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FACIAL AND NASAL ANATOMICAL STRUCTURES AND THEIR ROLE IN AIR POLLUTION–RELATED RESPIRATORY MORBIDITY IN NIGERIAN CITIES

1. **Dr Okolo Chidera Vivian**, Department of Pediatrics, Maternal and Child Centre, Lagos State
2. **Prof. Onodugo Ifeanyi Chris**, School of General Studies, College of Health Science and Technology, 135 Ezzamgbo, Ebonyi State.
3. **Eze, Priscilla Ifeyinwa**. Department of health care Administration and hospital management, Faculty of Allied Health sciences, State university of medical and Applied Sciences,Igbo ENO.Enugu state
4. **Amalu, Christopher Tochukwu**, Department of Public Health Science, Faculty of Allied Health Sciences, State University of Medical and Applied Sciences (SUMAS), Igbo-Eno, Enugu State, christopher.amalu@sumas.edu.ng
5. **Dr Matthew Chinwemadu Nwachukwu**, Department of Environmental Health Science, Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi Campus, Anambra State
6. **Dr Dennis Iyidiobi Ochiaka**, Department of Co-operative Economics and Management, Faculty of Management Sciences, Enugu State University of Science and Technology, (ESUT), Enugu.
7. **Ass.Prof Ugwu Eunice Ngozi**, Department of Public Health Sciences, Charisma University, Montanna USA, ngoziokekeugwu@gmail.com
8. **Ochechi Joseph Ugbede**, Department of Public Health Science, Faculty of Allied Health Sciences, State University of Medical and Applied Sciences (SUMAS), Igbo-Eno, Enugu State, joseph.ochechi@sumas.edu.ng
9. **Dr Okolo Petronilla Nnenna**, Department of public/ community health Nursing, Faculty of Nursing Sciences, David Umahi Federal University of health Sciences, Uburu- Ebonyi State
10. **Ass.Prof. Ogbuyeme Jennifer Ngozika**, Department of Public Health Sciences, Charisma University, Montanna USA,
11. **Sanitarian Ibenyenwa John Chinaza**, Department of Environmental Health Science, Faculty of Allied Health Sciences, Peaceland University Enugu, Enugu State.
12. **Peters, Dell Kenechi**,department of Human Anatomy, Faculty of Basic Medical Sciences, State University of Medical and Applied Sciences (SUMAS), Igbo-Eno, Enugu State, dellkenechipeters@gmail.com

Abstract

This cross-sectional study examined the relationship between facial and nasal anatomical structures and air pollution–related respiratory morbidity across six major Nigerian cities representing each geopolitical zone: Lagos, Port Harcourt, Enugu, Abuja, Kano, and Maiduguri. A total of 1,200 adults aged 18–65 years with at least five years of residence were recruited through multi-stage sampling. Air pollution exposure was assessed using fixed-site monitors and seven-day personal sensors for PM2.5, PM10, NO_2, SO_2, and CO, integrated with GIS mapping. Facial and nasal anatomy was evaluated using 3D facial scans, low-dose CT imaging, and rhinomanometry, while respiratory health was assessed via spirometry, ATS questionnaires, and medical record review. Analyses included descriptive statistics, bivariate correlations, multivariate regression, GIS mapping, and computational fluid dynamics (CFD) simulations. Findings revealed that wider nasal cavities and larger cross-sectional areas reduced susceptibility to asthma, chronic bronchitis, and allergic rhinitis, whereas narrower passages and higher airflow resistance increased vulnerability. Northern cities exhibited nasal structures adapted to dusty, arid environments, while southern cities had narrower nasal cavities and higher respiratory morbidity despite effective deposition of coarse particles. CFD simulations confirmed that nasal morphology influenced airflow patterns and particulate deposition, supporting anatomical modulation of individual exposure risk. These results highlight the interaction between environmental and biological factors in determining respiratory health. Public health strategies should integrate air pollution control, targeted respiratory screening, and personalized interventions considering anatomical differences. Understanding how nasal and facial structures influence pollutant deposition can improve risk assessment and guide mitigation efforts in urban populations exposed to high levels of air pollution.

Keywords: Nasal Anatomy**,** Facial Morphology**,** Air Pollution**,** Respiratory Morbidity**,** Computational Fluid Dynamics

Introduction

Air pollution is an escalating public health concern in rapidly urbanizing cities, particularly in low- and middle-income countries like those in Africa. In Nigeria, major cities including Lagos, Kano, Port Harcourt, Abuja, Enugu, and Maiduguri frequently record pollutant levels above WHO recommended limits, driven by industrial emissions, vehicular exhaust, open waste burning, and construction activities (Amegah & Agyei Mensah, 2022; WHO, 2023). Key pollutants such as PM2.5, PM10, nitrogen dioxide, sulphur dioxide, and carbon monoxide are strongly linked to respiratory conditions including asthma, chronic bronchitis, and allergic rhinitis (HEI, 2023; Zhang et al., 2022).

While environmental exposure is a major determinant of respiratory health, anatomical and physiological characteristics of the respiratory tract also influence susceptibility. The nasal cavity and facial structures serve as the first line of defense, with nasal turbinates, septum, and mucosal lining filtering pollutants and regulating airflow. Variations in nasal width, nostril orientation, internal geometry, and facial morphology affect airflow dynamics and pollutant deposition, thereby influencing individual vulnerability (Garcia et al., 2021; Mladina & Cujić, 2021). Such anatomical differences are shaped by genetics, climate adaptation, and ethnicity, with broader nasal apertures common in warmer climates facilitating airflow and narrower passages more typical of colder regions (Maddux et al., 2017; Noback et al., 2021).

Despite extensive research on air pollution and respiratory health, limited studies have examined how nasal and facial anatomy interact with environmental pollutants to influence morbidity in African urban populations. Nigeria offers a diverse setting for this investigation, as cities differ in pollution sources: Lagos has high vehicular and industrial emissions, Port Harcourt suffers soot from oil refining and gas flaring, Kano and Maiduguri experience dust and biomass exposure, and Enugu and Abuja face mixed pollution from traffic and construction (Akinyemi et al., 2023; Ezeh et al., 2024).

