Ethnic-Specific Normative Data for Bony and Mucosal Nasal Dimensions Derived from CT Scans: A Cephalometric Study in a Nigerian Population

Original Article

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Submitted: 26 December, 2025 Final revision: 30 April, 2026 Accepted: 24 May 2026

ABSTRACT

Background: The morphometric dimensions of the nasal cavity are crucial for surgical planning, forensic identification, and understanding craniofacial evolution. This study aimed to establish ethnic-specific normative data for bony and mucosal nasal cavity dimensions using Computed Tomography (CT) in a Nigerian population (Hausa, Fulani, Ibra, Yoruba and Igbo ethnic groups), with a focus on anterior, middle, and posterior nasal regions.

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 analyzed. Participants (Hausa, Fulani, Ibra, Yoruba and Igbo ethnic groups) were grouped into seven 10-year intervals from 0 to 70 years. Axial CT images were used to measure: Anterior Bony Width (ABW) Right and Left Anterior Bony Widths (RABW, LABW) Middle Minimal Mucosal Width (MMW) Right and Left Middle Minimal Widths (RMMW, LMMW).

Results: The middle nasal cavity (RMMW/LMMW) reached maximum width in the 31–40 years group, with RMMW at 5.05±1.653 mm and LMMW at 4.39±1.639 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 RMMW ($p = 0.007$) and LMMW ($p = 0.047$) 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.

Conclusion: This study provides the first comprehensive set of ethnic-specific normative data (Hausa, Fulani, Ibra, Yoruba and Igbo ethnic groups) for nasal cavity dimensions in a Nigerian population. The findings reveal dynamic age-related changes, variable sexual dimorphism, and high bilateral symmetry. These data are essential for evidence-based surgical planning in rhinoplasty and sinus surgery, forensic anthropology, and comparative craniofacial research in African populations.

Keywords: Cephalometry; Computed Tomography; Nasal Morphometry; Forensic anthropology

Online access: https://sjhrs.com.ng **DOI:** https://doi.org/10.60787/sjhrs.vol1no1.12

How to cite: Tijjani et. al. Ethnic-Specific Normative Data for Bony and Mucosal Nasal Dimensions Derived from CT Scans: A Cephalometric Study in a Nigerian Population. The Sub-Saharan Journal of Health & Radiation Sciences, 2026;1(1): 85 – 91

Introduction

The human nasal cavity is a complex structure involved in respiration, olfaction, immune defence, and facial aesthetics. Its dimensions vary among populations due to genetic, environmental, and developmental influences. Understanding these variations is important for clinical and scientific fields such as reconstructive surgery, otorhinolaryngology, forensic anthropology, and paleoanthropology. Accurate knowledge of nasal anatomy is also essential for procedures such as rhinoplasty, septoplasty, and endoscopic sinus surgery (Wackym & Snow, 2017). Surgeons depend on normative data for preoperative assessment, surgical planning, and postoperative evaluation. However, most reference data are derived from Caucasian or Asian populations and may not accurately reflect African nasal morphology. Using non-ethnic-specific standards can result in misdiagnosis, functional impairment, or poor aesthetic outcomes (Ishii et al., 2017).

In forensic anthropology, nasal dimensions (particularly those of the piriform aperture) are widely used for sex estimation and ancestry determination from skeletal remains. Discriminant function analyses based on nasal metrics have achieved accuracy rates exceeding 85% in some populations (White & Folkens, 2005). However, these models are often developed using non-African reference samples, limiting their applicability in regions like West Africa, where craniofacial morphology differs significantly due to genetic and climatic adaptations. The Nigerian population is one of the most ethnically diverse in the world, comprising over 250 ethnic groups, including the Hausa, Yoruba, Igbo, Fulani, and Ijaw. Each group exhibits distinct craniofacial characteristics shaped by evolutionary, environmental, and cultural factors. Despite this diversity, there is a notable lack of standardized, population-specific normative data for nasal cavity dimensions derived from modern imaging modalities such as computed tomography (CT). Most existing studies on Nigerian nasal morphology rely on dry skull measurements or surface anthropometry, which are limited in their ability to capture internal soft tissue and mucosal dimensions. For example, Garandawa et al. (2008) conducted a morphometric study on adult Nigerians using calipers, while Ese et al. (2013) reported nasal height in the Ijaw ethnic group. However, these methods cannot provide the detailed, three-dimensional (3D) spatial information required for modern surgical and forensic applications.

Computed tomography (CT) has transformed craniofacial morphometry by providing high-resolution assessment of both bony and soft tissue structures of the nasal cavity, including the nasal valve, turbinates, and choanae. Several CT-based studies have established normative nasal measurements and demonstrated developmental, ethnic, age-related, and sex-related variations in nasal anatomy (Syutkina et al., 2023). However, comparable CT studies are lacking in Nigerian and broader West African populations, contributing to the underrepresentation of Africans in biomedical research and potentially limiting the applicability of existing diagnostic, surgical, and forensic standards. Nasal morphology changes with growth and ageing, while males generally exhibit larger nasal dimensions than females, although these patterns vary among populations.

The Anterior Bony Width (ABW), measured at the pyriform aperture, is a key cephalometric parameter influenced by maxillary and nasal bone development. The nasal valve, the narrowest part of the airway, contributes about 50% of total airway resistance, while the posterior choana is important in diagnosing choanal atresia and congenital nasal pyriform aperture stenosis (CNPAS) (Evteev et al., 2018). Choanal stenosis is defined by a unilateral diameter <0.34 cm with a vomer thickness >0.55 cm, whereas pyriform aperture stenosis is diagnosed when the transverse diameter is <8 mm or <3 mm (Šebová et al., 2021).

