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Assessment of Standardized Peak Expiratory Flow Rate using the Fawibe Reference Equation and Associated Factors among Sawmill Workers in Osogbo, Nigeria

Ayodele Adekunle Alabi[1,4*]; Temitope Olumuyiwa Ojo[2]; Fehintola Olayemi Awopeju[3]
Ezekiel Gbadebo Adeyeni[4]; Oluwakemi Mary Owolabi[5]

[1]Department of Community Health, Obafemi Awolowo University, Ile-Ife, Nigeria
[2]Department of Community Health, Obafemi Awolowo University, Ile-Ife, Nigeria
[3]Department of Medicine, Obafemi Awolowo University, Ile-Ife, Nigeria
[4]Department of Science Laboratory Technology, Westland Polytechnic, Ilobu
[4]Department of Community Health, Obafemi Awolowo University, Ile-Ife, Nigeria

***Corresponding Author**

Abstract
Peak Expiratory Flow Rate (PEFR) is a safe, easy, quick test of lung function that is commonly applied in clinical and occupational health. PEFR values vary with physiological factors like age, height and sex, and hence the use of a reference equation is necessary to interpret the values accurately. This study aimed to determine PEFR and its correlates among sawmill workers in Osogbo, Nigeria, using the Fawibe reference equation for Nigerian adults. The study design used was descriptive cross sectional, comprising of 250 sawmill workers that were obtained by multistage sampling. PEFR was measured with the use of portable peak flow meter and highest of three measurements was recorded for each participant. The Fawibe equations that take into account age, sex, and height were used to calculate predicted PEFR values, and measured PEFR values were reported as % of predicted PEFR. Respiratory function was classified as normal (≥80% predicted) or reduced (<80% predicted). Associations between PEFR status and selected variables were assessed using chi-square tests, with statistical significance set at $p<0.05$. The mean observed PEFR among respondents was 437.1 ± 60.49 L/min, with 42.4% recording a reduced PEFR and 57.6% a normal lung function. The bivariate analysis demonstrated that gender ($p = 0.040$), regular participation in milling activities ($p = 0.001$), daily hours spent on milling ($p = 0.029$) and BMI ($p = 0.001$) were significantly associated with reduced PEFR. After standardization with the Fawibe reference equation, a significant number of sawmill workers had a reduced PEFR linked to specific demographic, anthropometric and/or occupational factors. The study underscores the importance of routine respiratory health monitoring and strengthening occupational dust control among workers exposed to wood dust.

Keywords: Peak Expiratory Flow Rate; Respiratory Function; Lung Function; Sawmill Workers; Wood Dust Exposure; Occupational Health

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1. Introduction

Peak Expiratory Flow Rate (PEFR) is the highest flow of air expelled during a forced expiratory breath after maximum inspiration and is a simple, rapid and non-invasive measurement of pulmonary function. It is commonly used in clinical practice and occupational health research to assess airway obstruction, monitor respiratory status and evaluate pulmonary function in individuals exposed to respiratory hazards (American Thoracic Society [ATS], 2019; Global Initiative for Asthma [GINA], 2025). PEFR is an important part of occupational health surveillance since exposure to airborne contaminants may lead to progressive respiratory dysfunction particularly useful in large population surveys such as epidemiological studies, especially in low- and middle-income countries where access to spirometry is limited, and is portable, inexpensive, easy to use, and does not require an electricity grid. (WHO, 2024; Miller *et al.*, 2019). Wood dust from the sawing, milling, sanding and finishing processes can be a high exposure risk for sawmill workers. Occupational exposure to wood dust has been seen to cause a number of respiratory symptoms such as chronic cough, phlegm production, wheezing, chest tightness, breathlessness, asthma, chronic bronchitis, and lung function decline among the saw mill workers, wood processing workers reported in other epidemiological studies (Ibhazehiebo & Iyawe, 2019; Eze *et al.*, 2021; Boschman *et al.*, 2017). The severity of respiratory impairment has been reported to worsen with duration and frequency of exposure, poor equipment ventilation and the failure to regularly wear personal protective equipment (PPE) (Boschman *et al.*, 2017; EU-OSHA, 2023). While such studies have made significant contributions to the knowledge of respiratory health of these sawmill workers, most studies have evaluated lung function in terms of measured PEFR or spirometric indices without utilizing the population-specific prediction equations for interpreting it. Physiological factors like age, sex, and height influence PEFR values, which must be taken into consideration if respiratory status is to be diagnosed solely based on PEFR measurements, or to enable comparisons between individuals and populations, and hence merit further investigation (American Thoracic Society [ATS], 2019; Quanjer *et al.*, 2019). It is currently recommended internationally that pulmonary function should be interpreted with the use of the appropriate reference equation to address the variation in normal physiology and better diagnose a patient (Global Initiative for Asthma, 2025; Pellegrino *et al.*, 2005). However, to account for ethnic and population differences in lung function, Fawibe et al (2017) used age, sex and height to develop reference equations for predicting PEFR in healthy Nigerian adults. The PEFR equations offer a standardised interpretation method for PEFR in the context of the Nigerian population and consider normal physiological changes that affects pulmonary function. However, this nationally validated reference equation is not widely used in the fields of occupational respiratory health research, although it is available.

