyperventilation of air with high pulmonary flows of up to 100 $L.min^{-1}$ in a state of stability, with a maximum consumption of oxygen greater than 67 $mL.kg^{-1}.min^{-1}$.

Additionally, the micro lesions generated by hyperventilation affect the cell permeability to Na^+, Cl^-, K^+ and Ca^{2+} ions. These lesions induce the release of chemical mediators involved in the initial inflammatory process of asthma. This large amount of ventilated air under unfavourable environmental and climatic conditions can cause airway damage and high asthma values. On the other hand, because of the important mixing of air with exercise, the airways of these athletes are frequently exposed to many allergens and particulate matter ($PM_{2.5}$ and PM_{10}). In fact, the concentrations of $PM_{2.5}$ and PM_{10} observed at the test sites were respectively double and triple those recommended by the WHO (Results). Thus, these studies indicate that ultrafine suspended particles are involved in airway dysfunction and even decrease respiratory function (Brauer M, Lee K, Spengler JD, Salonen RO, Pennanen A, Braathen OA, Mihalikova E, Miskovic P, Nozaki A, Tsuzuki T, Song RJ, Yang X, Zeng QX, Drahonovska H, 1997); (Levy JI, Lee K, Yanagisawa Y, Hutchinson P, 1998); (Rundell KW, 2003). In the context of this study, these considerations are likely to justify the 33 % prevalence by which EIB-sensitive subjects showed a decrease in FEV_1 of 18.37 % at the end of the stress test (Table 1).

The results of our study were obtained in the hot and humid climate of Brazzaville, although some studies have shown that the high prevalence of asthma or bronchospasm induced by exercise is observed in athletes who perform over long distances under cold, dry conditions (Burns J., Mason C., Mueller N., Ohlander J., Zock J.-P., Drobnic F., Wolfarth B., (...), 2015). Other studies argue that the hyperventilation of warm, moist air significantly reduces the mechanism that induces bronchospasm (Gomes RLM, Filho EAR, Júnior MAVC, Batista GR, Almeida AHS, 2018) and, as a result, a prevalence of 7 % was observed among semi-professional Brazilian football players who are not sensitive to exercise-induced asthma symptoms. Other investigators found an EIB prevalence of 11 % among children with asthma diagnosis (Ventura MT, Cannone A, Sinesi D, 2009); (Bousquet J, Van Cauwenberge P, Khaltaev N, 2001). In Tehran, Iran, a prevalence of 6 % was found in 100 adult non-asthmatic soccer players (Weiler JM, Anderson SD, Randolph C, 2010). These authors suggested that, the inhalation of hot, humid air during exercise in tropical regions generates a protective mechanism against bronchospasm in athletes. Therefore, this phenomenon would explain the low asthma prevalence values in athletes in hot and humid climates. These hypotheses are in contrast with our results, as our study, although conducted among runners in the hot and humid climate of Brazzaville, Congo, showed a prevalence of 33 %. A study conducted by (Messan F, Dansou P, Lawani M, Falola J, 2011) among basketball players in tropical (34 °C) and wet (54.5 %) climates showed a prevalence of asthma of 26 %.

Another study carried out in Abidjan in the Ivory Coast by (Ouattara, S., Balayssac-Siransy, A. E., Konaté, A., Tuo, N., Keita, M., Dah, C., and Bogui, 2012) found an asthma prevalence of 42.6 % in sportsmen in hot (30.1 °C) and humid (82.6 %) climates after a stress test, with a decrease in VEMS of at least 10 %. In our study, to clarify the possible effect of hot and humid air conditions on the occurrence of bronchospasm in high-level athletes, ambient temperatures and relative humidity were the same as the respiratory parameters at the end of each stress test. The various analysis of variance tests (Tables 2 and 3) performed to determine the effect of variables and their interactions on bronchospasm were inconclusive. To our knowledge, this study is the first to show that the inhalation of hot, humid air before, during and after exercise does not lessen the mechanistic induction of bronchospasm in high-level athletes in a hot and humid environment. The bronchospasm that occurs during and after physical exertion in high-performance athletes is primarily due to exercise. High prevalence values observed in long-endurance athletes, winter sports and swimming are associated with the intensity, duration and modalities of training (Bonini, M., and Silvers, 2018).

Conclusion

Under a continental climate of cold, dry air, the prevalence of exercise-induced bronchospasm (EIB) observed in athletes is increasing. On the other hand, this prevalence is less elevated in hot and humid climates. The hyperventilation of warm moist air would explain low prevalence values in tropical areas. This study found a 33 % prevalence of EIB in Congolese athletes training in hot, humid air conditions. Body mass and the interaction of moisture content and ambient temperature did not have a significant effect on FEV_1 change. The $PM_{2.5}$ and PM_{10} concentrations observed at training sites are twice and triple those recommended by the WHO. These results highlight a very high prevalence of EIB in hot and humid air conditions that is not consistent with the results in the literature. In hot and humid climates, the nature of sports disciplines, their training modalities and air hyperventilation associated with particulate matter may play a more important role in the initiation and exacerbation of post-exercise bronchospasm.

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