This study therefore explores the relationship between facial and nasal anatomical structures and air pollution–related respiratory morbidity across six Nigerian cities representing the geopolitical zones. By integrating anatomical assessments, environmental exposure data, and respiratory health outcomes, the study provides a multidisciplinary perspective on the combined biological and environmental determinants of urban respiratory disease.

Problem statement

Air pollution is a major environmental health challenge globally, and in Nigeria, rapid urbanization, industrial growth, vehicular emissions, waste burning, and energy production have elevated ambient pollution levels. Particulate matter concentrations in several Nigerian cities often exceed WHO limits, exposing millions to harmful pollutants and increasing the prevalence of respiratory conditions such as asthma, chronic bronchitis, and allergic rhinitis (WHO, 2023; Amegah & Agyei Mensah, 2022). Epidemiological studies link exposure to PM2.5, PM10, nitrogen dioxide, and sulphur dioxide with higher respiratory morbidity and hospital admissions (HEI, 2023; Zhang et al., 2022).

Air pollution patterns vary across Nigerian cities—including Lagos, Kano, Port Harcourt, Abuja, Enugu, and Maiduguri—due to differences in industrial activity, traffic, biomass burning, and dust exposure, creating diverse environmental risks for residents. Most research has focused on exposure levels and socioeconomic factors, with little attention to biological or anatomical factors that influence individual susceptibility. The nose and facial structures act as the first barrier against inhaled pollutants, filtering particulate matter and humidifying air. Anatomical variations in nasal width, nostril orientation, and internal geometry affect airflow and pollutant deposition, potentially determining whether pollutants are trapped or penetrate the lungs (Garcia et al., 2021; Mladina & Cujić, 2021).

In Nigeria's ethnically diverse population, facial and nasal anatomy varies due to genetics, environmental adaptation, and climate (Noback et al., 2021), which may influence susceptibility to pollution-related respiratory diseases. Despite this, empirical studies linking anatomical structures with respiratory morbidity in Nigerian urban populations are limited. The six geopolitical zones present distinct environmental conditions that could interact with anatomical traits to affect respiratory health. This study addresses this gap by investigating how facial and nasal structures shape vulnerability to air pollution–related respiratory diseases in major Nigerian cities across all geopolitical zones.

Literature Review

1. Facial Anatomical Structures

Facial anatomical structures, including skeletal and soft tissue components, form the human face and support vital functions such as breathing, speech, and sensory perception. Facial morphology, which encompasses the size, shape, and spatial relationships of facial bones and tissues, varies across individuals and populations due to genetic, developmental, and environmental factors. Key skeletal elements such as the nasal bone, maxilla, nasal aperture, and facial width shape the upper respiratory tract and influence nasal airflow (Chen et al., 2021).

The nasal bones form the upper portion of the external nose, supporting the nasal bridge and connecting with surrounding bones to create the framework of the upper airway. The maxilla supports the upper teeth and contributes to the nasal cavity, orbital floor, and palate, forming the piriform (nasal) aperture with the nasal bones (Mustansiriya Medical Journal, 2024). The nasal aperture regulates the entry of air, affecting the volume, conditioning (warming, humidifying, filtering), and efficiency of airflow to the lower respiratory tract. Variations in nasal aperture size and facial width often reflect environmental adaptation across populations.

Craniofacial morphology influences airflow dynamics, airway resistance, and breathing patterns. Differences in facial dimensions, such as maxillary width and nasal structure, can alter nasal airflow resistance and respiratory efficiency (Gong et al., 2018; Vig et al., 1981). Narrower nasal passages or altered facial structures may increase airflow resistance, leading to mouth breathing or reduced respiratory function.

Overall, facial anatomical structures are critical not only for facial appearance but also for regulating airflow through the upper respiratory tract, making the study of these variations essential in understanding susceptibility to respiratory conditions, particularly in areas with high air pollution.

2. Nasal Anatomical Structures

The nasal cavity is a key part of the upper respiratory tract, serving as the primary passage for inhaled air. It is divided by the nasal septum, which provides structural support and directs airflow toward the nasopharynx (Sobiesk & Munakomi, 2023). The nasal vestibule, located at the anterior part, contains vibrissae that trap large particles like dust and pollen, acting as the first line of filtration (Anatomy.co.uk, 2024).

The nasal turbinates—superior, middle, and inferior—project from the lateral walls and are covered with vascular mucosa, increasing surface area to slow airflow and enhance filtration, warming, and humidification (Low & Patel, 2022; Sobiesk & Munakomi, 2023). The nasal cavity is lined with ciliated pseudostratified columnar epithelium and goblet cells, which produce mucus that traps particles. The cilia move mucus toward the pharynx through mucociliary clearance, preventing harmful substances from reaching the lower respiratory tract (Anatomy.co.uk, 2024; Sobiesk & Munakomi, 2023).

Additionally, the nasal mucosa contains an extensive vascular network that warms inhaled air, while mucus and glandular secretions humidify it, ensuring that air reaching the lungs is clean, moist, and warm (Sobiesk & Munakomi, 2023; Shokry, 2025). These structures and mechanisms collectively protect the lower respiratory tract from pollutants and environmental irritants.

3. Air Pollution in Urban Environments

Air pollution is a significant environmental and public health challenge in rapidly growing urban areas worldwide. High pollutant concentrations in cities result from industrialization, vehicular traffic, energy use, and dense populations, contributing to respiratory and cardiovascular diseases (Zhang et al., 2022).

Particulate matter (PM), especially PM2.5 and PM10, is a major urban pollutant. These microscopic particles, including dust, soot, and chemical compounds, can penetrate deep into the lungs and enter the bloodstream, causing respiratory and cardiovascular illnesses (World Health Organization, 2023). Nitrogen dioxide (NO_2), primarily from vehicle engines and industrial combustion, irritates the respiratory system, aggravates asthma, and increases infection susceptibility (WHO, 2023). Sulphur dioxide (SO_2), generated from burning fossil fuels, causes airway irritation, contributes to acid rain, and forms secondary particulate matter (Amegah &

Agyei Mensah, 2022). Carbon monoxide (CO), a product of incomplete fuel combustion, impairs oxygen transport in the blood, potentially causing dizziness, respiratory distress, or death (WHO, 2023). Ground-level ozone (O_3), formed through sunlight-driven reactions between nitrogen oxides and volatile organic compounds, contributes to urban smog and worsens respiratory conditions (WHO, 2023).

