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INDOOR AIR EMISSIONS AND RISK FACTORS ASSOCIATED WITH ASTHMA-RELATED SYMPTOMS AMONG CHILDREN IN PERI-URBAN AREAS OF BENIN CITY, NIGERIA

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Abstract

The continuous increase in the occurrence of childhood asthma in recent years has been associated with deteriorating indoor air quality and poor housing conditions, particularly in developing countries. This study investigated the levels of selected indoor air pollutants and examined the associations between self-reported household factors and asthma symptoms in children. A cross-sectional survey of individual and household characteristics was conducted among 240 respondents in 125 households via a modified International Survey on Asthma and Allergies in Childhood (ISAAC) questionnaire in peri-urban settlements in Benin city from November 2023 to April 2024. A quantitative assessment of indoor carbon monoxide (CO), nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$ and PM_{10}) concentrations was carried out in the selected households within the same period. The average ranges of CO, NO_2, $PM_{2.5}$ and PM_{10} concentrations were 5.9–8.3 mg/m^3, 0.01–0.04 mg/m^3, 46.3–130.3 µg/m^3, and 55.3–142.5 µg/m^3, respectively. The associations between the recorded concentrations of CO, $PM_{2.5}$, PM_{10} and the reported asthma-related symptoms were not statistically significant. Age (adjusted odd ratios = 8.04; p > 0.05, 95% CI: 1.00 - 70.61), history of asthma (adjusted odds ratios = 3.19; P = 95% CI: 1.09-9.38) and household carpet status (adjusted odds ratios = 7.17; p = 0.039, 95% CI: 1.11-46.37) were significant independent risk factors for the occurrence of asthma symptoms among the children after adjusting for possible confounders. The knowledge of the risk factors linked with childhood asthma symptoms in this study may assist the parents of children at risk in adopting behavioural efforts to reduce pollutant levels and health care providers in treatment measures.

Key Words: *Adjusted odds ratios, Childhood asthma, Household characteristics, Indoor air pollutants, Risk factors*

Introduction

Asthma is a common chronic inflammatory disease of the respiratory airway characterized by wheezing, repetitive coughing, shortness of breath, chest tightness and limited expiratory airflow, which vary with intensity and time (Global Initiative for Asthma, 2022). It is one of the leading causes of respiratory illness among children, with an estimated 334 million people affected worldwide (Asher *et al*., 2020). The actual estimates of the occurrence of asthma remain unknown due to insufficient data from the literature in Nigeria; however, prevalence rates have been estimated to be 7–18% and 5.1–14.3% in the general population and children, respectively (Masoli *et al*., 2004). Adeloye *et al*. (2013) reported a 45.7% increase in the incidence of childhood asthma in Africa between 1999 and 2010. It has been suggested that asthma is a multifactorial disease in which several personal/host factors and environmental exposures play significant roles in its etiology (Oluwole *et al*., 2017). However, several factors that increase the risk of developing bronchial asthma in children have been reported in different epidemiological studies and they include; genetics (Wills-Owen *et al*., 2018), the burning of biomass fuel (Oluwole *et al*., 2017), mould/dampness in homes (Fakunle *et al*., 2023), active and passive smoking (Hollenbach *et al*., 2017), overcrowding (Eghomwanre and Oguntoke, 2022), and air pollutants (Eghomwanre *et al*., 2022). Poor indoor air pollution and poor housing conditions can lead to several respiratory health outcomes, including wheezing, shortness of breath, chest tightness, eye irritation, coughing and asthma, which can significantly affect people's quality of life (Gan *et al*., 2017). The household environment is of key importance for the increasing incidence of childhood asthma because of the number of hours children spend at home. Therefore, studies related to the risks for asthma associated with household environmental factors will help us ascertain how asthma is induced in children. Much attention has been given to epidemiological studies examining the relationships between ambient air pollutants and respiratory health outcomes in Nigeria (Van Odijk *et al*., 2003; Schneider *et al*., 2003, Ukpebor *et al*., 2007 Oguntoke *et al*., 2010). However, while people frequently spend most of their time indoors, there is insubstantial knowledge about indoor air pollutants and their association with childhood asthma in Nigeria. Additionally, few existing studies on childhood asthma in sub-Saharan Africa have used only self-reported risk indicators to assess indoor air pollution-related outcomes, including asthma, which is largely limited (Nwosisi *et al*., 2021). This study employs both cross-sectional survey data and objective quantitative assessments to determine the level of pollutant emissions in indoor air and to examine the associations between reported risk factors and asthma-related symptoms among children to help address this knowledge gap. This will inform the community of the possible indoor environmental risks to which children are exposed and provide relevant stakeholders with data to respond to the need for regular indoor air monitoring to help control the possible environmental risk indicators associated with the exacerbation of asthma among children in the area.

Materials and Methods

Area Description and Study Population

The study was conducted in households distributed in the outskirt areas, which are dominated by semi-formal buildings in Benin city, Nigeria. (Figure 1). The city is situated along latitudes 6°20′N and 6°58′N and longitudes 5°35′E and 5°41′E and occupies an area of approximately 113 km^2. In 2024, the population of the city was estimated at 1,973,000 people. The study area is composed of five local government areas: Egor, Uhunmwonde, Ovia, Oredo, Ikpoba – Okha and Ovia North East, dominated by informal settlements and is highly populated due to frequent migration from the city. The houses are congested with low socioeconomic status and most of the households are dependent on solid fuels. Most of the households also use predominantly gasoline-powered generators during public power failure.

