

Age-Related Changes in Nasal Cavity Architecture: A Radiological Anthropometry Study Using Axial CT Landmarking

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Research Article

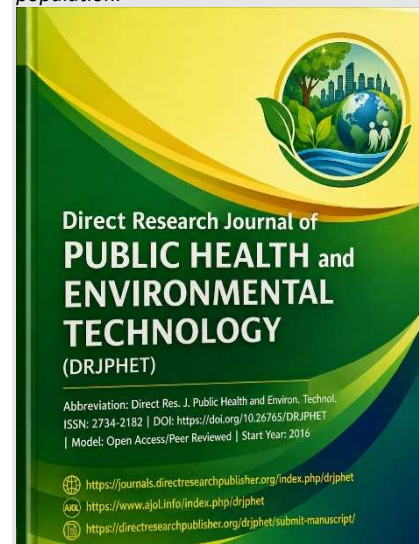
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ABSTRACT

The nasal cavity undergoes significant morphological changes throughout life, influenced by craniofacial growth, remodelling, and aging. Understanding these age-related architectural modifications is essential for accurate diagnosis, surgical planning, and forensic identification. However, longitudinal data on nasal cavity dimensions across the lifespan, particularly in African populations, are limited. Objective: This study aimed to investigate age-related changes in nasal cavity architecture using radiological anthropometry based on axial computed tomography (CT) landmarking in a Nigerian population. Methods: A retrospective cross-sectional study was conducted at Usmanu Danfodiyo University Teaching Hospital (UDUTH), Sokoto, Nigeria. A total of 130 head CT scans (84 males, 46 females) were analysed. Subjects were grouped into seven 10-year intervals from 0 to 70 years. Axial CT images were used to measure nine parameters across three regions of the nasal cavity of Anterior: Right and Left Anterior Bony Widths (RABW, LABW), middle: Right and Left Mid Bony Widths (RMBW, LMBW), posterior: Right and Left Posterior Bony Widths (RPBW, LPBW). Measurements were performed using Neusoft Dual Slide Helical CT software. Data were analyzed using SPSS version 20. One-way ANOVA was used to assess differences across age groups, and independent t-tests were used for sex comparisons. Statistical significance was set at $p < 0.05$. Results: Significant age-related changes were observed in multiple nasal dimensions. ABW (RABW+LABW) increased progressively from childhood, peaking in the 51–60 years group among males (12.85 ± 2.943 mm), followed by a decline in the 61–70 years group (10.44 ± 4.431 mm). The middle nasal cavity (RMBW/LMBW) reached maximum width in the 31–40 years group, with RMBW at 5.05 ± 1.653 mm and LMBW at 4.58 ± 3.651 mm in males. No consistent sexual dimorphism was observed across all age groups, although males generally exhibited larger dimensions. Notably, in the 31–40 years group, males had significantly greater RMBW ($p = 0.007$) and LMBW ($p = 0.047$) than females. Bilateral symmetry was preserved across all parameters ($p > 0.05$). The narrowest segment of the nasal cavity (middle third) was consistently < 4 mm in over 90% of subjects, indicating a high prevalence of anatomical nasal valve narrowing. RPBW and LPBW showed minimal variation across age and sex were symmetrical in all groups ($p > 0.05$), with no significant lateral differences Conclusion: Nasal cavity architecture undergoes dynamic changes with age, characterized by an initial increase in dimensions during growth, peak values in mid-adulthood, and a subsequent decline in the elderly. While males tend to have larger nasal dimensions, sexual dimorphism is not uniformly present across all age groups. These findings provide essential baseline data for developmental anatomy, surgical planning, and forensic anthropology in the Nigerian and broader West African

population.



Keywords: Nasal cavity; cephalometry; computed tomography; age variation; radiological anthropometry; nasal morphometry; Nigeria

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INTRODUCTION

The human nasal cavity is a complex anatomical structure that serves critical functions in respiration, olfaction, immune defence, and facial aesthetics. Its internal architecture is defined by bony and cartilaginous frameworks, with the anterior bony aperture (pyriform aperture), middle meatus (nasal valve), and posterior choanae representing three functionally distinct regions. The dimensions and spatial relationships of these regions are not static but evolve throughout life due to craniofacial growth, remodelling, and age-related degeneration (Pahor, 2023).

Understanding age-related changes in nasal cavity architecture is crucial for multiple clinical and scientific disciplines. In otorhinolaryngology, knowledge of normal developmental patterns aids in diagnosing congenital anomalies such as congenital nasal pyriform aperture stenosis (CNPAS) and choanal atresia (Ganjaei et al., 2019). In plastic and reconstructive surgery, particularly rhinoplasty, understanding the patient's baseline nasal anatomy at different life stages is essential for achieving both functional and aesthetic outcomes. In forensic anthropology, age estimation from craniofacial remains relies heavily on morphometric data, including nasal dimensions (Tuan et al., 2022).

