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Automobile Pollution and Risk of Impaired Lung Function and Oxygen Saturation among Vendors Near Road Traffic in Brazzaville, Congo

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Abstract

Context: Automobile pollution is becoming a potential threat to the cardiorespiratory health of the urban population of sub-Saharan Africa. The present study aims to evaluate the level of concentrations of fine particles (PM2.5 and PM10) near road traffic and the effects of exposure to automobile pollutants on pulmonary function and arteriolar blood oxygen saturation among sellers around road traffic. **Materials and Methods:** The study recruited 48 healthy people carrying out a sales activity near road traffic. PM2.5 and PM10 measurements were taken from 6 a.m. to 6 p.m. using a Temtop Airing-1000 portable particle detector. Spirometric measurements were taken in the morning and in the evening from a portable Spirobank G spirometer. Oxygen saturation measurements were also taken in the morning and evening using a Pulse oxymeter CMS50D pulse oxymeter. **Results:** Mean values of forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak expiratory flow (PEF), and forced expiratory flow between 25% and 75% of forced vital capacity (FEF25 - 75) recorded in the evening were significantly lower than those obtained in the morning in the subjects of the total group and in the men. Only the mean values of PEF and FEF25 - 75 obtained in the evening were significantly lower than those recorded in the morning in women. Minimum PM2.5 values recorded near road traffic were negatively correlated with evening PEF in men, while maximum PM10 values were negatively correlated with evening PEF in women. The blood oxygen saturation recorded in the evening

was significantly lower than that obtained in the morning. **Conclusion:** Short-term exposure to automobile pollutants has adverse effects on lung function and oxygen saturation in people carrying out a sales activity near road traffic.

Keywords

Automobile Pollution, Lung Function, Oxygen Saturation

1. Introduction

In the cities of sub-Saharan African countries, pollution from automobiles is becoming an increasing threat to the cardiorespiratory health of the urban population. This is explained by the year-on-year increase in the car fleet of used vehicles without the latest gas emission control technologies.

Exposure to air pollutants has negative effects on health. Pangou (2005) [1] reported that the populations of the cities of Brazzaville and Pointe-Noire in the Republic of Congo were exposed to respiratory diseases due to air pollution from industrial emissions and automobile exhaust gases. Short- and long-term exposure to ambient air pollutants can lead to alterations in lung function [2] [3] and risks of respiratory diseases [4]. In addition, residing near (less than 150 m) a main road with heavy traffic (with more than 10,000 vehicles per day) is responsible for 15% to 30% of new cases of asthma in children; and of chronic obstructive pulmonary disease and coronary heart disease in adults 65 years of age and older [5]. Impaired respiratory function has been demonstrated in people living less than 500 m from a motorway [6].

Fine particles (PM2.5 and PM10) have negative effects on lung function. Numerous studies have revealed an association between exposure to fine particles and the reduction of lung function parameters [7] [8] [9]. Xu *et al.* (2020) [2] found a decrease in FVC, FEV1 and PEF for each 10 μg/m^3 increase in average PM2.5 concentration over one day. Another study showed that exposure to PM2.5 and NOX was linked to significantly lower lung function [10]. PM2.5 was associated with lower FEV1 and FVC in subjects who lived near a highway [11]. Similarly, PM10 promotes the onset of chronic pulmonary function disorders, mainly associated with a decrease in FEV1 [12].

Furthermore, Luttmann-Gibson *et al.* (2014) [13] suggested that short-term increases in exposure to fine particles are linked to a decrease in oxygen saturation and may increase the risk of respiratory and cardiovascular morbidity. Another study showed that there was a relationship between the duration of exposure to ambient air pollution and the level of oxygen saturation in the blood [14]. In addition, oximetry performed on mechanics exposed to ambient air pollution in the city of Brazzaville revealed a decrease in oxygen saturation of 27.3% [15]. According to DeMeo *et al.* (2004) [16], the reduction in oxygen saturation associated with air pollution can result from subtle vascular, pulmonary and/or in-

flammatory modifications linked to particles. These same authors [16] demonstrated a statistically significant effect of ambient air pollution by fine particles on a decrease in oxygen saturation at rest in a population of elderly subjects. The objectives of this study were to assess the level of PM2.5 and PM10 concentrations near road traffic and the effects of exposure to automobile pollutants on lung function and blood oxygen saturation.

