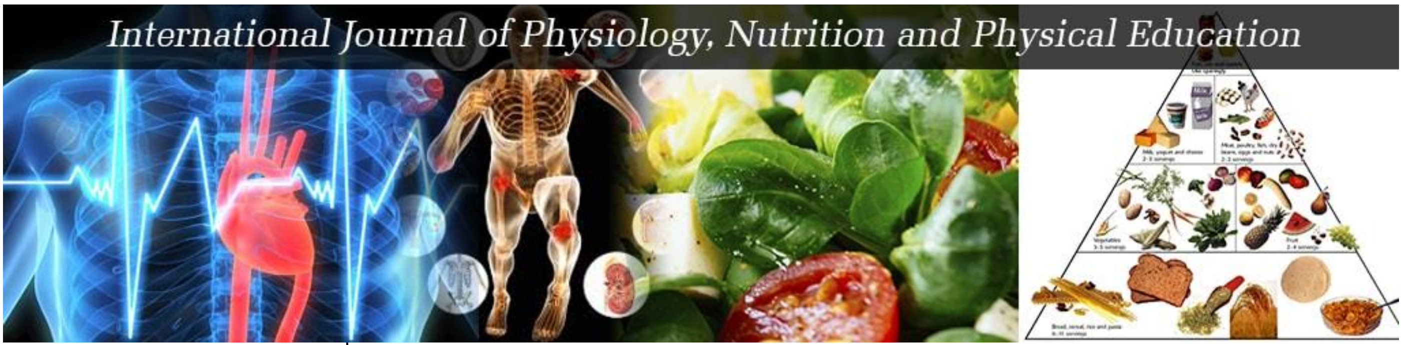

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Short-term impact of $PM_{2.5}$ fine particulate pollution on the ventilatory function of adults jogging in Porto-Novo (Benin)

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Abstract
Position of the problem: Air pollution in general has become one of the major problems today that threatens the daily health of the Beninese population and undermines the stability of the affected ecosystems. The rapid development of motorcycle taxis, the explosion of the used vehicle sector emitting particulate matter from exhaust gases and/or taxiways, and the consequences of poor household waste management, especially in large cities of Benin have amplified the magnitude of the phenomenon. Thus, the persistent presence of an opaque mixture of smoke, dust and moisture on the main arteries and at the major crossroads of the city centers during peak hours was noted. The aim of the research was to study the effects of short-term exposure of air pollutants on ventilatory function during the physical exercise of adults engaged in jogging in traffic.
Methods: Measurements of Particulate Matter (PM) were carried out at the sport site from 06 H to 20 H using a KNF membrane vacuum pump and a filter device equipped with a filter depth of quartz fiber Whatman cat.n. 1852047, QMA grade, Ø: 47 mm and Millipore AQFA code, Ø: 47 mm. The membranes were stored at 20 °C. ± 2 °C. for 48 hours and weighed under vacuum before and after measurement on site. Functional exploration was also performed for the determination of the ventilatory parameters of the subjects.
Results: The results obtained showed that the concentration of particles with an aerodynamic diameter of less than 2.5 µm was higher than that of the particles with an aerodynamic diameter greater than 2.5 µm in the jogging environment. Analysis of ventilatory parameters revealed that exposure to particles over a short period of time did not have a significant effect on the health of the subjects. Nevertheless, a long-lasting physical practice or repetitive in time and space, could therefore prove detrimental for these weekend maintenance sports practitioners.
Conclusion: The environment in which adults engaged in jogging was heavily concentrated in fine particles ($PM_{2.5}$). The frequent exposure to these particles can therefore create respiratory pathologies because they are aggressive and penetrate rapidly in the deep regions of the lungs.

