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## ORIGINAL ARTICLE

# Can the particulate matter concentrations in the ambient air at locations used by charcoal-smoke exposed food grillers influence respiratory symptoms among them?

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**Abstract**

**Background** A complex mixture of numerous volatile and particulate substances made up of different organic and inorganic compounds are emitted when wood smoke is produced following the combustion of charcoal for cooking. A significant number of these wood smoke constituents are known to be toxic or irritants for the respiratory system, including PM (PM10), carbon monoxide (CO), nitrogen and others. Particulate matter concentrations may exhibit an extremely wide temporal and spatial variability from one location to another, creating different microenvironments and variable exposures. We aimed to explore the charcoal smoke exposure of food grillers and the resultant respiratory symptoms and their relationship to the measured particulate matter.

**Methods** This was a comparative observational cross-sectional assessment of relationship between respiratory symptoms among charcoal smoke exposed food grillers and particulate matter concentrations in the ambient air at locations used by the charcoal smoke exposed food grillers. Participants were assessed using the Medical Research Council (MRC) Questionnaire to obtain information on respiratory symptoms and socio-demographic characteristics. Particulate matter (PM) sampling was done at food-grilling and fruit-selling locations. The instrument used was AEROCET 531SR, manufactured by Met One Instruments.

**Results** A total of one hundred and sixty (160) participants made up of eighty (80) food-grillers and fruit-sellers (controls) respectively were recruited for this study. The mean values for PM2.5 and PM10 were 42.99±4.56µg/m3 and 64.96±6.11µg/m3 respectively for food-grillers, and 12.08±1.43µg/m3 and 22.17±1.96µg/m3 respectively for controls- There was a statistically significant difference in the mean PM values between food-grillers and controls locations ($p$ value < 0.001).The study also revealed that the presence of respiratory symptoms was directly related to the concentration of PM2.5 (OR – 1.07; 95%CI:1.04 – 1.07; p – 0.001) and PM10 (OR – 1.05; 95%CI: 1.03 – 1.07; p – 0.001) in the ambient air around study participants.

**Conclusion** Charcoal smoke generates significant amount of particulate matter (PM2.5 and PM10) that may contribute to the development of respiratory symptoms among those using charcoal for food-grilling.

**Keywords:** Particulate matter, food grillers, respiratory symptoms, charcoal smoke

## 1 | BACKGROUND

There is a wide variation in the emission of pollutants produced when biomass is burned, depending mainly on the characteristics of combustion and the cooking practices.1Wood smoke is a complex mixture of numerous volatile and particulate substances made up of different organic and inorganic compounds.2,3,4A significant number of these wood smoke constituents are known to be toxic or irritants for the respiratory system causing respiratory symptoms, and these include PM (PM10), carbon monoxide (CO), nitrogen and others.3,4,5,6,7

Pollutant concentrations may exhibit an extremely wide temporal and spatial variability from one location to another, creating different microenvironments and variable exposures.8 Food-grilling is an age-long practice involving the application of dry heat to the surface of food and the use of significant amount of radiant energy produced from an energy source.9 The process of food-grilling may generate significant amount of noxious emissions capable of causing respiratory insult5.

Food drilling is a common occupation in Yenagoa, South-South, Nigeria. Operators are usually seen without the use of personal protective equipment and so, risk exposure to the emissions generated during the process.

Most studies10, 11, 12, 13, 14 have demonstrated significant association between such exposures and certain health hazards. Over 4 million people worldwide are believed to suffer health problems from biomass smoke exposure.15 The situation is even worse in developing countries such as Nigeria, where workers rarely use personal protective equipment at the workplace.16

Majority of the studies concentrated on the health effects of biomass fuel in the form of firewood. However, relatively few studies3, 8 are conducted specifically on charcoal smoke exposure, and the resultant respiratory symptoms and their relationship to the measured concentration of particulate matter.

It was therefore necessary to conduct this study in order to explore the charcoal smoke exposure of food grillers and the resultant respiratory symptoms and their relationship to the measured particulate matter.

The findings of the study will be beneficial to the participants, health care providers and policy-makers in creating awareness that will bring about the establishment of preventive measures that may reduce the health hazards of charcoal smoke exposure.

## 2| MATERIALS AND PROCEDURES

The study was conducted in Yenagoa, the capital city of Bayelsa State, and South-South, Nigeria. The city has an estimated population of 24,335 inhabitants with people of Ijaw ethnic extraction as the dominant percentage of the population. Bayelsa is essentially a civil service state and there are only few industrial activities in Yenagoa, where this study was conducted. Two-stage cluster sampling was used to recruit participants to make up the desired sample size of 160 participants, eighty (80) each, for food-grillers and controls. Also, an equal number of fruit-sellers were recruited as controls, making the total sample size to be 160.