2. Materials and Methods

2.1. Study Participants

The study recruited 48 people (31 men and 17 women) carrying out sales or commercial activity near road traffic in the city of Brazzaville. The subjects were 31.042 ± 7.957 years old on average, and no prior restrictive or obstructive ventilatory disorders were observed. They had a working life near road traffic of at least 3 years. The study was approved by the Scientific Council of the Higher Institute of Physical and Sports Education of MARIEN NGOUABI University in the Republic of Congo in accordance with the 1975 Helsinki Declarations relating to ethics. Written informed consent was provided by all study participants.

2.2. Experimental Design

Pulmonary function and arteriolar blood oxygen saturation tests were performed in the morning from 7:00 a.m. to 8:00 a.m. and in the evening from 5:00 p.m. to 6:00 p.m. for 5 days. The first Day 9 subjects were tested, the second Day 9 subjects were tested, the third Day 10 subjects were tested, the fourth Day 9 subjects were tested and the fifth Day 11 subjects were tested for a total of 48 subjects. All subjects were nonsmokers and were instructed to abstain from alcohol and drugs on the day of the test. After two spirometry test trials to become familiar with the spirometer, three spirometry tests were given to each subject. PM2.5 and PM10 concentrations, ambient temperature and relative humidity were continuously sampled every 10 minutes from 6 a.m. to 6 p.m. for 5 days. Only the minimum and maximum values of PM2.5 and PM10, ambient temperature and relative humidity recorded over 5 days were retained. Ambient temperature and relative humidity averaged between 29.7˚C and 35.8˚C and between 54.8% and 71.3%, respectively.

2.3. Pulmonary Function Test

The spirometric tests were carried out in the morning (7 a.m.-8 a.m.) and in the evening (5 p.m.-6 p.m.) using a Spirobank G portable spirometer, Product of Medical International Research (MIR). Three spirometric test trials were recommended for each subject.

2.4. Blood Oxygen Saturation Measurements

Blood oxygen saturation measurements were performed in the morning and evening using a CMS50D Pulse oxymeter from Contec Medical Systems (China). Mea-

surement accuracy: ±2% from 70% to 100% SpO_2, and insignificant if less than 70%. ±2 bpm for a pulse of 30 to 99 bpm and ±2% for a pulse of 100 to 250 bpm. The SpO_2 measurement is taken as follows:

- Pinch to open the oxymeter clip;
- Inserting the finger into the plastic channel, the finger is fully extended and the clip is released;
- During the measurement, it is preferable that the fingers do not move and that the body remains motionless;
- Read data directly from the screen.

2.5. Environmental Measures

Measurements of fine particles (PM2.5 and PM10) were carried out from 6a.m. to 6p.m. every 10 minutes using a Temtop Airing-1000 portable particle detector (China). Ambient temperature and relative humidity were also measured from 6:00 a.m. to 6:00 p.m. using an electronic SUNROAD type hygrometer (Japan). Only the minimum and maximum values of PM2.5, PM10, ambient temperature and relative humidity recorded during the day were taken into account.

2.6. Study Variables

Particulate pollutants (PM2.5 and PM10) and timing of lung function and oxygen saturation measurements were the independent variables of the study. Pulmonary function parameters (FVC, FEV1, PEF and FEF25 - 75) and arteriolar oxygen saturation (SpO_2) were the dependent variables. Ambient temperature and relative humidity were confounding variables.

2.7. Statistical Analysis

The normality of the statistical distribution and the homogeneity of the variances were verified by the Kolmogorov-Smirnov test and the Fischer-Snedecor F test, respectively. Mean values of pulmonary function and oxygen saturation variables recorded in the morning and evening were compared by Student's t test in subjects of the total group and in men and by nonparametric Wilcoxon test in women. Pearson's test was used to determine correlations between PM2.5, PM10 and lung function variables recorded in the evening. The variable data were recorded and processed using SPSS software, version 21.0 and the significance level was set at $p < 0.05$.

3. Results

The male subjects had an average age of 28.161 ± 6.996 years, a BMI of 22.384 ± 3.281 kg/m^2, and a normal weight profile. The female subjects, on the other hand, had an average age of 36.294 ± 6.989 years and a BMI of 25.443 ± 3.944 kg/m^2, *i.e.*, an overweight weight profile (Table 1).

