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RESEARCH ARTICLE

LUNG FUNCTION INDICES OF OBESE SECONDARY SCHOOL ADOLESCENTS IN PORT HARCOURT, NIGERIA

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ABSTRACT

Background: Obesity is associated with increased risk of respiratory symptoms, morbidity and mortality. There is a dearth of literature on the effect of obesity on lung functions among the adolescent age group. ***Objective:*** The aim of this study was to determine the effect of obesity on lung function test indices among obese secondary school adolescents. ***Methods:*** It was a descriptive analytical study carried out from May to July 2019. A multi-stage sampling technique was used to recur it adolescents from 16 secondary schools in Port Harcourt Local Government Area, Rivers State. Data were collected using a structured interviewer administered questionnaire. Weight and height were measured using a digital weighing scale and a stadiometer respectively. Body mass index was calculated as weight (kg)/height^2 (m^2) with WHO Anthro-Plus software and categorized using WHO standard BMI-for-age Z-score charts for boys and girls 5 to 19yrs. Lung function indices were measured using a digital hand-held Spiro bank II spirometer which was calibrated based on the GLI 2012 equation. ***Results:*** A total of 224 secondary school adolescents were recruited for the study out of which 108 (48.21%) were males and 116 (51.79%) were females, giving a M: F ratio of 0.93:1. Before controlling for confounders, obese females had significantly low mean percentage predictive values of FEV_1 and PEF compared to normal (FEV_1: 72.2 vs. 82.83; PEF: 67.73 vs. 71.7; p=0.011).After correcting for confounders (socioeconomic status and parental smoking) using a regression model, obesity was significantly associated with lower FEV_1 percentage predicted (p=0.010) and PEF percentage predicted (p=0.050). Among the obese adolescents, lung function indices correlated negatively with obesity severity, but was only statistically significant for FEV_1 (r=-0.43, 95%CI: -0.15, -0.003; p=0.041)and PEF (r=-0.41, 95% CI: -0.20, 0.00; p=0.051). ***Conclusion:*** Obesity was associated with reduction in lung function indices; and obese subjects with higher body mass index had worse lung function test indices Therefore, it will be worthwhile to routinely carry out lung function tests as part of School Health Program, so that necessary measures and referrals would be implemented. On the other hand, this study exposed the need to put in place measures (such as playground in schools, discouraging fast-food patronage) to reduce the prevalence of obesity among secondary school adolescents in Port Harcourt.

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INTRODUCTION

Lung function assessments are tests done to evaluate the function and wellbeing of the respiratory system.[1] It is one clinical assessment that is not routinely done in our hospitals in Nigeria, but in developed countries where the awareness is high, it is a valuable tool for diagnoses and management of respiratory diseases.[2] It has also become more useful in health surveillance, monitoring health outcome as well as in epidemiological surveys.[3]

Evaluation of lung functions using spirometry is the commonest method used in assessing the ventilatory functions of the lungs.[1,2] Spirometry parameters like forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), forced expiratory flow (FEF), peak expiratory flow (PEF) and FEV_1/FVC ratio are influenced by several factors like environmental factors, physiologic factors and disease factors.[2] Also, changes in body mass which occur with growth have effect on spirometry lung function measurements.[1] Excess body mass has been found to increase oxygen consumption, carbon dioxide production and mechanical work of breathing.