**Inclusion criteria for food-grillers:**

1. Current use of wood charcoal for food-grilling for at least four (4) weeks.
2. Adults between 18 – 60 years who gave consent.

**Exclusion criteria for food-grillers:**

1. Age less than 18 years or above 60 years.
2. Use of energy sources other than wood charcoal for food-grilling.
3. History of chronic lung disease prior to working as food-griller.
4. Previous or current cigarette smoking.
5. Engagement in other occupations that cause air pollution such as road construction work, painting, road traffic officer, petroleum worker, etc.

**Inclusion criteria for controls:**

1. Fruit-sellers between 18 – 60 years who gave consent.

**Supplementary information:** *The online version of this article (https://doi.org/10.52845/rrarjmcs/2022/8-10-3) Contains supplementary material, which is available to authorized users.*

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**Exclusion criteria for controls:**

1. Age less than 18 years and above 60 years formed a total of 160 participants, eighty (80) each, for food-grillers and controls.
2. History of lung disease.
3. Previous or current cigarette smoking.
4. Engagement in other occupations that cause air pollution such as road construction work, painting, road traffic officer, petroleum worker, etc.

**Inclusion criteria for controls**

1. Fruit-sellers between 18 – 60 years who gave consent.

**Exclusion criteria for controls**

1. Age less than 18 years and above 60 years.

**Questionnaire**

The Medical Research Council (MRC) Questionnaire17was administered to participants and a "one on one''interview was conducted by the researchers using the questionnaires. Information obtained included socio-demographic characteristics such as age, gender, marital status and level of education. Other information obtained with the questionnaire were respiratory symptoms such as cough, shortness of breath, production of phlegm, chest pain, chest tightness and wheeze as well as smoking and alcohol history. Other information in the questionnaire were source of energy for domestic cooking, limitation of daily activities and sleep, and information on duration of food-grilling with charcoal.

## 3 | PROCEDURE

Particulate matter (PM) sampling was done at food-grilling and fruit-selling locations. The instrument used was AEROCET 531SR, manufactured by Met One Instruments. The instrument was put on by turning on the power switch. At each of the locations, the instrument was raised to a height of about one meter, and the "start" button was pressed down to start the counting. Counting was usually indicated by a vibratory sound, which continued for two minutes for each sample event, after which the values were displayed automatically and the PM2.5 and PM10 values were recorded into their respective columns in the questionnaire.

A total of 160 locations, eighty (80) each for food-grillers and controls were used for the study.

Data was documented and analysed using the IBM Statistical Package for Social Sciences (SPSS) version 22 (IBM Corp., Armonk NY, USA) software.21Descriptive statistics was performed for socio-demographic characteristics and frequency of respiratory symptoms. The results were presented as percentages and tables as appropriate. Chi-square was used to analyse categorical variables such as respiratory symptoms, A p-value of less than or equal to 0.05 was considered statistically significant for all relevant tests

## ETHICAL CONSIDERATIONS

Ethical approval for the study was obtained from the Research and Ethics Committee (REC) of the Niger Delta University Teaching Hospital (NDUTH), Okolobiri

## 4 | RESULTS

### SOCIODEMOGRAPHIC CHARACTERISTICS

A total of one hundred and sixty (160) participants made up of eighty (80) food-grillers and fruit-sellers (controls) respectively were recruited for this study. Table 1 shows that the mean age was 34.5±9.5 years for food-grillers and 33.5±7.6 years for controls. Most of the study population were females (55, 68.7% for food-grillers and 61, 76.2 for controls)., while secondary level of education had the highest number of participants in the study population (42, 52.5% for food-grillers and 54, 67.5% for controls). The average number of years of food-grilling was 5.1 (± 3.7) years and 5.8 (± 3.6) years for controls (t = 1.27). There was no statistical difference in the duration of each occupation (p-value = 0.206).

