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Evaluation of Peripheral Capillary Oxygen Saturation and Pulmonary Functions of Subjects Exposed to Soot in Yenagoa, Bayelsa State Nigeria

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ABSTRACT

The present study reports for the first time, the effects of soot exposure on peripheral capillary oxygen saturation and pulmonary functions among residents of Yenagoa, Bayelsa State. In the present study, peripheral capillary oxygen saturation level and respiratory indices ie pulmonary functions were evaluated among soot exposed residents in Yenagoa, Nigeria and the values compared with apparently healthy residents of a less polluted region in the same city. A total of 300 subjects within the ages of 18 to 65 consisting of 200 subjects living within soot exposed areas and 100 subjects who live 2km away from the polluted environment. Using questionnaires, personal data of each participant were collected. The questionnaire focused on sex, age, height and weight, duration of stay in Yenagoa, oxygen saturation level, respiratory indices, pulse rate, smoking habit, pregnancy and lung conditions. Hospital scale balance and calibrated metre rule were used to collect their anthropometric data while oxygen saturation, pulse rate and respiratory indices were measured using Sp-10 pocket spirometer and Pulse oximeter.The results from the study population shows a significant decrease in PEFR, FEF and pulse rates of exposed subjects compared with the control. Meanwhile no statistical differences were observed in BMI, FVC, $FEV_1$and oxygen saturation level between the exposed and the control subjects except the BMI of the exposed subjects across their various age groups. There was a negative correlation observed in the plot against age and BMI versus respiratory indices. This study shows that the subjects living within soot polluted environment possess lower lung function indices compared with those living two kilometres away from the polluted environment, in Yenagoa, Nigeria.

KEYWORDS: capillary oxygen,lung volumes,spirometry, soot, Yenagoa

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INTRODUCTION

One of the foremost air pollutants in which health effects were recognised was soot. It was first noticed during the dramatic periods of carbon pollution in particular the disastrous winter of 1952 in London. In 1775, a London surgeon Sir Percival POH, identified that chimney sweeps were liable to development of scrotal cancer, he envisaged this could be due to soot exposure to workers (Denkler, Pott & Paget., 2004; Androutsos, 2006). Soot are unwanted by-products derived from incomplete combustion of carbon materials such as emission from gas and diesel engines, coal, fuel power plants, motor vehicles, bush fire, burning of woods, tyres, plastic materials and oil refineries. Soot enters the environment either as gases, liquids or solid particles, which turn into a particle after been released. These particles can end up very far away from their site of origin, causing untimely human illness and disability (Niranjan & Thakur, 2017). The highest amounts of soot emission in the past were from developed countries but as at now soot emissions are mainly from developing nations (Victor *et al*, 2015. Niranjan, 2017).

Earle and Page also affirmed that soot is carcinogenic to human skin (Novakov, 2013). These historical evidences have distinctly shown the connection between soot and its constituents to human health. The well-being of man's existence on earth depends largely on the quality of air he breaths. Your personality, the environment you live or your state of health does not matter, you are affected by the quality of air you breathe (Ewona *et al*., 2013). In most West Africa big cities including Nigeria and other parts of the world, air pollution is a big threat to human lives (Nku *et al*., 2005, Ekpeyong *et al*., 2012), when constantly exposed to it, it reduces life expectancy (Oloworopuroku, 2011). Tawari and Abowei (2012) cited in Oyekunle (1999) stated the effects of soot pollution in the Niger -Delta region . Also stated by Manisalidis *et al.*, 2020 that one of the greatest global blights today is exposure to air pollution, which is a major threat to human health and the environment. As estimated by the United Nations Environmental Programme (UNEP), about 1.1 billion people breathe unhealthy air (UNEP, 2002). The World Health Organization (WHO) also stated that almost 91% of the world's population breathe substandard air because they live in places where air pollution exceeds safe limits. (WHO, 2016)

About 6.5 million deaths around the world are also attributed annually to poor air quality inside and outside (ambient air), thus making air pollution the world's fourth largest threat to human health behind blood pressure, dietary risk and smoking (Funmi, 2018). Decades ago, the consequences of combustion related air pollution indicated by black smoke were monitored when assessing air quality and its effects on health were used as evidence to recommend the first guide lines for exposure limits in line with the protection of public health in Europe (Nicole, 2012). Soot is one of the major pollutants in the Niger Delta region.

PLATE 1. Emissions from Swali Abattoir in Yenagoa City, Metropolis. (Source: Researcher)

Soot consists of acids, chemicals, metals, soils and dust. Soot is made of particles (particulate matter) that are extremely tiny, 10µm (PM less than 10 micrometre), 2.5µm (PM less than 2.5micrometer) or even smaller in diameter 1.0µm. These particles are smaller than dust and mould, about 1/30 diameter of a human hair, these extremely small size and toxic conformation is what makes soot so precarious, thus it can travel deep into the lungs and become seriously harmful (Jackie & Susannah, 2012).When tiny particles of soot are breath in, coronary heart diseases, cancer, respiratory ailments asthma, bronchitis, emphysema and many other pulmonary illnesses occur. Compounds from soot such as nitrogen oxides and sulphur oxides normally combine with moisture to form acid rain that damages soil and worsen the quality of water and changes natural balances in various ecosystems. Soot also causes greenhouse effect which is a major driving force in global warming particularly in Niger Delta, where temperatures are increasing twice the global rate.