The growth of the nasal skeleton begins in utero and continues into early adulthood. Kim et al., 2025, demonstrated that the midface, including the nasal complex, undergoes active anteroposterior and transverse expansion until the third decade of life. This growth is driven by sutural expansion, cartilaginous proliferation, and mechanical forces from mastication and respiration. After this period, growth stabilizes, and the nasal framework undergoes gradual remodelling influenced by hormonal changes, environmental factors, and functional demands.

With advancing age, structural changes occur due to bone resorption, cartilage thinning, mucosal atrophy, and loss of facial fat pads. These degenerative processes can lead to nasal valve collapse, increased nasal resistance, and subjective nasal obstruction, even in the absence of overt pathology. Merrill & Kanaan (2023) reported that elderly patients often present with complaints of nasal blockage despite clear endoscopic findings, attributing this to age-related narrowing of the internal nasal valve.

Sexual dimorphism is another well-documented factor influencing nasal morphology. In general, males exhibit larger nasal dimensions than females, a phenomenon attributed to higher metabolic demands and greater oxygen requirements associated with increased body mass and muscle volume. This dimorphism is often exploited in forensic anthropology for sex estimation from skeletal remains. Moreddu et al. (2013) reported statistically significant differences in pyriform aperture width between males and females in a European population, supporting its utility in biological profiling.

However, findings on sexual dimorphism are not consistent across all populations. Some studies report no significant gender differences, while others find dimorphism only in specific age groups or ethnicities. For instance, Ese et al. (2013) found no significant sexual dimorphism in nasal height among the Ijaw ethnic group in Nigeria, contrasting with results from Indian and Polish populations.

These discrepancies highlight the importance of population-specific normative data, as extrapolating findings from one demographic to another can lead to misdiagnosis and suboptimal surgical outcomes. In the context of West Africa, and particularly Nigeria, there is a notable paucity of published data on nasal cavity morphometry derived from modern imaging modalities. Most existing studies rely on dry skull measurements or surface anthropometry, which lack the precision and detail afforded by CT. The few CT-based studies available are either limited in scope or focus on pathological conditions rather than normative anatomy.

Moreover, the Nigerian population is ethnically diverse, comprising over 250 ethnic groups with distinct craniofacial characteristics. Generalizing findings from one region or ethnic group to the entire country may not be valid. Regional variations in nasal morphology may reflect genetic, environmental, and climatic influences, further emphasizing the need for localized data (Adekoya et al., 2020).

The clinical relevance of nasal cephalometry extends beyond surgery. In sleep medicine, narrow nasal passages contribute to upper airway resistance, a key factor in the pathogenesis of obstructive sleep apnoea (OSA). Identifying individuals with anatomically constricted nasal cavities can guide interventions such as nasal valve surgery or CPAP titration. Mathematical models incorporating nasal dimensions have been developed to predict optimal CPAP pressures, improving treatment efficacy (Camacho et al., 2015). Despite these applications, there remains a lack of standardized, CT-derived reference values for nasal cavity dimensions in African populations. Most existing databases are based on Caucasian, Asian, or mixed-race cohorts, limiting their applicability to individuals of African descent. This disparity contributes to a broader issue in global health research: the underrepresentation of African populations in biomedical studies, leading to potential biases in diagnostic criteria and therapeutic guidelines.

Therefore, this study aims to address this gap by conducting a radiological anthropometric analysis of age-related changes in nasal cavity architecture using axial CT landmarking in a Nigerian population. Specifically, it seeks to:

1. Establish normative values for anterior, middle, and posterior nasal cavity dimensions across age groups.

2. Investigate the influence of age and sex on these dimensions.
3. Assess bilateral symmetry within the nasal cavity.
4. Provide clinically relevant data for developmental anatomy, surgical planning, and forensic identification.

Through focusing on a geographically defined population in Sokoto, North-Western Nigeria, this study contributes to the growing body of knowledge on craniofacial variation in sub-Saharan Africa. The findings will serve as a foundational reference for future research and clinical practice, promoting more personalized and culturally informed healthcare delivery.

MATERIALS AND METHODS (Likus et al., 2014)

Study Design and Setting

This was a two-year retrospective cross-sectional study conducted at the Department of Radiology, Usmanu Danfodiyo University Teaching Hospital (UDUTH), Sokoto, Nigeria. The hospital serves as a major tertiary referral centre for the North-West geopolitical zone of Nigeria, providing a diverse patient population.