*Table 1: Sociodemographic characteristics*

| Characteristics | Total | Food Grillers | Fruit Seller | $\chi^2$ | df | pValue |
|---|---|---|---|---|---|---|
| | N = 160 (%) | N = 80 (%) | N = 80 (%) | | | |
| **Sex** | | | | | | |
| Male | 44 (27.5) | 25 (31.3) | 19 (23.8) | 1.13 | 1 | 0.288 |
| Female | 116 (72.5) | 55 (68.7) | 61 (76.2) | | | |
| **Age group** | | | | | | |
| < 25 years | 15 (9.4) | 10 (12.5) | 5 (6.3) | 4.95 | 4 | 0.292 |
| 25 – 34 years | 72 (45.0) | 31 (38.8) | 41 (51.2) | | | |
| 35 – 44 years | 55 (34.4) | 28 (35.0) | 27 (33.8) | | | |
| 45 – 54 years | 13 (8.1) | 7 (8.8) | 6 (7.5) | | | |
| ≥ 55 years | 5 (3.1) | 4 (5.0) | 1 (1.3) | | | |
| Mean Age (±SD) in years | 34.0 (8.6) | 34.5 (± 9.5) | 33.5 (± 7.6) | t = 0.69 | | 0.493 |
| **Marital Status** | | | | | | |
| Single | 82 (51.2) | 32 (40.0) | 25 (31.3) | 8.22 | 3 | 0.042 |
| Married | 65 (40.6) | 40 (50.0) | 25 (31.3) | | | |
| Separated | 7 (4.4) | 4 (5.0) | 3 (3.8) | | | |
| Widowed | 6 (3.8) | 4 (5.0) | 2 (2.6) | | | |
| **Religion** | | | | | | |
| Christian | 129 (80.6) | 57 (71.3) | 72 (90.0) | 9.00 | 1 | 0.003 |
| Muslim | 31 (19.4) | 23 (28.7) | 8 (10.0) | | | |
| **Level of Education** | | | | | | |
| No formal Education | 21 (13.1) | 14 (17.5) | 7 (8.8) | 4.92 | 3 | 0.178 |
| Primary | 20 (12.5) | 10 (12.5) | 10 (12.5) | | | |
| Secondary | 96 (60.0) | 42 (52.5) | 54 (67.5) | | | |
| Tertiary | 23 (14.4) | 14 (17.5) | 9 (11.2) | | | |
| **Duration of Practice of the trade** | | | | | | |
| 1 – 5 years | 94 (58.8) | 50 (62.5) | 44 (55.0) | 1.46 | 2 | 0.481 |
| 6 – 10 years | 50 (31.3) | 24 (30.0) | 26 (32.5) | | | |
| >10 years | 16 (10.0) | 6 (7.5) | 10 (12.5) | | | |
| Mean Duration(SD) in years | 5.5 (± 3.6) | 5.1 (± 3.7) | 5.8 (3.6) | t = 1.27 | | 0.206 |

From table 2, the distribution of respiratory symptoms for food-grillers and controls were cough (58, 72.5% vs 17, 21.3%), wheeze (13, 16.3% vs 7, 8.8%), breathlessness (28, 35.0% vs 8, 10.0%), phlegm (40, 50.0% vs 8, 10.0%), sneezing (58, 72.5% vs 11, 13.8%), catarrh (41, 51.2% vs 19, 23.8%) and chest tightness (16, 20.0% vs 13, 16.2%). There was a statistically significant difference in respiratory symptoms such as cough, breathlessness, phlegm, sneezing and catarrh between food-grillers and controls (p-value < 0.001 for each).

*Table 2: Distribution of respiratory symptoms among food-grillers and fruit-sellers (control)*

| Characteristics | Total | Food Grillers | Fruit Seller | $\chi^2$ | df | pValue |
|---|---|---|---|---|---|---|
| | N = 160 (%) | N = 80 (%) | N = 80 (%) | | | |
| **Cough** | | | | | | |
| Present | 75 (46.9) | 58 (72.5) | 17 (21.3) | 42.19 | 1 | 0.001* |
| Absent | 85 (53.1) | 22 (27.5) | 63 (78.7) | | | |
| **Wheeze** | | | | | | |
| Present | 20 (12.5) | 13 (16.3) | 7 (8.8) | 2.06 | 1 | 0.151 |
| Absent | 140 (87.5) | 67 (83.7) | 73 (91.2) | | | |
| **Breathlessness** | | | | | | |
| Present | 36 (22.5) | 28 (35.0) | 8 (10.0) | 14.34 | 1 | 0.001* |
| Absent | 124 (77.5) | 52 (65.0) | 72 (90.0) | | | |
| **Phlegm** | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Present | 48 (30.0) | 40 (50.0) | | 8 (10.0) | 30.48 | 1 | 0.001* |
| Absent | 112 (70.0) | 40 (50.0) | | 72 (90.0) | | | |
| **Sneezing** | | | | | | | |
| Present | 69 (43.1) | 58 (72.5) | | 11 (13.8) | 56.29 | 1 | 0.001* |
| Absent | 91 (56.9) | 22 (27.5) | | 69 (86.2) | | | |
| **Catarrh** | | | | | | | |
| Present | 60 (37.5) | 41 (51.2) | | 19 (23.8) | 12.91 | 1 | 0.001* |
| Absent | 100 (62.5) | 39 (48.2) | | 61 (76.3) | | | |
| **Chest tightness** | | | | | | | |
| Present | 29 (18.1) | 16 (20.0) | | 13 (16.2) | 0.38 | 1 | 0.538 |
| Absent | 131 (81.9) | 64 (80.0) | | 67 83.8) | | | |

