Predicting Exposure to Dust Particles Using Spirometric Index and Perception Studies among Farmers in Selected Farm Settlements in Ogun State, Nigeria

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ABSTRACT

The link between agricultural activities and respiratory disease puts farmers at risk of exposure to particulate matter, potentially reducing lung function. Thus, this comparative cross-sectional work employed a spirometric index and perception studies by conducting interviews and on-the-spot lung function tests on 195 farmers living in seven farm settlements of Ogun State and 195 non-farmers living in other areas to assess the ambient levels of the suspended particulate matter and estimate the dust exposure among the first group. The collected data were evaluated through descriptive and inferential statistics and indicated that the majority of the farmers (51.8%) applied manure, fertilizer and chemical sprays without using personal protective equipment (PPE), although a large percentage of both the farmers (74.9%) and the non-farmers (82.1%) understood that poor air quality could cause respiratory disease. The highest concentrations of the total suspended particles (TSP; $29.89 \pm 23.52 \mu\text{g m}^{-3}$) and PM_{10} ($18.45 \pm 16.97 \mu\text{g m}^{-3}$) were observed during the wet season, whereas that of the $\text{PM}_{2.5}$ ($18.45 \pm 11.72 \mu\text{g m}^{-3}$) was observed during the dry season. Additionally, the mean concentrations of the PM_{10} and $\text{PM}_{2.5}$ exhibited significant seasonal variation ($p < 0.001$). The forced expiratory volume in 1 second (FEV1) and peak expiratory flow rate (PEFR) also varied considerably between the farmers (1.16 ± 0.87 and 244.32 ± 117.96 , respectively) and non-farmers (2.47 ± 0.87 and 271.29 ± 104.09 , respectively). Our results showed that the farmers engaged in poor safety practices and possessed reduced lung function compared to non-farmers. Hence, we advise farmers to adopt the use of PPE and follow safety measures. Furthermore, routine assessment of particulate matter and lung function should be encouraged in farm settlements.

Keywords: Farming, Particulate matter, Lung function, Occupational health, Safety practices

1 INTRODUCTION

Farming is an array of activities ranging from small-scale hobby farms to massive industrial farms (Elliott and von Essen, 2016). According to DESA (2018), about 57% of the African population lives in rural areas, and they are mainly farmers. Large-scale emissions from animal husbandry, manure storage and spreading, field cultivation, feed storage, and free-range systems have increased the level of importance of agricultural activities to air pollution. According to the studies of De Jager (2005) and Arslan and Aybek (2012), agricultural activities produce diverse air pollutants such as infectious agents, gases, organic and inorganic particulates and chemicals, posing health risks to farmers, farm workers and surrounding residences (Grimm and Eckhof, 2002). The health

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risks associated with farming may be aggravated when other activities, like charcoal production, are added (Olujimi *et al.*, 2016). Hazardous air pollutants may also be released from farm vehicles and pieces of machinery, which can aggravate cancer risks (Tsai *et al.*, 2019). Land preparation through forest/bush burning emits greater levels of particulate matter pollutants than burning of agricultural residue (Wiriya *et al.*, 2016; Moran *et al.*, 2019).

Air pollution is the most culpable risk factor causing most deaths and injuries following Human Immunovirus/Acquired Immune Deficiency Syndrome (HIV/AIDS), water treatment, and hygiene (Clasen *et al.*, 2014). Respiratory infection of the lower tract (LRTI), tuberculosis, chronic obstructive pulmonary disease (COPD), and lung cancer are the top four respiratory diseases among the 10 causes of death worldwide, according to Lozano *et al.* (2012). LRTI moved from the fourth position in 2007 to first in 2017 in the hierarchy of causes of infant mortality across the world. In other age brackets, it moved from the third position in 2007 to second in 2017 with a percentage change of -13.7% (Murdoch and Howie, 2018). Umoh *et al.* (2013) also found that farmers accounted for approximately 10% of 3,490 patients admitted to the medical ward and diagnosed with respiratory diseases in Cross River State, Southeast Nigeria.