Also, there is enough evidence that obesity represents an important burden on the respiratory system, which has been attributed to the mechanical and inflammatory effects of excessive fat on the intra and extra thoracic regions of the respiratory system, causing alterations in pulmonary volumes, pattern of breathing, and airway smooth muscle.[4,5] Outcome of these effects can manifest as deranged lung function indices which has also been reported in children and adolescents.[4 -6.] When present as a co-morbidity, obesity has been reported to negatively affect the respiratory system. For instance, excess body fat has been linked to a wide range of conditions, including asthma, obesity hypoventilation syndrome, pulmonary embolism, aspiration pneumonia, and obstructive sleep apnoea.[7]There is also an increased risk of respiratory symptoms, such as breathlessness, particularly during exercise, even in the absence of obvious respiratory illness.[7] Likewise individuals with lung diseases, like emphysema, chronic bronchitis, asthma, and interstitial/vascular lung diseases, where respiratory function is already compromised can be exacerbated or worsened by increased body fat; and shedding fat has shown improvement with these respiratory diseases,[1,7] making obesity a thing of great concern especially in children. Again, global increase in the prevalence of childhood obesity has made obesity related co-morbidity commoner in children.[8]Nigeria in the past few years has experienced an increase in childhood obesity from a prevalence of 3% - 5% to more than 11% due to urbanization and western lifestyle.[9-12]The prevalence of obesity has been found to be directly proportionate with pulmonary dysfunctions; this invariably increases respiratory co-morbidities in children, which directly affects the academic and social effectiveness of adolescents.[8,13]Reports show more respiratory symptoms among obese subjects and recommended early detection; and that obese people show more severity with respiratory diseases.[7,14]Considering the increasing prevalence of obesity among adolescents in Port Harcourt,[10,15,16] it is has become relevant to obtain information on the effect of obesity on their lung function test indices.

There are very few studies on lung function assessments especially in relation to obesity among children and adolescents in Africa and Sub-Saharan region.[3]Moreover, no study has been done in Port Harcourt on lung function tests among obese adolescents. As such, information from the study outcome may be relevant especially in the setting where few information is emerging regarding trends in obesity and information on lung function. Bearing in mind the several factors that predict lung function test values in childhood,[3,17-21] this study will elucidate relationship between lung function test indices and obesity in adolescents using the new standardized GLI equation recommended internationally;[3] and will also include measurement of forced expiratory flow (FEF) as few local studies measured FEF among subjects.[9,12,22-23] Forced Expiratory Flow measurement has become important as it helps to determine distal airway obstruction and in diagnosing minimal airflow obstruction.[24, 25]

MATERIALS AND METHODS

This descriptive analytical study was carried out over a period of two months (May to July 2019). Using the multistage sampling method, two hundred and twenty-four adolescent students aged 10 years to 19 years were selected from 16 secondary schools in Port Harcourt City Local Government Area (PHALGA) which is one of the Local Government Areas in the capital city of Rivers state. Rivers State is located in the South-South geo political zone of Nigeria. Adolescents who gave assent and whose parents gave informed consent were recruited for the study. Those excluded from the study were:

- Adolescents with existing bronchial asthma and cardio-pulmonary disease.
- Adolescents with structural disabilities of the chest and spine.
- Adolescents who had any respiratory illness prior to or within two weeks of recruitment.
- Adolescents who smoke.
- Adolescents who take medications that may affect the respiratory system e.g., Salbutamol.

Ethical clearance was obtained from the Research and Ethics Committee of the University of Port Harcourt Teaching Hospital, Rivers State, Nigeria before commencement of the study. Permission to carry out the study was also obtained from the Rivers State Ministry of Education. Adequate privacy was provided for students during examination and a designated teacher served as a chaperone during the examination of students. Research procedures carried out in were non-invasive and at no cost to the schools/students.

Procedure

Questionnaire: A structured investigator administered questionnaire was given to recruited students, which included bio data– gender, age, class; parents' occupation and education; socio-economic status (stratified using Oyedeji classification,[26] medical history; medication history (including Prednisolone and use of bronchiodilators e.g. salbutamol, etc.); family and social history, and review of the cardiovascular and respiratory systems. The questionnaire was completed before general examination, anthropometry and spirometry.

Anthropometry

Weight: Weight was measured on a flat/level platform using a digital weighing scale (Omron HN 289-ESL, Omron HealthCare Co. 617-0002, Japan).The subjects stood on the scale without their shoes and in their minimum clothing (school uniform only). Their pockets were freed of objects that might add to their weights such as mobile phones, wallets, keys, rings etc. Weight was read to the nearest 0.1kilogramme.It was ensured that the scale read 0.00 before the commencement of each measurement to ensure quality control.