* Statistically significant parameters

From table 3, limitation of daily activities was reported by 13 (16.2%) of food-grillers, while 14 (7.5%) reported interference of symptoms with sleep. There was a statistically significant difference between food-grillers and controls ($p < 0.001$). Table 4 also shows that out of the eighty (80) food-grillers, 58 (72.5%) had a modified medical research council (mMRC) dyspnea scale score of zero, 8 (10.0%) had a score of one, 9 (11.3%) had 2, while 5 (6.2%) had a score of 3. The results showed a statistically significant difference in the severity of dyspnoea between food-grillers and controls ($p = 0.002$).

***Table 3: Severity of respiratory symptoms among food grillers and fruit-sellers***

| **Characteristics** | **Total** | **Food Grillers** | **Fruit Seller** | $\chi^2$ | **df** | **pValue** |
|---|---|---|---|---|---|---|
| | **N = 160 (%)** | **N = 80 (%)** | **N = 80 (%)** | | | |
| **Symptoms limits daily activities** | | | | | | |
| Yes | 15 (9.4) | 13 (16.2) | 2 (2.5) | 8.90 | 1 | 0.001* |
| No | 135 (90.6) | 67 (83.8) | 78 (97.5) | | | |
| **Symptoms interfere with sleep** | | | | | | |
| Yes | 15 (9.4) | 14 (7.5) | 1 (1.3) | 12.43 | 1 | 0.001* |
| No | 135 (90.6) | 66 (82.5) | 79 (98.7) | | | |
| **MRC Dyspnoea Scale Score** | | | | | | |
| 0 | 134 (83.7) | 58 (72.5) | 76 (95.0) | 14.98 | 1 | 0.002* |
| 1 | 9 (5.6) | 8 (10.0) | 1 (1.3) | | | |
| 2 | 11 (6.9) | 9 (11.3) | 2 (2.4) | | | |
| 3 | 6 (3.8) | 5 (6.2) | 1 (1.3) | | | |

* Statistically significant parameters

Table 4 shows that the mean values for the measured anthropometric parameters for food-grillers were weight (71.69±9.87kg), height (1.64±0.08m) and Body Mass Index (26.49±3.33kg/m2). The mean physiologic parameters were pulse rate (78.65±5.46beats/min), respiratory rate (18.61±1.91cycles/min) and SpO2 (98.30±1.26%).

***Table 4: Anthropometric measurement and Physiologic Parameters***

| **Characteristics** | **Total** | **Food Grillers** | **Fruit Seller** | **t-Test** | **pValue** |
|---|---|---|---|---|---|
| | **Mean (SD)** | **Mean (SD)** | **Mean (SD)** | | |
| **Anthropometric parameters** | | | | | |
| Weight (in Kg) | 70.92 (8.79) | 71.69 (9.87) | 70.15 (7.53) | 1.11 | 0.270 |
| Height (in metres) | 1.65 (0.07) | 1.64 (0.08) | 1.67 (0.07) | 2.12 | 0.035* |
| BMI (Kg/m$^2$) | 25.79 (2.77) | 26.49 (3.33) | 25.13 (2.01) | 3.11 | 0.002* |
| **Physiologic Parameters** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Pulse rate (beats/min) | 77.87 (6.05) | 78.65 (5.46) | 77.09 (6.52) | 1.64 | 0.103 |
| Respiratory rate (cycles/min) | 18.55 (2.06) | 18.61 (1.91) | 18.55 (2.19) | 0.35 | 0.730 |
| $SPO_2$ (%) | 98.41 (1.21) | 98.30 (1.26) | 98.51 (1.15) | 1.11 | 0.268 |

* Statistically significant parameters

The mean values for PM2.5 and PM10 were 42.99±4.56µg/m3 and 64.96±6.11µg/m3 respectively for food-grillers, and 12.08±1.43µg/m3 and 22.17±1.96µg/m3 respectively for controls as shown in figures 1 and 2. There was a statistically significant difference in the mean PM values between food-grillers and controls locations (p value < 0.001). Logistic regression analysis showed that food-grillers are about 8 times more likely to have respiratory symptoms when compared to controls (OR-8.49; 95%CI: 3.91-18.43; p<0.001). The relationship between the presence of respiratory symptoms and the concentration of PM2.5) in the ambient air around study participants was (OR – 1.07; 95%CI: 1.04 – 1.07; p – 0.001) and PM10 (OR – 1.05; 95%CI: 1.03 – 1.07; p – 0.001).