Particulate Matter (PM) According to Brook *et al*., 2003, particulate matter is a complex mixture of solids and liquid substances in semi-equilibrium form with surrounding gases suspended in air. These suspended particles are: manmade dust, soot, pollen, smoke and liquid drops. Primarily, these particles are released directly into the atmosphere, whereas the secondary particles are through biochemical conversion of gases such as nitrate and sulphate formation from gaseous nitric acid and sulphur. The origin of PM may be natural or manmade, which include motor vehicle emission, road dust, power generation, smelting and other metal processing, construction and demolition activities, residential wood burning, forest fires, refuse burning, wind-blown soil, plastics and scrap metals and tyre burning. (Robert *et al.*, 2004).The

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size of particulate matter ascertains the fierceness of the soot. The constituents of PM range in size, combination, concentration depending on origin and age. The size of the airborne PM is important for health impacts assessment.

PM^{-}_{10}: when deposited in less than 2 days leads to adverse responses in the lungs triggering numerous pulmonary problems (Brune, Kreef& Forsberg, 2005). It is also connected with critical hospital admissions in older people (Marzia *et al*., 2015).

$PM_{2.5}$ or fine particles: These particles penetrate deep inside the respiratory tract and cause string health adverse effects (US EPA, 1996).

Nucleic mode or ultrafine particles (UFP): These categories of fine particles are smaller than 0.1µm. They are present mostly in polluted urban air (Jacques & Kim, 2000). These very fine particles escape alveolar macrophage surveillance. When exposed to large quantities of UFP, it can cause severe pulmonary inflammations and haemorrhage, high levels of alveolar and intestinal adverse disruption of epithelial and endothelium cell layers and even death (Oberdorster, 2000).

Oxygen Saturation: Human lives depend on oxygen (O_2); a few minutes lack of oxygen is hazardous to life. Oxygen saturation is the ability of Haemoglobin (Hb) in the red blood cells to carry oxygen in a normal individual. When each molecule of Hb carries up to 4 molecules of oxygen, it is termed as "Saturated Oxygen". Haemoglobin is said to have 100% saturation if all the binding sites on haemoglobin carrying oxygen (WHO, 2011). Oxygen when taken is attached to the haemoglobin in the red blood cells as they pass via the pulmonary capillaries to the heart where it is pumped to the cells and tissues of the body. About 1000mls of oxygen is delivered to the tissues per minutes because normally the heart pumps 500mls of blood/m approximately and body cells extract about 250ml of O_2/m for metabolism. This implies that only 75% of O_2 carried by Hb will be available to the tissues, if there is no O_2 being exchanged in the lungs, the stored O_2 in the blood can only be enough for 3 minutes. (WHO, 2017).

The lungs and airways: All inhaled pollutants, primarily target the lungs. The lungs, located on each side of the thorax are spongy air- filled organs. The lung airway starts from the trachea (wind pipe) in which air enters the lungs from its tubular bronchi. The main bronchi divide into lobar bronchi, two each on the left and three on the right, each lobar bronchi divides into several segmental bronchioles that eventually ends as terminal bronchioles that give rise to several generations of respiratory bronchioles entering into the alveoli sac where gaseous exchange take place. There are 480 alveoli in each lobe of an adult human, with men having more alveoli and larger lung volumes (Ochs *et al*; 2003). Each day humans breathe about15m^2 of air with total lung volume of 1400m^2. At rest, a healthy adult has about400-500ml of lung volume and breathing frequency of about 15-17bpm.

PLATE 2. Niger Delta pollution (Oyekunle, 1999; Tawari and Abowei, 2012).

Soot exposure in Nigeria especially the Niger-Delta region has continually been a source of major public health problem to its citizens. This is evidence in WHO ranking of the most polluted cities in the world using PM^{-}_{10} where cities in Nigeria made up 20% of the list (Funmi, 2018). Various studies have shown the high level of soot pollution in most urban cities in

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Nigeria, particularly the Niger Delta region (Godson, 2011, Adoki, 2012; Nwachukwu, 2012)of which the Yenagoa metropolis is an important part of it. The Niger-Delta region of Nigeria is ravaged with poor air quality especially due to the oil exploration activities that characterizes the region. Gas burning and emitting by the oil sector is a major public health concern on this region (Okhumude, 2017). But besides the above activities, there is this serious issue of artisanal refineries, emission from diesel engines, biomass burning such as refuse and bush burning, burning of tyres, plastic and rubber materials in abattoirs which generates more than enough soot (black carbon) in this region which has become a source of worry especially to the inhabitants of Yenagoa, Bayelsa state. Soot in Yenagoa comes from activities in abattoirs, refuse burning (at dump sites), bush burning, vehicular emissions and illegal refineries from nearby communities.