Sample Size Determination

The sample size was calculated using the formula for cross-sectional studies (Charan & Biswas 2013):

$$NS = \frac{Z^2 \times SD^2}{d^2}$$

Where:

1. $Z = 1.96$ (for 95% confidence level)
2. $SD = 0.23$ (standard deviation)
3. $d = 0.05$ (margin of error)

$$NS = \frac{(1.96)^2 \times (0.23)^2}{(0.05)^2} = 81$$

To ensure adequate statistical power and account for potential exclusions, a total of 130 CT scans were included—84 from males and 46 from females.

Inclusion and Exclusion Criteria

Inclusion criteria:

1. Head CT scans interpreted by certified radiologists.
2. No craniofacial trauma, tumours, or congenital anomalies.

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3. Normal brain development and absence of sinus pathology.

Exclusion criteria

1. Presence of nasal septal deviation, turbinate hypertrophy, or chronic rhinosinusitis
2. Poor image quality or motion artifacts
3. Incomplete demographic data

Imaging Protocol

All CT scans were acquired using a Neusoft C3000 Spiral CT machine (2005 model) with the following parameters:

1. Slice thickness: 5 mm
2. Field of view: 15 cm
3. Voltage: 120 kV
4. Current: 200 mA
5. Rotation time: 1 second

Axial images were reformatted into sagittal and coronal planes. DICOM files were processed using Neusoft Dual Slide Helical CT software for digital measurement.

Measurement Parameters and Landmarks

Measurements were taken on axial CT slices at three anatomical levels (Figure 1):

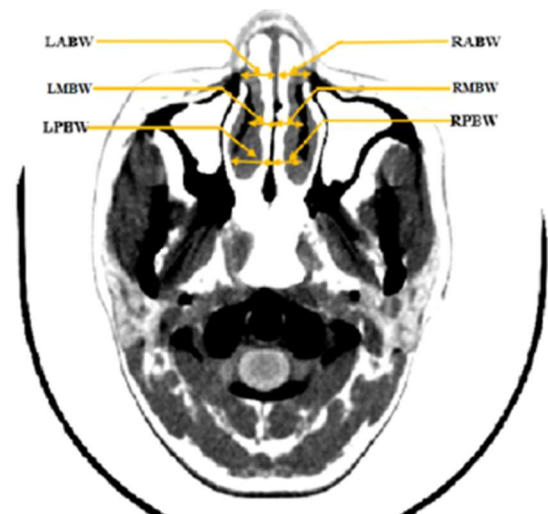


Figure 1: Axial Computed Tomography (CT) Scan Showing Nasal Cavity Measurement Landmarks

1. Anterior Nasal Cavity (at pyriform aperture):
 - a. RABW (Right Anterior Bony Width): distance from the right maxillary ridge to the septal mucosa.
 - b. LABW (Left Anterior Bony Width): (distance from the left maxillary ridge to the septal mucosa).
2. Middle Nasal Cavity (at inferior turbinate level):

- a. RMBW (Right Mid Bony Width): distance from the right inferior turbinate to the septal mucosa.
 - b. LMBW (Left Mid Bony Width): distance from the left inferior turbinate to the septal mucosa.
3. Posterior Nasal Cavity (choanal level):
- a. RPBW (Right Posterior Bony Width): distance from the right posterior bony wall to the septal mucosa.
 - b. LPBW (Left Posterior Bony Width): distance from the left posterior bony wall to the septal mucosa.

All measurements were performed independently by two observers, and inter-rater reliability was assessed using intraclass correlation coefficients (ICC).

Data Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 20. Descriptive statistics (mean $\pm$ SD) were computed. One-way ANOVA was used to compare age groups, and independent t-tests were used for sex comparisons. Statistical significance was set at $p < 0.05$. Ethical approval was obtained from UDUTH/HREC (Ref: UDUTH/HREC/2016/No.498).

RESULTS

Demographic Distribution

A total of 130 subjects were analyzed across seven age groups:

- A (0–10): 18
- B (11–20): 16
- C (21–30): 20
- D (31–40): 22
- E (41–50): 18
- F (51–60): 18
- G (61–70): 18

Male-to-female ratio: 1.83:1.

Anterior Nasal Cavity Dimensions

1. RABW: Increased progressively with age, reaching its peak value in males within group F (51–60 years) before declining in group G (61–70 years). High bilateral symmetry was maintained with the left side, showing no statistically significant lateral variation ($p > 0.05$).
2. RABW: Followed a growth and regression trajectory parallel to the right side, peaking in group F (51–60 years) among males and subsequently decreasing in group G (61–70 years).
3. Females exhibited less variation across age groups, and no statistically significant sexual dimorphism was observed in any age category ($p > 0.05$).

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Middle Nasal Cavity Dimensions

RMBW and LMBW peaked in group D (31–40 years).