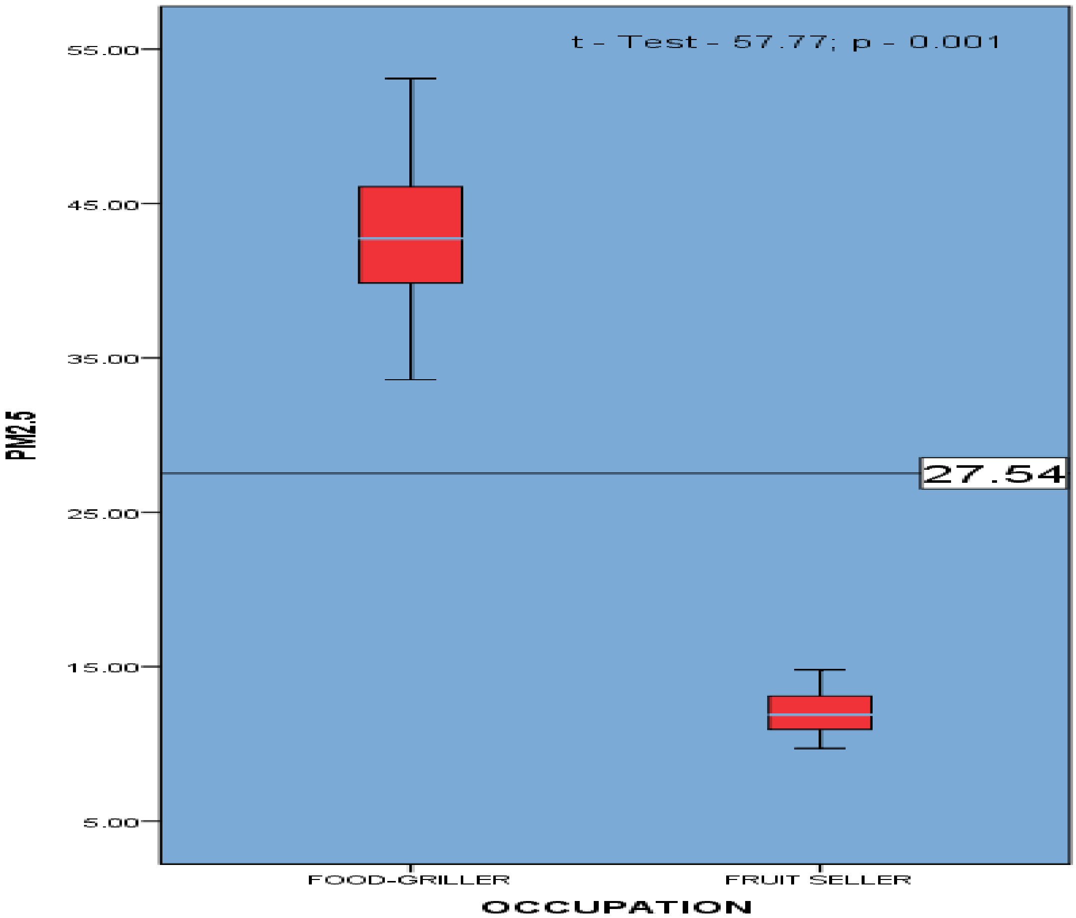


***Figure 1: Box and whisker chart comparing $PM_{2.5}$ around Food-grillers and controls***

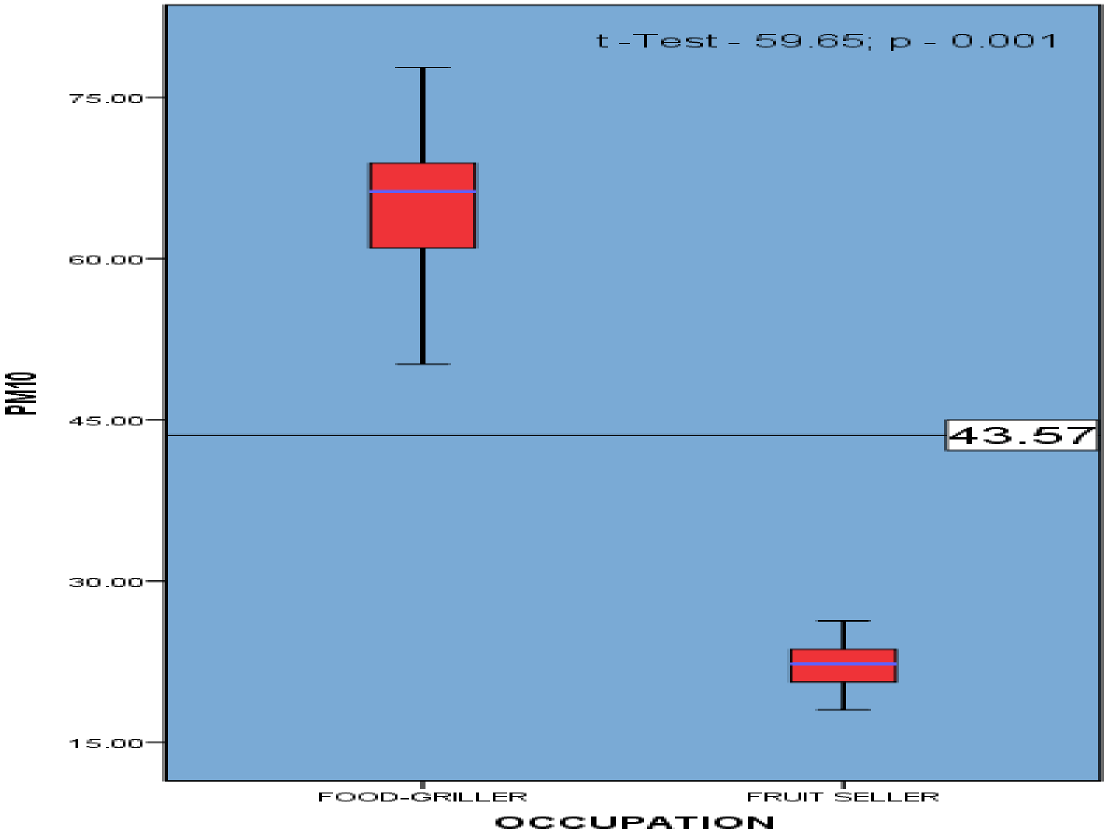


***Figure 1: Box and whisker chart comparing $PM_{2.5}$ around Food-grillers and controls***

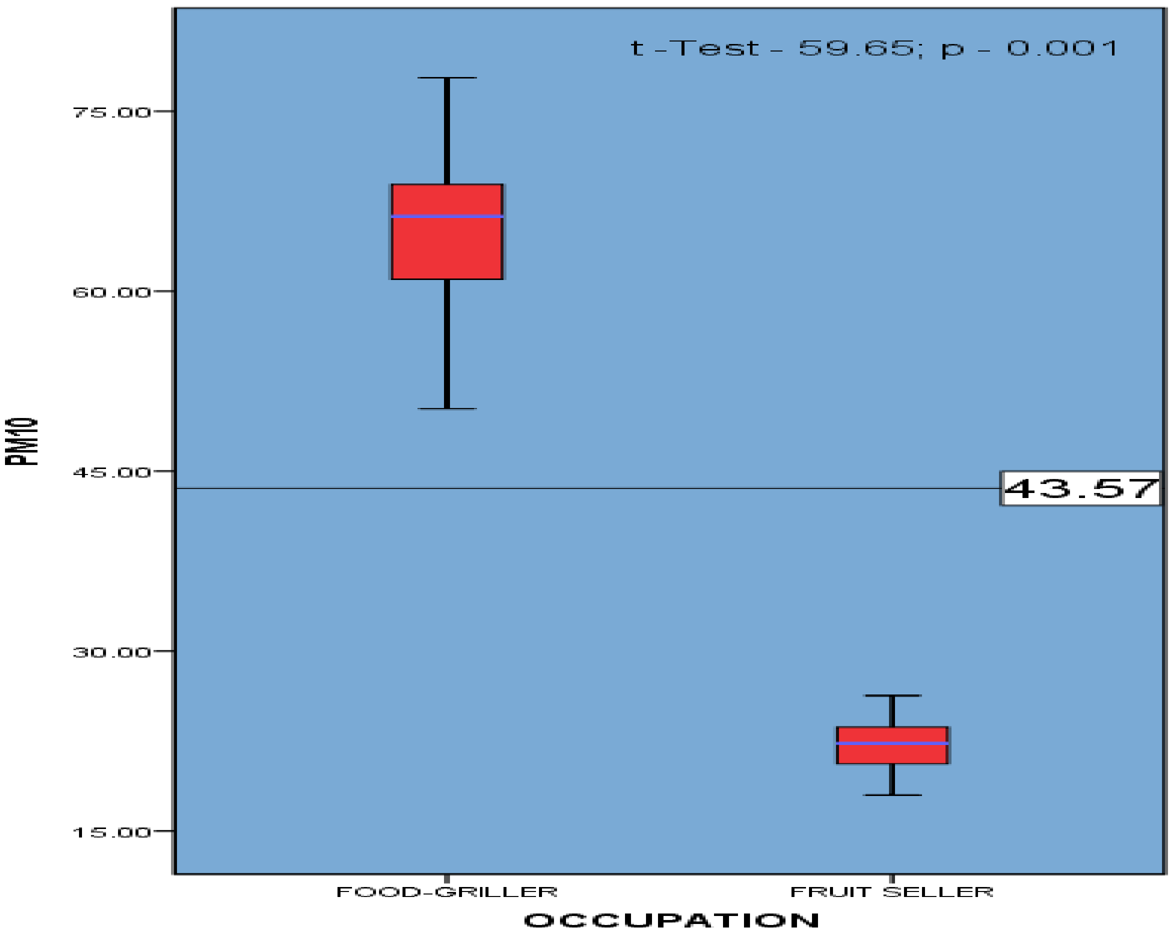


***Figure 2: Box and whisker chart comparing $PM_{10}$ around Food-grillers and controls***

Table 5 revealed factors relating to the presence of respiratory symptoms include increasing age (OR – 1.06; 95%CI:1.01 – 1.10; p = 0.013), body mass index (OR – 1.16; 95%CI: 1.02 – 1.31; p = 0.022), number of hours at work every day (OR – 1.44;95%CI:1.18 – 1.75; p < 0.001) and the concentration of PM2.5 (OR – 1.07; 95%CI:1.04 – 1.07; p – 0.001) and PM10 (OR – 1.05; 95%CI: 1.03 – 1.07; p – 0.001) in the ambient air around study participants

*Table 5: Factors relating to the presence of respiratory symptoms*

| Independent Variable | B | OR | 95%CI | | p Value |
|---|---|---|---|---|---|
| | | | Min | Max | |
| Age | 0.05 | 1.06 | 1.01 | 1.10 | 0.013* |
| BMI | 0.15 | 1.16 | 1.02 | 1.31 | 0.022* |
| Food-grilling | 2.14 | 8.49 | 3.91 | 18.43 | 0.001* |
| Hours per day | 0.36 | 1.44 | 1.18 | 1.75 | 0.001* |
| Number days per week | -0.19 | 0.83 | 0.49 | 1.40 | 0.476 |