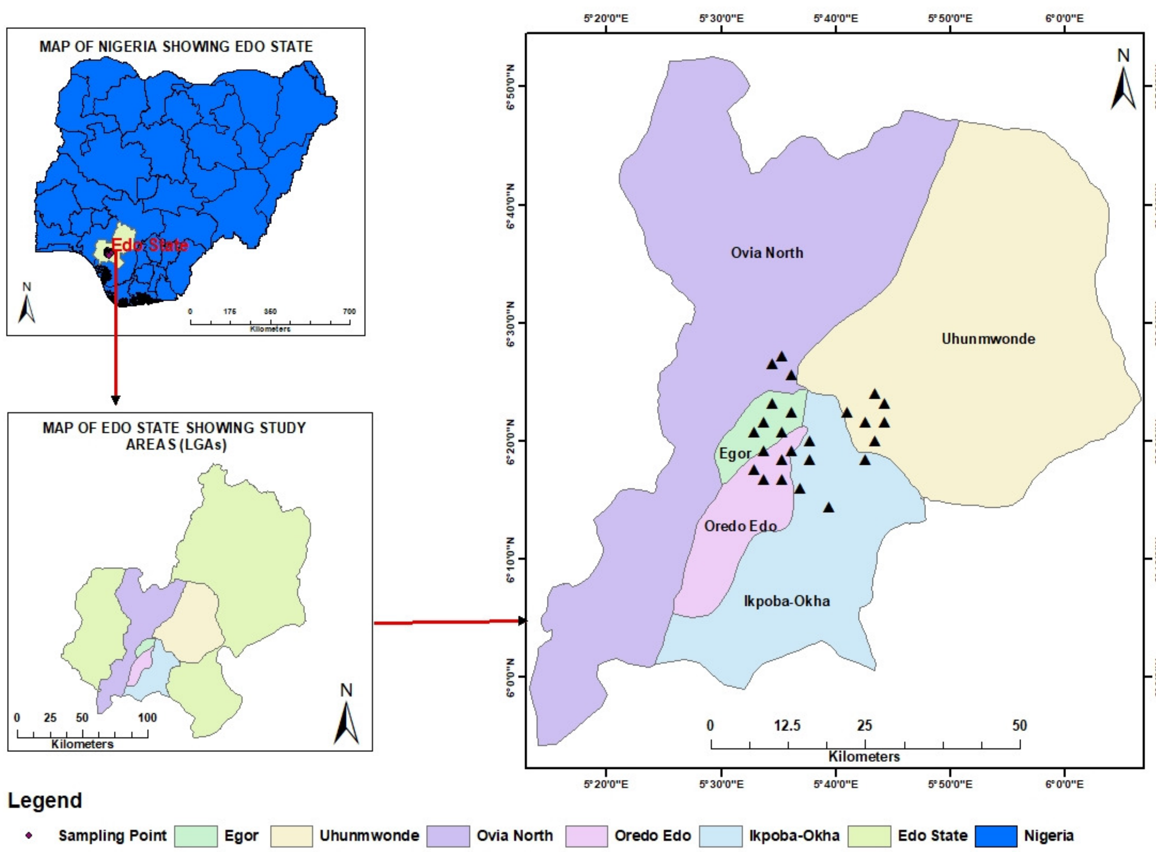

Fig. 1: Map of Benin city showing the sampling sites

Study Design

This study adopted both a cross-sectional survey using questionnaires and quantitative measurements of air pollutants across selected households in twenty-five communities from the five local government areas. The questionnaires were used to obtain data on asthma-related symptoms, including ever wheezing, wheezing after 12 months, dry cough, wheezing after exercise, chest tightness, and episodes of attacks among children between the ages of 0 and 17 years in the selected households.

Information about the following household and individual risk indicators was also collected: fuel type, floor type, number of occupants in a room, history of asthma and smoking in the household, and location of the kitchen.

Sample Size and Sampling Procedure

The sample size (240) was determined from the individuals who are residents in the selected households who are between the age of 0 and 17 years using sample size determination formulae based on the prevalence of asthma-related symptoms of 19.4% reported in previous studies (Kelly *et al*., 2015).

$$N=\frac{z^2pq}{d^2}$$

where q = (1-p)

$$N=\frac{z^2p(1-p)}{d^2}$$

N = minimum sample size

z = confidence interval of 95%, which is equivalent to a confidence coefficient of 1.96.

p = prevalence 19.4% = 0.194

d = desired level of precision, 0.05

Data Collection and Measurements

Questionnaire Survey

Twenty-five sampling sites (communities) designated as S_1-S_{25} and located on the outskirts of each local government area—Egor, Uhunmwode, Oredo, Ikpoba—Okha and Ovia Northeast, as shown in Figure 2—were purposively selected due to overcrowded households occasioned by migration from rural areas. The socioeconomic conditions of these economically poor areas warrant the use of unimproved fuel, poor ventilation, and indoor cooking, which inevitably contribute to the accumulation of air pollutants in the indoor environment. A multistage sampling approach was adopted to select the households for questionnaire administration and air quality measurements. Two hundred and forty modified ISAAC questionnaires were administered to children aged 0 -17 years found in the selected households across the selected communities in the five local government areas. The questionnaire survey was conducted with the help of trained volunteers who administered the questions to consenting individuals across the study location. The information was obtained from an adult, usually a caregiver or the child guardian, in each of the households. The questions were answered using pidgin English or the local Bini language for those who were not literate.