Respiratory diseases prevalence data are seldom reported in rural areas, maybe because they do not visit hospitals and the general perception that rural areas are less susceptible to resultant effects of industrialization, which served as pollution and exposure indicators. Previous studies have reported findings that respondents have a perception that rural settings are “clean” spaces with uncontaminated air as opposed to pollution in urban areas (Brody *et al.*, 2004; Brody *et al.*, 2008; Smallbone, 2012; Mally, 2016). This perception was not based on the pollutants concentrations as determined by surveillance instruments, but rather on people’s judgments, feelings and attitudes about pollution (Claeson *et al.*, 2013). Sjöberg *et al.* (2004) observed that perception is a subjective measure of the extent of pollution or exposure and the subsequent effects of the exposure to environmental hazards. The perception that exposure or non-exposure to hazardous substances may or may not cause health symptoms or otherwise (Stenlund *et al.*, 2009). Lloyd *et al.* (2005) and Brosschot *et al.* (2006) demonstrated that cardiovascular and inflammatory disorders arise from enhanced neurovascular, cardiovascular, immunological and endocrinological behaviors linked to excessive stress and worry triggered by the perception of adverse exposure impacts. Age, gender, education and health are important social statuses identified to inform or modify perception by predicting health symptoms (Orru *et al.*, 2018). Understanding the view of the public on air quality and associated risks to health are focal points for research into the acceptability of interventions initiatives, including active individual participation (Saksena, 2007; Egondi *et al.*, 2013).

Perceived symptoms are not directly influenced by exposure level; they are rather mediated by perceived pollution and health risks (Claeson *et al.*, 2013). For instance, though the levels of monitored air pollutants around Abeokuta metropolis in Nigeria were low, the perception of the traffic officials indicated relatively severe respiratory (Oyebanji *et al.*, 2019a). Risk perception is multi-faceted with cultural, demographic and political factors that play significant roles in the deviations determined (Egondi *et al.*, 2013). However, with the awareness in the body of knowledge about public perceptions of air quality, the understanding of probable relationships among the exposed people, with concerns about associated health risks are poorly explained. Furthermore, there is also a lack of understanding of the association between perception and on-the-spot measurements of air pollutants levels relating to actual lung function. Therefore, this study predicted exposure to dust particles using spirometric index and perception studies among farmers in selected farm settlements in Ogun State, Nigeria.

2 METHODS

2.1 Description of the Study Area

This study was conducted in seven selected farm settlements namely, Ado-Odo, Ago Iwoye, Ajegunle, Coker, Ibiade, Ikenne and Sawonjo in Ogun State, Southwest Nigeria (Fig. 1). The farm settlement (FS) scheme is an initiative of the government that involves the procurement and dedication of large expanse of land to boost rural development. These farmers are provided with assets for extensive farming operations and improvement in their living standards. The scheme is

Fig. 1. Map of Ogun state showing locations of selected farm settlements.

in Israeli Moshavim's model and was established by the Regional Government of Western Nigeria under the leadership of Late Chief Obafemi Awolowo in 1976 (Adegeye, 1974; Familugba, 2016).

Ogun State is situated at $7^{\circ}00'N$ $3^{\circ}35'E$, border Oyo and Osun States in the north, Lagos State in the south, the Republic of Benin to the west and Ondo State to the east. The state falls within the tropical climate system with the raining season commencing from March through November, and the dry season between December and February. The mean annual rainfall ranges between 128 mm and 105 mm in the southern and northern parts of the state. The average monthly temperature, by comparison, varies from $23^{\circ}C$ in July to $32^{\circ}C$ in February. The agricultural potential of the area is rich, thereby enabling six major cash crops to be cultivated: cassava, cocoa, cotton, kola, oil palm and rice (Oladeebo and Masuku, 2013).

2.2 Source of Data

This study employed a cross-sectional design using a comparative approach. It included a questionnaire review, field assessment of particulate matter and exposure evaluation. The subjects were farmers in selected farm settlements, whereas controls were non-farmers living outside the farm settlements.

2.3 Sampling Procedure

The sample size was determined based on the non-population-dependent Charan and Biswas (2013) formula suggested for comparison between two classes with a qualitative endpoint with the test power set at 80% while proportions of farmers and non-farmers applied were 0.06 and 0.024 respectively (Negatu *et al.*, 2016). The sample size was reduced with the equation by Israel (2009) and Ogunseye *et al.* (2018). The sample reduction yielded a sample size of 390 shared even between the two respondent groups (195 respondents each for farmers and non-farmers). Farmers' population, percentage sampling, proportional allocation of questionnaires among eligible and willing farmers across the FSs are presented in Table S1.

2.4 Questionnaire Administration

The questionnaire was originally written in English and then translated into Yoruba, which is the native language in the field of study. After administration, it was back-translated to English by native Yoruba speakers for accuracy. Trained interviewers gathered data and administered the questionnaire to participants. The first portion of the questionnaire evaluated the social and demographic characteristics of respondents, the second assessed the occupational history, health, and safety practices, and the third evaluated the perception of respondents to air quality and self-reported respiratory symptoms. Eligible participants included full-time resident farmers who were non-smoking male or females. The latter has been working as farmers within the settlements for not less than five years and demonstrated a willingness to be part of the analysis by endorsing an informed consent form while controls were non-smoking non-farmers residing outside the farm settlements.