While sawmill workers in several Nigerian studies have been investigated for their respiratory health, the majority of respiratory function assessment studies have been performed using measured PEFR instead of the conventional spirometric indices that are based on an equation developed specifically for the Nigerian population by Fawibe *et al.* (2017). For example, measured PEFR was used to evaluate respiratory symptoms among sawmill workers in the Osun state in comparison with those workers that were not exposed to the work in the sawmill, Adeoye *et al.* (2014) reported that the mean PEFR of workers exposed to the sawmill work was significantly lower than the mean PEFR of those workers who were not exposed to the sawmill work. The study was not standardized using predicted values from PEFR (corrected for age, sex and height). Similarly, Ibhazehiebo and Iyawe (2019) compared the lung function of sawmill operators in Nigeria measured by pulmonary function parameters and Eze *et al.* (2021) evaluated lung function in woodworkers without having the benefit of a PEFR prediction model developed for the Nigerian population. Therefore, the physiological differences that affect PEFR might not have been fully taken into consideration in these studies and this reduces the comparability and clinical interpretation of the results (ATS, 2019; Quanjer *et al.*, 2019). Hence, while previous studies have identified wood dust exposure as a risk factor for poor respiratory outcomes, little is known to address the burden of poor lung function in Nigerian sawmill workers when the use of PEFR is correlated to a population specific reference equation. There is a significant gap in methodology with standardized interpretation used to give a more clinically relevant assessment of respiratory function than PEFR alone and to enable comparison of respiratory function between occupational populations (Fawibe et al., 2017; ATS, 2019).

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Thus, this study involved the use of Fawibe reference equation to standardize PEFR for the standardization of lung function among the sawmill workers in Osogbo, Nigeria and the investigation of demographic, occupational and anthropometric factors associated with lung function. The study offers solid evidence for implementing occupational respiratory surveillance at the workplace and adds to the growing respiratory literature for workers exposed to wood dust, using a prediction model for a Nigerian population.

2. Methods

Study Design and Setting

A descriptive cross sectional design was used to study the Peak Expiratory Flow Rate (PEFR) and associated factors influencing respiratory function of sawmills workers in Osogbo, Nigeria. The study was carried out among the sawmill workers who were randomly picked from five registered sawmill sites in Osogbo metropolis. The chosen sawmills covered a range of different operational activities such as cutting, finishing and other wood processing activities to enable assessment of respiratory exposures and outcomes for workers having different occupational exposure patterns.

Study Population and Sampling Procedure

A multi-stage sampling technique was employed for obtaining samples of 250 sawmill workers. In the first stage, list of registered sawmills in Osogbo was obtained and five sawmill sites were selected using simple random sampling technique. In the second stage, the sample size was estimated according to the number of workers at each of the selected sawmills while allocation proportional to workforce distribution. Eligibility of workers was determined and they were selected by simple random sampling from the available workers in the final stage. Where formal worker registers were unavailable, eligible workers were recruited consecutively until the allocated sample size was achieved. Workers who were employed in the sawmill environment and agreed to participate were included, and workers who refused to participate or were unable to perform PEFR measurement were excluded. Inclusion criteria included: age ≥18 years, working at a sawmill for at least one year and informed consent. As a result of the fear of confounding from non-occupational disease, respondents who reported a diagnosis from physicians of a pre-existing cardiorespiratory disease (asthma, COPD, tuberculosis, heart failure) were excluded, and, to account for transient dyspnea due to pregnancy, respondents who were pregnant at the time of the survey were excluded.