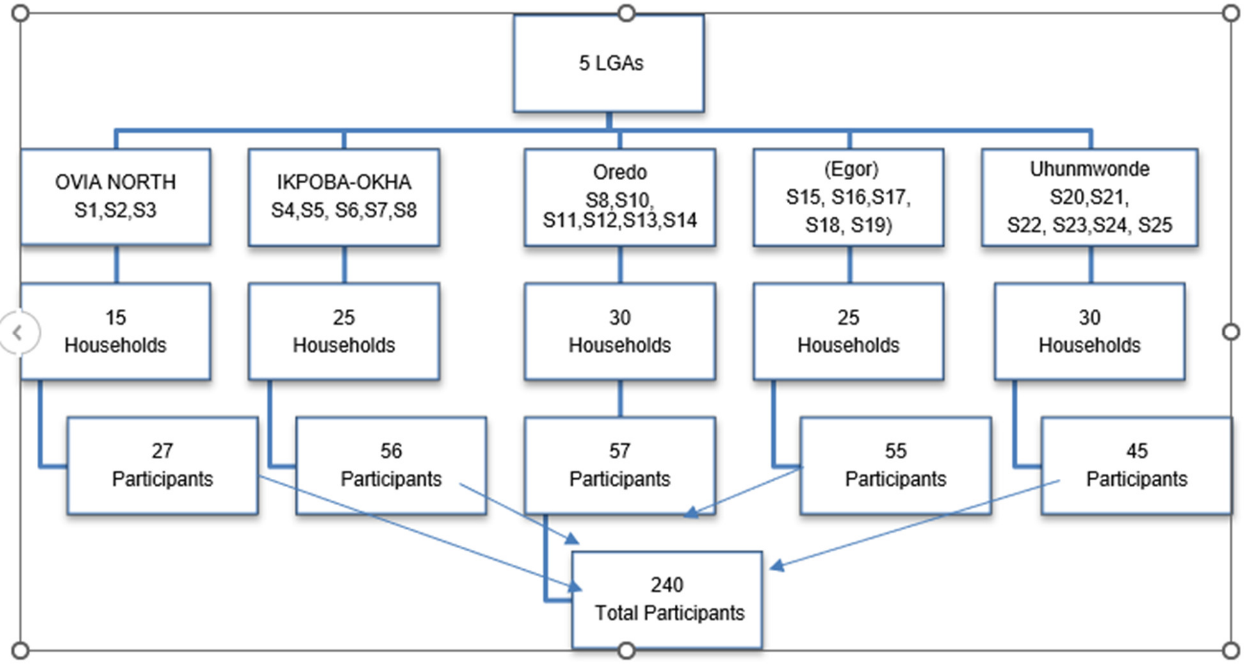

Fig. 2: Multistage sampling approach for the selection of participants

Description of Asthma Symptoms

The International Study on Asthma and Allergies in Childhood (ISAAC) questionnaire was used to collect data on the symptoms of asthma among the respondents (Uyan *et al*., 2003). The questions included "Has your child (name of the child) ever had wheezing (since birth)", "Has your child had wheezing within the last 12 months", "Has the child experienced chest tightness", "Have you noticed the child had a dry cough at night without cold or a breathing illness in the last 12 months", and "have you noticed the child wheezing after taking part in exercise in the last 12 months?". The responses to these questions were either yes (coded as 1) or no (coded as 0).

Individual and Housing Characteristics

Self-reported responses were obtained from the participants on the history of asthma, smoking in the household, and yes or no responses, whereas no occupants, type of floor covering material, and type of fuel for cooking were categorical responses. Sociodemographic characteristics (sex, level of education, marital status, proximity of household to highway, number of rooms, leakage in homes, use of insecticides) were identified as possible covariates or potential confounding variables.

Measurement of Air Quality and Meteorological Parameters

The measurement of indoor air pollutants was conducted in one hundred and twenty-five households across the selected twenty-five communities (S_1-S_{25}) in the five local government areas (Figure 2), using the MultiRae PDM-6208 series and BR- SMART-126S for CO, NO_2 and particulates ($PM_{2.5}$ and PM_{10}), respectively. The samplers are high-precision hand-held portable devices that are widely used in industry. The MultiRae sampler possesses a field replaceable photoionization detector (PID) with range and resolution for CO (0–500 ppm; 1

ppm) and NO_2 (0–20 ppm; 0.1 ppm), whereas the BR-SMART sampler quantifies particulates via a light scattering technique with a measurement range of 0–999 µg/m^3 and a resolution of 0.0 µg/m^3. The sampling was performed weekly in triplicate at each of the twenty-five locations across the randomly selected households for a period of six months (November 2023 to April 2024). The meters were placed 2 m above the ground surface away from the window and doors in the sitting room, and readings were taken in triplicate. The indoor temperature and relative humidity were measured using a Windmate 300 with a range and precision of -20–60°C and +/- 1°C, respectively, and the temperature and humidity ranged from 0 -100% and +/- 3%, respectively. The average of the measurements obtained in group of five households per sampling point (S) was taken, and the results were compared with the World Health Organization indoor air quality standards (WHO, 2010).

