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Effect of Exposure to Airborne Chalk Dust Particles on Students' Respiratory Function

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Abstract

The use and reuse function of chalkboard produces chalk dust particles in the classroom entering into the classroom occupants' respiratory system through their mouths and nasopharyngeal regions while talking or breathing. The potential impact of dust particles of the respiratory system includes airflow resistance, lung volumes impairment and lung damage. This study measured the expired volume of air from the lungs during a guided maximal expiration to determine the effect of chalk dust particles on the ultimate lung function in the classroom. The sociodemographic characteristics of the participants were assessed using oral interview while the assessment of the anthropometric data and the participants' lung function indices was done through the use of a stadiometer and digital spirometer, respectively. This study employed a quasi-experimental research design. It involved the exposed (n = 120) and control (n = 120) groups selected from classrooms where chalkboards and marker boards were used, respectively. The results revealed that among the lung functions indices investigated, there were statistical significant differences between the exposed and the control groups in FEV1 (%) (0.002), PEFR (L/s) (0.000), FEF25 (L/s) (0.000) FEF75 (L/s) (0.000), FEF25-75 (L/s) (0.000), FEV1 (%) (0.002) but no significant differences in FEV1 (0.135), FVC (0.493) and FVC (L) (0.506). Therefore, chalk dust particles from chalkboard usage had a negative effect on the respiratory function (lung function indices) in the classrooms.

Keywords*:* chalkboard, dust particles, spirometer, classroom, respiratory system

1. Introduction

Chalkboard creates dust in the classroom that becomes airborne when erasing the content of the board (Buchanan, 2018). The amount depends on the quality of the chalk used. Chalks labeled with either anti-dust or dustless by the producer still release a small number of dust particles into the atmosphere. Even though dusting and anti-dust chalks produce dust particles (Majumdar and William, 2009; Lin *et al.*, 2015), the harmful potentials of dust particles from dusting chalks could be higher than that of anti-dust chalks. The number of dangerous particles that dusting chalks generates is higher compared with that of dustless chalk. Dusting chalks for chalkboards produce particulate matter (PM) in the range of 4.5 and 11 μm (Majumdar and William, 2009).

Writing on and cleaning the chalkboard generate chalk dust in the classroom that enters the classroom occupants' respiratory system through their mouths and nasopharyngeal regions while talking or normal breathing (Majumdar and William, 2009). The study of Majumdar and William (2009) added that compared with writing, cleaning the chalkboard produces higher airborne dust. Chalk dust, like other particulate matters, as long as they are re-suspended in the atmosphere, exhibits random movement while they remain suspended in the air. However, after a while, the excitation reduces and they begin to settle on surrounding bodies and surfaces – the floor, students' desk, and teacher and student's body parts.

Air drift in the room and classroom occupants' feet movements can agitate the settled chalk dust particles on the floor back into the air and then enter either the upper or lower respiratory tract depending on the size (Heinke, 1996; Majumdar and William, 2009). Previous studies showed the entry principles of PM into the human respiratory tract and their effects on the respiratory system of humans (Gamble, 1998; Pinkerton *et al.*, 2000; Lewis *et al.*, 2005; Debray *et al*., 2008). Respiratory symptoms associated with dust particle entry in the respiratory tract include nose and throat irritation, inflammation, mucus production, coughing, sneezing, asthma, and decreased lung function (Delfino *et al.*, 1998; Norris *et al.*, 1999; Raabe, 1999; van der Zee *et al.*, 1999; Yu *et al.*, 2000; McConnell *et al.*, 2003). The ultimate function of the lung is dependent on the respiratory rate, airway resistance, compliance, and lung's elasticity (Mridha, 2012).

The dust-related respiratory diseases cause impairment in lung volumes and flow resulting in lung damage. The major challenge involving dust-related respiratory diseases is that they are often left unnoticed in earlier time. It can only be observed in the advanced stages; that is when the lung tissue had already been damaged. Adeyeye *et al*. (2012) noted that the global challenges of pulmonary disease are enormous. Worldwide, respiratory diseases principally represent a significant proportion of human disease (Lozano, 2012). It was pointed out categorically in a recent report that respiratory diseases, falling under five leading causes of death worldwide, were chronic obstructive pulmonary disease (COPD), lower respiratory tract infections and lung cancer (Obaseki *et al*., 2015). Also, the non-communicable chronic respiratory diseases (CRD) that resulted in an approximate proportion of 80% of deaths worldwide took place in low- and middle-income countries (Bousquet *et al*., 2007). Among the 23 countries found in the global burden of disease analysis that constituted the said death percentage, Nigeria ranked first in Sub-Saharan Africa (Abegunde *et al*., 2007). With the growing trend of respiratory disease in morbidity and mortality worldwide, according to the World Health Organization's (WHO) prediction on death rate determinants, COPD would be among the foremost causes of death worldwide by the year 2030, occupying the fourth position (WHO, 2011).