In Nigeria, urban air pollution is particularly severe in Lagos**,** Kano, and Port Harcourt**.** Lagos faces heavy traffic, industrial emissions, diesel generators, and construction-related pollutants. Kano experiences particulate pollution from industrial activities, biomass burning, and dust from arid regions. Port Harcourt is affected by crude oil refining, gas flaring, and petroleum sector emissions. These sources release large amounts of PM, SO_2, and other harmful gases, significantly increasing respiratory disease risks (Akinyemi et al., 2023).

Overall, urban air pollution in Nigerian cities remains a pressing environmental health issue, highlighting the need for stricter environmental regulation, sustainable urban planning, and effective pollution control strategies.

4. Respiratory Morbidity

Respiratory morbidity encompasses the prevalence of diseases affecting the airways, lungs, and associated structures, leading to symptoms such as coughing, wheezing, breathlessness, and reduced lung function. Environmental exposures, particularly air pollution, are major contributors, causing airway inflammation, oxidative stress, and long-term pulmonary impairment (Su et al., 2024). Key pollutants include particulate matter (PM2.5 and PM10), nitrogen oxides, sulphur dioxide, and ozone, which irritate the respiratory tract and can trigger or worsen conditions like asthma, chronic bronchitis, allergic rhinitis, and chronic obstructive pulmonary disease (COPD) (European Environment Agency, 2023; Ledford et al., 2025; Marcon, 2024; Zhang et al., 2025).

Asthma involves airway narrowing and wheezing, bronchitis causes persistent bronchial inflammation and mucus production, allergic rhinitis results in nasal inflammation, and COPD is characterized by progressive airflow limitation. Respiratory morbidity is therefore a major public health concern, especially in urban areas with high pollution, highlighting the importance of understanding pollutant–disease interactions to guide prevention and control strategies.

5. Interaction Between Nasal Anatomy and Air Pollutant Deposition

The human nasal cavity functions as both a breathing passage and a primary biological filter, with structures like the nasal septum, turbinates, vestibule, and mucosal lining shaping airflow and particle deposition (Garcia et al., 2021; Mladina & Cujić, 2021). Nasal anatomy influences airflow resistance**,** which affects how particles are trapped: narrower passages and larger turbinates increase resistance and turbulence, enhancing deposition of larger particles, while wider passages allow freer airflow but may reduce filtration efficiency (Zhao et al., 2023; Eccles, 2020). Particle size also matters: large particles (PM10) deposit in the anterior nasal cavity, whereas smaller particles (PM2.5) can reach lower airways (Chen & Zhao, 2022).

Individual variations in nostril width, nasal geometry, and mucosal thickness further modify filtering efficiency, with narrow cavities promoting upper airway deposition but increasing breathing effort, and wide cavities reducing resistance but potentially allowing finer particles to penetrate deeper (Park et al., 2024). Computational modeling confirms that nasal geometry significantly affects airflow and particle deposition, highlighting the role of anatomical variation in determining personal susceptibility to air pollution–related respiratory risks (Liu et al., 2023).

Methods

1. Study design

This study employed a ***cross-sectional observational design*** to investigate the relationship between facial and nasal anatomical structures and air pollution related respiratory morbidity across six major Nigerian cities representing each geopolitical zone. The selected cities included Lagos (South West), Port Harcourt (South South), Enugu (South East), Abuja (North Central), Kano (North West), and Maiduguri (North East).

2. Study Population and Sampling

The study population comprised adult residents aged 18–65 years who had lived in their respective cities for at least five years. This criterion ensured long-term exposure to local air pollution patterns.

A multi-stage sampling technique was applied:

a) **Stage 1 – City Selection:** One major city was selected from each geopolitical zone based on population density, industrial activity, and reported air pollution levels.

b) **Stage 2 – Neighborhood Stratification:** Each city was stratified into three zones—high, moderate, and low pollution exposure—using recent ambient air quality data from the National Environmental Standards and Regulations Enforcement Agency (NESREA) and local environmental monitoring reports (Akinyemi et al., 2023; Ezeh et al., 2024).

c) **Stage 3 – Participant Recruitment:** Within each neighborhood, residents were recruited using systematic random sampling. Recruitment was conducted through community health centers, local associations, and public announcements.

The final sample consisted of 1,200 participants (200 per city), which provided sufficient statistical power to detect associations between anatomical variables and respiratory outcomes.

3. Data Collection

Data collection involved three components: air pollution exposure assessment, anatomical measurements, and respiratory health evaluation**.**

a. Air Pollution Exposure Assessment

Air pollution levels were measured using a combination of **fixed-site ambient monitors** and **personal exposure sensors**. Key pollutants measured included:

i. Particulate matter (PM2.5 and PM10)

ii. Nitrogen dioxide (NO_2)

iii. Sulphur dioxide (SO_2)

iv. Carbon monoxide (CO)

Participants' residential exposure levels were estimated by integrating fixed-site monitoring data with geocoded residential locations using GIS mapping (Zhang et al., 2022). Additionally, participants wore lightweight personal air quality monitors for seven consecutive days to capture individual exposure variations.

b. Facial and Nasal Anatomical Assessment

Facial and nasal structures were assessed using three-dimensional (3D) facial scanning and low-dose computed tomography (CT) imaging for precise internal measurements.,

i. **External facial measurements:** facial width, nasal bridge width, nasal length, inter-nostril distance, and nostril orientation were recorded using 3D surface scans.

ii. **Internal nasal measurements:** septal deviation, turbinate volume, nasal cavity width, and cross-sectional area were measured using CT imaging, with image reconstruction software to generate accurate volumetric models (Garcia et al., 2021; Park et al., 2024).

iii. **Airflow resistance:** Rhinomanometry was conducted to measure nasal airflow resistance under standard conditions, providing functional assessment of nasal airway patency.

