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ASSESSMENT OF SPIROMETRIC PARAMETERS AND SENSITIVITY TO EXERCISE-INDUCED BRONCHOSPASM IN SCHOOL CHILDREN ATTENDING SCHOOLS LOCATED NEAR ROAD TRAFFIC IN BRAZZAVILLE

NSOMPI Florent*[1, 2, 3], BOUSSANA Alain[1,3], MOUSSOUAMI Simplice Innocent [1], BOUHIKA Eddie Janvier[1], MABOUNDA KOUNGA Paul Roger[1,3], TITO Albérick[2] and MESSAN Folly[2]

[1]Laboratory of Molecular and Cellular Biology, Physical Activity and Health, Marien Ngouabi University, Higher Institute of Physical Education and Sport (ISEPS), Congo; [2]Respiratory, Hormonal and Gerontological Sports Explorations Unit. University of Abomey-Calavi (UAC), National Institute of Youth, Physical Education and Sport (INJEPS), Benin; [3]Laboratory Education, Health, Expertise and Motor Performance (LESEPM)

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Corresponding author: NSOMPI Florent,

ABSTRACT

Background: The purpose of this study was to assess spirometric parameters and determine the level of sensitivity to exercise-induced bronchospasm (EIB) in schoolchildren exposed to automotive pollutants. ***Materials and Methods:*** This is a cross-sectional study involving 156 subjects divided into two groups: The exposed group (EG) made up of 84 subjects from a school located near a main road and the less exposed group (LEG) made up of 72 subjects from a school located away from road traffic. A 6 minute stress test was performed. The spirometric measurements were made before and 5 minute after the stress test. ***Results:*** The results showed a significant decrease in the mean values of the peak expiratory flow (PEF) and maximal expiratory flow at 25-75 % of the forced vital capacity (FEF2575) recorded before exercise in girls and boys from the EG compared to those obtained before exercise in girls and boys from the LEG. A total of 15.48 % of the EG subjects were sensitive to the EIB compared to 9.72% of the LEG subjects. ***Conclusion:*** Long-term exposure to automotive pollutants can to alter lung function and increase the sensitivity rate to EIB in schoolchildren attending school located near road traffic.

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INTRODUCTION

Vehicles emit many harmful pollutants into the air and exposure to these pollutants can lead to hospitalizations and the onset of death (Gouveia *et al*., 2017; Brugge *et al*., 2007), alterations in lung function (Dandan Xu *et al*., 2020; Gehring Ulrike *et al*., 2013) and risks of respiratory diseases in schoolchildren (Hwang and Lee, 2010; Messan *et al*., 2011). Numerous studies have shown an association between exposure to fine particulates (PM) and reduced parameters of lung function (Zwozdziak *et al*., 2016; Roy *et al*., 2012; Badyda *et al*., 2015). A recent study by Dandan Xu *et al*. (2020) reported a decrease in forced vital capacity (FVC), maximal expiratory volume in one second (FEV1), and peak expiratory flow (PEF) for each 10 µg/m3 increase in mean $PM_{2.5}$ concentration, out if 5 days in school children. Another study showed that exposure to fine particulates with an inferior diameter to 2.5µm ($PM_{2.5}$) and nitrogen monoxide (NO_X) was linked to significantly lower lung function in schoolchildren (Bergstra *et al*., 2018). The results of a study by Hwang and Lee (2010) in children aged 12 to 14 years with and without asthma exposed to air pollutants showed significant effects of nitrogen dioxide (NO_2) and carbon monoxide (CO) on bronchoconstriction. In addition, living near (within 150 m) a major road axis (with more than 10,000 vehicles per day) has led to 9 to 25% of new cases of asthma among children (Aphekom, 2011). Impaired respiratory function between 10 and 18 years of age has been demonstrated for children living within 500 m of a motorway (Gauderman *et al*., 2007). The work of Isabella Annesi-Maesano *et al*. (2012) revealed that nearly 30% of students, or 3 out of 10 children, are exposed to pollutant levels higher than the standards authorized by the World Health Organization (WHO). The same authors reported that exposure to high concentrations of particulates and volatile organic compounds (VOCs) were associated with an increased prevalence of asthma and rhinitis in school children. Brazzaville, capital of the Republic of Congo, had approximately 1,370,612 inhabitants in 2016 according to the United Nations Development Program in Congo and today its population has increased and its road traffic is very dense. In 2009, the National Center for Statistics and Economic Studies (CNSEE, 2011) recorded 8,935 used vehicles in Brazzaville city. Today, the number of used vehicles has increased exponentially in the Congolese capital. These vehicles are devoid of the latest gas emission control technology and emit thick black smoke, thus polluting the ambient air of the city. In addition, several schools are located close to road traffic, and students are exposed to automobile pollution. To this end, the objectives of this study were to assess the pulmonary function parameters and determine the sensitivity rate to EIB in students exposed to road traffic pollution. Then, we hypothesized that students attending school located near road traffic have altered lung function and are sensitive to EIB.