An early investigation, diagnosis, and provision of appropriate interventions are needed ultimately for the improvement of quality health care. Respiratory diseases, which caused morbidity and mortality tendency in the low- and middle-income countries, demand close observation of people and timely identification of nature or causation factors of both acute and CRD (WHO, 2003).

In developing countries like Nigeria, where the tools for the investigation of lung volumes and flows are inadequate, it is essential to effectively maximize the use of the available, simple non-invasive tools such as the spirometer (Adeyeye *et al*., 2012). Spirometry has been proven to be a dynamic lung volume timed measurement during forced inhalation and exhalation for quantification of how quick and effective the lungs can be filled and emptied (Pierce *et al*., 2005). It is used to improve diagnosis and monitor acute and CRD. Fairall *et al*. (2005) revealed that many respiratory illnesses are preventable if diagnosed and controlled at an early stage. Application of spirometry tests in a pre-selected high-risk population substantially improved the competence and case-finding for COPD (Hamers *et al*., 2006).

Forced vital capacities (FVC), forced expiratory volume in the first second (FEV1), and peak expiratory flow rate (PEFR) are the most common lung function indices used in the estimation of lung function (Akhiwu and Aliyu, 2017). Established in the literature, factors influencing lung function include age, sex, height, weight, ethnicity, and environment (Nku *et al*., 2006). The various pulmonary function tests mostly used in the epidemiological and clinical examinations to investigate the functional status of the human respiratory system can be restrictive, obstructive, or mixed-type processes (Lebowitz, 1991; Mridha, 2012). However, these tests only help in understanding the physiology, impairment course, progress, and severity of the respiratory diseases, since they only serve as guide in several respiratory disease management but not in the provision of specific diagnosis (Swaminathan, 1999).

A range of studies in Nigeria that assessed children and teens specifically considered ethnicity and geographical locations with no specifics, covering the proximate inhibiting environment factors such as classroom (Aderele and Oduwole, 1983; Onadeko *et al*., 1984; Jaja and Fagbenro, 1995; Mojiminiyi *et al*., 2006; Mohammed *et al*., 2015). In studies that considered the environmental factors, occupational dust particles such as cement, grain and flour dust, among others, were the main focus (Cotton and Dosman, 1978; Taytard *et al*., 1988; Alakija *et al*., 1990; Bachmann and Myerset, 1991; Abou-Taleb *et al*., 1995; Nag *et al*., 1996; Rafnsson *et al*., 1997; Noor *et al*., 2000; Al-Neaimi *et al*., 2001; El Badri and Saeed, 2008; Zeleke *et al*., 2010; Mishra and Azam, 2018).

Although the use of chalkboard is significant, conventional teaching aid, there is no valid evidence yet in the pieces of scholarly literature that precisely characterized the respiratory risk of chalk dust particles on the classroom occupants in Nigeria. This was revealed by the result of online databases search made by the authors of the present study. Students spent most of their time (6 to 8 h) at schools particularly in classroom; hence, good quality classroom environment has to be assured for the well-being of the students (Kekare, 2015). Therefore, this study investigated the effect of chalk dust particle from chalkboard usage on students' respiratory function.

2. Methodology

2.1 Study Site and Participants

In Abeokuta metropolis, the average annual rainfall, relative humidity, ambient temperature, and wind speed are 750 mm, 74%, 28 °C, 2.9-4.0 m/s, respectively (Ajayi *et al*., 2017). Abeokuta has an elevation of 66 m height above sea level. The respiratory function assessment of chalkboard usage as dust exposure risk factor in classroom environment was conducted in six different schools in Abeokuta City, Nigeria. The study involved 240 participants (120 exposed and 120 control) within the interval of two months from May to July 2018 (rainy season). The selected 120 students from five schools that used chalkboards were the ones who sit in first and second rows of their respective classrooms. These students were chosen as exposed because of their proximity and high level of exposure to chalk dust. The schematic diagram of the classrooms in six different schools where the selection of study population samples was made is presented in Figure 1.

