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Respiratory Symptoms and Spirometry Profile of Plastic Factory Workers in Ogun State, Southwest Nigeria

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Abstract

Background: Exposure to plastic fumes can lead to severe occupational hazards due to inhalation, ingestion or direct contact wide variety of potentially harmful by-products during the manufacturing and burning of plastics. **Objectives:** To determine the prevalence of respiratory symptoms in plastic factory workers, evaluate the respiratory function of plastic factory workers and the association between respiratory symptoms and the duration of employment. **Methods:** This was a cross-sectional study done among plastic factory workers. Using a random sampling technique, 190 individuals (95 subjects and 95 control) above 18 years of age were recruited. Data were obtained with a validated questionnaire and Spirometry was done. **Result:** The mean age of the study group and control were 30.27 ± 7.38 and 25.92 ± 4.63 respectively ($t = 4.877$; $p < 0.001$). There were 27 males and 68 females in the study group and 28 males and 67 females as control. Cough was the most prevalent symptom among study subjects and control with no statistical significance. There was statistically significant difference between mean pre bronchodilator volumes and PEFR between study group and control ($p < 0.05$). Restrictive pathology was seen more in study group than controls ($p < 0.04$). **Conclusion:** Workplace exposure to plastic fumes can lead to development of respiratory symptoms and impaired pulmonary function.

Keywords

Plasticos, Thermoset, Thermoplastic, Styrene, 1,3-Butadiene, Microplastics

1. Introduction

The health challenges posed by environmental pollutants in work places had been a subject of numerous studies in the past [1] [2]. Some of these studies have been linked with decrease in pulmonary function [3]. These declines in lung function are closely linked to the nature and level of exposure to these pollutants. The effects of plastic on the body and the environment have been well documented [4] [5] [6] but the effect of its bye products especially during the process of manufacturing has also been generating concerns in scientific cycle. In recent memory, there had been increasing concerns on the effect of synthetic polymers of plastic being inhaled as small fibers by plastic factory workers worldwide but particularly plastic factory workers in USA, Canada and India [3].

The word plastic comes from a Greek word "plasticos" which means the ability to be shaped or molded by heat. Plastic can be categorized into: 1) Natural plastics which are naturally occurring pine tree resins which can be shaped and molded by heat, 2) Semi synthetic plastics which are naturally occurring materials that can be molded or shaped by mixing other materials with them e.g., cellulose acetate and 3) Synthetic plastics often gotten from breaking down or "cracking" carbon-based materials like crude oil, coal or gas [4].

Synthetic and semisynthetic plastics are further divided into two main types of plastics: thermoset and thermoplastic. This distinction is based on the ways in which these two react to heat. Thermoset has rigid chemical structure and cannot be changed, reshaped or melted after initial molding. Thermoplastic can be re-melted and reshaped easily making it the most widely used plastic type in packaging industries [5].

Plastic fumes can potentially cause severe occupational hazards as a result of a wide variety of byproducts (e.g. Microplastics) or additives released during the manufacturing process, heat treatment and burning of plastics [3]. During manufacturing of plastics injection molding machines require purging to remove residual resin from the machine and this process occurs at a very high temperature in order to melt the plastic and purging agents which lead to the release of smoke and plastic fumes. The fumes released during heating may contain potentially harmful agents such as styrene (STY) and 1,3-Butadiene (BD). Styrene is an aromatic hydrocarbon, liquid at room temperature naturally occurring as exudates of certain trees and can be made commercially. BD is a carbon olefin, gaseous at room temperature and produced during "cracking" of petroleum [6].

Microplastics are synthetic solid particles with regular or irregular shape and with varying sizes which may range from 1 μm to 5 mm. They are often produced during either primary or secondary manufacturing processes of plastics.