Height: Height was measured using a pre-validated stadiometer (Techmel and Techmel ZT 120, Texas, USA) with the subjects standing straight on the stadiometer without their shoes, head-gear or cap. Subjects stood with their head held erect such that the external auditory meatus and the lower border of the orbit are in one horizontal plane (Frankfurt plane). With their knees and legs together, and the back of their head, buttocks, shoulder blades and heels touching against the stadiometer, a pointer was pressed firmly against the crown and the measurement read at maximum inspiration on the scale in meters to the nearest 0.1cm. Body mass index (BMI) was calculated as weight (kg)/height^2 (m^2) using the WHO-Anthro-Plus software. Calculated BMI was compared with WHO BMI-for-age Z-score charts for boys and girls 5 to

19yrs. BMI Z scores of less than -2 Z-scores were categorized as thinness, BMI Z-scores that were within -2 to +1 were categorized as normal weight, BMI Z-scores above +1 and up to +2 were categorized as overweight. Obesity was regarded as Z-scores of greater than +2.[27]

Lung Function Assessment: Lung function assessment was done for all enrolled subjects using a portable digital hand-held spirometer, the Spiro bank II®, (Medical International Research (MIR) via Del Magggiolino 125 00155 Italy). Its design for lung function analysis in compliance with the standard UNI CEI EN ISO 13485:2012 quality assurance specifications.[28] Technical specifications, precision and accuracy are within the limits specified in the American Thoracic Society (ATS) spirometry test protocol.[29]It calculates up to 30 functional respiratory parameters. The equipment was calibrated based on the GLI 2012 equation.[3]The flow and volume measurement sensor are digital turbine which works on the infrared interruption principle. The transducer ensures the accuracy and reproducibility of the measurements, without requiring periodic calibration. Also, the digital volume transducer is extremely stable and measures expired air directly at BTPS (Body Temperature and Pressure with Saturated water vapor) thus avoiding the inaccuracies of temperature corrections.

The participants performed spirometry sequentially: after each student had their anthropometry measured, they proceed to perform the spirometry but were allowed to rest while sited for 5mins before performing spirometry. They sat comfortably on a chair with both feet on the ground and tight clothing loosened. They began by tidal breathing with their lips and teeth around the disposable mouth piece and thereafter took a deep breath as large as possible and then rapidly and immediately blew out as hard and as fast as possible, and was encouraged to continue blowing till a beep was heard. The beep was a guide to ensure that all the air in the lungs was exhaled. After a full and complete expiration, the participant inhaled maximally again in a relaxed manner. Each participant performed at least 3 maneuvers and rested≥30 seconds between maneuvers to avoid bronchoconstriction caused by forced expiration. A maneuver was acceptable if: there was an explosive start. The flow and volume curves were followed on the screen to detect whether or not subjects displayed enough effort during inspiration and expiration. The best of three trials were obtained and the best effort taken. Readings for FEV_1, FVC, PEF, $FEF_{25\%-75\%}$and FEV_1/FVC automatically displayed on the screen were documented. Diagnosis was displayed automatically on the spirometer screen to show the pattern of lung disease. The interpretation is based on the forced vital capacity (FVC) test. For infection control, disposable mouth-piece was used for the spirometry. Students found to have abnormal Spirometry Result Interpretations were counseled and referred to the Respiratory Clinic in Paediatric department of the University of Port Harcourt Teaching Hospital for further evaluation.