| Number of Years | 0.04 | 1.05 | 0.95 | 1.15 | 0.340 |
| $PM_{2.5}$ | 0.07 | 1.07 | 1.04 | 1.09 | 0.001* |
| $PM_{10}$ | 0.05 | 1.05 | 1.03 | 1.07 | 0.001* |

* Statistically significant parameters

## 5 | DISCUSSION

This study was conducted to explore the charcoal smoke exposure of food grillers and the resultant respiratory symptoms and their relationship to the measured particulate matter.

To achieve this, assessment of respiratory symptoms, and measurement of particulate matter (PM2.5 and PM10) concentration were done in the two populations for comparison. It was observed from the current study that cough and sneezing presented the highest burden of respiratory symptoms, whereas, wheeze and chest tightness were the least of symptoms.  This could be explained by the irritant effect of charcoal smoke in activating the cough and sneezing reflexes.18The respiratory symptoms were by far more with food-grillers than with controls (Table 2).

Also, more food-grillers reported limitation of daily activities and sleep interference by symptoms when compared with controls. Furthermore, a greater number of food-grillers had higher modified medical research council dyspnoea scale scores when compared with controls (Table 3). These findings are a reflection that the respiratory symptoms were more severe in food-grillers than controls. A study by Desalu OO, et al, determined whether respiratory symptoms and chronic bronchitis are associated with the use of biomass fuel among women residing in rural areas. In that study, the researchers demonstrated that the proportion of women who reported respiratory symptoms was greater among those using biomass fuels.19This study, like the current study, also reported that cough was the most frequent symptom. In another population study to investigate biomass exposure and its association with respiratory symptoms, quality of life and lung function, Obaseki D, et al, demonstrated that the use of biomass fuel was associated with cough and lower quality of life20indicating that exposure to biomass fumes may be associated with severe adverse clinical outcomes. Similar findings of increased respiratory symptoms were also observed in a case-control study by Dienye, et al, on respiratory effects of biomass fuel combustion on rural fish smokers in the Niger Delta.21The findings in all the above studies were similar to those in the current study and underscores the importance of exposure to biomass fumes and the development of respiratory symptoms.