They are insoluble in water and can gain entrance into the human body through ingestion (through contaminated food and water), through inhalation, or direct skin contact. Some studies showed that microplastics with sizes less than 10 μm can penetrate most organs of the body including the ability to cross the blood brain barrier and the placenta bed. Following the intake of microplastics into the human body, their fate and effects are still controversial and not well understood [7].

The low cost, resistant to chemical agents and corrosion has led to increased use of plastic materials for, construction, storage and packaging in Nigeria. In Nigeria with a population of approximately 200 million, there are neither data on the numbers of industries manufacturing plastic nor any data on the use of plastic, their disposal, collection and recycling method [8] [9]. However, the production and consumption of plastic in Nigeria has increased many folds reaching about 411,000 tons between 2007 and 2015 and estimated to reach 513,000 tons by 2020 [10]. There has been an increased concern on the potential negative health effects of inhaled plastic vapor during the process of manufacturing which may lead to inhalation of synthetic polymers as micro fibers or flocks which had led to several cases of interstitial lung diseases called "flock workers lung" in USA and Canada [11] [12] [13]. Other adverse effects of plastic fumes on the body include aggravated asthma, chronic obstructive pulmonary diseases, headaches, kidney, liver and lung failures, skin irritations, leukemia, lymphomas and cancers of the lungs [13]. There are no documented evidences of acute or long-term inhalation or exposure to plastic vapor directly causing death in plastic factory workers. However, long term exposure has been associated with increased risk of malignancies which may shorten the life span of plastic factory workers [14] [15] [16].

There are peculiar challenges associated with measurement of exposure to hazardous agents in workplaces especially in developing economy like Nigeria where government oversight is deficient and occupational laws are not obeyed by industries. Greater awareness and improved communication are needed to further prevent work related health effects of hazardous chemical agents. To the best of our knowledge the effects of exposure to plastic fumes has not been studied in plastic factory workers in Nigeria. This underlines the need for this study and the importance of this evaluation in adding to the limited knowledge of effects of plastic fumes on the respiratory function of black Africans. This study was designed to determine the prevalence of respiratory symptoms in plastic factory workers, evaluate the respiratory function of plastic factory workers, investigate the relationship between respiratory symptoms, respiratory functions and the duration of employment, in plastic factory workers.

2. Materials and Method

Study location

This study was carried out among plastic factory workers in a private plastic manufacturing company located at kilometer 158, KM farms, Benin-Sagamu expressway, Soyindo, Sagamu local government area, Ogun State, Nigeria.

Study design and population

This descriptive, cross-sectional study which employed both quantitative and qualitative data collection methods was done among plastic factory workers in Sagamu, Ogun State, Nigeria.

Study duration

The study commenced on 1st of April, 2021 and was completed on 20th of June, 2021.

Subject selection

This descriptive cross-sectional study involved all factory workers in this plastic factory who voluntarily expressed their desire to participate in the study. Consenting healthy controls were recruited to match for age, sex, weight and height from among healthy hospital health workers. All consecutive plastic factory workers and controls that fulfilled the inclusion criteria and gave informed consent were included in this study.

Inclusion criteria

Participants and controls subjects must be 18 years and above, must have worked in the factory for more than 1 year and must not have history of asthma, chronic obstructive pulmonary disease or any other chronic lung diseases.

Sample size determination

The minimum sample size of 94 required for this study was determined using the formula for estimating proportions of population parameter where the significant level was set to 0.05, standard normal variate of 1.96 (at 95% confidence level), precision of 5%) and prevalence of 50% from a sample with comparison groups.

Sampling technique

Random sampling technique was used in this study. The list of all plastic factory workers and controls was compiled and all consenting individuals above 18 years of age who fulfilled the inclusion criteria were recruited for the study.

Data collection tools and techniques

Data was obtained by a trained interviewer with a validated questionnaire and Spirometry was then done with Spirolab III. The questionnaire was adapted from relevant sections of Medical Research Council's Committee questionnaire (MRCQ) on Environmental and Occupational Health. Information obtained included the socio-demographic characteristics and respiratory symptoms of the plastic factory workers. The participants and controls then performed spirometry (pre and post bronchodilator) in line with the standard operating procedure of American Thoracic Society (ATS) and European Respiratory Society (ERS) [17] by a trained doctor. The spirometer was calibrated daily to check appropriate quality control measures will be observed during the spirometry.