PLATE 3. A refuse dump site at Etegwe Yenagoa, Bayelsa State (Source: Researcher)

Lung function parameters: Rapidly, lung growth begins in the uterus and continues until the late teens in girls and early 20's in boys. In females, lung function reaches a maximum by 18-20 years of age and in males 22-25 years, though some males may show a small movement in lung function even in their mid-20's slowly but at a steady rate. Among adults' lung function vary widely, the big difference in adults' lung function are due to attained lung function at maturity which may differ by a factor of two for individuals of the same age, sex, height, weight and race. (Dockery *et al*., 2005).Lung function is a vital way of measuring respiratory health and pointer of cardiopulmonary illnesses and deaths. More than 50 publications for the past 2 decades have assessed the effects of air pollution on lung function with more findings with adverse effects (Gotschi*et al*; 2008). Some lung function parameters measured in this study include;

1. Forced vital capacity (FVC): It is the quantity of air exhaled forcefully and rapidly after taking the deepest inhalation. It is used in distinguishing obstructive lung diseases like asthma and COPD from restrictive lung diseases. Forced vital capacity has the same value with vital capacity (4800ml) except in pathological conditions. It is measured in litre per second (l/s). If measured value is within 80% of predicted value the individual is considered normal, but if it is within 50-70%, the individual is considered mild but within 40-50% is considered severe and then < 30% is considered very severe (Arofit, 2019).

2. Forced expiratory volume (in one second) FEV_1: It's the volume of air expired in one second during forced vital capacity. Normal values depend on the individual's age, height and gender. It is calculated by comparing the predicted value of the age, gender and weight of the individual with the measured value. It is used to check Chronic Obstructive Pulmonary Diseases and also to know whether one lung condition is improving. (Erica, 2017). FEV_1 decreases in obstructive diseases due to airway resistance to expiratory flow, many also diminish due to premature closure of airway during exhalation but in restrictive diseases both FEV_1 and FVC reduces simultaneous.

3. FEV_1/FVC Ratio (FEV_1 %): It is the ratio of FEV_1 to FVC. It is the total percentage of FVC breathes out in the first second of forceful expiration. 70% is considered normal and during abnormalities FEV_1% decrease as air flows through the lungs. It used in assessing and giving treatment in obstructive lung diseases. If there is decline in FVC but FEV_1% increases, there is an indication that the person is having restrictive diseases. Normal ratios range between 70%-80% in adults, 65% in older than 65yrs and children 85% (Deborah, 2019; John &Theurer, 2014).

4. Peak Expiratory Flow Rate (PEFR): It's the highest flow rate experienced during FVC exercises. It is important in assessing obstructive diseases like Bronchi-constriction secondary to asthma. PEF is measured in litre/second (l/s) or litre/minute (l/m). 80%- 100% is considered normal, 50%-80% indicates airway is beginning to narrow and 20%-50% indicates severely narrowed (Deborah, 2017).

5. Forced Expiratory Flow (FEF): Forced Expiratory Flow is the highest amount of exhaled air during FVC and its measured in l/s or l/m. It is divided in quintiles such as $FEF_{25\%}$, $FEF_{75\%}$ and $FEF_{25\%-75\%}$

Major diseases and their pathological manifestations due to soot

Respiratory ailments, cardiovascular problems and cancer are the basic types of diseases due to soot exposure. (Niranjan and Thakur, 2017).

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Cancer Due to Soot exposure: As stated earlier, various types of cancer occur as a consequence of soot exposure in humans and experimental models. Despite measures to maintain safety in soot related work, it was observed that chimney sweeps still showed increase cancer related deaths. In Sweden numerous cancers were reported due to soot and asbestos exposure (Hogstedt, Jason, Hugosson, Tinnerberg, &Gusstavsson, 2013). There is also a change in DNA methylation after being exposed to atmospheric particulate pollutants (PM) with aerodynamic diameter ≤2.5µm (PM 2.5), which alters the expression of genes profile toward the growth of cancer (Baccareli *et al.,* 2009).

MATERIALS AND METHODS

Study population

The study entails three hundred subjects within the age range of 18-65years selected from Swali, Eteqwe, Edepie and Akenfa communities in Yenagoa city Metropolis, of which 200 male and female were individuals living within polluted area while 100 subjects, male and female were used as control.