The average values of fine particles (PM2.5 and PM10) obtained near road traffic were well above the threshold values recommended by the WHO (Table

2).

The average values of ambient temperature and relative humidity recorded near road traffic were 32.8˚C (29.7˚C; 35.8˚C) and 63.1% (54.8%; 71.3%), respectively (Table 3).

Table 1. Average values of the anthropometric characteristics of the total group, men and women carrying out a sales activity near the avenue de Djoué in Brazzaville.

	Minimum values	Maximum values	Mean ± SD
Total Group (n = 48)			
Age (year)	17.000	49.000	31.042 ± 7.957
Height (cm)	155.000	183.000	168.958 ± 6.500
Weight (kg)	48.000	97.000	67.083 ± 11.642
BMI (kg/m^2)	17.630	32.240	23.467 ± 3.789
Men (n = 31)			
Age (year)	17.000	44.000	28.161 ± 6.996
Height (cm)	162.000	183.000	171.871 ± 5.136
Weight (kg)	48.000	97.000	66.516 ± 12.072
BMI (kg/m^2)	17.630	31.740	22.384 ± 3.281
Women (n = 17)			
Age (year)	28.000	49.000	36.294 ± 6.989
Height (cm)	155.000	171.000	163.647 ± 5.314
Weight (kg)	48.000	91.000	68.118 ± 11.096
BMI (kg/m^2)	17.650	32.240	25.443 ± 3.944

BMI: body mass index.

Table 2. Comparison of the average PM2.5 and PM10 values recorded around Avenue de Djoué with the values recommended by the WHO.

(A) Sampling sites	(B) Duration	(C) $PM_{2.5}$ (µg/m^3)	(D) Tolerated threshold (WHO) (µg/m^3)	(E) PM_{10} (µg/m^3)	(F) Tolerated threshold (WHO) (µg/m^3)
		Mean		Mean	
Avenue of Djoué	24 hours	173.74 [46.74; 300.74]	15	229.85 [61.18; 398.52]	45

(A), (B) respectively represent the site and the duration of sampling of the particles in suspension; (C), (E) denote respectively the mean values of $PM_{2.5}$ and PM_{10}; (D), (F) denote the WHO threshold values for $PM_{2.5}$ and PM_{10} respectively.

Table 3. Average values of ambient temperature and relative humidity recorded at avenue de Djoué (formerly avenue de l'OUA).

Site	AT (˚C)	RH (%)
	Mean	Mean
Avenue of Djoué	32.8 [29.7 - 35.8]	63.1 [54.8 - 71.3]

AT: ambient temperature; RH: relative humidity.

The mean values of FVC, FEV1, PEF and FEF25 - 75 recorded in the evening were significantly lower than those obtained in the morning in the subjects of the male group and the group as a whole. The average DEP and DEM25 - 75 recorded in the evening were significantly lower than those obtained in the morning among female subjects carrying out sales activities near road traffic. The mean values of arteriolar blood oxygen saturation observed in the evening were significantly lower than those obtained in the morning in the subjects of the total group, in the male and female subjects carrying out a commercial activity near road traffic (Table 4).

The minimum values of PM2.5 and the maximum values of PM10 recorded near road traffic were negatively correlated with evening PF in men and women respectively (Table 5).

Table 4. Comparison between the mean values of the parameters of pulmonary function and arteriolar blood oxygen saturation obtained in the morning and those recorded in the evening in the subjects of the total group, in men and in women engaged in retail sales activity around the avenue of Djoué.