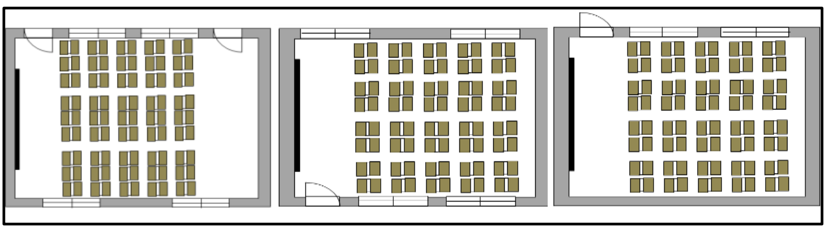

Figure 1. The schematic diagram of classrooms in six different schools

Aligned as part of the wall, chalkboards used in the classrooms were of black color and made with sand-concrete. The average period in a day that students spend in their classrooms for teaching and learning process was 6 h. There was no regular change of seating positions in each classroom. The 120 participants in the control group were randomly selected from the sixth school that typically use marker board.

2.2 Instruments and Data Collection

This study utilized bathroom scale, stadiometer and Contec SP-10 digital spirometer (Contec Medical Systems Co. Ltd., China). According to Mridha (2012), spirometers are devices that essentially calculate or display the FEV1, FVC, and PEFR.

The participants were notified about the aim of the study and their selection to participate after permission was granted by the school management. Oral interview was conducted using a designed questionnaire which extracted the participants' sociodemographic characteristics (age and gender). The results served as bases as to whether or not a student would be qualified to participate in the study. The health issues that served as exclusion criteria were cardiopulmonary diseases and respiratory symptoms, namely nasal block, asthma, pneumonia, cough, shortness of breath when walking, phlegm production, sneezing, chest tightness, pneumothorax, and hemoptysis. Students who had thoracic, recent abdominal and eye surgeries, myocardial infarction or unstable angina, and suspected or confirmed cerebral or aortic aneurysm of communicable infectious disease (influenza or tuberculosis) were also excluded to participate including those who smoke and drink alcohol.

The anthropometric data (weight, height, and body mass index) were assessed using a stadiometer. Instructions given through explanation and demonstration concerning the participants' role were performed. The participants who understood the detailed procedure through self-demonstration with sufficient proficiency needed for the lung function assessment and who expressed their willingness to participate, were included. It was ensured that the participants neither performed strenuous exercise nor ate heavy meals a few hours before the scheduled test time, which was done on weekdays. However, Wednesdays (sports day) were excluded since participants from the selected schools play sports during break time. For participants' optimum performance, a secluded tent was designated for the participants, entering one at a time, and the researcher for data collection. Upon arrival, a two- to three-minute rest was given for each participant before the spirometry test.

The personal data of the participants (age, gender, height and weight) were entered into the digital spirometer. While standing, participant inhaled deeply, clipped his or her nose, occluded his or her lips tenaciously around the spirometer's disposable mouthpiece, and exhaled as hardly and as quickly as possible at a maximal inhalation until the participant could no longer blow. For each participant, three readings were taken with a two- to three-minute rest interval in between. The best among three readings was analyzed. The lung function indices assessed and recorded using the digital spirometer were forced expiratory volume in 1 s (FEV1), forced expiratory volume in 1 s as a percentage of forced vital capacity (FEV1%), FVC, PEFR, 25% flow of the FVC (FEF25%), 75% flow of FVC (FEF75%) and average flow between 25 and 75% of FVC (FEF25-75%).

2.3 Data Analysis

The data obtained from exposed and control groups was analyzed descriptively. To determine whether there was a relationship between PEFR and FEV1 of the exposed group, the Pearson correlation was used at alpha level 0.05 or 95% confidence level for significance. Independent sample T-*t*ests were conducted to compare the mean lung function indices of the two groups (exposed and control) and to determine whether there were significant differences between the groups. These analyses were performed using the Statistical Package for the Social Sciences (SPSS) 20.0.

3. Results and Discussion

The data from participants, who met the inclusion criteria from the targeted population, was subjected to data analysis. These gave a response rate of 82% (120/146) for the control group and 80% (120/150) for the exposed group. The result of the descriptive statistical analysis carried out on the sociodemographic characteristics, anthropometric data, and lung function indices obtained from the exposed participants are presented in Table 1. The mean ± SD of age, height, weight, and body mass index of the subjects was 14.08 ± 2.24 years, 155.09 ± 14.81 cm, 39.54 ± 11.16 kg, and 16.09 ± 2.23 kg/m^2, respectively (Table 1).