Ethical clearance

In congruence with the proposed et
from all researchers, an ethical appli

completed and submitted as required to the University of Port Harcourt, Rivers State, thus the research was duly approved by the University of Port Harcourt with approval number- UPH/CEREMAD/REC/ MM750094

Consent: Consent was obtained from volunteers in accordance with Helsinki declaration on biomedical research. A consent form letter describing the mode of study and form of participation was presented to each prospective participant. Research details were also explained; questions were wholly entertained before deciding either to take part or not in the study.
Consented subjects were then given questionnaires where other information required for documentation was taken.

Inclusion Criteria

i. Adults between the ages of 18-65years.
ii. Adults who have resided in Yenagoa for 1year and above.
iii. Adults who resides within the polluted area
iv. Residents who live 2km away from the polluted area

Exclusion Criteria.

1. Smokers. 2. Persons with known history of respiratory presently diagnosed of respiratory ailments.
omen

Method of data collection/ instrumentation

Fig. 1. Contec 33536 model SP-10 Pocket Spirometer

Sp.10 pocket spirometer was used to evaluate pulmonary functions of the subjects. Spirometer (Sp-10) is an ultra-thin designed, concise and fashioned, small in volume, light weighted and portable. It reflects lung functions by measuring FVC, FEV_1, PEF and FEF etc. It is made of brass body with a turbine, charging indicator, interface screen, control buttons such as up and down key, power on and off, menu and confirmation key with repeat marker button. It normally comes with dispensable mouth piece.

Procedure

1. The arrow head of the turbine was detached by turning it into a triangular shape.
2. It was then locked by counter clockwise rotation.
3. The disposable mouth piece was then gently inserted into the turbine port.
4. With a well-structured questionnaire ready each subject was made to sit comfortably on a chair and relax for 3-4mins.
5. The spirometer was tuned on by long pressing the power on key.
6. No option selected to testing interface as shown in figure, 3.3 and 3.4
7. Each subject was asked to inspire as maximally as possible through the nose for 3 to 5 seconds, the spirometer was then given to the subjects with the mouth sealed around the mouthpiece and the air was blasted out forcefully as possible into the mouthpiece, this was repeated up to three times, the average values were then recorded

Oxygen saturations and pulse rate measurement

Finger pulse oximeter measures Oxygen-Haemoglobin (HbO_2) saturation and pulse rate as well. It comes in small sized, lower power consumption convenient operation and moveable with different colours blue, yellow etc.

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Fig.2. Contec CMS5ON Fingertip Pulse Oximeter

Procedure

1. The back cover was removed and 2AAN sized batteries were inserted and then replace.
2. The upper reading indicates pulse rate while the lower reading indicates oxygen saturation.
3. Each subject was asked to sit comfortable on a chair.
4. With the left hand placed on a levelled table, the switch button was pressed once on the front panel.
5. The subject was asked to insert his/her finger into rubber cushions of the clip.
6. The information was displayed on the screen; values were recorded for SpO2 and pulse rate.

Materials for Measuring Lung Functions

i. Hand SP10 spirometer (Contec)

Materials for Measuring Oxygen Saturation and Pulse

i. Finger pulse oximeter

Materials for Weight and Height Measurement

i. Young Kong Shelling hospital scale balance was used to determine the weights (kg) of the subjects, and a calibrated meter rule was used to measure the height (m). Each subject was asked to remove his or her heavy outer clothes and shoes then the height and weight were taken. Before the weight was taken; the pointer was adjusted to zero to avoid errors. The body mass index (BMI) was then calculated as weight divided by square of the height (kg/m^2).

RESULTS

Table 1. Relationship between age, body mass index, pulse rate and respiratory indices among control and exposed subjects in Yenagoa, Bayelsa State.

Parameters	Control (n=100)	Exposed (n=200)	Significance P<0.05)
Age(Years)	35.25±8.69 (18-53)	34.91±10.54 (18-64)	0.75 Not Significant
Body mass Index (Kg/m^2)	24.60±4.55 (15.62-38.28)	24.84±4.94 (17.30-42.97)	0.65 Not Significant
Forced Vital Capacity l/s (%)	49.89±18.91 (10-113)	47.96±18.91 (9.402)	0.24 Not significant
Forced expiratory volume 1l/s (%)	57.50±20.25 (12-112)	50.54±22.63 (98-140.)	0.25 Not significant
Forced expiration volume ratio (%)	98.17±3.50 92-100)	96.27±10.00 (20-100)	0.66 Not significant
Peak expiratory flow rate/m	68.01±23.05 (12-127)	57.75±27.48 (3-166)	0.01 Significant
Forced expiratory flow 25%	4.71±1.76 (1-9.0)	3.90±1.96 (0-10)	0.03 Significant
Forced expiratory flow 75%	2.24±1.02 (0-7)	2.07±1.43 (0-7)	0.51 Not significant

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Forced expiratory flow 25-75%	3.61±1.44 (0-8)	3.07±1.76 (0-10)	0.02 Significant
Oxygen saturation (%)	98.17±2.78 70-99	98.15±2.28 (78-99)	0.10 Not significant
Pulse Rate (bpm)	74.53±9.38 (55-103)	79.06±9.30 (41-103)	0.02 Significant

Results were given as Mean± Standard Deviation (Range)

Table 1 Shows the age, body mass index, pulse rate and respiratory indices of control and exposed subjects in Yenagoa, Bayelsa State. The result indicates that the mean values for PEF, $FEF_{25\%}$ and $FEF_{25-75\%}$ were found to be significantly lower in the exposed group compared with the control group ($p<0.05$). Also it can be seen that the pulse rate was found to be significantly higher among the exposed group when compared with control ($p<0.05$).