	Morning measures	Evening measures	p Value	Delta (%)
	Mean ± SD	Mean ± SD		
Total group	**n = 48**			
FVC(L)	3.697 ± 0.973	3.581 ± 0.877*	0.023	−3.138
FEV1 (L)	3.185 ± 0.812	3.057 ± 0.784*	0.013	−4.019
PEF (L/s)	7.492 ± 2.337	6.742 ± 2.516***	0.000	−10.011
FEF25 - 75 (L/s)	3.998 ± 1.359	3.616 ± 1.437**	0.002	−9.555
SpO_2 (%)	96.354 ± 2.462	94.854 ± 2.961***	0.000	−1.581
Men	**n = 31**			
FVC(L)	4.222 ± 0.721	4.067 ± 0.655**	0.009	−3.69
FEV1 (L)	3.607 ± 0.611	3.492 ± 0.592**	0.002	−3.194
PEF (L/s)	8.482 ± 2.147	7.738 ± 2.324***	0.001	−8.774
FEF25 - 75 (L/s)	4.365 ± 1.372	4.048 ± 1.502*	0.041	−7.243
SpO_2 (%)	96.194 ± 2.857	94.355 ± 3.272***	0.000	−1.912
Women	**n = 17**			
FVC(L)	2.740 ± 0.546	2.695 ± 0.402	0.266	−1.631
FEV1 (L)	2.417 ± 0.515	2.265 ± 0.343	0.053	−6.305
PEF (L/s)	5.686 ± 1.428	4.927 ± 1.744***	0.000	−13.356
FEF25 - 75 (L/s)	3.331 ± 1.079	2.828 ± 0.904**	0.002	−15.084
SpO_2 (%)	96.647 ± 1.539	95.765 ± 2.078*	0.016	−0.913

FVC: Forced Vital Capacity; FEV1: Forced expiratory volume per second; PEF: peak expiratory flow; FEF25 - 75: Maximum expiratory flow between 25% and 75% of forced vital capacity; SpO_2: Arteriolar blood oxygen saturation; *: Significant difference; Delta %: percentage change in the values of the lung function variables and Arteriolar blood oxygen saturation recorded in the morning compared to those obtained in the evening.

Table 5. The results of correlations between the minimum values of PM2.5, the maximum values of PM10 and the evening DEP in subjects carrying out a sales activity near the avenue of Djoué.

	Evening PEF	
	r	p value
Men		
Minimum values of $PM_{2.5}$ ($\mu g/m^3$)	−0.967**	0.007
Women		
Maximum values of PM_{10} ($\mu g/m^3$)	−0.956*	0.011

PM2.5: Fine particles with a diameter of less than 2.5 μm; PM10: Fine particles with a diameter of less than 10 μm; *: Significance ($p < 0.05$).

4. Discussion

The present study examined 48 healthy people (31 men and 17 women) exposed to pollutants from road traffic over the course of a day and assessed the effects of exposure to vehicle pollution on lung function and saturation in oxygen and then determined correlations between fine particles (PM2.5, PM10) and morning and evening lung function variables.

It should be noted that only the concentrations of fine particles (PM2.5 and PM10) were measured near road traffic. The average concentrations of PM2.5 and PM10 recorded near road traffic were 173.74 $\mu g/m^3$ (46.74 $\mu g/m^3$; 300.74 $\mu g/m^3$) and 229.85 $\mu g/m^3$ (61.18 $\mu g/m^3$; 398.52 $\mu g/m^3$), respectively (**Table 3**). These average values are well above the values recommended by the World Health Organization. The high concentrations of PM2.5 and PM10 recorded around road traffic can be explained by the increase in the number of second-hand vehicles in the city of Brazzaville. Indeed, in 2009, Brazzaville had approximately 11,490 vehicles, of which 8935 were second-hand vehicles [17]. Today, the number of obsolete vehicles has increased exponentially in Congolese cities.

It is known that vehicles emit several gases and particulate matter such as PM2.5 and PM10 into the ambient air [18]. These gaseous and particulate pollutants have negative effects on cardiorespiratory health, morbidity and mortality [19]-[24]. Traffic-related air pollution has been implicated as a factor in airway dysfunction, and PM2.5 has been shown to be more responsible for adverse cardiopulmonary effects [25]. Studies have shown decreases in pulmonary volumes and flows and alterations in pulmonary function associated with exposure to fine and ultrafine particles related to road traffic [7] [11] [26] [27] [28]. Wu *et al.* (2014) [29] found associations between fine particles, high ambient temperature and a decline in lung function. In addition, the results of a study showed decreases in lung function 6 hours after exposure to ultrafine particles in cyclists [30].