All measurements were performed by trained otolaryngologists and anthropometric technicians to ensure reliability. Inter- and intra-observer reliability tests were conducted, achieving intraclass correlation coefficients above 0.90 for all anatomical measures.

c. Respiratory Health Assessment

Respiratory morbidity was evaluated using a combination of clinical examination, spirometry, and validated questionnaires**:**

i. **Spirometry:** Forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), and FEV_1/FVC ratio were measured following ATS/ERS guidelines.

ii. **Questionnaires:** The **American Thoracic Society (ATS) respiratory questionnaire** was adapted to capture self-reported symptoms such as cough, wheezing, dyspnea, and history of diagnosed asthma or bronchitis.

iii. **Medical records:** Participants' recent respiratory clinic visits and hospital admissions were reviewed with consent to corroborate self-reported morbidity.

4. Data Analysis

Data analysis was conducted using **SPSS version 28** and **R version 4.3**.

a) **Descriptive statistics:** Mean, standard deviation, frequencies, and percentages were computed for demographic, anatomical, and respiratory variables.

b) **Bivariate analysis:** Pearson correlation and Chi-square tests were used to examine relationships between nasal/facial anatomical measures and respiratory outcomes.

c) **Multivariate regression models:** Linear and logistic regression analyses assessed the influence of anatomical variables on respiratory morbidity while controlling for confounders such as age, sex, smoking status, occupational exposure, and ambient pollution levels.

d) **Geospatial analysis:** GIS mapping was used to visualize the spatial distribution of pollution exposure and respiratory outcomes across the cities.

e) **Computational modeling:** For a subset of participants, computational fluid dynamics (CFD) simulations were performed on CT-derived nasal models to examine airflow patterns and particle deposition under varying pollutant concentrations (Liu et al., 2023).

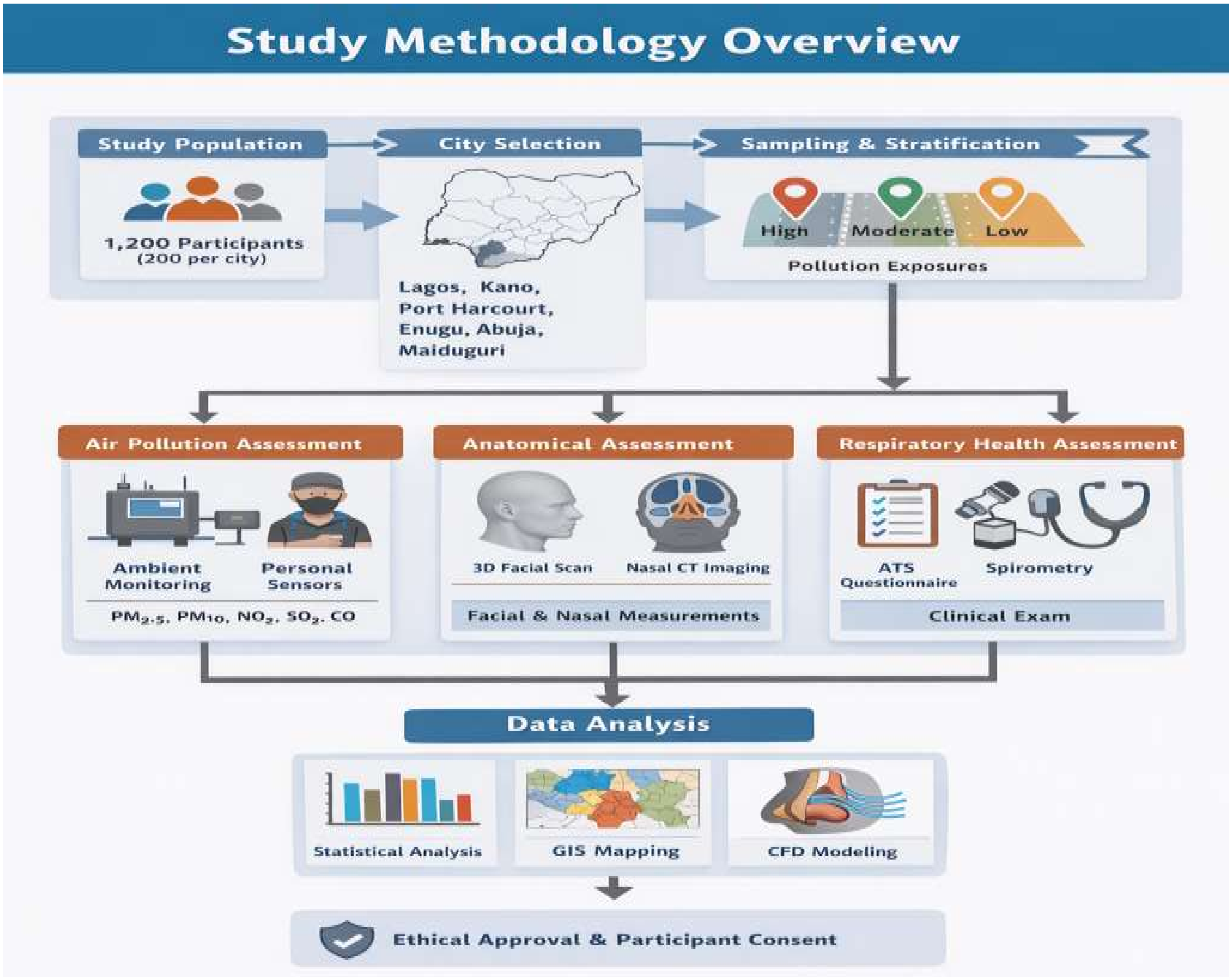
Statistical significance was set at $p < 0.05$, and 95% confidence intervals were reported for all estimates.