Data analysis: Data collected from subjects were entered into the Microsoft Excel™ worksheet version 2019 and analyzed using Epi Info Version 7.02. BMI status was classified as thinness, normal weight, overweight and obese. The lung function indices (FEV_1, FEV_1 /FVC, $FEF_{25\%-75\%}$ and PEF) were summarized as mean and standard deviation. Fisher's exact test were used in comparing differences in proportions, where the count is less than 5 (<5). Analysis of Variance (ANOVA) was used to test for a statistical significant difference among three or more means. The Pearson's correlational coefficient (r) was used to associate the linear relationship between BMI values and the lung function indices (FEV_1, FEV_1 /FVC, $FEF_{25\%-75\%}$ and PEF). Multiple linear regression analysis was performed to assess the degree of prediction (association) of obesity with lung function while controlling for other determinants of lung function (age, gender, exposure to tobacco smoke and socioeconomic status). Numerical dummy coding was done for categorical variables in the regression models and 95% confidence interval was used. Level of significance was set at p≤ 0.05 for all analyses

RESULTS

A total of two hundred and twenty-four (224) secondary school adolescents were recruited for the study, out of which 108 (48.21%) were males and 116 (51.79%) were females, giving a M: F ratio of 0.93:1. Twenty three (10.3%) secondary school adolescents were obese, and females were significantly more obese than males (p<0.001) (Table I). There was no statistically significant association between the lung function indices and BMI status among male adolescents. (Table II). However, among the female, percentage predictive values of FEV_1 and PEF were lower in the obese and thinness group when compared to normal and this was statistically significant (FEV_1: 72.2 vs 82.83; PEF: 67.73 vs. 71.7; and FEV1: 58.67;vs 82.83; PEF: 40.67 vs. 71.7 respectively; p=0.011) (Table III).

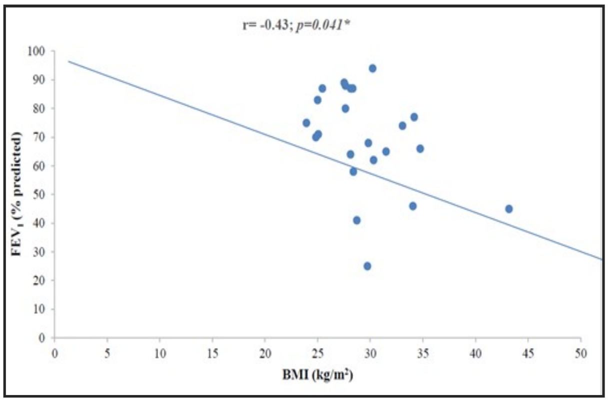

Figure I. Correlation between BMI and FEV_1 (% predicted) in the obese adolescents (n= 23)

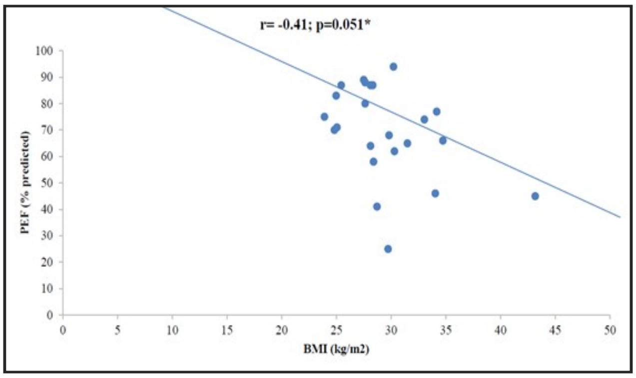

Figure II. Correlation between BMI and PEF (% predicted) in the obese adolescents (n= 23)

Table I. BMI status of study population.

	Gender		
Variable	Male n (%)	Female n (%)	Fishers Exact p
BMI Classification			
Thinness (≤ -2.00)	1 (0.93)	3 (2.59)	
Normal (-2.01 – 1.00)	82 (75.93)	58 (50.0)	*0.001**
Over-weight (1.01 – 2.00)	17 (15.74)	40 (34.48)	
Obese (>2.00)	8 (7.41)	15 (12.93)	