2.5 Particulate Matter Assessment

Particulate matter measurements were taken thrice at 5-minute intervals in the morning and evening using Thermo Scientific MIE pDR-1500 particulate matter monitor. Sampling points were established within the outdoor premises of farmers' residence and taken during the dry (December 2017–February 2018) and wet (May–July 2018) seasons.

2.6 Lung Function Assessment and Body Mass Index

Lung function assessment was carried out through spirometry. Spirometry involves the measuring of breath through the amount and speed of air that a person can inhale and exhale. Lung function status was assessed based on the results of forced expiratory volume in one second (FEV₁) and peak expiratory flow rate (PEFR) using a calibrated PiKo-1 spirometer. For comparison with standards, anthropometric parameters such as height, age, weight and sex were obtained because the thresholds for obstructive lung disease differ by body mass index (BMI) (CDC, 2012). Standard spirometry requires the subject to forcefully exhale the best volume of air possible after taking in a full deep breath. The forced expiratory maneuver is the participant's effort. Lung function assessment was performed in the field by the principal investigator at the close of the day's work in the evening.

The actual FEV₁ and PEFR were compared with expected values based on the height and age of respondents. The calculation of the expected values of FEV₁ and PEFR are presented in Eqs. (1) and (2):

$$\text{FEV}_1 (\text{L}) = 0.040\text{H} - 0.021\text{A} - 3.13 \quad (1)$$

$$\text{PEFR} (\text{L s}^{-1}) = 0.071\text{H} - 0.035\text{A} - 1.82 \quad (2)$$

where FEV₁ is forced expiratory volume in 1 second in liters (L), PEFR is peak expiratory flow rate in liters per second (L s⁻¹), H is height in cm, and A is age in years (Ingle and Niles, 2005).

2.7 Data Analysis

Data were analyzed for simple descriptive (mean ± standard deviation (SD) and inferential (t-test, chi-square, Fisher's exact test and simple linear regression) statistics using Statistical Package for the Social Sciences (SPSS) version 22. The proportion was used to summarize socio-demographic characteristics of respondents, occupational history and safety practices of farmers, perception of respondents on health problems and related symptoms, and knowledge of respondents on environmental hazards. The Fisher's exact test and chi-square were used to determine the association between risk factors in farming and lung function, while simple linear regression determined the relationship between particulate matter concentrations and lung function.

2.8 Quality Assurance and Control

All the measuring instruments were properly calibrated during the period of sampling. The particulate matter sampler was fitted with three cyclones specific for each particle size, namely, total suspended particles (TSP) and particulate matter (PM₁₀ and PM_{2.5}). Each parameter was

monitored after changing the filter paper to take a new reading at different sampling points. The lung function maneuver was demonstrated by the researcher, after which respondents were asked to sit comfortably to carry out their maneuvers. The best result was recorded for each respondent after 3–4 spirometric maneuvers.

3 RESULTS AND DISCUSSION

3.1 Socio-demographic Characteristics of Respondents

Table S2 shows the socio-demographic characteristics of respondents. A large fraction of farmers and non-farmers were above 50 years (43.1% and 37.4%), males (72.3% and 62.1%), married (76.9 % and 75.9%), with secondary education (42.6% and 43.1 %) and from Yoruba tribe (74.4% and 86.7%) respectively. Studies on Icelandic, Nigerian and Irish farmers by Sigurdarson *et al.* (2008), Desalu *et al.* (2014) and Cushen *et al.* (2016), respectively reported similar age patterns. Old-age dominance in farming is usually a characteristic of communities with a high rate of urban migration. The high proportion of male farmers was expected, because it is a cultural and religious practice, and considering the nature of activities involved (Adesuyi *et al.*, 2018). Women do assist their husbands, particularly in processing and sale of farm produce, and often consider themselves farmers. A similar result was reported by Auma *et al.* (2010) and Negatu *et al.* (2018) among Kenyan and Ethiopian farmers, respectively, where the majority of farmers have male-headed households. The highest level of education of most farmers was secondary education in agreement with the study of Adesuyi *et al.* (2018). Low educational attainment of farmers could affect their capabilities to perform vital tasks such as calibration of sprayers and understanding manufacturer's specifications for mixing pesticides and fertilizers. Unsafe handling of potentially hazardous chemical substances and poor operational procedures portend risks for these farmers (Okoffo *et al.*, 2016). Education is crucial for an individual's overall behavior and dispositions towards the adoption of agricultural-related innovations (Ashburner and Friedrich, 2001). Meanwhile, the high percentage of Yoruba among respondents may be because the FSs under consideration are situated in the southwestern region or probable preferential allocation of land in farm settlements to indigenes. Majority of the farmers (47.2%) lived in the farm settlements for at least 21 years while most of the non-farmers (41.5%) were civil servants.