1. RMBW: Highest in males (5.05 ± 1.653 mm), lowest in females of group C (2.80 ± 0.471 mm)
2. LMBW: Highest in males (4.39 ± 1.639 mm), lowest in females of group C (2.38 ± 0.502 mm)

Significant sex differences were observed in group D:

1. RMBW: $p = 0.007$
2. LMBW: $p = 0.047$

Posterior Nasal Cavity Dimensions

RPBW and LPBW showed minimal variation across age and sex were symmetrical in all groups ($p > 0.05$), with no significant differences.

Bilateral Symmetry

No statistically significant differences were found between right and left measurements for RABW/LABW, RMBW/LMBW, or RPBW/LPBW ($p > 0.05$), indicating high bilateral symmetry.

DISCUSSION

This study provides a detailed radiological anthropometric evaluation of age-related changes in nasal cavity architecture using axial CT landmarking in a Nigerian population. Our findings confirm that nasal dimensions are not static but undergo dynamic changes throughout life, with distinct patterns of growth, peak, and regression.

Age-Related Changes in Nasal Morphometry

One of the most significant findings is the dynamic nature of nasal cavity dimensions with age. ABW increased progressively from childhood to middle age, peaking in the 51–60 years group among males, followed by a decline in the elderly. This pattern aligns with known principles of craniofacial growth. The midface, including the nasal complex, undergoes active growth until the third decade, after which remodelling continues under mechanical and hormonal influences (Rengasamy Venugopalan & Allareddy, 2022).

The peak in ABW during the fifth decade may reflect skeletal maturation and soft tissue hypertrophy. In males, androgen levels remain relatively stable until later life, potentially contributing to sustained turbinate volume. Conversely, the decline in ABW in the 61–70 years group may be attributed to age-related bone resorption, cartilage thinning, and loss of facial fat pads, leading to collapse of the nasal framework (Anawalt & Matsumoto, 2022). The middle nasal cavity, particularly the nasal valve area, showed the most pronounced age-related variation.

RMBW and LMBW reached their maximum in the 31–40 years group, coinciding with peak physical activity and metabolic demand. The subsequent decline in middle cavity width in older adults may explain the increased prevalence of subjective nasal obstruction in the elderly, even in the absence of overt pathology. This is in line with the findings of Ganjaei et al, 2019, who found that nearly all nasal airspace volumes are increased in older adults independent of sex and head size.

Interestingly, the posterior nasal cavity (choanal aperture) exhibited minimal variation with age, suggesting that the bony framework of the nasopharynx is relatively stable after adolescence. This coincided with the findings of Chen et al, 2024, who reported that female individuals' development of pharyngeal airway spaces reaches a stage of near maturation by middle adolescence (14–17 years).

Sexual Dimorphism: Population-Specific Patterns

While males appeared to have larger measurements, consistent sexual dimorphism was absent across all age groups. Significant differences were observed only in the 31–40 years group for RMBW and LMBW, suggesting that dimorphism is age-dependent rather than universal.

This finding contrasts with studies in Indian and Polish populations, where males consistently displayed larger nasal dimensions across all age groups (Adil et al., 2016; Likus et al., 2014). The discrepancy may be attributed to ethnic variation, sample size, or methodological differences.

Clinical and Forensic Relevance

The high degree of bilateral symmetry observed in this study is reassuring for surgeons. It indicates that significant asymmetry is likely pathological rather than developmental. This has direct implications for diagnosing conditions such as unilateral turbinate hypertrophy, septal deviation, or neoplastic expansion.

In forensic anthropology, the piriform aperture (measured as ABW) is a reliable marker for sex estimation. Our mean ABW values (9.43–12.85 mm) fall within the range reported for other African populations but are narrower than those in Caucasians, supporting the hypothesis of climatic adaptation.

Limitations and Future Directions

This study is limited by its retrospective design, single-center sample, and potential selection bias. Future research should include multicenter cohorts, 3D volumetric analysis, and correlation with airflow dynamics using computational fluid dynamics (CFD).

CONCLUSION

Using axial computed tomography (CT) landmarking, this

study effectively assessed age-related morphological changes in nasal cavity architecture in a Nigerian population. The results suggest that nasal dimensions are dynamic, growing steadily starting in childhood and peaking in mid-adulthood. Males' anterior nasal cavity measurements grew and peaked in the 51–60 age range before decreasing as they aged.

The middle nasal cavity reached its widest dimensions in individuals aged 31 to 40, indicating an important stage of structural development. The size of the posterior nasal cavity showed little difference among various age groups and genders. Bilateral symmetry was consistently maintained across all assessed aspects of the nasal cavity. Males typically had larger nasal dimensions, but this difference between sexes was not consistent across all age groups. Notable differences in sexual characteristics were found in the widths of the middle nasal cavity among individuals aged 31 to 40 years. The common occurrence of narrow middle segments suggests that there are specific anatomical features of the nasal valve associated with this group. These CT-derived standard values provide important information for African populations in medical and radiological research. These insights offer important foundational information for developmental anatomy, surgical planning, and forensic anthropology.

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