MATERIALS AND METHODS

Study participants and design: A total of 156 middle first-year students in good health participated in this study. They were divided into two groups: the exposed group (EG) comprising 84 subjects (42 girls and 42 boys) attending primary school October 30, 1984 located near (7 m) a main road, and the less exposed group (LEG) , composed of 72 subjects (37 girls and 35 boys) from the Joseph MOUTABALA primary school, very far (700 m) from road traffic. These two schools are located in the 7 Mfilou district in Brazzaville. Participants were, on average, 10 years old (girls) and 11 years old (boys), in both groups, and had been attending these two schools 5 years or more. Prior to student participation, informed consent was signed by the parents. The study was approved by the Scientific Council of the Higher Institute of Physical and Sports Education of MARIEN NGOUABI University in accordance with the Declaration of Helsinki.

Lung function test: Spirometry tests were carried out by a specialist technician using a portable Spirobank G-type spirometer manufactured by" Medical International Research (MIR) " (volume precision: ± 3% or 50 ml and flow rate precision: ± 5% or 200 ml/s). The Spirobank G consists of a central unit, monitor and turbine with "WinspiroPRO" software installed in the central unit.

The Spirobank G was connected to a portable DELL-branded microcomputer with a USB cable, which allowed for the measurements of the ventilatory variables and the flow-volume curve of the spirometry test to be displayed on a screen. The ventilatory parameters were measured between 8:00 a.m. and 12:00 p.m. before and after the stress test in the cell set up in schools.

Bronchial provocation stress test: A 6-minute endurance race was performed according to the recommendations of the European Respiratory Society (ERS) (ERS, 1993) and the American Thoracic Society (ATS) (ATS, 1991). Ambient temperature and relative humidity were measured simultaneously at the start and end of the stress test using a "SUNROAD" type electronic hygrometer. The stress test was carried out in the courtyard of the schools concerned.

Diagnosis of exercise-induced bronchospasm (EIB): A subject was diagnosed as sensitive to EIB if the drop in their post exercise FEV1 is greater than or equal to 10% compared to their pre-exercise FEV1 by applying the formula:

Delta FEV1 (%) = [(FEV1 post-effort - FEV1 pre-effort)] x 100 / FEV1 pre-effort

Study variables: In this study, automobile pollution, ambient temperature and relative humidity were the independent variables, and lung function parameters were the dependent variables.

Statistical analyses: Descriptive statistics were used to generate the means and standard deviations of the different variables of the subjects of the exposed group (EG) and the less exposed group (LEG). After checking the normality and homogeneity of the variances using the Kolmogorov-Smirnov test and Snedecor's F test, Student's t test for unpaired series was used to compare the anthropometric variables between the girls of the EG and those of the LEG and between the boys of the EG and those of the LEG. The ANOVA parametric test was also used to compare the mean values of the ventilator variables recorded before and after the stress test between the girls of the EG and the girls of the LEG and between the boys of the EG and the boys of the LEG. Data analysis was performed using SPSS software, version 21.0, and the level of significance was s*et al* p <0.05.

RESULTS

The anthropometric characteristics obtained from the subjects of the EG and LEG, the ambient temperature and the relative humidity recorded during the stress test are presented in Table 1. The mean values of the anthropometric variables obtained from the subjects in the EG were not significantly different from those obtained from the LEG subjects. The mean temperature and humidity values recorded during the stress tests for the EG subjects were not significantly different from those obtained from the LEG subjects (Table 1).

Table 1. Comparison of the mean values of anthropometric characteristics, ambient temperature and relative humidity between subjects of the exposed group (EG) and of the less exposed group (LEG).