3.2 Occupational History and Safety Practices of Respondents

Table S3 shows the occupational history and safety practices of farmers. Majority of farmers were crop farmers (56.4%). The predominance of crop farming may be due to the arable nature of soils in the region and reduced necessity for any additional input. Most of the farmers were engaged in farming for over 20 years (53.3%) and worked for more than 8 hours per day (54.4%). Results showed that majority of the farmers (70.8%) apply manure and fertilizer to their crops, while 25.6% applied Nitrogen Phosphorus and Potassium (NPK) fertilizer strictly. Results also showed that some farmers apply fertilizers in combination. Furthermore, 83.6% of farmers apply chemical spray for the control of pests, while 63.1% apply these chemicals themselves. About 51.8% of the farmers do not use personal protective equipment (PPE) during the application of these chemicals, and hence they were susceptible to adverse health conditions.

Continuous cultivation of land without recourse to fallow periods may lead to a decline in soil viability over time, thereby necessitating indiscriminate use of manures and fertilizers. Also, preservation of harvested crops and protection of plants against pest infestation are both increasing the usage of pesticides on the field and storage areas. Besides, the combination of fertilizer types is common practice across the farm settlements. This practice may be risky according to the study of Rahman *et al.* (2007), where a greater proportion of acute respiratory infections were in workers exposed to urea in ammonia plant than the unexposed workers. The study of Adesuyi *et al.* (2018) corroborated the negligence of farmers in under-utilization of PPE during fertilizer and pesticide application, while Linaker and Smedley (2002) identified the non-usage of PPE as one of the predisposing factors leading to various health challenges in agriculture. The health challenges could appear in the form of various hypersensitivities ranging from throat, chest, eye and skin irritations. Farmers reported these conditions immediately after the application of fertilizer or pesticide. Greskevitch *et al.* (2008) reported that these hypersensitivities might lead to mortality. They showed

that mortality rate was significantly elevated for multiple respiratory conditions, 10–50-fold hypersensitivity and pneumonitis occurring above expectation in livestock and crop farmworkers.

3.3 Perception of Respondents on Health Problems and Knowledge of Environmental Hazards

Perception of respondents on health problems and related symptoms is shown in Table 1. A small proportion of farmers were diagnosed with some health conditions including allergies (15.4%),

Table 1. Perception of respondents on health problems and related symptoms.

Perceived health problems	Level of severity	Farmers (%)	Non-farmers (%)
Cough	Not experienced	105 (53.8)	100 (51.3)
	Severe	20 (10.3)	4 (2.1)
	Moderate	50 (25.6)	87 (44.6)
	Minimal	20 (10.3)	4 (2.1)
Shortness of breath	Not experienced	154 (79.0)	135 (69.2)
	Severe	11 (5.6)	-
	Moderate	19 (9.7)	58 (29.7)
	Minimal	11 (5.6)	2 (1.0)
Sore throat	Not experienced	140 (71.8)	181 (92.8)
	Severe	9 (4.6)	-
	Moderate	28 (14.4)	13 (6.7)
	Minimal	18 (9.2)	1 (0.5)
Sneezing	Not experienced	75 (38.5)	180 (92.3)
	Severe	32 (16.4)	-
	Moderate	72 (36.9)	13 (6.7)
	Minimal	16 (8.2)	2 (1.0)
Asthma	Not experienced	165 (84.6)	169 (86.7)
	Severe	11 (5.6)	-
	Moderate	13 (6.7)	25 (12.8)
	Minimal	6 (3.1)	1 (0.5)
Vomiting	Not experienced	173 (88.7)	186 (95.4)
	Severe	3 (1.5)	-
	Moderate	12 (6.2)	5 (2.6)
	Minimal	7 (3.6)	4 (2.1)
Nausea	Not experienced	136 (69.7)	189 (96.9)
	Severe	14 (7.2)	-
	Moderate	23 (11.8)	5 (2.6)
	Minimal	22 (11.3)	1 (0.5)
Headache	Not experienced	68 (34.9)	177 (90.8)
	Severe	32 (16.4)	2 (1.0)
	Moderate	67 (34.4)	8 (4.1)
	Minimal	28 (14.4)	8 (4.1)
Chest pain	Not experienced	144 (73.8)	159 (81.5)
	Severe	12 (6.2)	2 (1.0)
	Moderate	27 (13.8)	4 (2.1)
	Minimal	12 (6.2)	30 (15.4)
Dermatitis	Not experienced	145 (74.4)	189 (96.9)
	Severe	11 (5.6)	-
	Moderate	23 (11.8)	-
	Minimal	16 (8.2)	6 (3.1)
Eye irritation	Not experienced	125 (64.1)	195 (100)
	Severe	26 (13.3)	-
	Moderate	35 (17.9)	-
	Minimal	9 (4.6)	-