Table II. Lung Function Indices and BMI Status among male adolescents

	BMI classification					
Variables	**Thinness (≤ -2.00) Mean ± SD (Range)**	**Normal (-2.01 – 1.00) Mean ± SD (Range)**	**Over-weight (1.01 – 2.00) Mean ± SD (Range)**	**Obese (>2.00) Mean ± SD (Range)**	**F-test**	**p-value**
Lung Function Indices						
FEV_1 (% predicted)	99.0 ± 1.41 (98.0-99.0)	84.83 ± 15.05 (76.5 – 95.0)	92.18 ± 18.03 (80.0 – 91.0)	96.88 ± 24.52 (85.0 – 115.5)	2.41	0.072
FVC (% predicted)	109.0 ± 1.41 (108.0 – 109.0)	99.18 ± 21.34 (85.0 – 110.5)	99.18 ± 22.47 (91.0 – 110.0)	117.75 ± 41.11 (84.5 – 148.5)	1.64	0.183
FEV_1/FVC	90.50 ± 0.71 (90.0 – 90.5)	87.46 ± 17.23 (79.0 – 100.5)	93.76 ± 15.96 (88.0 – 104.0)	85.38 ± 20.87 (67.0 – 105.0)	0.72	0.540
$FEF_{25-75\%}$ (% predicted)	75.5 ± 0.71 (75.0 – 75.5)	68.95 ± 33.93 (39.0 – 93.5)	83.71 ± 45.09 (58.0 – 115.0)	62.88 ± 40.74 (24.0-93.0)	0.90	0.428
PEF (% predicted)	84.0 ± 1.41 (83.84 – 84.0)	67.01 ± 18.61 (53.0 – 79.5)	78.71 ± 23.68 (69.0 – 91.0)	73.25 ± 16.95 (65.5 – 87.5)	2.22	0.090

**Statistically significant (p<0.05), BMI = Body Mass Index, SD – Standard; F-test=Analysis of Variance, FEV_1 =Forced Expiratory Volume in one second, FVC = Forced Vital Capacity, $FEF_{25-75\%}$ =Mid Forced Expiratory Flow, PEF=Peak Expiratory Flow*

Table III. Lung Function Indices and BMI Status among female adolescents.

	BMI classification					
Variables	Thinness (≤ -2.00) Mean ± SD (Range)	Normal (-2.01 – 1.00) Mean ± SD (Range)	Over-weight (1.01 – 2.00) Mean ± SD (Range)	Obese (>2.00) Mean ± SD (Range)	F-test	p-value
Lung Function Indices						
FEV_1 (% predicted)	58.67 ± 14.50 (44.0-73.0)	82.83 ± 18.77 (73.0 – 92.0)	84.98 ± 14.19 (75.5 – 95.5)	72.2 ± 18.49 (63.0 – 85.0)	3.88	*0.011**
FVC (% predicted)	102.67 ± 35.0 (68.0 – 138.0)	96.78 ± 30.24 (79.0 – 107.0)	103.7 ± 26.14 (82.0 – 122.0)	81.67 ± 21.35 (67.5 – 99.5)	2.30	0.081
FEV_1/FVC	64.0 ± 37.24 (42-107)	87.98 ± 16.74 (75.0 – 103.,5)	84.85 ± 17.59 (72.0 -100.0)	89.67 ± 16.38 (85.0-101.50)	2.06	0.109
$FEF_{25-75\%}$ (% predicted)	43.33 ± 37.29 (17.0 – 86.0)	68.31 ± 34.12 (35.0 – 100.05)	66.33 ± 30.82 (38.5 – 90.0)	61.33 ± 31.03 (38.5 – 85.0)	0.68	0.566
PEF (% predicted)	40.67 ± 24.66 (24.0-69)	71.7 ± 18.62 (61.5 – 101.0)	72.5 ± 17.71 (60.0 – 84.0)	67.73 ± 18.27 (60.0 – 85.0)	2.98	*0.034**

**Statistically significant (p<0.05), BMI = Body Mass Index, SD – Standard; F-test=Analysis of Variance, FEV1 =Forced Expiratory Volume in one second, FVC = Forced Vital Capacity, FEF25-75% =Mid Forced Expiratory Flow, PEF=Peak Expiratory Flow*