Table 1. Descriptive statistics of sociodemographic characteristics, anthropometric and lung function indices of exposed group (n = 120)

Variables	Minimum	Maximum	Mean	Std. Deviation
Age (years)	10.00	18.00	14.08	2.24
Height (cm)	124.00	180.00	155.09	14.81
Weight (kg)	20.00	68.00	39.54	11.16
BMI (kg/m^2)	12.19	22.15	16.09	2.23
FVC (L)	0.72	6.42	1.98	0.99
FEV1	0.52	6.42	1.48	0.81
PEFR (L/s)	0.59	9.54	2.92	1.36
FEF25 (L/s)	0.13	5.95	2.29	1.19
FEF75 (L/s)	0.20	3.33	1.18	0.61
FEF25-75 (L/s)	0.23	3.90	1.66	0.90
FEV1 (%)	16.00	100.00	79.35	23.37
FER	0.16	1.37	0.80	0.25

Table 2 shows the comparative analysis of sociodemographic characteristics, anthropometric data, and lung function indices of the exposed and control participants to ascertain the effect of chalk dust particles in the classroom environment. The mean ± SD PEFR of the exposed participants in this study was 2.92 ± 1.36 L/s), which was statistically lower than the control participants (3.9 ± 1.37 L/s).

Table 2. Comparison of sociodemographic characteristics, anthropometric and lung function indices of exposed group

Variables	Exposed group	Control group	P-value
Age (years)	14.08 ± 2.24	14.09 ± 1.99	0.977
Gender	1.39 ± 0.49	1.48 ± 0.50	0.139
Height (cm)	155.09 ± 14.81	154.71 ± 20.13	0.987
Weight (kg)	39.54 ± 11.16	38.66 ± 12.34	0.558
BMI (kg/m^2)	16.09 ± 2.23	16.56 ± 2.94	0.383
FVC (L)	1.98 ± 0.99	2.05 ± 0.71	0.506
FEV1	1.48 ± 0.81	1.74 ± 0.48	0.002
PEFR (L/s)	2.92 ± 1.36	3.9 ± 1.37	0.000
FEF25 (L/s)	2.29 ± 1.19	3.06 ± 1.24	0.000
FEF75 (L/s)	1.18 ± 0.61	1.73 ± 0.84	0.000
FEF25-75 (L/s)	1.66 ± 0.90	2.31 ± 1.07	0.000
FEV1 (%)	79.35 ± 23.37	88.13 ± 17.32	0.002
FER	0.80 ± 0.25	0.89 ± 0.17	0.594

FVC assessment which technically measured the maximal volume of air and not the flow rate that an individual can forcibly expel from the lungs at a maximal inhalation for the two groups showed that the FVC for exposed group was statistically higher (1.98 ± 0.99 L) than the control group (2.05 ± 0.71 L). It was observed that the exposed group also had statistically lower FEV1 (1.48 ± 0.81 L) compared with the control group (1.74 ± 0.48 L), $p = 0.002$ (Table 2). The mean forced expiratory ratio of the exposed group (79.35 ± 23.37%) was found to be lower compared with the control (88.13 ± 17.32%). This is statistically different at $p < 0.05$. The relationship between the PEFR and FEV1 analyzed using Pearson's correlation analysis gave an "r" value of 0.436, which was a positive correlation significant at $p < 0.01$ (Table 3).

Table 3. Correlations analysis between the PEFR and FEV1 of exposed group

		PEFR (L/s)	FEV1
PEFR (L/s)	Pearson Correlation	1	0.436**
	Sig. (2-tailed)		0.000
	N	120	120
FEV1 (L)	Pearson Correlation	0.436**	1
	Sig. (2-tailed)	0.000	
	N	120	120

** – correlation is significant at the 0.01 level (2-tailed).

The identification and assessment of the degree of airflow limitations of the participants conducted using PEFR showed that the mean ± SD of the exposed (2.92 ± 1.36 L/s) was statistically lower than the control group (3.9 ± 1.37 L/s) (Table 2). The reduction in the speed of expiration observed among the exposed participants buttresses the study of Meo (2004), who stated that the dust exposure doses and frequency reduce an individual's PEFR. The observation in this study is also in line with the results from previous works (Neas *et al*., 1995, 1996), wherein it was found out that dust particles are associated with PEFR declination in children. Dust particles entrance into the respiratory tracts narrows the tubes as such lowers PEFR (Diner *et al*., 2001). Glory *et al*. (2017) attributed the narrowing of the pipes to the rapid response of the receptors within the airway, thereby causing inflammation termed bronchoconstriction. The bronchoconstriction is either an effect of indirect airway fibrosis or direct smooth muscle tone increase, which thickens the walls of the respiratory tubes leading to airway narrowing, and increased airflow limitation as observed from the exposed person (Glory *et al*., 2017).