	EG			LEG			Value	Delta
	Mean ± SD			Mean ± SD			p	(%)
Girls	n = 42			n = 37				
Age (years)	10.64	±	1.05	10.78	±	1.20	p > 0.05	-1.298
Height (cm)	141.31	±	8.40	144.89	±	7.62	p > 0.05	-2.470
Weight (kg)	33.95	±	4.97	36.62	±	6.94	p > 0.05	-7.291
BMI (kg/m^2)	16.96	±	1.54	17.28	±	1.79	p > 0.05	-1.851
Boys	n = 42			n = 35				
Age (years)	11.14	±	1.28	11.57	±	1.19	p > 0.05	-3.716
Height (cm)	138.59	±	6.89	142.82	±	6.55	p > 0.05	-2.961
Weight (kg)	33.31	±	4.15	34.74	±	4.55	p > 0.05	-4.116
BMI (kg/m^2)	17.30	±	1.31	17.01	±	1.72	p > 0.05	1.704
Environmental ambient conditions								
AT (°C)	33.750	±	0.856	33.687	±	0.704	p > 0.05	0.187
RH (%)	57.000	±	2.804	56.937	±	2.205	p > 0.05	0.001

BMI : Body mass Index ; EG: Exposed Group; LEG: Less Exposed Group; Delta % : percentage change in values of subjects of the exposed group (EG) compared to values of subjects of the less exposed group (LEG) ; AT (°C) : Ambient Temperature ; RH (%) : Relative Humidity

The values of the pulmonary function parameters obtained before and after exercise from the subjects in the EG and those in the LEG are presented in Table 2. The mean PEF values obtained before and after the stress test from the girls in the EG exposed to motor vehicle pollution were significantly lower than those obtained before and after from girls in the LEG.

The mean value of FEF2575 obtained before exercise from the girls in the EG was significantly reduced compared to that measured before exercise in their counterparts in the LEG. Boys from the EG presented mean PEF and FEF2575 values significantly lower than those of their counterparts in the LEG before and after exercise (Table 2). The level of sensitivity to exercise-induced bronchospasm (EIB) in the subjects of the exposed group (EG) and the less exposed group (LEG) is presented in Table 3. At the level of the exposed group, 13 subjects or 15.476% were sensitive to EIB versus 7 subjects, i.e., 9.722% in the less exposed group (Table 3).

Table 2. Comparison of the mean values of the pulmonary function before and after exercise between girls of the exposed group and those of the less exposed group and between boys of the exposed group and those of the less exposed group

	EG						LEG					
	Before effort			After effort			Before effort			After effort		
	Mean	±	SD	Mean	±	SD	Mean	±	SD	Mean	±	SD
Girls	n = 42			n = 42			n = 37			n = 37		
FVC (L)	1.84	±	0.37	1.89	±	0.36	1.95	±	0.42	1.99	±	0.43
FEV1 (L)	1.65	±	0.34	1.68	±	0.30	1.79	±	0.34	1.77	±	0.31
PEF (L/s)	3.27	±	0.96†	3.48	±	0.94†	4.22	±	0.89	4.01	±	0.80
FEF25-75 (L/s)	2.19	±	0.70†	2.37	±	0.64	2.76	±	0.45	2.34	±	0.51
Boys	n = 42			n = 42			n = 35			n = 35		
FVC (L)	1.94	±	0.36	2.03	±	0.31	1.96	±	0.29	2.00	±	0.27
FEV1 (L)	1.75	±	0.34	1.73	±	0.26	1.77	±	0.28	1.77	±	0.25
PEF (L/s)	3.83	±	1.05‡	3.60	±	1.11‡	4.38	±	0.78	4.19	±	0.84
FEF25-75(L/s)	2.31	±	0.63‡	2.08	±	0.51‡	2.54	±	0.68	2.33	±	0.61

FVC: Forced Vital Capacity; FEV1: Forced Expiratory Volume in one second; PEF: Peak Expiratory Flow; FEF25-75%: Forced Expiratory Flow at 25–75% of forced vital capacity; EG: Exposed Group; LEG: Less Exposed Group; †: Significance between girls from the exposed group (EG) and girls from the less exposed group (LEG); ‡: significance between boys from the exposed group (EG) and boys from the less exposed group (LEG).

Table 3. Level of sensitivity to EIB in subjects from the exposed (EG) and less exposed (LEG) group, both sexes combined

Diagnostic of EIB	EG n = 84	LEG n = 72
Number of Subjects who had a drop in post-effort FEV1 of at least 10% compared to pre-exercise FEV1	13 subjects (15.476 %)	7 subjects (9,722 %)