Keywords: $PM_{2.5}$, respiratory function, physical activity, short term effect

Introduction

Environmental pollution in general has become one of the major problems that threaten the health of populations and undermine the stability of the affected ecosystems (Ramade, 1992) [24]. Lindsey *et al*. (2011) [19] showed in a study of the impacts of ambient air pollution on Atlanta-exposed subjects from 1994-2004 that affected the development of the fetus in pregnant subjects. Bell *et al*. (2008) [4] have established a relationship between the risk of cardiac ischemia and air pollution mainly by particulate matter. This form of pollution is now very worrying, the causes of which are both natural and anthropogenic. Natural causes are mainly volcanic eruptions, wildfires, natural wind erosion or desert advances with long-distance transport of inorganic particulate matter from desert areas to inhabited areas (Bell *et al*., 2008) [4]. Major anthropogenic causes are heating (including wood and charcoal), combustion of fossil fuels in vehicles, thermal power plants and many industrial processes. Fredrick *et al*. (2000) [9] reported that urban air pollution increases the risk of lung cancer and that vehicle emissions were the main cause. Particulate matter is an air pollutant whose composition is extremely heterogeneous, both from a chemical and a dimensional point of view. It can be considered as a complex mixture of organic and inorganic substances suspended in air, in solid or liquid form. Particulate matter of sizes less than 10 µm are the most dangerous because of aerodynamics and their penetration into the respiratory tract especially those with sizes smaller than 2.5 µm. These particulate matters were² regulated by the WHO Air Quality Guidelines and are subject to environmental monitoring (WHO, 2005). The WHO estimates that 3.7 million premature deaths worldwide caused by ambient pollution in urban and rural areas in 2012. This mortality would be due to exposure to PM_{10}, which would cause serious cardiovascular and respiratory diseases, and cancers. Faced with the modern scourge of air pollution, Benin's major cities are not spared. The persistent presence of an opaque mixture of smoke, dust and moisture on the main arterial roads and at the major crossroads of urban centers was noted. It is the activities of the transport sector, the rapid development of motorcycle taxis, the explosion of the used vehicle sector and the consequences of poor household waste management. A 2007 study by the World Bank and carried out by the Clean Air Initiative (CAI) in Benin revealed that direct emissions from combustion engines or the suspension of particles caused by their circulation on dusty roads constituted the one of the main causes of air pollution in Cotonou. The mean annual PM_{10} concentration was estimated to be 78 $\mu g/m^3$, with daily peaks exceeding 300 $\mu g/m^3$. Data on trends in the incidence rate of acute respiratory infections (ARI) from 2005 to 2009 in a few localities in Benin, including the three cities with special status, namely Cotonou, Porto-Novo and Parakou, showed an evolution of ARI (Sanitary Statistics of Benin, 2005, 2006, 2007, 2008 & 2009). This statistic applies only to medically reported cases. Gbonsou's study of screening for naso-sinus and pulmonary disorders among taxi-motorcycle drivers in 2012 revealed that the prevalence of the triad symptomatology of rhinosinusopathies was 70.6%, 66.1% and 73.3% respectively for sneezing, nasal obstruction and rhinorrhea. That of chronic cough was 26.7%. For sinus infections, the maxillary sinuses were the most affected, standing for a prevalence of 91.66%. The prevalence of lung damage was lower with 24.4% of bronchial syndrome. 35% of drivers have cardiothoracic index higher than the normal one. It is therefore well established that the respiratory system which unfortunately is a vital and irreplaceable organ was most affected by the phenomena of atmospheric pollution in these taxi-motorcycle drivers.

Significant longitudinal studies have clearly demonstrated that physical activity reduces the risk of premature death. This benefit continues at older ages and is most pronounced when the most active individuals are compared with the most sedentary individuals. The link is even stronger when:

1. Measuring the concentration of fine particles on the jogging site and;
2. Studying the impact of this pollution on ventilatory parameters, measured twice, 15 days apart.

Material and Methods

Area study

This prospective, anthropometric and spirometric study was carried out in the city of Porto-Novo on adults who spent their weekends on the esplanade of the National Assembly of Benin. It was spread over a period of 15 days and did not involve the integrity of the subjects; consequently it did not introduce any particular risk.

Study population

The sampling strategy has led to explaining to all athletes the object of the study. They are subjects who practice the sport of maintenance by jogging on weekends on the esplanade of the National Assembly of Benin. Participants in the study gave their free, written and informed consenment. The non-random sampling technique was used. Seventy (70) subjects met the study criteria and participated in the entire experiment.