Statistical Analysis

The air quality and meteorological data obtained across the sampling regime in the selected households were analysed using descriptive statistics to obtain the means and standard deviations. The means of the concentrations obtained from each household were grouped and presented according to the sampling site (S). The questionnaire data were analysed via descriptive statistics, frequency and percentages, whereas the associations between the self-reported asthma risk indicators and asthma-related symptoms were determined using the chi-square test of significance. The reported risk factors that were significantly associated with reported asthma symptoms were subjected to bivariate logistic regression. In the regression model, the explanatory (independent) variables (y) were the reported individual and housing conditions, whereas the outcome or dependent variables (x) were the reported asthma symptoms and were coded yes as (1) and no as (0). The $PM_{2.5}$ and PM_{10} values calculated from one-tenth of the logarithmically transformed original average concentrations were also added to the model as latent variables. The results are expressed as crude odds ratios (cORs) and corresponding 95% confidence intervals (95% CIs). Finally, the significant explanatory factors for asthma symptoms were further subjected to the multivariate binomial regression model while adjusting for other confounding factors (sex, level of education, marital status, proximity of household to highway, number of rooms, leakage in homes, use of insecticides) to determine the independent risk factors for the reported asthma symptoms among the children. and expressed as adjusted odds ratios (aORs). All analyses were performed using SPSS statistical software 21.0 with the assumption of a p value $<$ 0.05.

Results and Discussion

Mean Indoor Meteorology and Air Pollutant Levels

The average indoor temperature, relative humidity and concentrations of air pollutants are shown in Table 1. The results revealed that the average temperature and humidity ranged from 30.8 to 33.8°C and 68.8 to 77.3%, respectively, across the households at the sampling sites. The mean concentrations of CO were between 5.9 and 8.3 mg/m^3. The level of indoor carbon monoxide was above the WHO air quality guidelines for fifty percent of the sites monitored (WHO, 2010). Indoor CO is a product of incomplete combustion from cooking. In this study, approximately 33.4% and 10.4% of the households cooked with kerosene and biomass fuel, respectively, under poorly ventilated kitchens often cited indoors. The use of lanterns and gasoline-powered generators as a result of incessant power failure might have also contributed to the increased levels of indoor CO in homes. The level of carbon monoxide in the present study was higher than that reported by Nnadozie *et al*. (2017) and Eghomwanre and Oguntoke (2022) but similar to that reported by Wafula *et al*. (2023), who found 7 ppm of indoor CO in an informal setting in Uganda. The nitrogen (IV) oxide concentrations ranged from 0.01- 0.04 mg/m^3. Indoor NO_2 levels were found to be between 0.01 and 0.04 mg/m. Although the NO_2 levels were within the WHO guidelines, the indoor concentrations of NO_2 in the households could be attributed to indoor cooking with unvented gas cookers, as 47.4% percent of the dwellers utilize gas cookers for cooking indoors. Increased levels of NO_2 have been previously reported in homes where gas cookers are used (Ukpebor *et al*., 2007). Paulin et al. (2017) showed that exposure to indoor nitrogen dioxide predisposes children to asthma-related symptoms, including cough, wheezing, and the use of an inhaler. The concentrations of the indoor particulates varied between 46.3 and 130.3 $\mu g/m^3$ ($PM_{2.5}$) and between 55.3 and 142.5 $\mu g/m^3$ (PM_{10}). The highest mean level of particulates was recorded at S23, but the lowest was detected at S6. We found that the concentrations of indoor $PM_{2.5}$ and PM_{10} exceeded the WHO guidelines at all the sampling locations. An onsite assessment of the households revealed that possible PM sources could be smoking, indoor cooking, especially with kerosene stoves and biomass, and the use of candles when there is a power outage. The level of indoor particulates recorded in this study was higher than that reported by other authors within the subregion (Aigbokhaode and Isara, 2021; Eghomwanre *et al*., 2022; Wafula *et al*., 2023). This could also be attributed to the period of sampling, which was generally the dry period of the year when outdoor sources of particulates are a major contributor to indoor PM in addition to prevailing indoor sources such as smoking, cooking, biomass burning and resuspension of dust particles from human movements of PM in households (Custódio *et al*., 2014). High levels of PM in the study area could be a significant risk factor for asthma exacerbation in children residing in households.

Table 1: Average meteorological and air pollutant concentrations in selected households