Data Collection Instrument

A semi-structured interviewer-administered questionnaire adapted from the American Thoracic Society (ATS) respiratory symptoms questionnaire was used for data collection. Socio-demographic characteristics, wood dust exposure characteristics, use of personal protective equipment (PPE), workplace dust control measures, and respiratory-related information were obtained using the questionnaire.

Measurement of Peak Expiratory Flow Rate

Portable Omron Peak Flow Meter (measurement range: 60-800 L/min) was used to measure Peak Expiratory Flow Rate (PEFR). Standardized procedures were used in conducting measurements. The participants were asked to stand upright, inhale as deeply as possible, put the mouth piece firmly between the lips and then breathe out as fast as possible and strongly into the mouth piece. All participants made three successive attempts with sufficient rest intervals between measurements. The greatest of the three was noted as the participant's PEFR (L/min).

Standardization of PEFR Using the Fawibe Reference Equation

Observed PEFR values were adjusted using the reference equations developed by Fawibe *et al.* for Nigerian adults. The equations involved age and height and provide sex-specific predicted PEFR values.

For males:

$$Predicted\ PEFR = 543.3 + (4.2 \times Height(cm)) - (2.3 \times Age(years))$$

For females:

$$Predicted\ PEFR = 367.5 + (3.2 \times Height(cm)) - (2.6 \times Age(years))$$

The percentage predicted PEFR was calculated as:

$$\%Predicted\ PEFR = \frac{Observed\ PEFR}{Predicted\ PEFR} \times 100$$

Respondent's Respiratory function was categorized based on the percentage predicted value, with values ≥80% considered normal and values <80% considered reduced PEFR. Reduced PEFR values indicate decreased expiratory flow and may suggest impaired respiratory function needs further respiratory evaluation.

Anthropometric Measurements

A stadiometer was used to determine the heights of the sawmill workers and a weighing scale was used to determine their weights. Body Mass Index (BMI) was calculated using the following formula: BMI = Body Weight (in kg)/ Body Height (in m2) according to the standard BMI underweight, normal weight, overweight, and obese categories were used.

Data Analysis

The data that were collected were entered and analyzed using the Statistical Package for Social Sciences (SPSS) version of 26. Means and standard deviations were used to summarize continuous variables and frequencies and percentages were used to summarize categorical variables. The mean observed PEFR and percentage predicted PEFR were calculated to describe respiratory function among participants. The chi-square test was used to assess the associations between PEFR status (normal versus reduced) and selected socio-demographic, occupational, and anthropometric variables. Statistical significance was determined at a 5% level, with p-values less than 0.05 considered statistically significant.

Ethical Considerations

Ethical clearance for the study was obtained from the Health Research Ethic Committee of Public Health, Obafemi Awolowo University, HREC No.: IPH/OAU/12/2721, Ile-Ife and the permission/consent of the study participants was obtained. Respondents were informed and able to give informed consent and that they would not be subjected to any consequences if they withdrew from the study. No data collected were shared or released without consent. Data collected was kept confidential. Only serial numbers were used to identify all the participants in order to ensure anonymity.

3. Results

Demographic Information

The demographic distribution of the respondents is presented in Table 1. The age of the workers ranged from ≤20 to ≥51 years, with the highest proportion in the 31–40 years category (33.6%). Male respondents constituted 85.2% of the study population. The majority of workers belong to Yoruba ethnicity (96.0%) and Muslims (78.4%). Most workers were also married (73.6%). Regarding education, 57.6% had completed secondary education, while 27.6% had tertiary education

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Table 1: Demographic Information of the Respondents (n=250)

Variable	Category	Frequency, n (%)
Age (years)	≤20	27 (10.8)
	21–30	45 (18.0)
	31–40	84 (33.6)
	41–50	42 (16.8)
	≥51	52 (20.8)
Gender	Female	37 (14.8)
	Male	213 (85.2)
Ethnicity	Hausa	1 (0.4)
	Igbo	5 (2.0)
	Tiv	4 (1.6)
	Yoruba	240 (96.0)
Religion	Christianity	54 (21.6)
	Islam	196 (78.4)
Marital Status	Married	184 (73.6)
	Single	66 (26.4)
Educational Level	No formal education	13 (5.2)
	Primary	24 (9.6)
	Secondary	144 (57.6)
	Tertiary	69 (27.6)

Summary of PEFR Descriptive Statistics (n = 250)

The mean observed Peak Expiratory Flow Rate (PEFR) among respondents was **437.1 L/min**, indicating variability in lung function across the study population.