A maximum of eight trials were carried out to obtain a minimum of three acceptable tests with reproducible FEV1, FVC and ratio of FEV1/FVC values after maximal expiration within 5 % predictive value for age, sex and height. The post bronchodilation values were obtained 5 - 20 minutes after the administration of 400 μg of inhaled salbutamol via a spacer device. Significant response to bronchodilation was measured as >12% or 200 mls increase in the values of FEV1 or FVC. Spirometry pattern was characterized as obstructive (FEV1/FVC < lower limit of normal (LLN) with FVC < LLN, probably restrictive (FVC < LLN with FEV1/FVC ≥ LLN), mixed FWV1/FVC < LLN with FVC < LLN) and normal (FEV1≥ and FVC≥ LLN). The environment was monitored and efforts were made to ensure that ambient conditions were within accepted ranges [18].

Data analysis

The data obtained were analyzed using International Business Machine-Statistical Package for Social Sciences (IBM-SPSS) version 25.0 software. All numerical quantitative variables were summarized in mean and standard deviation. The means and standard deviations of the numerical variables were compared using student t-test. The level of statistical significance was set at p values of less than 0.05. Percentages and proportions were used to describe categorical variables. Relationships between dependent and independent variables were analyzed using Chi-square at 5% level of significance.

Ethical clearance/approval

Ethical approval was obtained from Department of Health Planning, Research and Statistics, Ogun State Ministry of health, Abeokuta, Ogun State (*HPRS/*381*/*379), Nigeria. Confidentiality and privacy of participants was duly respected during and after the period of collecting and collating of data. Serial numbers rather than names w used to ensure confidentiality.

3. Results

The sociodemographic and Anthropometric characteristics of both groups are highlighted in **Table 1**. The mean age of the study group and the control were 30.27 ± 7.38 and 25.92 ± 4.63 respectively ($t = 4.877$; $p < 0.001$). there were 27 males and 68 females in the study group and 28 males and 67 females in the control group. There were no statistical differences in the sex ($p = 0.873$), marital status ($p = 0.338$), weight ($p = 0.311$) and heights ($p = 0.059$) between the study group and controls.

The prevalence of respiratory symptoms in the study and control groups is shown in **Table 2**. Cough is the most prevalent symptom among study subjects. 69 (72.6%) of study subject complained of cough on frequent basis compared to only 11 (11.6%) among the control group. The difference was statistically significant. The differences observed in whether participants had other symptoms of phlegm production, breathlessness on walking along a flat terrain and wheezing between study group and controls were not statistically significant ($p > 0.05$).

The mean pre bronchodilator lung volume parameters (FEV1 and FVC) and peak expiratory flow rate were significantly decreased in the plastic factory workers compared to the control group ($p < 0.05$) while the differences recorded

Table 1. Socio-demographic and anthropometric characteristics of study participants.