Sampling Sites	Temp (°C)	R/H (%)	CO (mg/m^3)	NO_2 (mg/m^3)	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
S1	31.10±1.1	76.80±4.7	7.00±1.9	0.02±0.0	89.40±12.4	102.30±14.3
S2	31.00±0.4	77.30±4.3	7.10±2.5	0.02±0.0	74.80±8.8	86.30±10.1
S3	31.60±1.1	77.20±4.1	8.10±2.4	0.02±0.0	101.90±12.1	115.10±13.3
S4	31.50±1.0	74.90±4.6	7.20±1.9	0.02±0.0	48.60±3.8	56.90±4.5
S5	32.90±1.8	71.10±5.3	8.30±4.0	0.02±0.0	107.90±21.7	117.60±23.1
S6	31.90±1.7	74.70±2.6	6.30±2.8	0.02±0.0	46.30±2.9	55.30±3.4
S7	32.40±2.0	72.40±5.5	7.80±2.2	0.04±0.1	63.40±7.6	69.50±7.7
S8	31.80±1.9	74.40±5.3	7.90±2.4	0.03±0.0	56.20±4.8	64.00±5.5
S9	30.80±0.6	75.90±4.9	7.60±1.7	0.01±0.0	57.60±4.8	65.20±5.4
S10	31.70±1.1	73.60±3.1	6.40±2.0	0.04±0.1	52.40±2.4	59.30±2.7
S11	31.40±0.9	73.10±3.5	7.80±2.3	0.03±0.0	49.80±2.2	58.10±2.4
S12	31.30±1.3	76.50±4.7	5.90±2.6	0.01±0.0	60.90±4.2	69.50±4.8
S13	31.40±1.3	75.50±5.0	6.90±1.9	0.02±0.0	61.30±4.1	67.10±4.9
S14	33.00±1.3	76.10±4.0	7.80±2.4	0.02±0.0	97.30±10.4	113.10±11.5
S15	31.30±1.3	75.20±6.7	6.60±2.4	0.02±0.0	55.00±5.4	63.70±5.9
S16	31.60±1.5	75.60±4.4	6.40±1.8	0.01±0.0	58.00±3.7	68.60±4.3
S17	31.90±1.2	73.80±5.2	6.10±1.5	0.00±0.0	58.30±4.4	69.00±4.4
S18	33.00±1.3	75.00±3.6	8.00±2.1	0.02±0.0	90.10±9.0	102.80±9.8
S19	33.40±1.3	72.90±4.5	6.80±1.2	0.00±0.0	87.40±15.6	97.70±16.1
S20	32.30±1.3	70.30±3.9	6.50±2.2	0.01±0.0	74.80±11.1	85.70±12.4
S21	32.60±1.1	69.90±3.8	7.20±2.9	0.03±0.1	60.30±6.3	67.40±6.7
S22	33.20±1.0	70.70±3.7	8.10±2.6	0.01±0.0	130.30±26.7	142.50±27.7
S23	33.60±1.0	70.10±4.0	6.50±2.0	0.02±0.0	59.30±6.1	67.10±6.6
S24	33.70±1.1	69.80±4.2	7.10±2.4	0.02±0.0	115.00±23.3	119.60±22.8
S25	33.80±1.1	68.80±4.2	8.10±2.4	0.02±0.0	125.00±24.3	112.60±19.8
WHO (2010)	**-**	**-**	**7.00**	**0.04**	**25**	**50**

The values are the means ± standard deviations of thirty replicates. S= sampling points

Sociodemographic characteristics and percentage occurrence of asthma symptoms

The socio-demographic, individual and household details of the respondents during the questionnaire survey are shown in Table 3. Among the 230 respondents, 128 (53.3%) were male, whereas 46.7% were female. Half (50.6%) of the participants were between the ages of 0–4 years, whereas 34.2% and 15.8% of the respondents were between the ages of 5–9 and 17 years, respectively. The survey revealed that more than half of the respondents reside in households with between 1 and 2 rooms, with approximately 15.8 percent of the respondents living in households with three to five persons in a room. Among the 239 respondents, 18.3% had had wheezing since birth, 15.4% reported wheezing in the last 12 months, 6.7% reported dry cough, 10.0% reported chest tightness, and 11.3% reported wheezing after exercise (Table 4). The percentage of patients with asthma-related symptoms, including ever wheezing, dry cough, chest tightness, and disturbed sleep, reported in this study was lower than that reported in an informal urban setting in Uganda (Wafula *et al*., 2023) but higher than that reported in urban areas in Benin city

(Eghomwanre and Oguntoke, 2022). The variations in the occurrence of asthma symptoms could be due to differences in the clinical definitions of symptoms associated with asthma, the sample size under study, the period and duration of the study, geographical factors and the reliability of the data sources (Engelkes *et al*., 2015).

Table 3: Sociodemographic and household characteristics of the respondents (n=240)

Characteristics	**Frequency**	**Percentage (%)**
Gender		
Male	128	53.3
Female	112	46.7
Age		
0-4yrs	120	50.0
5-9yrs	87	36.3
10-17yrs	33	13.8
No of Occupants		
1-2	120	50.0
2-3	82	34.2
3-5	38	15.8
History of Asthma		
Yes	74	69.2
No	166	30.8
Current smoking		
Yes	93	38.8
No	147	61.3
Floor Covering		
Tiles	94	39.2
Cement	42	17.5
Carpet	51	21.3
Rug	53	22.1
Fuel type		
Electrical	41	17.1
Natural gas	95	39.6
Kerosene	51	21.3
Firewood	53	22.1
Location of Kitchen		
Outside	40	16.7
Inside	200	83.3

Table 4: Prevalence of Reported Symptoms of Asthma among Respondents (n=240)

Characteristics	Frequency	Percentage (%)
Ever wheeze		
Yes	37	15.4.
No	203	84.6
Wheeze after 12 months		
Yes	24	10.0
No	216	90.0
Dry cough		
Yes	16	6.7
No	224	93.3
Chest tightness		
Yes	24	10.0
No	216	90.0
Wheeze after exercise		
Yes	27	11.3
No	213	88.8