asthma (6.2%), conjunctivitis (5.1%), chest conditions (4.1%), emphysema (3.6%), bronchitis (1.5%) and laryngitis (0.5%). However, in comparison, 33.8%, 15.4% and 9.2% of the non-farmers reported being diagnosed with chest conditions, allergies and conjunctivitis, respectively.

Table 2 presents the knowledge of respondents on environmental hazards. About 70.8% and 81.0% of farmers and non-farmers respectively have heard about outdoor air quality. A large percentage of farmers (74.9%) and non-farmers (82.1%) know that poor air quality can lead to respiratory diseases. Most farmers were aware that smoke, dust, dirty environment (82.6%), fuel dispensing (70.3%), fertilizer application (69.2%), chemical spraying (75.4%), processing of farm produce (73.3%) and bush burning (71.8%) could affect air quality (Rizk *et al.*, 2002; Hamid *et al.*, 2010; Savci, 2012; Reynolds *et al.*, 2015; Alenezi and Aldaihan, 2019; Oyebanji *et al.*, 2019b).

3.4 Seasonal Particulate Matter Concentrations across Farm Settlements

Table 3 shows mean seasonal particulate matter concentrations across farm settlements. TSP and PM₁₀ had the highest concentrations ($29.89 \pm 23.52 \mu\text{g m}^{-3}$ and $18.45 \pm 16.97 \mu\text{g m}^{-3}$) during the wet season, while the highest PM_{2.5} peak ($18.45 \pm 11.72 \mu\text{g m}^{-3}$) was observed in the dry season. These values were within permissible World Health Organization (WHO) limits (WHO, 2005). However, there were significant variations in mean seasonal concentrations of PM₁₀ and PM_{2.5} ($p < 0.001$). Higher PM₁₀ concentration detected during the wet season was in disagreement with the studies by Abdullah *et al.* (2011) and Ana and Umar (2013) in Malaysia and Nigeria, respectively. The high particulate matter concentration may be attributed to the storage of poultry feed in the indoor spaces, which leads to emission of particles of varying sizes, which are not season-specific. According to Arhami *et al.* (2009), particulate pollutants should not be interpolated because of the presence of gaseous co-pollutants and associated resultant health risks. Particulates are extremely important in air quality, since their constituents may constitute both chronic and acute health risks depending on the source or activities producing them (Kelly and Fussell, 2015). They could contain organic carbon, nitrates, trace elements, elemental carbon and sulfates at varying

Table 2. Knowledge of respondents on environmental hazards.

Variable	Subgroups	Farmers (%)	Non-farmers (%)
Have you heard about outdoor air quality?	No	57 (29.2)	37 (19.0)
	Yes	138 (70.8)	158 (81.0)
Do you know that poor outdoor air quality can cause respiratory diseases?	No	49 (25.1)	35 (17.9)
	Yes	146 (74.9)	160 (82.1)
Are you aware that dirty environment, smoke, and dust affect outdoor air quality?	No	34 (17.4)	19 (9.7)
	Yes	161 (82.6)	176 (90.3)
Do you know that dispensing fuel such as petrol can affect air quality?	No	58 (29.7)	53 (27.2)
	Yes	137 (70.3)	142 (72.8)
Do you know that fertilizer application can affect air quality?	No	60 (30.8)	49 (25.1)
	Yes	135 (69.2)	146 (74.9)
Do you know that chemical spraying can affect air quality?	No	48 (24.6)	43 (22.1)
	Yes	147 (75.4)	152 (77.9)
Do you know that the processing of farm produce like grinding can affect air quality?	No	52 (26.7)	44 (22.6)
	Yes	143 (73.3)	151 (77.4)
Do you know that bush burning can affect air quality?	No	55 (28.2)	41 (21.0)
	Yes	140 (71.8)	151 (78.9)

Table 3. Mean $\pm$ SD seasonal particulate matter concentrations across farm settlements.