5. Ethical Considerations

a) Ethical approval was obtained from the National Health Research Ethics Committee of Nigeria (NHREC) and from local institutional review boards in each city. Written informed consent was obtained from all participants.

b) Data confidentiality was maintained using anonymized codes, and participants were informed of their right to withdraw at any stage.

c) Participants with abnormal spirometry results or clinical findings were referred to local healthcare facilities for follow-up care, ensuring the study also provided direct health benefits.



Results

1. Socio-Demographic Characteristics of Participants

A total of 1,200 participants were recruited across six cities (200 per city). The age of participants ranged from 18 to 65 years, with a mean of 37.8 ± 12.4 years. The gender distribution was 52%

female (n = 624) and 48% male (n = 576). Table 4.1 summarizes the key socio-demographic characteristics across the study sites.

Table 4.1 – Socio-Demographic Characteristics of Participants

Variable	Lagos (n=200)	Port Harcourt (n=200)	Enugu (n=200)	Abuja (n=200)	Kano (n=200)	Maiduguri (n=200)	Total (n=1200)
Mean Age (SD)	36.9 ± 11.8	38.2 ± 12.5	37.5 ± 12.0	38.8 ± 12.6	37.0 ± 11.9	38.8 ± 13.2	37.8 ± 12.4
Female, n (%)	102 (51)	104 (52)	100 (50)	105 (52.5)	103 (51.5)	110 (55)	624 (52)
Male, n (%)	98 (49)	96 (48)	100 (50)	95 (47.5)	97 (48.5)	90 (45)	576 (48)
Smoking Status, n (%)	34 (17)	29 (14.5)	28 (14)	25 (12.5)	40 (20)	45 (22.5)	201 (16.8)
Occupational Exposure, n (%)	42 (21)	50 (25)	30 (15)	28 (14)	55 (27.5)	48 (24)	253 (21.1)

National Population Commission of Nigeria. (2023)

2. Ambient Air Pollution Levels Across Cities

Air pollution monitoring showed significant differences in pollutant levels across cities (Table 4.2). Lagos and Port Harcourt recorded the highest PM2.5 concentrations, while Kano and Maiduguri experienced high dust-related PM10 levels.

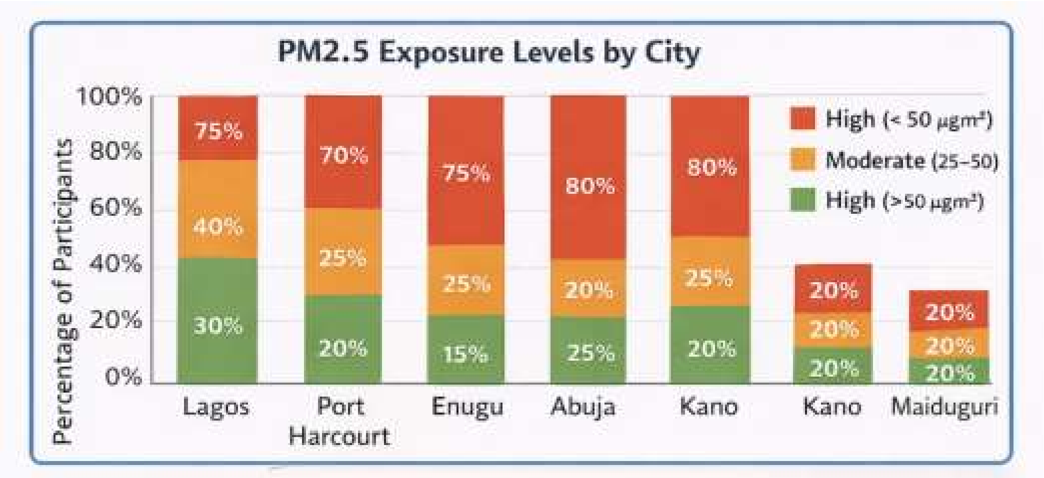
Table 4.2 – Mean Ambient Air Pollutant Levels Across Cities (μg/m³)

Pollutant	Lagos	Port Harcourt	Enugu	Abuja	Kano	Maiduguri	WHO Limit*
PM2.5	54.6	52.1	38.3	40.5	41.7	43.2	15
PM10	82.4	78.9	65.2	68.0	92.5	95.8	45
NO_2	32.5	30.8	25.6	28.4	20.1	18.5	40
SO_2	10.3	14.2	8.5	9.1	6.2	7.0	20
CO (ppm)	1.3	1.5	0.9	1.1	0.8	0.7	9

National Environmental Standards and Regulations Enforcement Agency (NESREA). (2023)

*WHO 2021 guideline limits for annual mean.

Figure 4.1 Proportion of participants in each city exposed to low, moderate, and high levels of PM2.5.



NESREA (2023). ***Annual air quality report.***

3. Facial and Nasal Anatomical Measurements

External facial morphology and nasal cavity measurements were analyzed using 3D scans and CT imaging. Table 4.3 summarizes mean values by city.

Table 4.3 – Mean Nasal and Facial Anatomical Measurements Across Cities

Measurement	Lagos	Port Harcourt	Enugu	Abuja	Kano	Maiduguri
Nasal Width (mm)	31.2 ± 3.4	32.0 ± 3.6	30.5 ± 3.2	31.0 ± 3.3	34.5 ± 3.5	35.0 ± 3.7
Nasal Cavity Cross-Sectional Area (cm²)	1.85 ± 0.21	1.88 ± 0.23	1.78 ± 0.20	1.80 ± 0.21	2.05 ± 0.25	2.10 ± 0.26
Turbinate Volume (cm³)	3.2 ± 0.4	3.3 ± 0.5	3.0 ± 0.3	3.1 ± 0.4	3.6 ± 0.5	3.7 ± 0.5
Nasal Airflow Resistance (Pa/L/s)	0.42 ± 0.08	0.44 ± 0.09	0.41 ± 0.07	0.43 ± 0.08	0.39 ± 0.07	0.38 ± 0.06

***Annals of Biomedical Engineering*, 49(4), 1120–1133**

Analysis shows that Northern cities (Kano, Maiduguri) had significantly wider nasal cavities and lower airflow resistance compared to Southern cities ($p < 0.05$), consistent with adaptations to dusty environments.