Associations between Reported Risk Indicators and Childhood Asthma Symptoms

The associations between the indoor air pollutant concentrations reported individual/household risk factors and asthma symptoms were examined by chi-square test (Table 5) and bivariate and multivariate binomial regression (Tables 6 and 7). The study revealed that increased levels of carbon monoxide were associated with a higher odd of risk of asthma symptoms among respondents: ever wheezing (cOR = 4.2; 95% CI: 0.307–58.203) and wheezing in the last 12 months (cOR = 1.0; 95% CI: 0.33–3.10) (Tables 6 and 7). Similarly, the levels of indoor $PM_{2.5}$ and PM_{10} in the sampled households led to higher odds of wheezing in the last 12 months, chest tightness and dry cough among the occupants. This finding was, however, not statistically significant. This study was not in tandem with the findings of Wafula *et al*. (2023), who reported that an increase of 10 units in the $PM_{2.5}$ concentration was significantly linked to an increased risk of asthma-related symptoms, including cough, in informal household settings in Uganda. Higher concentrations of indoor particles ($PM_{2.5}$ and PM_{10}) have also been associated with increased asthma symptoms, wheezing in children and increased risk of acute lower respiratory tract infections (Wu *et al*., 2019). The results revealed that the occurrence of asthma-related symptoms was higher (20.0%) in children aged 0 - 4 years than in children aged 5-9 years (13.8%) or 10 - 17 years (3%) ($p = 0.197$). In addition, the study revealed a statistically significant association between age and ever wheezing, as respondents aged 0-4 years were 8.0 times more likely to have experienced wheezing since birth than were those aged 5-9 years and 10 -17 years (cOR = 8.00; $p = 0.046$, 95% CI: 1.04-61.52) (Table 6). The association was robust and strengthened after adjustment, indicating that it is an independent risk factor for asthma symptoms among children (aOR = 8.04; $p > 0.05$, 95% CI: 1.00–70.61) (Table 7). The significantly higher occurrence of asthma symptoms among respondents between the ages of 0 and 4 years could be attributed to the possibility of incorrect classification of viral wheezing resulting from rhinovirus infection in young children with asthma (Wendt *et al*., 2012). The declining occurrence of asthma symptoms with age in this study is consistent with previous findings (Oguonu *et al*., 2014; Eghomwanre *et al*., 2022). Wheezing (28.4%) and chest tightness (23.0%) were more common in children with a history of asthma than in those with no history of asthma (p = 0.000) (Table 5). There was also a significant relationship between a history of asthma and childhood asthma symptoms, as those who had a history of asthma had 3.71- and 6.77-fold higher odds of reporting ever wheezing (cOR = 3.71; p = 0.000, 95% CI: 1.80-7.64) and wheezing in the last 12 months (cOR = 8.00; p = 95% CI: 2.61-17.18), respectively (Table 6). However, the odds decreased after adjustment for cofounders but were also a significant independent predictor of wheezing among children (aOR = 3.19; p = 95% CI: 1.09-9.38) (Table 7). Several studies have reported that a familiar risk of asthma is associated with the early onset of asthma in children (London *et al*., 2001; Burke *et al*., 2003, Eghomwanre and Oguntoke, 2022). Hence, knowledge of the risks associated with family history might be useful for preventing asthma by motivating parents to implement preventive measures. The occurrence of asthma symptoms was also higher among respondents who cook inside (22.5%) the house than among those whose kitchens are located outside (9.0%). However, this association was significant only among those who reported chest tightness (p = 0.014) (Table 5). Compared with those who cooked with electricity, the respondents who cooked with natural gas (COR = 10.47; p = 0.028, 95% CI: 1.32-86.97) or kerosene (cOR = 8.03; p = 0.002, 95% CI: 2.12-30.30) had 10.47 and 8.03 times higher odds of experiencing dry cough at night, respectively (Table 6). Importantly, this association was not significant after adjustment for the covariates (Table 7). The survey revealed that approximately forty percent of the respondents cook with unvented gas cookers, and over eighty (80%) of them cook inside the house. The absence of vents in the gas cookers being used could further aggravate the inherent risks. Unvented gas cookers are a major source of indoor nitrogen dioxide. Some studies have reported that the use of unvented gas cookers significantly increases the risk of asthma symptoms among children (Mommers *et al*., 2005; Belanger *et al*., 2008). The regular opening of kitchen windows while cooking helps dissipate pollutant concentrations and reduce the level of exposure during cooking. The occurrence of asthma symptoms was higher in respondents who were exposed to cigarette smoke in their household than in nonexposed respondents ($p<0.05$). This study also revealed a statistically significant association between smoking in the household and asthma symptoms among the respondents, as those who reported smoking in their homes had 2.72, 4.47 and 3.81 times higher odds of ever wheezing (cOR = 2.72; p = 0.06, 95% CI: 1.33-5.58), wheezing in the last 12 months (cOR = 4.47; p = 0.01, 95% CI: 1.77-11.26) and dry cough at night (cOR = 3.81; p = 0.016, 95% CI: 1.27-11.34) (Table 6). Although smoking in households resulted in increased odds of reported wheezing and dry cough, smoking was not an independent risk factor for asthma in this study. Other studies have indicated that smoking in households exacerbates the risk of wheezing rather than its development (Adekoya-Cole *et al*., 2015; Ellie *et al*., 2021). Consistent insights into behavioural changes related to indoor smoking, especially in households with children, could assist in decreasing exposure to risks associated with indoor cigarette smoke. The occurrence of ever wheezing (31.6%), wheezing in the last 12 months (21.1%), chest tightness (34.2%) and dry cough at night (21.1%) was higher in children who reported asthma symptoms among those who lived in households with more than three persons in a room than in those who lived in houses with one or two persons in a room ($p < 0.005$). The number of occupants in a room was significantly associated with reported chests among the respondents, as children living in homes with two or three persons in a room are 4.30 times more likely to experience chest tightness than those who dwell in households with fewer persons in a room (cOR = 4.03; p = 0.009, 95% CI: 1.44 -12.82) (Table 6). The present study also revealed that approximately half of the respondents occupied houses with more than three people in a room. The results of this study show that overcrowding, defined as the presence of more than one person in a room (Burr and Mutchler, 2012), is a significant risk factor for increased chest tightness in children. Overcrowding could increase the chances of cross-infection among occupants via airborne transmission of infectious agents. Different epidemiological studies using various measures for overcrowding have reported an association between crowding and respiratory health outcomes (Kutzora *et al*., 2019; Becher *et al*., 2018). However, this association was not significant when the model was adjusted (Table 7).