The current study also showed that the values of particulate matter (PM2.5 and PM10) concentrations measured at food-grilling locations were much more than that of controls, and demonstrated a statistically significant difference between the two groups. Particulate matter is one of the major materials generated during the use of wood charcoal for food-grilling.8 the result is therefore not surprising. The mean PM2.5 and PM10 concentrations from the study results were 42.99±4.56ug/m3 and 64.96±6.11ug/m3 respectively for food-grillers, and 12.08±1.43ug/m3 and 22.17±1.96ug/m3 respectively for controls. The values for food-grillers far exceeded the World Health Organization (WHO) recommended air quality guideline values.

The WHO recommended values22 are 10ug/m3 annual mean and 25ug/m3 24-hour mean respectively for PM2.5, and 20ug/m3 annual mean and 50ug/m3 24-hour mean respectively for PM10. It has been documented that particulate matter inhalation is both directly and indirectly related to poor health outcomes23. Studies have demonstrated that exposure to particulate matter leads to respiratory tract infections, wheezing, lung cancer, Asthma and COPD8, 9, 24 with the particulate matter concentrations in the study population exceeding the WHO recommended values, inhaled PM could contribute to the abnormal findings observed in the study. Similar findings were also observed by Olujimi and colleagues25who reported that charcoal workers were exposed to high levels of particulate matter resulting in reduced respiratory function.

The association between biomass fume exposure and development of respiratory symptoms has been explained; inhaled particles may have direct toxic effects themselves, or they may function as vehicles for adsorbed gaseous agents that are toxic to terminal bronchioles and alveolar cells.26 These compounds may activate irritant receptors in the upper airways, provoking a bronchoconstrictor reflex that may lead to symptoms such as cough, sneezing and production of phlegm.26,27 Yet some other compounds in charcoal smoke such as the oxides of nitrogen have low water solubility and thus fail to cause immediate irritation, promoting longer exposure and deeper penetration of the lower airways.28 Irritation of the lower airways may trigger inflammatory process leading to pathophysiologic changes such as alveolar edema and impaired gas exchange, giving rise to respiratory symptoms such as breathlessness. The same pathophysiologic processes may cause damage to the lungs and consequently lead to lung function impairment among food-grillers.29, 30

One important factor to consider in the assessment of exposure to a substance, is the duration of exposure.31, 32The more time an individual spends around the vicinity of a toxic substance, the more the exposure to the substance and the more the chances of being affected by the toxic effects of that substance. Therefore, the relationship between increasing number of hours and increasing number of days of food-grilling, increasing PM concentration, and the presence of respiratory symptoms and lung function abnormalities, as was observed in the current study, was not surprising.

## 6 | CONCLUSIONS

1. Charcoal smoke generates significant amount of particulate matter (PM2.5 and PM10) that may contribute to the development of respiratory symptoms among those using charcoal for food-grilling.
2. Increasing exposure time to charcoal smoke and high concentrations of PM2.5 and PM10increase the likelihood of developing respiratory symptoms

## 7 | RECOMMENDATIONS

From the study outcomes, the following recommendations were made:

1. An alternative source of energy such as electricity and liquefied natural gas should be used for food-grilling to minimize the emissions generated during the process.
2. Food-grillers using charcoal should use personal protective equipment such as face masks and face shields during their occupational activities to prevent the level of exposure to noxious emissions generated during the process. This should be backed up and enforced with government and WHO policies.
3. Food-grillers using charcoal should have regular medical check-ups, including periodic spirometry to assess their lung functions.
4. There should be periodic measurement of the concentrations of particulate matter in the ambient air of the locations where the food grillers operate.
5. A larger study would be necessary to adequately assess the health implications of local food-grilling with charcoal.

## 8 | LIMITATIONS

1. The study was limited to Yenagoa aloneand may require a larger area to increase the strength.
2. Some measurements and investigations such as arterial blood gas and chest radiograph were not done due to financial constraints. These would probably have uncovered more findings in the study.

## ACKNOWLEDGEMENT

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