Table 2: Summary Statistics for Peak Respiratory Flow Rate (PEFR) (N= 250)

Measure	PEFR (L/min)
Mean ± Standard Deviation	437.1 ± 60.49
Median	430.0
Minimum – Maximum	340.0 – 590.0
Range	250.0

Distribution of PEFR Status

A total of 106 respondents (42.4%) had reduced PEFR, while 144 (57.6%) had normal lung function.

Table 3: Distribution of Respondents by PEFR category based on Fawibe Method

PEFR Category	Frequency (n)	Percentage (%)
Normal (≥80%)	144	57.6
Reduced (<80%)	106	42.4
Total	250	100

Peak Expiratory Flow Rate categories were derived using the Fawibe method where ≥ 80% predicted PEFR is considered normal and <80% predicted PEFR indicates reduced lung function

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Association between Demographic Characteristics and PEFR

Gender showed a statistically significant association with PEFR status ($\chi^2 = 4.202$, $p = 0.040$). A higher proportion of males (45.1%) had reduced PEFR compared to females (27.0%). Age and educational level were not significantly associated with PEFR status ($p > 0.05$).

Table 4: Association between Demographic Characteristics and PEFR Status of the Respondents

Variable	Category	(Reduction) f (%)	(Normal) f (%)	χ^2	df	Sig. (p)
Age	**≤ 20**	**8 (29.6)**	**19 (70.4)**	**8.979**	**4**	**0.062**
	21 – 30	**15 (33.3)**	**30 (66.7)**			
	31 – 40	**43 (51.2)**	**41 (48.8)**			
	41 – 50	**22 (52.4)**	**20 (47.6)**			
	51+	**18 (34.6)**	**34 (65.4)**			
Gender	**Female**	**10 (27.0%)**	**27 (73.0%)**	**4.202**	**1**	**0.040***
	Male	**96 (45.1%)**	**117 (54.9%)**			
Religion	**Christian**	**22 (40.7%)**	**32 (59.3%)**	**0.078**	**1**	**0.781**
	Islam	**84 (42.9%)**	**112 (57.1%)**			
Marital Status	**Single**	**32 (48.5%)**	**34 (51.5%)**	**1.359**	**1**	**0.244**
	Married	**74 (40.2%)**	**110 (59.8%)**			
Educational Level	**None**	**4 (30.8%)**	**9 (69.2%)**	**3.528**	**3**	**0.317**
	Primary	**8 (33.3%)**	**16 (66.7%)**			
	Secondary	**68 (47.2%)**	**76 (52.8%)**			
	Tertiary	**26 (37.7%)**	**43 (62.3%)**			
Do you work seven days/week?	**No**	**49 (43.8%)**	**63 (56.3%)**	**0.108**	**1**	**0.743**
	Yes	**55 (41.7%)**	**77 (58.3%)**			

***Significant at $p < 0.05$**

Association between Work-Related/Exposure Variables and PEFR

Among those whose daily work did not regularly involve milling, 40 (31.7%) had mild or moderate PEFR reduction while 86 (68.3%) had normal PEFR. In contrast, among respondents who milled regularly, 66 (53.2%) had mild or moderate PEFR reduction while 58 (46.8%) had normal PEFR. The association was statistically significant ($\chi^2 = 11.807$, $p = 0.001$).

Considering the number of hours spent milling per day, respondents who milled for 0–3 hours recorded 50 (36.8%) mild/moderate reduction and 86 (63.2%) normal PEFR. Those who milled for 4–7 hours had 33 (55.0%) mild/moderate reduction and 27 (45.0%) normal PEFR, while those who milled for 8 hours or more had 23 (52.3%) mild/moderate reduction and 21 (47.7%) normal PEFR. This relationship was statistically significant ($\chi^2 = 7.050$, $p = 0.029$). Body Mass Index (BMI) showed a significant association ($\chi^2 = 16.975$, $p = 0.001$). Respondents with normal weight had 53 (32.9%) mild/moderate reduction and

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108 (67.1%) normal PEFR; those overweight had 40 (60.6%) and 26 (39.4%) respectively; obese respondents had 9 (60.0%) and 6 (40.0%); while underweight respondents had 4 (50.0%) and 4 (50.0%).