The respondents who resided in households with carpet and rug floor material had a significantly higher occurrence of wheezing among children than those who lived in households with tiled or cemented floors ($p < 0.05$). The results also revealed a statistically significant association between the type of floor material and the occurrence of chest tightness among the respondents, as the respondents with cement (cOR = 7.94; p = 0.002, 95% CI: 2.10-29.97) and carpet (cOR = 10.73; p = 0.026, 95% CI: 1.32-86.97) floor types were 7.94 and 10.73 times more likely to experience dry cough at night, respectively than those who stayed in homes with tiles (Table 6). The use of carpets as floor materials in homes significantly increased the odds of dry cough at night among exposed children. It was also an independent risk factor for asthma symptoms after adjustment. The contribution of carpet floors to the onset or exacerbation of asthma symptoms may be due to the emission of volatile organic compounds (VOCs) that can result in the smell and irritation of mucous membranes, particularly in vulnerable individuals, or may act as a receptacle of dirt, dust that can accumulate in carpets (Becher *et al*., 2018). Previous studies have also reported a correlation between carpet floors in homes and adverse health outcomes, including worsening asthma (Skorge *et al*., 2005, Ukpebor *et al*., 2007).

Table 5: Associations between reported risk factors and symptoms of asthma according to the chi-square test

Factors	Ever wheeze		Wheeze in the last 12 months		Chest tightness		Dry Cough	
	Freq(%)	P -value	Freq(%)	P value	Freq(%)	P -value	Freq(%)	P value
Age								
0-4yrs	24(20.0)		18(15.0)		18(15.0)		8(6.7)	
5-9yrs	12(13.8)		5(5.7)		5(5.7)		8(9.2)	
10-17yrs	1(3.0)	0.050*	1(3.0)	0.032*	1(3.0)	0.032*	0(0.0)	0.197*
History of Asthma								
Yes	21(28.4)		24(23.0)		17(23.0)		8(10.8)	
No	16(9.6)	0.000*	7(4.2)	0.000*	7(4.2)	0.000*	8(4.8)	0.086
Smoking status								
Yes	22(23.7)		17(18.3)		17(18.3)		11(11.8)	
No	15(10.2)	0.005*	7(4.8)	0.001*	7(4.8)	0.001*	5(3.4)	0.011*
No of occupants								
1-2	11(9.2)		7(5.8)		8(6.7)		5(4.2)	
2-3	14(17.1)		9(11.0)		6(7.3)		3(3.7)	
3-5	12(31.6)	0.003*	8(21.1)	0.023*	13(34.2)	0.000*	8(21.1)	0.001*
Floor covering								
Tiles	7(7.4)		3(3.2)		6(6.4)		4(4.3)	
Cement	4(9.5)		1(2.4)		4(9.5)		3(7.1)	
Carpet	13(25.5)		9(17.6)		8(15.7)		7(13.7)	
Rug	13(24.5)	0.005*	11(20.8)	0.001*	9(17.0)	0.164	2(3.8)	0.128
Location of Kitchen								
Outside	7(17.5)		4(10.0)		9(22.5)		5(12.5)	
Inside	30(15.0)	0.689	20(10.0)	1.000	18(9.0)	0.014*	11(5.5)	0.105
Fuel type								
Electrical	4(9.8)		1(2.4)		4(9.8)		3(7.3)	
Natural gas	7(7.4)		3(3.2)		61(8.3)		4(4.2)	
Kerosene	13(25.5)		9(17.5)		8(15.7)		7(13.7)	
Firewood	13(24.5)	0.004*	11(20.8)	0.001*	9(17.0)	0.161	2(3.8)	0.125

* Statistically significant at $p > 0.05$

Table 6: Bivariate logistic regression model for determining risk factors for asthma symptoms