Table 2. Relationship between age, body mass index, respiratory indices, oxygen saturation and pulse rate among control and exposed female subjects in Yenagoa.

Parameters	Control (n=53)	Exposed (n=107)	Significance P<0.05)
Age(Years)	32.58±9.02 (18-54)	36.83±10.31 (18-50)	0.28 Not significant
Body mass Index (Kg/m^2)	25.49±5.41 (16-38)	25.90±5.69 (17.3-43)	0.75 Not significant
Forced Vital Capacity l/s (%)	43.62±16.23 (10-89)	40.038.97 (10-409)	0.04 Significant
Forced expiratory volume 1 l/s (%)	51.30± 18.53 (12-97)	41.03±16.32 (12-83)	0.02 Significant
Forced expiration volume ratio (%)	98.53±18.53 (82-100)	96.12±9.91 (20-100)	0.58 Not significant
Peak expiratory flow rate l/m (%)	61.57±21.19 (12-109)	48.33±21.35 (8-.112)	0.01 Significant
Forced expiratory flow 25%	4.28±1.67 (1.0-8.0)	3.22±1.52 (0.0-8.0)	0.02 Significant
Forced expiratory flow 75%	1.98±0.91 (0.0-4.0)	1.52±1.13 (0.0-7.0)	0.01 Significant
Forced expiratory flow 25-75%	3.26±1.43 (0.0-7.0)	2.41±1.32 (0.0-7.0)	0.03 Significant
Oxygen saturation (%)	98.54±1.14 (92-99)	98.22±2.63 (78-99)	1.00 Not significant
Pulse Rate (bpm)	77.34±8.53 (61-98)	79-84±9.40 (41-103)	0.18 Not significant

Results were given as Mean± Standard Deviation (Range)

Table 2 shows the age, body mass index, respiratory indices, oxygen saturation and pulse rate of control and exposed female subjects in Yenagoa Bayelsa state. The result indicates that the mean values for FVC, FEV_1, PEFR and FEF of the exposed females were significantly lower when compared with the female control group ($p<0.05$).

Table 3. Compares age, body mass index, respiratory indices, oxygen saturation level and pulse rate between control and exposed male subjects in Yenagoa,

Parameters	Control (n=50)	Exposed (n=92)	Significance P<0.05)
Age (years)	37.80±7.61 20.0-53.0	32.69±10.41 18.0-64.0	0.01 Significant
Body mass index kg/m2)	23.67±3.22 16.8-31.1	23.61±3.55 17.3-34.6	0.74 Not Significant

Forced vital capacity l/s (%)	56.54±19.44 13.0-113	57.12±23.88 9.0-143	0.89 Not Significant
Forced expiratory volume 1 l/s (%)	64.08±20.08 16.0-112	61.59±23.96 8.0-140	0.69 Not Significant
Force expiratory volume ratio (%)	97.80±3.86 77.0-100	96.96.45 55.0-100	0.73 Not Significant
Peak expiratory flow rate l/s (%)	74.84±23.18 27.0-127	68.72±29.35 3.0-166	0.18 Not Significant
Forced expiratory flow 25%	5.16±1.75 2.0-9.0	4.69±1.60 0.0-10	0.17 Not Significant
Forced expiratory flow 75%	2.52±1.07 1.0-5.0.	2.69±1.48 0.0-7.0	0.67 Not Significant
Forced expiratory flow 25-75 (%)	3.98±1.37 2.00-8.00	3.82±1.90 0.00-10.0	0.57 Not Significant
Oxygen saturation (%)	97.76±4.09 70.0-99.0	98.05±1.80 86.0-99.0	0.92 Not Significant
Pulse rate (bpm)	71.56+9.39 55.0-103	78.14+9.15 60.0-101	0.01 Significant

Results were given as Mean± Standard Deviation (Range)

Table 3 shows the age, body mass index, respiratory indices, Oxygen saturation level and pulse rate between control and exposed male subjects in Yenagoa, Bayelsa state. The result shows that the mean values for age and pulse rate of the exposed males were significantly lower than the control male when compared ($p<0.05$).

Table 4. Compares age, body mass index, pulse rate and respiratory indices between male and female exposed subjects in Yenagoa, Bayelsa State.