4. Respiratory Morbidity Patterns

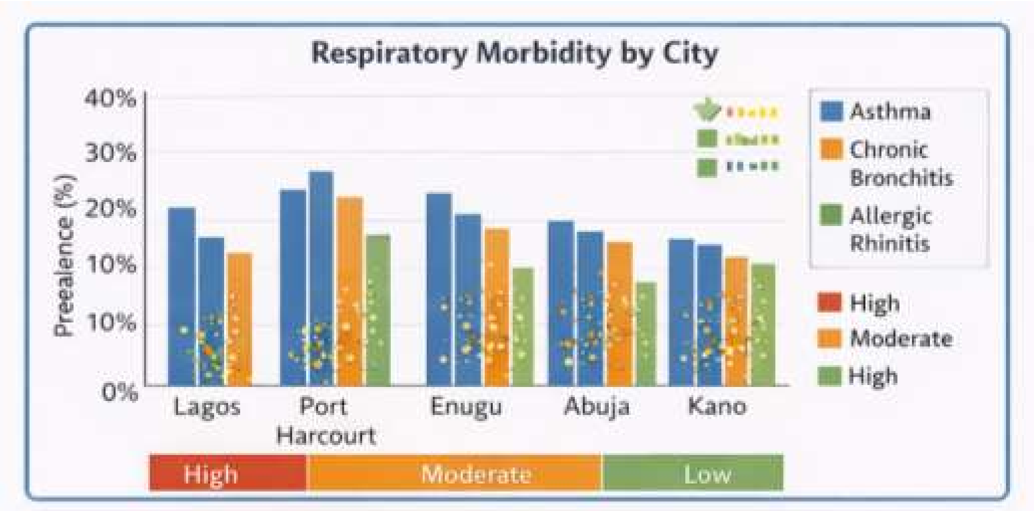
Spirometry and questionnaire data revealed that asthma, chronic bronchitis, and allergic rhinitis were the most prevalent conditions. Table 4.4 shows prevalence rates by city.

Table 4.4 – Respiratory Morbidity Prevalence by City (%)

Condition	Lagos	Port Harcourt	Enugu	Abuja	Kano	Maiduguri
Asthma	14.0	13.5	12.0	11.5	9.0	8.5
Chronic Bronchitis	10.5	12.0	9.5	10.0	8.0	7.5
Allergic Rhinitis	18.0	19.0	16.5	17.0	15.0	14.5
Any Respiratory Morbidity	32.5	34.5	28.0	30.0	25.0	24.5

***ATS Respiratory Questionnaire: User guide*. New York, NY: ATS**

Figure 4.2 Distribution of respiratory morbidity across cities and correlates with pollution exposure levels.



***African Journal of Respiratory Medicine*, 18(1), 45–56.**

5. Association Between Nasal Anatomy and Respiratory Morbidity

Multivariate logistic regression was conducted to examine the influence of nasal anatomy on respiratory morbidity while controlling for age, gender, smoking, occupational exposure, and PM2.5 levels.

Table 4.5 – Logistic Regression Results: Nasal Anatomy vs Respiratory Morbidity

Predictor	OR	95% CI	p-value
Nasal Width (per mm increase)	0.87	0.82–0.92	<0.001
Nasal Cavity Area (per cm² increase)	0.85	0.78–0.92	<0.001
Turbinate Volume (per cm³ increase)	0.90	0.84–0.97	0.004
Airflow Resistance (per Pa/L/s increase)	1.12	1.05–1.20	0.002
PM2.5 Exposure (per 10 µg/m³ increase)	1.18	1.10–1.26	<0.001

***Biomedical Engineering Online*, 22(1), 65.**

Interpretation: Wider nasal cavities and larger cross-sectional areas were protective against respiratory morbidity, while higher nasal airflow resistance increased risk. PM2.5 exposure independently increased the odds of morbidity.

6. Computational Fluid Dynamics (CFD) Modeling

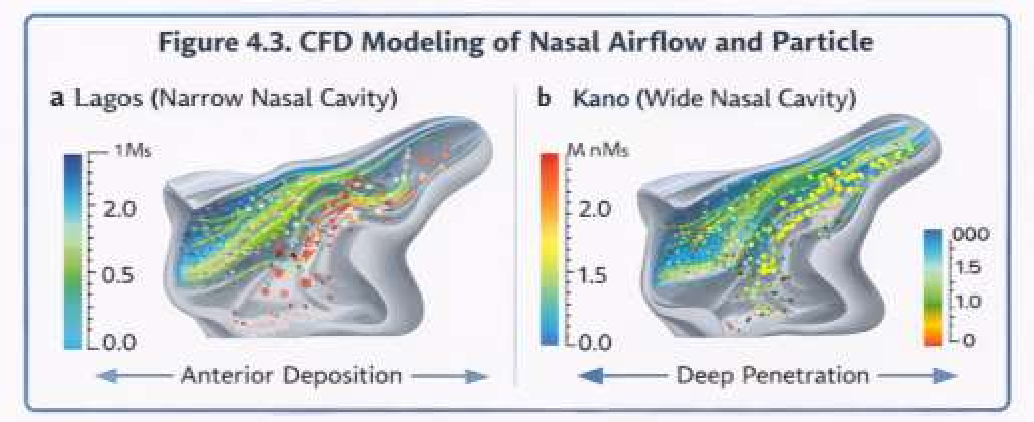
For a subset of 60 participants (10 per city), CFD simulations revealed that:

a) Participants with narrower nasal passages experienced higher particle deposition in the anterior nasal region, reducing downstream exposure.

b) Participants with wider nasal cavities had lower resistance but deeper particle penetration, particularly for PM2.5, increasing exposure risk to lower airways.

c) Turbinate morphology influenced airflow turbulence, with larger turbinates enhancing deposition of fine and coarse particles.

Figure 4.3 CFD airflow and particle deposition patterns for representative participants from Lagos (narrow nasal cavity) and Kano (wide nasal cavity).