FEV1 represents the volume of air forcefully expired from full inhalation in the first second of FVC or expiratory maneuver starting from total lung capacity (TLC) that reflects the caliber of airway and measures airway obstruction (Nwagha, 2011; Oni *et al*., 2014). The spirometry analysis of the various average lung function indices, FEV1 and FVC, assessed among the exposed participants in the present study showed an average mean of 2.92 (SD = 1.36) L/s, 1.48 (SD = 0.81) L, 1.98 (SD = 0.99) L (Table 1).

The FEV1 and FVC values obtained in this study when compared with the referenced value range stated by Tietze (2012) for lung function indices (FVC = 0.8, FEV1 = > 1.0), showed that the participants had healthy lungs. The comparison of the ultimate lung function using the lung function indices for the decline in the lung function revealed the FEV1 and FVC of the exposed subjects in the present work were statistically lower than the control participants although not significant in terms of FVC (Table 2). This result signifies that chalk dust affects the respiratory systems of the exposed participants as the degree of airflow limitations was higher than that of the control. This result also implies that the airway of the control had higher quality and less airway obstruction than the exposed.

The result of this study is in agreement with Meo (2004), who underscored that PEFR decreases by doses and frequency of dust exposure. In the same manner, the outcome of the present investigation was the same with Noor *et al*. (2000), Zeleke *et al*. (2010), and Shobana *et al*. (2015), who did related works of similar purpose. This study also added to the majority of evidence suggesting that dust exposure affects human respiratory functions (Praveen *et al*., 2015; Shobana *et al*., 2015). The chalk dust particles defied the mechanisms of the respiratory system in filtering out dust particles efficiently from entering the airway shown in the level of significance of the functional changes in the lungs (Nwagha, 2011). Likewise, the results agree with the study of Majumdar and William (2009), who revealed that dusting chalks from chalkboard produce potentially dangerous particulate matter that enters into the human body through the oral and nasal cavities. The particulate matter in the respiratory system narrows the airways and reduces the air in and out the flowability of the lungs (Glory *et al*., 2017).

The relative amount of FEV1 to FVC expressed in percentage is called forced expiratory ratio (FER [%]). The FER helped in the investigation and diagnosis of lung functional status for the distinctive prognosis of airway restriction from possible obstruction at the reduced FEV1 (Paraskeva *et al*., 2011). The mean FER of the exposed group in this study was found to be 0.80 ± 0.25 while the control was 0.89 ± 0.17 (Table 2). The FER was not statistically different at $p < 0.05$. The FEV1 of a healthy individual with a normal lung function is within a percentage ratio of 75-80 of the FVC where the normal ratio of FEV1/FVC should be within the range of 0.8 to 1 (Nwagha, 2011). The obtained result showed that the exposed and control groups had no restriction on their airway as the values obtained from both categories (exposed and control) of analysis fell within the range of individuals having healthy lungs. However, there was a decline in the lung function of the exposed group compared with the control.

PEFR in detecting obstructive changes in the respiratory tract using spirometer has a good correlation with the FEV1 (Tiwari, 2016). Earlier studies showed range values of 0.5 to 0.9, which were moderate to good correlation coefficients between percent predicted PEF and percent predicted FEV1 (Kelly and Gibson, 1988; Thiadens *et al*., 1999). In addition, Nwagha (2011) stated that either PEFR and FVC or FEV1 has a positive correlation between them. A similar observation was also made by Gibson, 2000. In this study, the relationship between the PEFR and FEV1 analyzed using Pearson's correlation analysis gave an "*r*" value of 0.436, which was a positive correlation significant at $p < 0.01$ (Table 3).

4. Conclusion and Recommendation

Environmental factors play a significant role in the decrements in pulmonary function and the development of respiratory diseases. In this study, participants exposed to chalk dust particles in classrooms were screened to determine their lung function in comparison with the control participants. Based on the lung function indices standard value (FVC = 0.8, FEV1 = > 1.0, FEV1/FVC = > 0.7), the average value obtained in the study showed no lung disease for the exposed and control group. However, the attained result also showed that chalkboard usage was a significant respiratory health risk factor as the independent samples T-*t*est, used to compare the lung function indices means between exposure and control subjects, revealed that there was a statistical difference in all cases. This study found out that chalk dust particles in the classroom affected the respiratory function specifically the lung function indices. Hence, this study recommends that in continuing the usage of chalkboard in classrooms, the students' sitting positions should be changed. However, the better option is to utilize marker board.

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