Inclusion and Exclusion Criteria

The study subjects met the following criteria:

1. Be a regular member of an association of weekend sports practitioners;
2. Have at least two (02) hours of practice of the sport of maintenance within the association;
3. No-smoking;
4. Apparently breast and respiratory pathologies;
5. Be no allergic to dust, heat, perfume and suffer from any allergenic pathology.
6. Reside in the city of Porto-Novo in Benin;
7. Be knowledgeable about the study and give its free and informed consent to participate in the study. In order to avoid the influence of certain professions involving permanent exposure to pollutants, masons, carpenters, millers, painters and taxi-motorcycle drivers were excluded from the study.

Spirometric measurements

After reading the study and giving its free, written and informed consent, the anthropometric data were recorded. The subject performs a trial familiarization with the SPIROBANK II S / N 001267 MIR spirometer regularly calibrated. The standard used was that of the African ethical group incorporated in the software of the spirometer. Disposable mouthpieces were used to observe medical hygiene. The forced spirometry test was performed to record the ventilatory parameters before and after jogging.

At the end of physical exertion, the subject observed a pause of 5 min in order to avoid the influence of fatigue on the respiratory muscles and on the quality of the spirometric data (Anderson *et al.*, 2001) [1]. Then in the sitting position, he breathes through the mouthpiece that he puts into the mouth. He receives instructions to inflate his thorax to the maximum and then to empty his lungs as quickly and continuously as possible. Maximum instantaneous flows were measured at all points of the curve, but by convention four were selected: peak expiratory flow (DEP) and flow rates at 75, 50, 25% of vital capacity (Fry and Hyatt, 1960) [10]. The DEP reflects the diameter of the central airway and the force exerted by the expiratory muscles. It decreases in obstructive and restrictive ventilatory disorders. The mean expiratory flow rates DEM, DEM50%, DEM25% and DEM25-75% make it possible to explore the small airways. After the respiratory functional exploration, the subject resumed normal breathing

Measurement of particles in the atmosphere by gravimetry

The sampling was carried out continuously for 8 hours at low volume (LVS) using a KNF membrane vacuum pump with a flow rate of 15 L/min, ie 0.6 m^3/h, connected to a head of inertial impact separation which selects the fraction of particulate matter of interest, namely PM_{10} and $PM_{2.5}$. The suction air is conveyed in a collector tube to a depth filter of quartz fiber Whatman cat. n. 1852047, QMA grade, Ø: 47 mm and Millipore AQFA code, Ø: 47 mm in order to retain PM_{10} or $PM_{2,5}$. The filters were conditioned under a horizontal laminar flow hood before and after sampling (T = 20 ± 1 °C, RH = 50 ± 5%) for 48 hours; once stabilized, they were weighed on an analytical balance of the type "KERN 770, max 220 g, d = 0.0001 g" to sort the filters of interest first and calculate the mass of sampled particulate material. Two weighings were performed before and after sampling for each filter. All filters whose σ / rapport ratio (σ = difference between the two weighings and χ = arithmetic mean of the two weighings) is greater than 0.1 were discarded. Thus, the mass of particulate material sampled is obtained by the following formula.

$$m_{mpé} = m_{av} - m_{ap}$$

With $m_{mpé}$: The mass of particulate material sampled; m_{av}: masses of the filter before sampling and m_{ap}: masses of the filter after sampling.
Similarly, the concentration of particulate material is obtained by:

$$[mp] = \frac{m_{mpé}}{v_{air}}$$

With [mp]: the concentration of particulate matter and v_{air}: the volume of air drawn in during the sampling period.
The transport of the filters from the measurement site to the analysis laboratory was carried out using filter holders and refrigerated cooler bags with cold storage to minimize the loss of semi-volatile material. During operation the filters were handled with clean stainless steel clips to reduce interference.

Statistical analysis
Comparisons of the mean values of the two sessions were made using the Wilcoxon nonparametric test for matched samples. The level of significance is set at $p < 0.05$.

Results and Discussion
Main characteristics of the subjects
The anthropometric characteristics and the jogging time per session of the subjects of the study are recorded in Table I. This table indicates that the body mass index (BMI) of the subjects is between 20 and 25 Kg/m^2. With this BMI value and according to the WHO classification, subjects have normal corpulence and are not obese.