Table IV. Pearson's correlation of Lung Function Indices and Obesity among Adolescents in the Study Population

	BMI (kg/m^2)			
	The Pearson correlation coefficient	**R-Square**		
Variable	**R**	**r^2**	***p-value***	**95% CI**
Lung Function Indices				
FEV_1 (% predicted)	-0.43	0.184	*0.041**	-0.15, – 0.003
FVC (% predicted)	-0.17	0.030	0.429	-0.079, -0.035
FEV_1/FVC	-0.29	0.089	0.168	-0.18, -0.033
$FEF_{25-75\%}$ (% predicted)	-0.30	0.092	0.159	-0.093, 0.016
PEF (% predicted)	-0.41	0.170	*0.051**	-0.20, 0.00

**Statistically significant (p<0.05), BMI = Body Mass Index*

Among the obese subjects (n=23), there was a statistically significant correlation between obesity with FEV_1 and PEF. A point increase in obesity resulted in a 0.43 decrease in FEV_1(r=-0.43, 95%CI: -0.15, -0.003; p=0.041) (Figure 1), and also a one-point increase in obesity also resulted in a 0.41 decrease in PEF(r=-0.41, 95%CI: -0.20, 0.00; p=0.051) (Figure 2). No statistically significant correlation was observed between obesity and FVC, FEV_1/FVC and $FEF_{25-75\%}$ (Table IV). After adjusting for age, gender, history of tobacco smoking in parents and socioeconomic status, a 1-point increase in obesity was significantly associated with a 0.462 decrease in FEV_1 (% predicted) (p=0.044).

Table V: Multiple Linear Regression showing the relationship between Obesity and FEV_1 after controlling for confounders among Adolescents

	Multiple Linear Regression			
	Standardized B-coefficient	95% CI		
Variable		Lower bound	Upper bound	*p-value*
FEV_1 (% predicted)				
Obesity	-0.462	0.616	43.36	*0.044**
Age (years)	-0.057	-25.65	19.89	0.791
Gender (female)	-0.608	-51.13	-8.39	*0.010**
Parents smoke tobacco	-0.057	-35.10	25.87	0.752
Socioeconomic status	-0.082	-19.09	13.06	0.695

**Statistically significant (p<0.05), FEV_1 = Forced Expiratory Volume in one Second, R-Regression co-efficient*

Table VI: Multiple Linear Regression showing the relationship between Obesity and PEF after controlling for confounders among Adolescents

	Multiple Linear Regression			
	Standardized B-coefficient	95% CI		
Variable		Lower bound	Upper bound	*p-value*
PEF (% predicted)				
Obesity	-0.565	0.019	40.55	*0.050**
Age (years)	0.052	-19.62	23.56	0.848
Gender (female)	-0.241	-29.67	11.37	0.364
Parents smoke tobacco	-0.072	-33.29	24.53	0.751
Socioeconomic status	-0.175	-20.12	10.38	0.506

**Statistically significant (p<0.05), PEF= Peak Expiratory Flow, R-Regression co-efficient*

Also, being a female gender was significantly associated with a 0.608 decrease in FEV_1 (% predicted) (p=0.010) (Table V).There was also a 1-point increase in obesity was statistically significantly associated with a 0.565 decrease in PEF (% predicted) (p=0.050) (Table VI). The selected secondary schools for their cooperation during the study.