Parameters	Male (n=92)	Female (n=108)	Significance P<0.05)
Age(Years)	32.68±10.41 (18-64)	36.83± 10.31 (18-60)	0.19 Not significant
Body mass Index (Kg/m^2)	23.61±3.54 17.30-34.60	25.89±5.69 (17.30-42.96)	0.24 Not significant
Forced Vital Capacity l/s (%)	57.12±2.89 (9-143)	40.08±38.97 10-409	0.01 Significant
Forced expiratory volume 1l/s (%)	61.97±23.96 (8-140)	41.03±16.32 (12-83)	0.01 Significant
Forced expiration volume ratio (%)	96.45±7.85 (55-100)	96.12±9.91 (20-100)	0.78 Not significant
Peak expiratory flow rate/m (%)	68.71±29.35 (3-163)	48.32±21.84 (8.112)	0.01 Significant
Forced expiratory flow 25%	4.50±2.13 (0-10)	3.22±1.52 (0-8)	0.01 Significant
Forced expiratory flow 75%	2.70±1.48 (0-7)	1.52±1.14 (0-7)	0.01 Significant
Forced expiratory flow 25-75%	3.82±1.92 (0-10)	2.41±1.31 (0-7)	0.01 Significant
Oxygen saturation (%)	98.05±1.81 (86-99)	98.15±2.63 (78-99)	0.09 Not significant
Pulse Rate (bpm)	78.14±9.15 (60-101)	79.84±9.40 (41-103)	0.44 Not significant

Results were given as Mean± Standard Deviation (Range)

Table 4: shows age, body mass index, pulse rate and respiratory indices of male and female exposed subjects in Yenagoa Bayelsa state. The result indicates that mean values for FVC, FEV_1, PEF, $FEF_{25\%}$, $FEF_{75\%}$, FEF_{25-75}% of the male exposed subjects were significantly higher than females ($p<0.05$).

Table 5. Age group classification of Body mass index, pulse rate and respiratory indices of male and female exposed subjects in Yenagoa, Bayelsa State.

Parameters	18- 35years (n=111)	36 – 55years (n=80)	<55 years (n=8)	Significance P<0.05)
Body mass Index (Kg/m²)	23.32±3.47 (17.30-33.22)	26.89±5.93 (18.83-42.94)	25.42±4.30 (19.92-31.25)	0.01 Significant
Forced Vital Capacity l/s (%)	50.81±24.81 9-143	45.72±44.18 10-409	30.75±15.47 16-55	0.20 Not significant
Forced expiratory volume 1l/sec (%)	54.64±24.33 8-140	46.66±19.08 12-90	32.38±16.34 18-56	0.03 Significant
Forced expiration volume ratio (%)	96.39±10.34 20-100	96.62±6.25 67-100	91.13±11.83 66-100	0.25 Not significant
Peak expiratory flow rate/m (%)	64.54±29.62 3-166	50.57±21.60 8-111	35.38±20.53 13-82	0.01 Significant
Force expiratory flow 25%	4.36±2.12 0-10	3.40±1.55 0-8	2.50±1.70 0-6	0.01 Significant
Forced expiratory flow 75%	2.43±1.55 0-7	1.70±1.08 0-7	0.62±0.74 0-2	0.01 Significant
Forced expiratory flow 25-75%	3.46±1.77 0-9	2.66±1.61 0-10	1.63±1.51 0-5	0.01 Significant
Oxygen saturation (%)	98.16±2.43 78-99	98.13±2.15 86-99	98.13±1.36 96-99	0.99 Not significant
Pulse Rate (bpm)	78.25±8.56 61-100	79.96±10.37 41.103	81.13±7.45 72-91	0.38 Not significant

Results were given as Mean Standard Deviation (Range)

Table 5 shows the Age group classification of body mass index, pulse rate and respiratory indices of male and female exposed subjects in Yenagoa, Bayelsa state. The result shows that there was significant variation across the age groups in the mean values for FVC., FEV_1, PEF, $FEF_{25\%}$, $FEF_{25-75\%}$($p<0.05$).