Table 5: Associated Factors with PEFR Status

Variable (Question)	Category	(Reduction) f (%)	(Normal) f (%)	χ^2	df	Sig.
Is milling a regular part of your daily work responsibilities?	No	40(31.7%)	86(68.3%)	11.807	1	0.001*
	Yes	66(53.2%)	58(46.8%)			
How many hours per day do you spend milling?	0–3	50(35.2%)	92(64.8%)	7.050	2	0.029*
	4–7	33(53.2%)	29(46.8%)			
	8+	23(50.0%)	23(50.0%)			
Describe the type(s) of wood-related activities you are involved in	Cutting	55(36.4%)	96(63.6%)	5.731	2	0.057
	Finishing	48(51.1%)	46(48.9%)			
	Sanding	3(60.0%)	2(40.0%)			
Are there measures at your workplace to control wood dust exposure?	No	75(39.5%)	115(60.5%)	2.776	1	0.096
	Yes	31(51.7%)	29(48.3%)			
If YES, please describe the measures.	No	92(41.1%)	132(58.9%)	1.557	1	0.212
	Yes	14(53.8%)	12(46.2%)			
Do you wear protective equipment (e.g., masks, respirators) to reduce wood dust exposure?	No	59(37.8%)	97(62.2%)	3.563	1	0.059
	Yes	47(50.0%)	47(50.0%)			
Are you provided with personal protective equipment (PPE)?	No	37(38.1%)	60(61.9%)	1.175	1	0.278
	Yes	69(45.1%)	84(54.9%)			
How often do you go for medical checkups?	Never	49(41.5%)	69(58.5%)	6.296	3	0.098
	Rarely	14(63.6%)	8(36.4%)			
	Sometimes	27(35.1%)	50(64.9%)			
	Always	16(48.5%)	17(51.5%)			
BMI	Underweight	4(50.0%)	4(50.0%)	16.975	3	0.001*
	N. weight	53(32.9%)	108(67.1%)			
	Overweight	40(60.6%)	26(39.4%)			
	Obese	9(60.0%)	6(40.0%)			

Significant at $p < 0.05$

4. Discussion

The study assessed the respiratory function of sawmill workers in Osogbo, Nigeria, using the standardized Peak Expiratory Flow Rate (PEFR) values obtained from the Fawibe reference equation. The results showed that 42.4% of the respondents have reduced PEFR (<80% of predicted values) indicating that there is a significant burden of impaired expiratory function among wood-processing workers. Use of a Nigerian-specific reference equation will lead to a more appropriate interpretation of lung function than simply relying on measured PEFR values because the respiratory parameters are different in population subgroups (Fawibe *et al.*, 2017). This study confirms previous reports of occupational groups as a percentage of reduced PEFR in workers exposed to wood dust. Ibhazehiebo and Iyawe (2019) reported that the respiratory function was impaired among the saw mill workers in Nigeria and attributed this to the exposure of the workers to the wood air particles released during sawing, sanding and milling operations. Likewise Akinbami *et al.* (2019) noted that occupational exposure to particulate matter can lead to decreased pulmonary function due to irritation of airways

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and inflammatory responses. The parallels between these observations and this study is due to the similar working environment as both workers are often exposed to wood dust in a work environment with inadequate dust controls.

The incidence of decreased PEFR in this study, however, differs from the reports of some occupational studies. For instance, Eze et al (2021) noted that wood workers in Nigeria had different respiratory impairments, which was due to differences in the assessment methods used in measuring the impairment, dust control measures available at the work places and the duration of exposure. These differences underscore the need to employ standardized reference equations and to account for other factors affecting the interpretation of respiratory responses, such as occupation and individual.

The findings of this study indicate that there is a strong relationship between the frequency of milling activities and decreased PEFR, implying a workers' respiratory compromise may be greater when working with dust generation activities. The same has been observed by Boschman *et al.* (2017) who showed an exposure-response relationship between wood dust exposure and lung function decline in exposed workers. Milling workers may be more likely to be exposed to higher levels of fine wood particles than workers who carry out work activities that are not dust intensive. Fine particles can enter the respiratory tract deeper causing inflammation of the airways and decreasing the flow during expiration. However, owing to the nature of the design used (cross-sectional), the observed association can only be interpreted as a relationship and not as a direct cause.