DISCUSSION

This study evaluated the effects of obesity on the lung function test indices of obese secondary school adolescents in Port Harcourt. Effects of obesity on lung function indices showed that female obese subjects have significantly low mean percentage predictive values for FEV_1 and PEF. Low FEV_1 and PEF in obese adolescent females were also observed by Choudhuri and Choudhuri[30] among 187 Indian adolescents aged 12-16yrs. Also, Mohammed *et al*[12] and Eisenmann *et al*[31]reported low FEV_1 among their female obese subjects. Finding significantly low FEV_1 and PEF in only the obese female adolescents could be attributed to the fact that obesity was significantly higher among the females than the males in this study. Negative effects of excess body fat on FEV_1 and PEF have been documented.[1,12, 30] Respiratory muscular efforts and chest wall compliance are necessary for forced expiratory manoeuvres.[1, 32] PEF measures the strength of the expiratory muscles, the mechanical properties of the lungs and the airway limitation.[32]PEF is determined by the interplay between lung volume, lung elastic recoil, expiratory muscle strength, and airway resistance.[1] Firstly, maximum inspiration at total lung capacity is required to achieve a maximum expiratory flow. Thus, how the lungs were stretched prior to PEF maneuver will affect the results. Secondly, pressure gradient in the thoracic cage to a large extent helps in the recoil of the elastic lung fibers. Alveolar pressure falls below atmospheric pressure for expiration to occur. Peak expiratory flow also depends on the speed with which maximal alveolar pressure is reached, which depends on the force-velocity properties of the expiratory muscles. Thirdly, bronchial muscles tone, neuronal control, mucosal secretions, and pressure determines airway resistance. Expiratory accessory muscles are key during forced breathing, their effort is required to increase expired air, improve pressure gradient and overcome resistance to airflow. Abdominal muscles give extra push to the diaphragm to achieve maximum exhalation. Thus, a low PEF value basically reflects reduced respiratory muscular strength and airway limitation in the large airways.[1,32] Similarly, FEV_1 reflects expiratory muscle strength at the early phase and airway movement through large airways.[33]

In obese subjects, excessive subcutaneous and intramuscular fat on the chest wall can affect effective muscular contraction and can also cause inadequate pressure gradient thereby affecting maximum expiration. Also, abdominal fat interferes with the maximum filling of the lungs by pushing the diaphragm upwards and also reducing intra thoracic lung volume. There is resultant limitation of chest wall and diaphragmatic movement, reduced thoracic wall compliance/recoil, increased work of breathing and fatigue of expiratory muscles. Ineffective input from the respiratory muscles to maintain alveolar pressure can lead to increased closure of dependent airways. Some reports argue that peripheral airway closure results from the mechanical compression of excessive fat, leading to dynamic airway narrowing.[1,7] Increased BMI causes airway narrowing over and above causing reduced lung volume alone.[7]Therefore, significantly low PEF and FEV_1 found in female obese adolescents in this study can be attributed to impaired expiratory force generated by their expiratory and accessory muscles, and airflow limitation. However, airflow limitation in the large airways may not only be explained by the mechanical effect of excess body fat, since they are farther away from the thoracic wall periphery where change in pressure from excess subcutaneous fat can narrow airways. Intra-airway fat deposits with inflammatory response and hyper secretions which eventually increases airflow resistance have been recently reported in obese adults.[34]

Similar studies in the paediatric group will also add to body of knowledge. In addition, obesity has been shown to have similarities with asthma as adipocytes exhibit chronic inflammatory and hypersensivityproperties.[35] Ulger *et al*[4] reported hypersensivity changes and reduced lung function test indices among their subjects. This may further explain why female obese subjects in this study had low PEF and FEV_1. El-Baz *et al*[13] reported low FEV_1 and PEF in both sexes among 30 Egyptian adolescents, which was different from the study outcome. Obese males in this study did not have significantly low FEV_1 and PEF; also, obese male adolescents had all their lung function indices higher than those of their female obese counterparts. This outcome is in keeping with reports that adolescent males have higher lung function indies than the females due to larger lungs and muscularity of males compared to females.[1,17] In an attempt to further buttress the effect of obesity on lung function indices, possible confounders where controlled using a regression model, obesity was found to be significantly associated with lower FEV_1 and PEF. The association was also stronger with PEF. Goswami *et al*[8] highlighted; that there is a strong association of PEF with obesity and concluded that the association is due to increased airway resistance and respiratory muscle dysfunction as a result of excess fat deposition. They also highlighted that the elementary factors upon which PEF values depend on are voluntary effort; strength of the expiratory muscles generating the force of contraction, lung volume and airway size; and elastic recoil strength of the lung. Similar association between obesity and PEF was reported by Gundogdu and Eryilmaz[36] in a study in Turkey among subjects aged 6-14yrs. Also, a study in the South-Eastern part of Nigeria by Chukwudi *et al*[37] reported an association of obesity with FEV_1, although they measured only FEV_1 and used WHR as a measure of obesity. On the contrary, Yao *et al*[38] did not find any association with obesity, PEF and FEV_1. Most of their subjects had atopy, confounding their outcome.