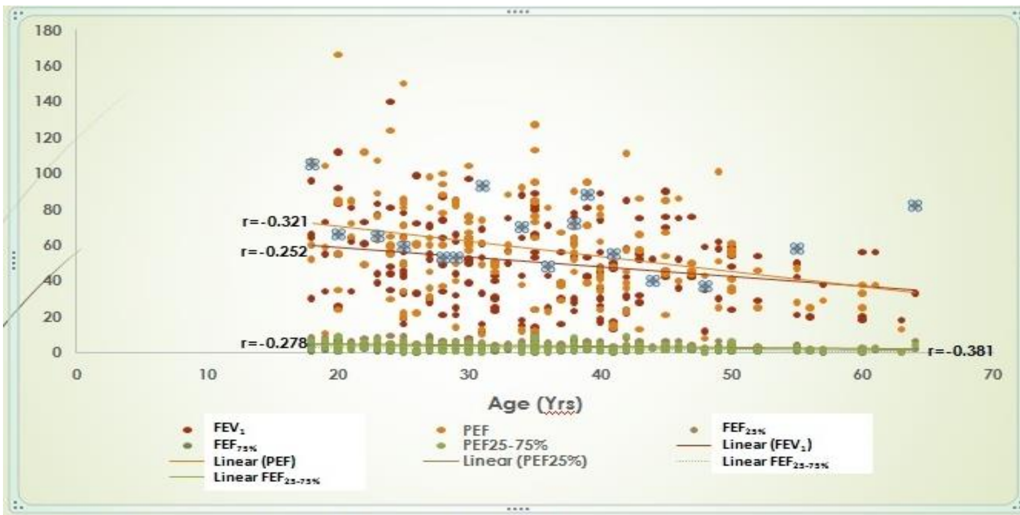

Figure 3. A scatter plot of Age versus FEV1, PEFR, FEF25%, $FEF_{75\%}$, $FEF_{25\%-75\%}$of exposed subjects

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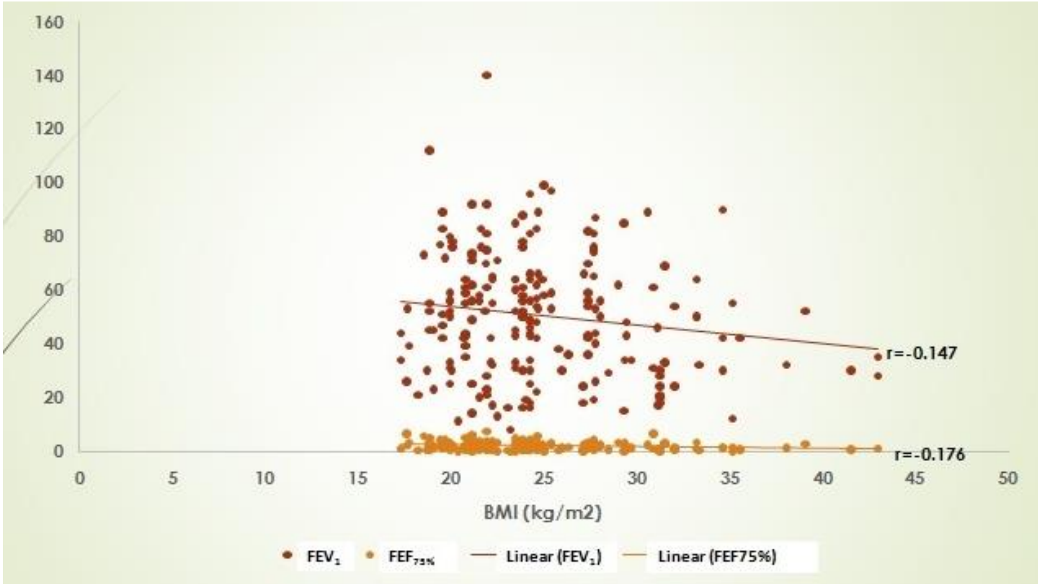

Fig 4. A scatter plot of BMI vs FEV_1 and $FEF_{75\%}$ of exposed subjects

DISCUSSION

The results from this study indicate a significant difference in the mean values for BMI of the exposed subjects across their age groups with adult age range (36-55yrs) showing the highest BMI of 26.89kg/m² while least BMI was observed among the younger adults (18-35yrs) with mean BMI value of 23.32 kg/m².This could be attributed to the fact that adulthood is associated with the accumulation of adipose tissue and hence the maximum BMI value for this age group. This report is corroborated by earlier research by Tzotzas *et al*., 2004; Joffa *et al*., 2013). Meanwhile statistical differences were not seen between the exposed and control, female exposed and control, male exposed and control and among the exposed male and female subjects.

Also observed was statistical difference in the mean values for FVC between the female control and exposed subjects with the female exposed subjects having a lower significant value of 40.08% and control with higher value of 43.62%. Significant difference was also observed in the values between the exposed subject males having a higher significant value of 57.12% and females lower values of 40.08%. This lower value of FVC for females could attribute to the fact that females have smaller airways and lung size (2.3% smaller than male), (Jacques, 2000). More so, significant difference was again observed in the mean values of the exposed across their various age groups. Mean values were highest between the age group of 18-35yrs (50.81%) and least in the elderly <55yrs (30.75%). Meanwhile no statistical differences were seen in the mean values between the exposed and control subjects, and between the exposed and control males. When constantly exposed, the respiratory epithelium is the foremost tissue affected by soot, there is a change in lung functions due to disruption of respiratory processes (Born & Driscoll, 1996). These dangerous processes may be direct contact-mediated defection of lung cells that include: Reactive Oxygen Species (ROS) generation, cell hypergenesis, cell death or lung airway epithelium apoptosis and other adjoining cells (Hussain *et al*., 2010),or the evolvement of tissue alteration and fibrosis that leads to respiratory problems.