The length of time spent in the milling during the day also had a significant association with PEFR status. The workers with longer durations of exposure to the milling activities had a higher proportion of low PEFR than those with shorter durations of exposure. The results of this study concur with earlier studies that showed cumulative occupational exposures are critical factors in determining the respiratory health status of woodworkers (Boschman *et al.*, 2017; Olatoke, 2020). Exposure over long periods of time can also result in a higher total amount of inhaled wood dust, causing a greater risk of symptoms and functional damage of the respiratory system. The magnitude of the respiratory effects, however, may vary depending on the type of wood, the ventilation conditions and the level of protection afforded in various work environments. The study also showed a significant correlation between gender and PEFR status, with more male workers having reduced PEFR than female workers. Occupational respiratory studies also have found gender differences, with men having higher exposures because they tend to be more likely to be exposed to physically demanding and high-exposure occupations (Meo, 2019). In addition to the physiological differences in lung sizes and airway characteristics that could affect PEFR values, occupational role distribution should be taken into consideration. The differences observed may be partly attributed to the higher percentage of male workers in direct wood-processing in the present study.

Another factor that was significantly associated with PEFR status was Body Mass Index (BMI). A higher percentage of reduced PEFR was seen in those with overweight or obese BMI than in those with normal BMI. This finding agrees with earlier studies that showed that obesity adversely affects respiratory mechanics, such as decreasing chest wall compliance, diaphragmatic movement, and expiratory reserve volume (Forno & Celedón, 2017; Peters *et al.*, 2018). Therefore, changes in respiratory physiology due to obesity may be another factor which can contribute to reduced PEFR in non-occupational settings. These results demonstrate the need to take both the physiological response of the worker and the physiological response of the worker into consideration in respiratory health assessment.

The use of the Fawibe reference equation represents an important methodological strength of this study. Past research has pointed out the possibility of misclassification of respiratory impairment when interpreting lung function measurements using the wrong reference population (Quanjer *et al.*, 2019). The Fawibe equation was constructed from data of Nigerian adults and hence it takes into account the relevant physiological characteristics which make it more applicable in the evaluation of respiratory function of Nigerian occupational groups. This study helps to more accurately estimate respiratory impairment in sawmill workers by converting the observed PEFR into percentage predicted values.

5. Contribution to Knowledge

The study is valuable contribution of the existing literature because it improves the use of the Fawibe reference equation as a context dependent reference standard for measurement of PEFR for Nigeria occupational groups. It demonstrates the value of sex, height and age in the assessment of lung function and overcomes the limitations of the unadjustable measurements, making the results of these field based investigations more accurate and precise. It also offers empirical data of the burden of impaired lung functioning in sawmill workers in a standardized method, thus enhancing the local evidence base on occupational respiratory health. Furthermore the study establishes very clear linkages between work related exposure and lung function and between BMI and assessment of the risk of health in the workplace in a context-specific fashion. It also lays a methodological and empirical ground for further research and intervention from the policy perspective in the same workplace involving predicting respiratory rates of people of varying ages and health status using local models derived from his study.

6. Conclusion

This study revealed that there was a significant number of saw mill workers from Osogbo with decreased PEFR after adjustment with the reference equation of Fawibe. The variations revealed the need to take into consideration population-specific reference standards when evaluating respiratory function, since taking PEFR values into consideration, adjusted PEFR values will provide more accurate estimates of KU on respiratory impairment in a population of people of Nigeria occupational group. Significant associations between PEFR reduction and selected occupational and/or physiological factors, such as regular participation in milling activities, the duration of the milling work, gender and BMI, were reported for the study. The results indicated that the respiratory function of sawmill workers depends on both exposures at the work place and other health factors. The results have confirmed the substantial respiratory health impact that exists in the sawmill industry and that occupational health interventions must be significantly enhanced. Sawmill workers' risks to their respiratory health can be minimized through regular respiratory health surveillance, good dust control measures, proper and consistent use of respiratory protection equipment, worker education, and periodic assessment of lung function.

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