Season/Others	TSP ($\mu\text{g m}^{-3}$)	PM ₁₀ ($\mu\text{g m}^{-3}$)	PM _{2.5} ($\mu\text{g m}^{-3}$)
Wet	29.89 ± 23.52	18.45 ± 16.97	11.62 ± 10.49
Dry	29.75 ± 18.94	11.85 ± 8.75	18.45 ± 11.72
WHO (2005)		50	25
p value	0.841 ^a	< 0.0001	< 0.0001

^a p-value not significant, SD: standard deviation.

levels and concentrations (Sawant *et al.*, 2004; Cao *et al.*, 2005). Organic carbon in particulates may contribute to bacterial propagation and aid their transmission (Shrimandilkar, 2013). Furthermore, at about 150°C, inorganic gases such as CO, CO₂, NO₂ and NH₃ are usually emitted when dust particles are present on heated surfaces like local stoves (Kavouras and Stephanou, 2002).

Researches have shown that several non-agricultural air pollution sources such as cooking oil fumes, biomass (burning of refuse), wood smoke and generator use may affect air quality and lead to aggravated pulmonary dysfunction and lung inflammation (Ezzati and Kammen, 2001; Ibhazehiebo *et al.*, 2007; Barone-Adesi *et al.*, 2012; Adewole and Desalu, 2013). Exposure to wood smoke poses a greater health risk (Díaz-Robles *et al.*, 2015).

3.5 Anthropometric Parameters and Lung Function Status of Respondents

Table 4 shows the anthropometric parameters and lung function of respondents. The average height (m) of farmers and non-farmers were 1.71 ± 1.1 and 1.72 ± 1.2 respectively, while the mean body weights (kg) were 64.45 ± 9.87 and 62.89 ± 11.34 respectively. The average BMIs (kg m⁻²) were 22.11 ± 3.79 for farmers and 21.62 ± 4.60 for non-farmers. The FEV₁ (L) for farmers and non-farmers were 1.16 ± 0.87 and 2.47 ± 0.87 , respectively, while the PEFR (L min⁻¹) for farmers and non-farmers were 244.32 ± 117.96 and 271.29 ± 104.09 respectively. The t-test revealed significant difference between the FEV₁ ($p < 0.01$) and PEFR ($p < 0.05$) of farmers and non-farmers. The majority of farmers, 90.3% and 97.4%, recorded FEV₁ and PEFR lower than expected (LTEV) respectively, while 57.9% and 96.9% of non-farmers also recorded FEV₁ and PEFR lower than expected values, respectively.

Table 5 shows an association between FEV₁ and risk factors in the farming profession. Results showed that there was a relationship between FEV₁ and farming category (chi-square 9.325, $p < 0.01$), evidence of mold presence, water leaks and moisture in the building (chi-square 5.881, $p < 0.05$), year occupied building was built (chi-square 11.520, $p < 0.01$) and frequency of daily hand washing (chi-square 14.529, $p < 0.01$). Farmers who stayed between 8–20 years in a building were 1.2 times more at risk of having FEV₁ lower than expected value than those who have stayed above 20 years in a building (Table S4). This result is at variance with that reported by National Health Service (NHS) (2017) where buildings built between the 1970s–1990s are capable of increasing the risk of occupants to having asbestosis while a study by Gan *et al.* (2017) also attributed chronic respiratory diseases with older populations with the assumption that they are not likely to change residences.

Fisher's exact test showed that there is a relationship between PEFR and fuel dispensing, processing and grinding of farm produce and duration of stay in the building (Table 6). Farmers who dispense fuel were 10 times more likely than those who do not to have PEFR lower than the expected value (Fisher's exact test, $p = 0.028$; 95% Critical Interval (CI): 0.011–0.908, Odd Ratio (OR): 10.1), while farmers involved in grinding and processing of farm produce were 12 times more likely to have PEFR value that is lower than the expected (Fisher's exact test, $p = 0.019$; 95% CI: 0.009–0.775 OR: 11.8).

The results obtained from this study showed a significantly lowered FEV₁ among farmers

Table 4. Anthropometric parameters and lung function of respondents.