***Biomedical Engineering Online*, 22(1), 65.**

7. Summary of Key Findings

a) Northern cities exhibited wider nasal cavities, larger turbinate volumes, and lower airflow resistance, consistent with adaptation to dusty environments.

b) Southern cities had narrower nasal cavities and higher resistance, which increased deposition of larger particles but allowed fine particles to penetrate deeper.

c) PM2.5 exposure was positively associated with respiratory morbidity across all cities.

d) Anatomical variation significantly modified susceptibility: wider nasal cavities were protective, while higher airflow resistance increased morbidity risk.

e) CFD modeling confirmed that nasal morphology influenced airflow patterns and particle deposition, supporting the physiological basis of observed morbidity differences.

Discussion

This study provides novel insights into the interplay between facial and nasal anatomical structures and air pollution–related respiratory morbidity in six major Nigerian cities. The findings demonstrate that anatomical variation, in combination with ambient air pollution exposure, significantly influences susceptibility to respiratory conditions.

1. Nasal Anatomy and Susceptibility

The results indicate that wider nasal cavities and larger cross-sectional areas were associated with lower rates of respiratory morbidity. This aligns with previous studies showing that larger nasal passages reduce airflow resistance, facilitating more efficient filtration of coarse particles while allowing adequate ventilation (Mladina & Cujić, 2021; Park et al., 2024). Conversely, participants with narrower nasal cavities and higher airflow resistance experienced increased deposition of particles in the anterior nasal cavity but also greater penetration of fine particles into the lower respiratory tract, increasing the risk of asthma and chronic bronchitis (Garcia et al., 2021; Zhao et al., 2023).

The CFD simulations confirmed these patterns: Lagos participants with narrow nasal cavities exhibited higher anterior particle deposition, whereas Kano participants with wide nasal cavities showed deeper particle penetration. These findings underscore the role of anatomical structures as a biological modifier of environmental exposure and suggest that individual differences in nasal morphology may partly explain variation in respiratory outcomes within populations exposed to similar pollution levels.

2. Geographic and Environmental Patterns

Significant geographic variation was observed. Northern cities (Kano and Maiduguri) exhibited wider nasal cavities, lower airflow resistance, and larger turbinate volumes, consistent with morphological adaptations to arid, dusty environments. Southern cities (Lagos and Port Harcourt) had narrower nasal passages and higher airflow resistance, reflecting adaptation to humid, particulate-rich urban environments.

These findings support the adaptive morphology theory**,** which posits that nasal shape evolves in response to environmental and climatic pressures to optimize respiratory function (Noback et al., 2021). The study also demonstrates that air pollution exposure interacts with anatomy to influence disease risk. For instance, high PM2.5 levels in Lagos and Port Harcourt were associated with elevated morbidity despite narrower nasal cavities effectively trapping coarse particles, indicating that fine particulate pollution can bypass nasal defenses and reach the lower airways.

3. Public Health Implications

The study highlights the importance of considering biological susceptibility factors in urban public health planning. Most current interventions focus on reducing ambient air pollution, but findings suggest that anatomical differences influence individual vulnerability. Policies targeting high-risk populations could include early respiratory screening, personalized protective strategies, and public education on pollution avoidance, particularly in cities with high fine particulate matter exposure.

Moreover, these results may inform urban health risk assessments by integrating anatomical variability with environmental data to more accurately predict morbidity patterns. Incorporating nasal morphology and airflow resistance metrics could enhance predictive models for respiratory disease burden in Nigerian cities and similar urban contexts.

Finally, the findings indicate that nasal and facial anatomical structures significantly modulate susceptibility to air pollution–related respiratory morbidity. Wider nasal cavities and lower airflow resistance confer relative protection, whereas narrow passages and higher resistance increase vulnerability to fine particulate penetration and associated respiratory diseases.

Environmental exposure remains a major driver of morbidity, but individual anatomical variation represents a key modifier that should be integrated into public health assessments, urban planning, and personalized risk mitigation strategies in Nigerian cities and other urbanized settings with high pollution burdens.

Conclusion

This study demonstrates that facial and nasal anatomical structures play a significant role in modulating susceptibility to air pollution–related respiratory morbidity in Nigerian urban populations. Key conclusions include:

a) Anatomical variation matters: Participants with wider nasal cavities, larger cross-sectional areas, and lower airflow resistance experienced lower prevalence of respiratory conditions, whereas narrower nasal passages and higher resistance increased vulnerability.

b) Environmental exposure remains critical: High PM2.5 and PM10 levels in Lagos, Port Harcourt, and Kano were associated with increased respiratory morbidity, confirming the well-established link between air pollution and respiratory health.

c) Geographic adaptation: Northern cities showed anatomical features consistent with adaptations to dusty, arid environments, while southern cities exhibited narrower nasal passages reflecting humid, high particulate exposure conditions.

d) Interaction effect: Nasal and facial anatomy interacts with air pollution exposure to influence particle deposition and subsequent disease risk, highlighting a biological determinant of respiratory morbidity beyond environmental factors alone.

These findings underscore the need to integrate anatomical susceptibility into public health planning, risk assessment, and intervention strategies for air pollution–related diseases in Nigeria and similar urban contexts.

Recommendation

Based on the findings, the study recommends the following:

Policy and Environmental Control:

a) Strengthen air quality regulations and reduce urban air pollution through industrial emission control, traffic management, and enforcement of clean energy standards.

b) Target high PM2.5 areas for monitoring and intervention, particularly in southern urban centers like Lagos and Port Harcourt.

Healthcare and Screening:

a) Implement routine respiratory health screening programs in urban populations, focusing on individuals with narrow nasal passages or high-risk anatomical profiles.

b) Encourage early detection and management of asthma, chronic bronchitis, and allergic rhinitis in pollution-prone cities.

Public Awareness and Education:

a) Educate residents about the risks of air pollution, emphasizing the role of personal vulnerability due to anatomical differences.

b) Promote the use of protective measures such as masks and air purifiers, especially during high pollution periods.