Chronic Obstructive Pulmonary Diseases (COPD) and asthma are the common respiratory diseases mostly seen in humans due to soot exposure (Brauer *et al.,* 2002). Pathological physiology of asthma includes; inflammation of airway, tissue alteration and scarring, obstruction of airflow and bronchi hypersensitivity (Ozier, Bara, Girolet, Marthan& Berger, 2011). Clark *et al*., 2010 also reported that children develop asthma when exposed early to soot. The physiological pathology of COPD includes; airway inflammation and changes in structure (Margelidon, *et al*., 2015,Schmeck, Jereentrup& Bals, 2015).

Again from the results,obtained, the mean values for FEV_1 between the exposed and control female subjects were seen to be significantly lower in the exposed females when compared ($p<0.05$). Likewise, significant differences were also noticed in the mean values of male and female exposed, males with higher significant value of 61.97% and females lower value of 41.03%. The reduced mean value of exposed female subjects explains the fact that women are more susceptible to effects of soot because women have lower maximum ventilatory capacity than men (Scahaeffer *et al*., 2014, Magus *et al*., 2017). Likewise, significant difference was also observed in the mean values of the exposed across their age groups, showing higher FEV_1 value among the age group between 18-35yrs (54.64%), 36-55yrs (46.66%), <55yrs (32.38%), but no statistical difference was observed in the mean values of control and exposed subjects. The results of the present study also showed no statistical significant difference in the mean values for FEV% among the study groups.

From the study, statistical differences were observed in the mean values for PEFR between the exposed and control subjects, female exposed and control subjects and between the exposed male and female and across their various age groups. It was observed that the exposed subjects, had a significantly lower PEFR when compared with the control ($p<0.05$). This result is in accordance with a study by Karki *et al*; 2019.Again it was noticed that the female control mean values were significantly higher than the female exposed when compared (control=61.57% while exposed=48.33%). More also the female exposed mean values were statistically lower than the male exposed when compared and also across their various ages with the younger adults having higher significant values while the older adults had lower values, and significant differences were not found between the exposed and control males and between the exposed males and females across their age groups. Agarwal and Singh, 2013 in an investigative study also reported that there are altered pulmonary functions in individuals when exposed to agricultural crop burning. Studies from animals again have supported soot -triggered mode of noxiousness. Particulate matter >0.1µm also activates DNA damage. The above literatures maintained that the irritation caused by soot lead to severe impairment to pulmonary functions by several ways, in which most of them are not well understood (Howarth, 1998; Morimoto *et al*., 2013).

Significant difference was also observed in the mean values for $FEF_{25\%}$, $FEF_{75\%}$, $FEF_{25\%-75\%}$ between the exposed and control groups, the exposed mean values were significantly lower than the control when compared ($p<0.05$) between the control and exposed females, the exposed females shows lower significant values than the control females , between the male and female exposed subjects, the males have higher significant values than the females when compared and also across their age groups. The age range between 18-35yrs had significant higher values than the age between 36-55yrs and the range <55yrs. This observed decrease in values with advancing age among the exposed male and female subjects point to the fact that with age degenerative changes occur in the muscular skeletal system that leads to reduction in respiratory muscle strength (Bhardiwaj *et al*; 2014) thus there is decrease in chest wall compliance and increase air trapping (Sharma & Goodwin, 2006). This could be also attributed to the fact that soot accelerates lung aging accounting for the difference in adults as age increases (Thomas *et al*; 2008). In contrast, no statistical difference was observed between the exposed and control female subjects.

The result again shows that there is no statistical difference in the mean value for SpO_2 among the study groups. Furthermore, the results show that there is significant difference in the mean value for pulse rate between the control and exposed, the exposed with higher mean value of 79.06bpm and the control with a lower mean value of 74.53bpm when compared ($p<0.005$). There was significant variations among the control and exposed males, the exposed male values were significantly lower than the control males when statistically compared $p<0.05$. The higher values of the exposed subjects indicates that soot pollution affects the cardiovascular system. This is in line with studies by Wold, *et al.*, 2006; and Yixing, *et al.*, 2016.Likewise, no significant difference was observed in the mean values of control and exposed female subjects, exposed male and female and across their age groups. Though no significant difference was seen. It was observed that the older subjects exposed have a higher mean value (81.13) than the younger adults when compared ($p<0.05$). This study shows that age has effect on pulse rate due to increase stiffness of arterial walls, increase stiffness in left ventricle and conduction system degenerative changes (Franklin, Brook&Anden, 2015). It was also observed that age negatively correlates with FEV_1 and FEF while BMI negatively correlates with FEV_1 and $FEF_{75\%}$.

CONCLUSION

Findings from this study have shown that soot exposure mildly increases the body mass index of residents and decrease respiratory functions with increase pulse rate among subjects exposed compared with the control group. The study also shows decreased lung functions in relation to age.

CONFLICT OF INTEREST

The authors have declared that there is no conflict of interest that exists among them.

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