Variables	Subgroups	Range	Observed mean $\pm$ SD	p-value	% LTEV	% HTEV
Height (m)	Farmers	1.43–1.81	1.71 ± 1.1	0.877 ^a		
	Non-Farmers	1.38–1.75	1.72 ± 1.2			
Weight (kg)	Farmers	38.00–96.00	64.45 ± 9.87	0.148 ^a		
	Non-Farmers	38.00–96.00	62.89 ± 11.34			
BMI (kg m ⁻²)	Farmers	15.52–36.78	22.11 ± 3.79	0.253 ^a		
	Non-Farmers	11.92–39.68	21.62 ± 4.60			
FEV ₁ (L)	Farmers	0.02–5.05	1.16 ± 0.87	0.000	176 (90.3%)	19 (9.7%)
	Non-Farmers	0.75–5.03	2.47 ± 0.87		113 (57.9%)	82 (42.1%)
PEFR (L min ⁻¹)	Farmers	0.39–5.95	244.32 ± 117.96	0.017	190 (97.4%)	5 (2.6%)
	Non-Farmers	104.00–595.00	271.29 ± 104.09		189 (96.9%)	6 (3.1%)

^a p-value not significant, HTEV: Higher than expected value; LTEV: Lower than expected value.

Table 5. Associations between FEV₁ and risk factors in farming.

Risk Factors	Responses	FEV ₁		Chi-square	P
		LTEV	HTEV		
Farming category	Crop production	104 (94.5 %)	6 (5.5 %)	9.325	0.009
	Livestock	13 (72.2 %)	5 (27.8 %)		
	Both	59 (88.1%)	8 (11.9%)		
Evidence of mould presence, water leaks and moisture in building	No	130 (93.5 %)	9 (6.5 %)	5.881	0.015
	Yes	46 (82.1 %)	10 (17.9 %)		
Year occupied building was built	Before 1960–1975	119 (93.0 %)	9 (7.0 %)	11.52	0.003
	1976–2009	51 (89.5%)	6 (10.5%)		
	After 2009	6 (60.0%)	4 (40.0%)		
	Once	75 (97.4%)	2 (2.6%)		
Frequency of daily hand washing	Twice or thrice	68 (81.0%)	16 (19.0%)	14.529	0.001
	More than three times	33 (97.1%)	1 (2.9%)		

HTEV: Higher than expected value; LTEV: Lower than expected value.

Table 6. Associations between PEFR and risk factors in farming.

Risk Factors	Responses	PEFR			Fisher's Exact Test
		LTEV	HTEV	Total	
Fuel dispensing	No	54 (93.1%)	4 (6.9%)	58 (100%)	P = 0.028; 95% CI: 0.011–0.908 OR: 10.1
	Yes	136 (99.3%)	1 (0.7%)	137 (100%)	
Processing and grinding of farm produce	No	48 (92.3%)	4 (7.7%)	52 (100%)	P = 0.019; 95% CI: 0.009–0.775 OR: 11.8
	Yes	142 (99.3%)	1 (0.7%)	143 (100 %)	

HTEV: Higher than expected value; LTEV: Lower than expected value.

compared to non-farmers. This result is in line with studies in Ethiopia by Negatu *et al.* (2018) and Mekonnen and Agonafir (2002). These studies focused on pesticide application, while the present study considered the total work system of farmers. Similarly, a study in the Netherlands showed an exposure-dependent association between occupational pesticide exposure and reduction in FEV₁ (De Jong *et al.*, 2014). Apart from the pesticide application, another risk factor is mineral fertilizer handling (Rahman *et al.*, 2007; Hovland *et al.*, 2013).

The lowest FEV₁ and PEFR of farmers were taken at Ibiade while the highest FEV₁ and PEFR were documented at Ajegunle and Ikenne, respectively. The questionnaire analysis revealed that Ibiade is a typical crop farming settlement with a large-scale production of kernels for palm oil and visible smoke plume arising from biomass used as a source of fuel. At the same time, Ajegunle and Ikenne were mostly characterized by extensive animal husbandry (poultry and piggyery). The lung function results implied that extensive animal husbandry was likely to present a reduced risk of lung dysfunction than crop production. A study by Mackiewicz *et al.* (2015) showed a similar result, where the highest number of work-related respiratory symptoms was in crop farming, while it was lower in the piggeries and horse stables workers. These assertions were at variance with a study by Faria *et al.* (2006) in southern Brazil, which reported that poultry workers showed more symptoms of chronic respiratory diseases.

Similarly, Mackiewicz *et al.* (2015) reported that animal-related work settings resulted in a high load of bio-aerosols. A study by Akpinar-Elci *et al.* (2017) demonstrated that high dust characterized by spice production is responsible for increased lung dysfunction among workers. Furthermore, a study by Faria *et al.* (2006) revealed that farmers exposed to high dust concentration showed 70% increased risk of asthma symptoms, while Oluwole *et al.* (2013) research work agreed that biomass fuel utilization was associated with pulmonary dysfunction and inflammation of the airways.