Variable	Study Group n (%)	Control n (%)	Test Statistics
Age (Years)			
≤20	5 (5.3)	10 (10.5)	
21 - 30	46 (48.4)	70 (73.7)	
31 - 40	34 (35.8)	14 (14.7)	
≥41	10 (10.5)	1 (1.1)	
Mean	30.27 ± 7.38	25.92 ± 4.63	$t = 4.877$; $p < 0.001$
Sex			
Male	27 (28.4)	28 (29.5)	
Female	68 (71.6)	67 (70.5)	$X^2 = 0.026$; $p = 0.873$
Religion			
Christianity	69 (72.6)	85 (89.5)	
Islam	26 (27.4)	10 (10.5)	$X^2 = 8.773$; $p = 0.003$
Marital Status			
Single	62 (65.3)	66 (69.5)	
Married	27 (28.4)	25 (26.3)	
Divorced/Separated	5 (5.3)	1 (1.1)	
Widowed	1 (1.1)	3 (3.2)	$X^2 = 4.535$; $p = 0.338$
Job Description			
Factory Worker	82 (86.3)	23 (24.2)	
Administrative Staff	6 (6.3)	22 (23.2)	
Others	7 (7.4)	50 (52.6)	$X^2 = 74.734$; $p < 0.001$
Duration of employment (Years)			
<1	7 (7.4)	27 (28.4)	
1 - 5	77 (81.1)	58 (61.1)	
6 - 10	9 (9.5)	6 (6.3)	
≥11	2 (2.1)	4 (4.2)	$X^2 = 15.705$; $p = 0.001$
Height (Cm)			
≤150	6 (6.3)	5 (5.3)	
151 - 160	27 (28.4)	19 (20.0)	
161 - 170	43 (45.3)	42 (44.2)	
≥171	19 (20.0)	29 (30.5)	$X^2 = 3.577$; $p = 0.311$
Weight (kg)			
≤50	8 (8.4)	6 (6.3)	
51 - 60	21 (22.1)	20 (21.1)	
61 - 70	37 (38.9)	23 (24.2)	
≥71	29 (30.5)	46 (48.4)	$X^2 = 7.430$; $p = 0.059$

in mean post-bronchodilator values of FEV1, FVC, PEFR and FEV1/FVC between the two groups were not statistically significant (Table 3). The participants were then divided into three subgroups on the basis of duration of exposure as unexposed(A), less than 5 years of exposure (B) and more than 5 years of exposure (C). Significant difference between A & B, A & C, and between B & C were observed for most of the parameters (Table 4).

The spirometry outcome in majority of participants in the study group (n = 82, 86.3%) and control group (n = 93, 97.8%) were normal. However, 12 study participants comprising of 11 (11.6%) subjects and 1 (1.1%) control had restrictive lung pathology while 2 (2.1%) subjects and 1 (1.1%) control had obstructive pathology (Table 5).

Table 2. Clinical Symptoms parameters in study group and controls.

Variables	Study group n (%)	Control n (%)	X^2	p-value
Cough				
Yes	69 (72.6)	11 (11.6)	7.552	0.001
No	26 (27.4)	84 (88.4)		
Phlegm production				
Yes	21 (22.1)	15 (15.8)	1.234	0.267
No	74 (77.9)	80 (84.2)		
Breathless while walking on level ground or up a slight hill				
Yes	21 (22.1)	9 (9.4)	5.700	0.017
No	74 (77.9)	86 (90.6)		
Had wheezing attack at any time in past 12 months				
Yes	14 (14.7)	9 (9.4)	1.237	0.266
No	81 (85.3)	86 (90.6)		

Table 3. Comparison of spirometry parameters between study group and Control.

Variables	Study group (N = 95) Mean ± SD	Control group (N = 95) Mean ± SD	T test	p-value
Pre-bronchodilator FEV1 (L)	1.93 ± 0.43	2.17 ± 0.54	3.38	0.001
Pre-bronchodilator FVC (L)	2.54 ± 0.37	2.88 ± 0.62	4.49	<0.001
Pre-bronchodilator FEV1/FVC (%)	91.23 ± 6.17	98.69 ± 4.33	-	0.677
Post-bronchodilator FEV1 (L)	2.19 ± 0.46	2.30 ± 0.55	1.50	0.136
Post-bronchodilator FVC (L)	2.92 ± 0.41	2.97 ± 0.66	0.59	0.560
Post-bronchodilator FEV1/FVC (%)	96.23 ± 7.27	98.92 ± 2.43	-	0.347
Pre-bronchodilator PEFR (L/min)	3.91 ± 0.74	4.42 ± 1.26	3.38	0.001
Post-bronchodilator PEFR (L/min)	4.37 ± 0.81	4.58 ± 1.37	1.28	0.202

Table 4. Comparison of lung function parameters on the basis of duration of exposure.