Suspended particles
The measured PM concentrations are reported in Table II. From the analysis of the table, it appears that the concentration of particles with an aerodynamic diameter of less than 2.5 µm is 387 $\mu g/m^3$ significantly higher than that of particles whose aerodynamic diameter is greater than 2.5 µm, the PM_{10} (150 $\mu g/m^3$). The WHO standards recommend for each family of particles 25 and 50 $\mu g/m^3$ respectively for a 24-hour exposure. By extrapolating over 24 hours (considering the unlikely condition of zero particle recorded on the rest of the time to close the 24h), the $PM_{2.5}$ concentrations in air have a concentration of 129$\mu g/m^3$ and 50 $\mu g/m^3$ for PM_{10}. If, after extrapolation, PM_{10} complies with WHO recommendations, $PM_{2.5}$, which was the most dangerous, is 5.16 times the limit value (Karila, 2002, Kippelen *et al*., 2003, Fredrick *et al*., 2000) [16, 17, 9]. Several causes justify this massive presence of particulate matter in the air. This is very intense urban road traffic (on average, one car every 5 seconds) at this location, with approximately five crossroads serving several strategic locations in the capital such as the church, Notre Dame Catholic school, police force and national headquarters, the seat of parliament, the district hospital, the supreme court, the examinations and examinations department, the Plant Protection Department, the Porto-Novo Court of First Instance, etc. This road traffic is likely to release organic particulate matter into the air through exhaust gases, as well as inorganic particulate matter through tires that run on unpaved or paved roads covered with sand. Epidemiological studies have demonstrated an association between ambient particulate matter, morbidity and mortality associated with the respiratory tract. In addition, studies by McCreanor *et al*. (2007) [15] showed that diesel engines emit relatively low concentrations of carbon monoxide and carbon dioxide, but compared to gasoline engines of similar size, diesel engines can generate more than 100 times the number of particles per distance and contribute significantly to atmospheric pollution of particles. Apart from road traffic, we can also mention the day-to-day operations of sweeping the courtyards and fronts of houses or places of sale that raise a lot of dust. To all the examples quoted are added the illicit sale of adulterated gasoline at all the street corners in the city of Porto-Novo which releases in the air a significant quantity of volatile hydrocarbons able to contain PAHs. According to Fabriès (1992) [8], particles deposited at different levels of the respiratory system can cause various health effects that depend on their toxicological properties and their deposition site.

Effects of environmental particles on respiratory parameters
The ventilatory functional deficit was divided into five classes according to the scale of impairments of respiratory function (Decree No. 93-1216 of 4 November 1993 in Benin). It is a mild, moderate, severe and severe deficit (Laraqui Hossini *et al*., 2001) [18]. This deficit is observed in some studies on an exploration whose values are compared with theoretical values (Ben Saad *et al*., 2003) [5]. This exploration is based on the diagnosis of respiratory dysfunctions by spirometry. The results (Table III and IV) indicate a decrease in respiratory variables, mostly distal at the second session and after the practice of jogging. This decrease is much more significant at the level of the DEM50 (p = 0.005: 1st session, p = 0.0008: 2nd session). The results obtained in this study corroborate those of many authors who have discovered that particles of very small diameter cross the upper respiratory tract to reach the lower lungs (bronchioles and alveoli) where they will stagnate. (Hofmann and Bergmann, 1998, Hetland *et al*., 2000, Gebbers and Schlapferb, 2001, Witschger and Fabries, 2005) [14, 13, 12, 26]. This causes an obstructive bronchial hyper responsiveness, the site of inflammation. In addition, exposure to PM_{10} and $PM_{2.5}$ could induce oxidative lesions capable of causing abnormal secretion of inflammatory mediators closely involved in the development of pulmonary pathologies (Monn and Becker 1999; Calcabrini *et al*., 2004) [20, 7].
During physical practice, humidification and warming of the air in the airways before reaching the alveoli (Karila, 2002) [16], leads to hyperemia (vascular engorgement) of the bronchial microcirculation responsible for edema and of a narrowing of the airways. This may further justify the observed decrease in the distal respiratory variables of these subjects.
This instant maximum expiratory flow rate measured at 50% of the FVC explores the medium of exhalation (medium