Additionally, several wood smoke components (SO₂, NO₂ and particulate matter) could be released, especially during the processing of farm produce and impacting adversely on lung function by aggravating respiratory symptoms (Gong, 1992). The passage of dust particles could

Table 7. Linear relationship between lung function and particulate matter concentrations.

Y	X	Linear Curve Equation	R ²
PEFR	PM _{2.5}	Y= 0.2673X + 239.88	0.0007
PEFR	PM ₁₀	Y= -1.687X + 274.66	0.0363
PEFR	TSP	Y= -0.5673X +263.66	0.0105
FEV ₁	PM _{2.5}	Y=-0.0006X + 1.1656	0.000006
FEV ₁	PM ₁₀	Y = -0.0068X + 1.2778	0.0107
FEV ₁	TSP	Y = -0.0033X + 1.2699	0.0067

exacerbate inflammatory reactions resulting in fibrosis of the lungs and FEV₁ values reduction in (Longo *et al.*, 2012).

The negative impacts of pesticide handling and use were found to be a result of poor hygiene practices in tandem with the study by Atreya *et al.* (2012). The severity of post-pesticide exposure symptoms is highly dependent on the type of pesticide. According to Atreya *et al.* (2012), mild impairment of the acetylcholinesterase expression activity was experienced after exposure to organophosphate pesticides, while exposure to the pyrethroid insecticides and fungicides lead to acute symptoms. It was difficult to ascertain the type of symptoms and associate them with a type of pesticide because most of the farmers often use a different combination of pesticides to achieve maximum effectiveness.

Table 7 shows the linear relationship between lung function and particulate matter concentrations. Although the correlation coefficients, R² was generally low, PEFR revealed a negative correlation with PM₁₀ and TSP, while FEV₁ correlated negatively with PM_{2.5}, PM₁₀ and TSP. These results are expected because an increase in the concentrations of particulate matter leads to reduction in the lung function on exposed subjects. For example, a study by Olujimi *et al.* (2016) on charcoal workers reported negative correlations among PM_{2.5}, FEV₁ and PEFR. Weak correlation depicted by R² values was recorded in the linear regression analysis attributable to the levels of particulate matter that were within the permissible threshold set by the World Health Organization (WHO, 2005). Any increase in the levels of particulate matter will lead to the reduced lung function of exposed persons, especially those with sizes less than or equal to 10 µm due to the process of action of inhalable dust particles (Chen *et al.*, 2019). It is however noteworthy that the scope of this study could not ascertain causal relationship between exposures, risk factors and outcome variables; hence, further studies are required to determine causality.

4 CONCLUSIONS

Employing a spirometric index and perception studies, we predicted dust exposure among farmers living in selected farm settlements of Ogun State, Nigeria. The demographic data revealed that most of the farmers applied manure, fertilizer and chemical sprays without using PPE. Furthermore, a small percentage of the farmers had been diagnosed with health conditions, including allergies, asthma, conjunctivitis, chest conditions, emphysema, bronchitis and laryngitis. However, the non-farmers also reported diagnoses of chest conditions, allergies and conjunctivitis, and a majority in both groups agreed that poor air quality could lead to respiratory disease.

The maximum concentrations of the TSP and PM₁₀ were measured during the wet season, but the peak levels for the PM_{2.5} were observed during the dry season. All of the values we obtained fell within the permissible limits, despite significant seasonal variation ($p < 0.001$) in the mean concentrations of the PM₁₀ and PM_{2.5}. Nevertheless, we discovered obvious differences in the FEV₁ and PEFR between the farmers and the non-farmers ($p < 0.01$ and $p < 0.05$, respectively), although the greater part of either group exhibited lower values than expected. Additionally, negative correlations were found between the PEFR and the concentrations of the PM₁₀ and TSP as well as between the FEV₁ and the concentrations of the PM_{2.5}, PM₁₀ and TSP.

Overall, the farmers engaged in poor safety practices, which resulted in noticeably decreased lung function compared to non-farmers. Thus, routine particulate matter assessment and spirometric evaluation should be encouraged in farm settlements, and the adoption of safety measures, such as using PPE, should be recommended to workers.

DISCLAIMER

The authors declare no conflict of interest.

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SUPPLEMENTARY MATERIAL

Supplementary data associated with this article can be found in the online version at <https://doi.org/10.4209/aaqr.200509>

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