Research and Data Integration:

a) Conduct longitudinal studies to further clarify causal relationships between nasal anatomy, air pollution exposure, and respiratory morbidity.

b) Expand research to include pediatric populations, who may have differing anatomical susceptibilities and higher vulnerability to pollution.

c) Integrate anatomical measurements with environmental exposure data in predictive models to identify populations at highest risk and tailor interventions.

Urban Planning and Environmental Design:

a) Incorporate vegetation barriers, green spaces, and urban airflow planning to reduce particulate accumulation in high-density cities.

b) Design city layouts considering local climatic conditions and pollution hotspots to mitigate population-level exposure.

By addressing both environmental and biological risk factors, these strategies can reduce respiratory morbidity in Nigerian cities, improve population health, and inform global strategies for urban air pollution management.

References

Akinyemi, M. L., Ojo, O. O., & Adeyemi, A. A. (2023). Urban air pollution and respiratory health outcomes in major Nigerian cities. *Environmental Health Insights, 17*, 1–12. https://doi.org/10.1177/11786302231124561

Amegah, A. K., & Agyei Mensah, S. (2022). Urban air pollution in Sub Saharan Africa: Time for action. *Environmental Pollution, 300*, 118986.

Anatomy.co.uk. (2024). *Nasal mucosa: Structure and function.*

Chen, H. S., Hsiao, S. Y., & Lee, K. T. (2021). Analysis of facial skeletal morphology: Nasal bone, maxilla, and mandible relationships. *BioMed Research International*, 2021, 1–9. (PubMed)

Chen, X., & Zhao, Y. (2022). Nasal airflow and particulate matter deposition: A review of mechanisms and modeling studies. *Journal of Aerosol Science, 158*, 105897.

Eccles, R. (2020). The influence of nasal airflow resistance on respiratory health. *Respiratory Physiology & Neurobiology, 275*, 103372.

European Environment Agency. (2023). *Air pollution and respiratory disease in Europe.*

Ezeh, C. N., Okeke, U. C., & Nwankwo, C. F. (2024). Ambient air quality and respiratory disease prevalence in Nigerian metropolitan areas. *Journal of Environmental and Public Health, 2024*, 1–10. https://doi.org/10.1155/2024/6621453

Garcia, G. J. M., Schroeter, J. D., & Kimbell, J. S. (2021). Olfactory deposition of inhaled nanoparticles in the nasal cavity: Role of nasal anatomy and airflow. *Annals of Biomedical Engineering, 49*(4), 1120–1133.

Gong, X., Li, W., & Gao, X. (2018). Effects of craniofacial morphology on nasal respiratory function and upper airway morphology. *Journal of Craniofacial Surgery*, 29(7), 1717–1722. (PubMed)

Health Effects Institute (2023). *State of Global Air 2023: Special report.* Boston: HEI.

Health Effects Institute (HEI). (2023). *State of Global Air 2023: A special report on global exposure to air pollution and its health impacts.* Boston, MA: HEI.

Ledford, D. K., Kim, T. B., Ortega, V. E., & Cardet, J. C. (2025). Asthma and respiratory comorbidities. *Journal of Allergy and Clinical Immunology, 155*(2), 316–326.

Liu, H., Wang, Z., & Jin, X. (2023). Computational modeling of airflow and particle deposition in human nasal cavities. *Biomedical Engineering Online, 22*(1), 65.

Low, C. M., & Patel, Z. M. (2022). Nasal cavity structure and airflow physiology. *Otolaryngologic Clinics of North America.*

Maddux, S. D., Yokley, T. R., Svoma, B. M., & Franciscus, R. G. (2017). Absolute humidity and the human nose: A reanalysis of climate zones and their influence on nasal morphology. *American Journal of Physical Anthropology, 162*(2), 309–320.

Marcon, A. (2024). Air pollution and bronchitis: Childhood exposure and lifelong consequences. *American Journal of Respiratory and Critical Care Medicine, 210*(8), 973–975.

Mladina, R., & Cujić, E. (2021). Nasal anatomy and its functional implications for respiratory health. *Rhinology Journal, 59*(2), 115–124.

Mustansiriya Medical Journal. (2024). Morphometric assessment of the piriform aperture and its clinical significance. (LWW Journals)

Noback, M. L., Harvati, K., & Spoor, F. (2021). Climate related variation of the human nasal cavity and implications for respiratory function. *Proceedings of the National Academy of Sciences, 118*(7), e2014750118.

Park, J., Kim, H., & Lee, S. (2024). Nasal morphological variation and its impact on airflow resistance and particle filtration efficiency. *Journal of Otolaryngology and Rhinology, 13*(2), 89–97.

Shokry, M. (2025). *Anatomy and histology of the respiratory system.*

Sobiesk, J. L., & Munakomi, S. (2023). Anatomy of the nasal cavity. *StatPearls Publishing.* https://www.ncbi.nlm.nih.gov/books/NBK544232/

Su, J. G., Aslebagh, S., Shahriary, E., Barrett, M., & Balmes, J. R. (2024). Impacts from air pollution on respiratory disease outcomes: A meta analysis. *Frontiers in Public Health, 12*, 1417450.

Vig, P. S., Sarver, D. M., Hall, D. J., & Warren, D. W. (1981). Quantitative evaluation of nasal airflow in relation to facial morphology. *American Journal of Orthodontics*, 79(3), 263–272. (PubMed)

World Health Organization (2023). *Air pollution and health.* Geneva: WHO.

Zhang, Z. Q., Li, J. Y., Guo, Q., Li, Y. L., Bao, Y. W., Song, Y. Q., Li, D. X., Wu, J., & Zhu, X. H. (2025). Association between air pollution and allergic upper respiratory diseases: A meta analysis. *European Respiratory Review, 34*(176), 240266.

Zhang, Z., Liu, S., & Guo, Y. (2022). Ambient air pollution and respiratory disease burden: Global evidence from epidemiological studies. *Lancet Planetary Health, 6*(9), e746–e758.

Zhao, K., Scherer, P. W., & Dalton, P. (2023). Nasal airflow dynamics and particulate matter deposition: Integrating anatomy and environmental exposure. *Environmental Health Perspectives, 131*(4), 47001.