bronchi and some of the small). It may be disrupted despite normal FEV1. Its variability is greater than that of DEM 25-75 (Wanger *et al*., 2006) [25]. Mean expiratory flow rates are fractional measurements at different levels of FVC. They make it possible to better locate the level of bronchial obstruction. Beyond the DEM75, flow rates are considered to be independent of effort because they correspond anatomically to flows in the airways lacking cartilage protection, and therefore liable to subside as a function of trans parietal pressure (Antonello *et al*., 2005) [2]. This is responsible for the small airway syndrome.

The most frequent small airway syndrome is broncho-bronchopnetic bronchopathy with bronchospasm, resulting in a reduction in the luminal size localized to small airways. The lung, because of its interaction with ambient air, constitutes a target organ for fine particles. Indeed, several studies have demonstrated the decrease of the airways (proximal and distal) following exposure to atmospheric pollutants. After inhalation, $PM_{2.5}$ reaches the most distal regions of the lungs

Table I: Main characteristics

Main Features	Topics (N = 70)
Age (Year)	48,5 ± 3,84
Size (m)	1,70 ± 0,70
Weight (kg)	70,38 ± 7,43
BMI (kg / m2)	24,14 ± 1,67
Average jog time / session (min)	120, 34 ± 21,06

BMI = Body Mass Index N = Workforce min = minutes

Table II: Result of particles on the site of physical practice

Particle	Concentration	Who Standards
Fine (diameter < 2.5 µm)	0,387×10^3 µg/m^3	- 10 µg/m^3 annual average - 25 µg/m^3 24 hour average
Large (diameter > 2.5 µm)	0,15×10^3 µg/m^3	- 20 µg/m^3 annual average - 50 µg/m^3 24 hour average

Table III: Proximal respiratory variables

Sessions	Proximal Respiratory Variables					
	VEMS		CVF		DEP	
	Before	After	Before	After	Before	After
1st session	2,80 ± 0,24	2,78* ± 0,49	2,89 ± 0,39	2,91* ± 0,56	6,52 ± 1,08	6,92* ± 1,53
2nd session	2,77 ± 0,68	2,78 ± 0,55	2,87 ± 0,36	2,92 ± 0,58	7,11 ± 1,13	7,18* ± 1,63

FEVS: Maximum expiratory volume per second; CVF: Forced vital capacity; DEP: Expiratory flow peak; * :significant; **: Very significant

Table IV: Distal respiratory variables

Sessions	Distal Respiratory Variables					
	DEM 50		DEM 25		DEM 75	
	Before	After	Before	After	Before	After
1st session	4,78 ± 0,32	4,41** ± 0,71	2,27 ± 0,17	2,32 ± 0,28	4,45 ± 0,43	4,31* ± 0,68
2nd session	4,33 ± 0,65	3,08** ± 0,77	2,42 ± 0,14	2,27* ± 0,44	4,40 ± 0,32	4,11* ± 0,40

DEM 75: Immediate maximum expiratory flow rate at 75% of the CVF DEM 50: Immediate maximum expiratory flow rate at 50% of the CVF; DEM 25: Immediate maximum expiratory flow rate at 25% of FVC; * :significant; **: Very significant

Conclusion

Measurements of $PM_{2.5}$; PM_{10} in the atmosphere by gravimetry and the spirometric measurements in the subjects running in full traffic at Porto-Novo in Benin made it possible to evaluate the short-term impact of the $PM_{2.5}$ fine particles pollution on the ventilatory function of the latter. The results obtained from gravimetric measurements of atmospheric particulate matter indicate that the environment in which these amateur athletes work is rich in fine particles ($PM_{2.5}$). Analysis of ventilatory parameters revealed that exposure to particles over a short period of time did not have a significant effect on the health of the subjects. Nevertheless, a long-lasting physical practice or repetitive in time and space, could therefore prove detrimental for these weekend maintenance sports practitioners.

It is therefore necessary to raise public awareness of the risks involved by engaging in physical activity in a high-traffic environment.

Conflict of Interest: None

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