In this study, the mean values of forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak expiratory flow (PEF), and forced expiratory

flow between 25% and 75% of vital capacity force (FEF25 - 75) recorded in the evening were significantly lower ($p < 0.05$) than those obtained in the morning in the subjects of the total group and in the men (**Table 4**). In women, the PEF and the FEF25 - 75 recorded in the evening were significantly lower ($p < 0.05$) than those obtained in the morning (**Table 4**). These results can be explained by the fact that men and women carrying out sales activities near highways are exposed to gaseous and particulate pollutants in automobile origin, and the short-term inhalation of these pollutants has induced an alteration of lung function. The results of work by Zhang *et al.* (2015) [31] showed that a 10 μg/m^3 increase in PM2.5 was associated with a −2.09 L/min change in evening PEF after adjusting for season, size and sex, temperature and relative humidity. The results from the same study suggested that PM 2.5 from ambient air has an acute adverse effect on lung function in healthy young adults [31].

The temperature recorded in the present study varied between 29.7˚C and 35.8˚C, and the relative humidity oscillated between 54.8% and 71.3% (**Table 3**). One study showed that fine particles and higher temperatures can synergistically weaken lung function in healthy young college students [29]. In this research work, ambient temperature and PM2.5 and PM10 played an important role in the decrease in evening lung function observed in vendors near road traffic.

On the other hand, several previous studies have examined the associations between fine particles (PM2.5 and PM10) and morning and evening PEF and have shown inconsistent results. A study in children with chronic respiratory symptoms in Finland found that the changes in morning and evening PEF for the interquartile range (14 μg/m^3) of PM 2.5 on the previous day were −1.06 L/min ($p < 0.05$) and −0.43 L/min (not significant), respectively [32]. In 2011, Yamazaki *et al.* (2011) [33] studied the effect of hourly concentrations of fine particles on PEF in hospitalized children in Japan and no difference was found in the effect of fine particles on morning/evening PEF. Our results are not in line with the results of these studies. Another study conducted in European countries found that a 10 μg/m^3 increase in PM10 was associated with changes in PEF of 0.01 L/min (not significant) in the morning and −0.06 L/min ($p < 0.05$) in the evening, respectively [34]. These results are in line with our results.

In addition, in this study, the minimum concentrations of PM2.5 recorded near traffic were negatively correlated with the evening PEF in men and the maximum concentrations of PM10 were negatively correlated with the evening PEF in women (**Table 5**). These results show that PM2.5 and PM10 induced a decrease in evening PEF in men and women carrying out commercial activity near road traffic, respectively. It should be noted that fine particles can penetrate deep into the lungs, irritate and corrode the alveolar wall and, consequently, alter lung function [35].

In addition, a significant decrease was observed in the mean value of arteriolar blood oxygen saturation obtained in the evening compared to that recorded in the morning in men and women carrying out commercial activity near road traf-

fic (Table 4). These results can be explained by the fact that these men and women are exposed to pollutants of automobile origin in general and to high levels of concentrations of PM2.5 and PM10 in particular. Luttmann-Gibson *et al.* (2014) [13] suggested that short-term increases in exposure to fine particles are linked to a decrease in blood oxygen saturation and therefore may increase the risk of respiratory morbidity and cardiovascular disease. According to DeMeo *et al.* (2004) [16], the reduction in oxygen saturation associated with air pollution can result from subtle vascular, pulmonary and/or inflammatory modifications linked to particles. These same authors [16] demonstrated a statistically significant effect of ambient air pollution by fine particles on a decrease in oxygen saturation at rest in a population of elderly subjects. Another study showed that there was a relationship between the duration of exposure to ambient air pollution and the level of oxygen saturation in the blood [14]. In addition, oximetry performed on mechanics exposed to ambient air pollution in the city of Brazzaville revealed a decrease in oxygen saturation of 27.3% [15]. The results of this work are in the same direction as our results.

The results of this study showed that men and women carrying out sales activities near the roads of Brazzaville are exposed to the harmful effects of air pollution of automobile origin.

5. Conclusion

Short-term exposure to fine particles of automobile origin induced an impairment of evening lung function and arteriolar oxygen saturation in vendors near road traffic. Draconian measures must be taken with regard to the circulation of old vehicles in Congolese cities to reduce the level of concentrations of particulate pollutants near urban roads and the risk of respiratory ailments.

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Author Contributions

Nsompi F., Bouhika E.J., Mabounda Kounga P.R., Moussouami S.I. made a significant contribution to the conception of the work. Messan F., Boussana A., Tito A. have revised the article considerably. All authors drafted the work, agreed on all versions of the article prior to submission, and agreed to take responsibility and be responsible for the content of the article. All authors agree to the final version of the manuscript being published.

Conflicts of Interest

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

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