Variables	Controls (A) n = 95	Study group (B): exposure ≤ 5 years n = 84	Study group C: exposure > 5 years n = 11
Pre-bronchodilator FEV1 (L)	2.17 ± 0.54*	1.98 ± 2.33	1.55 ± 0.76
Pre-bronchodilator FVC (L)	2.88 ± 0.62#	2.49 ± 0.54	2.72 ± 0.11
Pre-bronchodilator FEV1/FVC (%)	98.69 ± 4.33	92.18 ± 4.31	83.98 ± 6.73
Post-bronchodilator FEV1 (L)	2.30 ± 0.55*	2.32 ± 0.19	2.14 ± 0.47
Post-bronchodilator FVC (L)	2.97 ± 0.66*	2.98 ± 0.73	2.46 ± 0.78
Post-bronchodilator FEV1/FVC (%)	98.92 ± 2.43*	100.76 ± 4.82	83.23 ± 4.11
Pre-bronchodilator PEFR (L/min)	4.42 ± 1.26	4.01 ± 2.31	3.98 ± 6.44
Post-bronchodilator PEFR (L/min)	4.58 ± 1.37	4.21 ± 065	3.92 ± 1.22

Data presented are mean ± SD; *Significant difference between A & B and A & C; #Significant difference between B & C.

Table 5. Spirometry outcomes in study group and Controls.

Spirometry Variables	Study group (%) n = 95	Controls (%) n = 95
Normal	82 (86.3)	93 (97.8)
Obstructive	02 (2.1)	1 (1.1)
Restrictive	11 (11.6)	1 (1.1)

$X^2 = 1.821$, $p = 0.042$.

4. Discussion

The result of this study has shown that plastic fumes have effect on the health status of plastic factory workers. These workers are susceptible to developing respiratory symptoms such as cough and abnormal respiratory function. The flow rate and volumes were decreased in plastic factory workers compared to controls. It was also observed that plastic factory workers who had worked for more than five years in the industry had lower lung volumes and rates compared to controls. This shows poor ability of the thoracic cavity to adequately expand which limits respiratory excursion and ventilation.

The findings in our study are similar to findings in other studies [7] [8] [9]. Cases of direct injuries to the lung like flock lung have been reported and amply documented [11] [12]. Eschonbacher WL *et al.* reported that nylon flock associated, respiratory symptoms, systemic symptoms and interstitial lung diseases were seen in nylon flock workers in North America [13]. These symptoms often get worse during working hours and were directly related to the duration of work hours [13]. Mortality have also been reported in plastic factory workers who were exposed to styrene/plastic fumes [19] [20] [21].

Restrictive lung pathology was the dominant abnormal spirometry pathology found in our study while majority of study subjects and controls had normal lung functions. This finding is in agreement with findings in studies done in other parts of the world [3] [13] [21] [22]. This study also suggests that short duration of exposure to plastic fumes as low as one year can cause the damage to the lung and impair respiratory function. These could be prevented to a large extent by ensuring adequate ventilation within the factory, melting plastics during manufacturing at correct melting temperature and provision of personal protective equipment to factory workers such as respirators, aprons and gowns [23] [24]. This observation is supported by experimental models observed in rats in a study carried out by Hesterberg TW *et al.* [25].

5. Conclusion

Workplace exposure to plastic fumes is associated with development of respiratory symptoms and pulmonary function impairment among plastic factory workers. Adequate provision of required protective equipment and appropriate surveillance and enforcement of factory rules and regulation may help in mitigate potential future health challenges.

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Authors' Contribution

All the authors participated in the conception and design of the study, literature review, data analysis and interpretation, drafting of the manuscript and review of the draft manuscript for sound intellectual content. All the authors approved the final version of the manuscript.

Conflicts of Interest

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

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