It is also important to mention that PEF and FEV_1 were also significantly low among the 3 females in the thinness group. Glew*et al*[22]reported lower lung function indices among their underweight group and attributed it to muscle weakness from muscle wasting; buttresses the fact that respiratory muscles are needed for effective ventilation and airway patency; which can be affected by extremes of body mass index. Additional findings in this study were that severity of obesity also has an impact on lung function indices. There was a significant negative correlation between the BMI of obese adolescents, FEV_1 and PEF. A study in China by Li *et al*[39] among 54 children aged 7-18yrs reported the effects of degree of obesity and severity of abnormal lung function parameters using DEXA in assessing adiposity. As such, this finding in the study can be attributed to worsening effects of adipose fat on ventilation as BMI increases in obesity, leading to worsening lung function parameters. Similar correlation of obesity severity with FEV_1 and PEF was found by El-Baz *et al*[13] as well as Choudhuri and Choudhuri[30] among their obese subjects. On the other hand, Mohammed *et al* [12] and Ulger *et al*[4] showed negative correlation of all their subjects' BMI with PEF and FEV_1, still reflecting the effect of increasing fat-free mass on respiratory function. The implication of this study outcome is that obese secondary school adolescents are more prone to airflow limitation and as such, strenuous activities like outdoor sports, tedious chores could be a thing of concern because it can trigger expiratory flow limitation which is detrimental to respiratory physiology. Also, airflow limitation in obesity has been likened to that found in asthma; as such, obese secondary school adolescents in Port Harcourt may likely be at increased risk of asthma and asthma-like symptoms.

In addition to other co-morbidities, reported lung function indices derangement among obese adolescents in this study and others studies has made obesity in adolescent age group a thing of concern; and as such the need for periodic assessment of body mass index status of adolescents. Goswami *et al*[8] highlighted the relationship between increasing prevalence of respiratory illness with increasing prevalence of obesity.

CONCLUSION

Female secondary school adolescents had significantly low FEV_1 and PEF. There was a significant relationship between obesity, FEV_1 and PEF, as FEV_1 and PEF decreased with increasing Obesity severity. We therefore recommend more research on lung function in Paeditrics, so that data would be available from the Sub-Saharan region to inculcate in the next GLI equation modification. We also recommend discouraging fast-food restaurant patronage by putting high taxation on their products, and implementation of adequate school landscape in secondary schools to promote physical activities.

Competing interests: The authors declare that they have no competing interest.

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GLOSSARY OF ABBREVIATIONS

ANOVA - Analysis of Variance
ATS - American Thoracic Society
BMI- Body Mass Index
BTPS -- Body Temperature and Pressure with Standard water vapor
DEXA -- Dual-energy X-ray Absorptiometry
$FEF_{25-75\%}$ – Forced Expiratory Flow during expiration of 25 to 75% of the FVC
FEF - Forced Expiratory Flow
FEV_1- Forced Expiratory Volume in one Second
FVC – Forced Vital Capacity
GLI -- Global Lung Initiative
MIR -- Medical International Research
PEF - Peak Expiratory Flow
PHALGA - Port Harcourt Local Government Area
WHR -- Waist Hip Ratio
WHO -- World Health Organization

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