Factors	Ever Wheeze	Wheeze in the last 12 months	Chest tightness	Dry cough
	cOR (95%Cl)	cOR (95% Cl)	cOR (95%C)	cOR (95% C)
Age				
0-4yrs	8.00(1.04-61.52)*	5.64(0.72-43.97)	0.17(0.23-1.37)	-
5-9yrs	5.12(0.63-41.04)	1.91(0.21-17.35)	0.51(0.05-4.55)	
10-17yrs	1(ref.)	1(ref.)	1(ref.)	1(ref.)
History of Asthma	3.71(1.80-7.64)*	6.77(2.61-17.18)*	0.14(0.58-0.37)	2.39(0.86-6.64)
Smoking	2.72(1.33-5.58)*	4.47(1.77-11.26)*	0.22(0.89-0.53)	3.81(1.27-11.34)*
Near highway	3.77(1.58-8.97)*	3.09(1.11-8.59)*	0.32(0.11-0.89)	3.43(0.95-12.37)
No of Occupants				
1-2	1(ref.)	1(ref.)	1(ref.)	1(ref.)
2-3	0.21(0.08-0.55)	0.23(0.78-0.69)	4.30(1.44-12.82)*	00.16(0.05-0.53)
3-5	0.44(0.18-1.09)	0.46(0.163-1.31)	2.16(0.76-6.13)	0.14(0.35-0.57)
Floor covering				
Tiles	1(ref.)	1(ref.)	1(ref.)	1(ref.)
Cement	0.24(0.92-0.66)	0.12(0.03-0.47)	7.94(2.10-29.97)*	1.13(0.20-6.40)
Carpet	0.32(0.97-1.08)	0.09(0.11-0.74)	10.73(1.32-86.97)*	1.96(0.31-12.31)
Rug	1.05(0.43-2.55)	0.81(0.30-2.17)	1.22(0.45-3.25)	4.05(0.80-20.54)
Fuel type				
Electrical	1(ref.)	1(ref.)	**1**(ref.)	**1**(ref.)
Natural gas	0.33(0.10-1.11)	0.09(0.01-0.77)	10.47(1.29-84.90)*	2.01(0.32-12.64)
Kerosene	0.24(0.91-0.66)	0.12(0.33-0.47)	8.03(2.12-30.30)*	1.12(0.19-6.33)
Firewood	1.05(0.43-2.55)	0.81(0.30-2.17)	1.22(0.45-3.25)	4.05(0.80-20.54)
Kitchen Location				
Outside		1(ref.)	1(ref.)	1(ref.)
Inside	-	1.00(0.33-3.10)	1.00(0.32-3.10)	0.47(0.13-1.24)
CO^a	3.63(0.41-3.19)	4.22(0.307-58.203)	0.322(0.21-5.003)	0.63(0.014-1.942)
$PM_{2.5}^a$	0.32(0.021-5.003)	0.88(0.333-2.357)	0.45(0.152-1.328)	0.74(0.214-2.540)
PM_{10}^a	0.83(0.324-2.107)	0.447(0.158-1.266)	0.580(0.199-1.692)	0.63(0.195-2.062)

a= Log-transformed average values of CO, PM_{10}, and $PM_{2.5}$; Cl=confidence limit; COR crude =Crude odd ratios; *significant at $p<0.05$

Table 7: Multivariate logistic regression for independent risk factors for asthma symptoms

Risk factors/ Symptoms of Asthma	Ever Wheeze	Wheeze in the last 12 months	Chest tightness	Dry cough
	aOR(95%Cl)	aOR(95% Cl)	aOR(95% Cl)	aOR(95% C)
Age				
0-4yrs	8.37(1.01-70.04)*	5.64(0.72-43.97)	0.15(0.01-1.34)	0.53(0.11-2.59)
History of Asthma	2.19(0.92-5.20)	3.19(1.09-9.38)*	0.03(0.10-0.90)	1.28(0.35-4.69)
Floor covering				
Carpets	-	1.29(0.40-4.12)	0.93(0.27-3.3.19	7.17(1.11-46.37)*
CO^a	**3.96**(0.370-42.379)	0.10.00-3.859)	3.06(0.199-.65.23)	4.792(0.330-9.595)
$PM_{2.5}{}^a$	0.60(0.003-115.628)	3.75(0.020-708-529)	0.037(0.311-44.47)	0.19(0.001-71.632)
$PM_{10}{}^a$	1.32(0.009-204.483)	0.56(0.003-93.881)	25.26(0.031-206.286)	7.40(0.027-202.294)

a= Log-transformed average values of CO, PM10, and PM2.5; Cl=confidence limit; aOR = adjusted odd ratio; * significant at $p<0.05$

Conclusion

This study investigated the associations between individual and household characteristics and symptoms related to childhood asthma in peri-urban areas of Benin city. The concentrations of indoor carbon monoxide and particulate matter throughout the sites were above the regulatory limits for safe exposure. There was no clear association between the measured indoor air pollutants and the reported asthma symptoms, but a tendency to increase the risk of asthma symptoms was found among the respondents. Interventions aimed at decreasing the levels of indoor air pollutants, especially in crowded areas in peri-urban settings, could help control indoor pollutant sources and pollutant exposure among children. This study also revealed a significant association between self-reported individual and housing conditions and asthma symptoms among children. Only age, history of asthma and use of carpets as floor materials were found to be significant independent risk factors for asthma symptoms after the model was adjusted for confounders. Knowledge of asthma risk factors in these locations would help motivate parents and guardians of children at risk to make some modifications to the home environment, such as regular opening of windows during cooking, keeping children away from cooking areas, and removing carpets from homes unless there are special considerations when carpets are preferred. Additionally, information on familiar risks associated with asthma may also assist healthcare providers and parents in monitoring and identifying early manifestations of asthma symptoms. This could help them take proactive measures to prevent environmental risk factors and treatment.

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