EG: Exposed group; LEG: Less exposed group

DISCUSSION

This study was carried out to assess lung function parameters and to determine the level of susceptibility to exercise-induced bronchospasm (EIB) in schoolchildren exposed to pollution from automobile sources. The mean values of the anthropometric characteristics obtained from subjects in the exposed group (EG) and those recorded in subjects in the less exposed group (LEG) did not show a significant difference in either girls or boys (Table 1). In addition, the mean values of ambient temperature and relative humidity recorded during the stress tests in the EG subjects were not significantly different from those obtained from the LEG subjects during the stress tests. These results show that subjects in both groups exercised in the same ambient conditions of warm and humid air. The EG girls presented significantly reduced pre- and post-exercise PEF values compared to their LEG counterparts recorded before and after exercise. In addition, the mean FEF2575 value obtained before exercise from the girls in the EG was significantly lower than that obtained before exercise from the girls in the LEG (Table 2). These results reveal disturbances in the proximal and distal airways. It is known that a decrease in PEF and FEF2575 indicates bronchial obstruction (Pocock and Richards, 2004; Bhalla and Jennings, 2007). In boys, the comparison of the mean values of PEF and FEF2575 recorded before and after exercise in EG subjects was significantly lower than those obtained before and after exercise in their colleagues in the LEG (Table 2). Note that PEF explores the large pulmonary bronchi, while FEF2575 explores the small pulmonary bronchi. These results lead us to believe that subjects in the EG (girls and boys) have an abnormal state of the proximal and distal respiratory airways compared to subjects of both sexes in the LEG. Long-term exposure to pollution from automobile sources is thought to be responsible for the changes observed in the proximal and distal airways. The results of a study suggested that exposure to fine particles (PM_{10}, $PM_{2.5}$) reduces the growth of lung function in children and causes reduced lung function in healthy individuals (Sun Young Kyung and Sung Hwan Jeong, 2020). In this study, we carried out a count of subjects with post exercise FEV1 values reduced by at least 10% within each Group (Table 3). In relation to this diagnostic criterion for exercise-induced bronchospasm (EIB), 13 subjects (15.48%) were identified as sensitive to EIB in the EG, and 07 subjects (9.72%) were identified as sensitive in the less exposed group. The number of EIB-sensitive subjects recorded in the EG is practically double the number of BIE-sensitive subjects observed in the LEG. In this study, schoolchildren attending the school located close to road traffic, a source of automobile pollution, were twice as likely to develop EIBs than those attending the school far from the source of pollution.

This result can be explained by the fact that the concentrations of air pollutants decrease as one moves away from the source of pollution. Note that the diffusion of particles decreases with size, while the speed of transfer by inertia and sedimentation increases with size or mass. In fact, the smaller the particles are, the greater their spatial variability is reduced. Larger particles such as PM_{10} have greater spatial variability than finer particles such as $PM_{2.5}$ (Wilfried Endlicher *et al*., 2008). In addition, ultrafine particles and nitric oxide (NO) decay exponentially within 100 to 150 m of the roadside (Martin Adam *et al*., 2015). In this study, subjects in the LEG located approximately 700 meters from road traffic were more exposed to large particles; on the other hand, those in the EG located approximately 7 meters away were exposed to fine and ultrafine particles. $PM_{2.5}$ particles are very dangerous for lung health. The results of one study showed that exposure to $PM_{2.5}$ particles was associated with a significant reduction in PEF (Yunquan Zhang *et al*., 2015). The levels of NO_2 and benzene decrease rapidly within the first 20 meters from the source and then decrease more gradually until approximately 150 meters. These patterns of decrease in atmospheric pollutant concentrations are largely influenced by meteorological and urbanization conditions (Airparif, 2008). Exposure to NO_2 and SO_2 induces disturbances in lung volumes and flows (Santé Canada, 2016). In addition, studies have shown that with exercise, airway dehydration leads to airway narrowing (McFadden and Gilbert, 1994; Anderson and Daviskas, 2000). As exercise was exhaustive in this study, it is likely that exercise not only reduced FEV1 but also inhalation of high levels of automotive pollutants due to hyperventilation occurred in the subjects. These inhaled pollutants can directly reach the alveoli. Indeed, studies have revealed respiratory tract inflammation and airway hyper responsiveness in subjects exposed to road traffic pollutants such as $PM_{2.5}$, PM_{10} and NO_2 (Sun Young Kyung and Sung Hwan Jeong, 2020; Ana *et al*., 2009). Road traffic, with the increase in the number of obsolete vehicles in the city of Brazzaville, would have played an important role in the deterioration of pulmonary function observed in schoolchildren attending a school located near a main road. In the next study, assessment of air pollutant concentrations in classrooms and in the schoolyard would be needed to investigate associations between pollutants and impaired lung function.

CONCLUSION

Long-term exposure to automotive pollutants can to alter lung function and increase the sensitivity rate to EIB in schoolchildren attending school located near road traffic. The decline in lung function and the high rate of susceptibility to EIB observed in this study require the installation of air quality monitoring stations and the prohibition of circulation of old vehicles in the municipality of Brazzaville.

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