Despite their clinical and forensic importance, normative data for nasal dimensions are lacking in Nigerians, limiting accurate diagnosis, surgical planning, and anthropological studies.

This study aims to address this gap by establishing CT-based ethnic-specific reference values for bony and mucosal nasal dimensions in a Nigerian population.

Specifically, it seeks to:

I) Provide baseline morphometric values for anterior, middle, and posterior nasal cavity dimensions.
II) Investigate the influence of age and sex on these dimensions.
III) Assess bilateral symmetry within the nasal cavity.
IV) Contribute to the development of population-specific reference standards for clinical and forensic applications.

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

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, providing a diverse patient population.

Sample Size Determination

The sample size was calculated using the formula for cross-sectional studies:

n=d2Z2·SD2

Where:

- Z = 1.96 (for 95% confidence level)
- SD = 0.23 (standard deviation from Likus et al., 2014)
- d = 0.05 (margin of error)

n= (0.05)2(1.96)2· (0.23)2=81

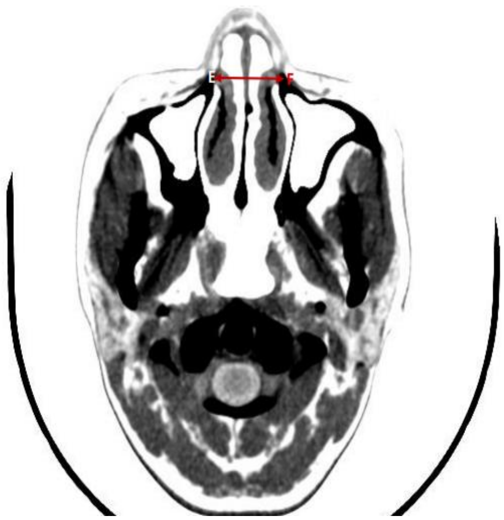
To ensure adequate statistical power and account for potential exclusions, a total of 130 CT scans were included—84 from males and 46 from females.

Inclusion and Exclusion Criteria: To be included in this study, patients must have head CT scans that were interpreted by certified radiologists. These participants must demonstrate normal brain development and an absolute absence of sinus pathology. Additionally, eligible scans must show no evidence of craniofacial trauma, tumours, or congenital anomalies. Conversely, scans are excluded if the patient presents with nasal septal deviation, turbinate hypertrophy, or chronic rhinosinusitis. The study also excludes any scans with poor image quality, motion artifacts, or incomplete demographic data.

Imaging Protocol: All CT scans were acquired using a Neusoft C3000 Spiral CT machine (2005 model). The scan protocol utilized a 5 mm slice thickness and a 15 cm field of view. Exposure settings were established at a tube voltage of 120 kV and a tube current of 200 mA. The gantry rotation time was set to 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

Anatomical measurements were performed on axial CT slices across three specific levels of the nasal cavity. At the level of the anterior nasal cavity, which corresponds to the pyriform aperture, three distinct distances were recorded. These included the total distance between the maxillary ridges (ABW), the distance from the right maxillary ridge to the septal mucosa (RABW), and the distance from the left maxillary ridge to the septal mucosa (LABW).
Moving posteriorly to the middle nasal cavity at the level of the inferior turbinates, measurements captured the minimal distance between the opposing turbinates (MMW). This level also included measurements from the septal mucosa to both the right turbinate (RMMW) and the left turbinate (LMMW). Finally, at the posterior nasal cavity corresponding to the choanal level, the protocol evaluated the overall distance between the pterygoid processes (BCAW).



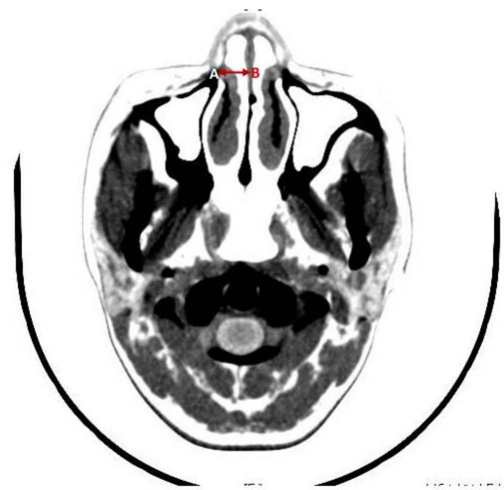


Figure 1: Shows the Anterior Nasal Aperture (Pyriform Aperture) = E-F

This was complemented by measuring the distance from the septal mucosa to both the right bony wall (RPBW) and the left bony wall (LPBW).

Data Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 20. Descriptive statistics (mean ± SD) were computed. Independent t-tests were used to compare sexes, and one-way ANOVA was used for age group comparisons. Post-hoc Tukey tests were applied where appropriate. Statistical significance was set at $p < 0.05$. Ethical approval was obtained from UDUTH/HREC ((Ref: UDUTH/HREC/2016/No.498).

Results ABW increased with age, peaking in group F (51–60 years) in males (12.85±2.943 mm), followed by a decline in group G (10.44±4.431 mm).

All measurements (figure and 2) were performed independently by two observers, and inter-rater reliability was assessed using intraclass correlation coefficients (ICC).

Demographic Distribution

Group	Age Range (Years)	Sample Size (130)
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

Age Range	Gender	Mean Width ± Standard Error of ABW	
A (0–10)	M	9.43±1.967	0.266
	F	8.35±1.894	
D (31–40)	M	11.39±2.070	0.749
	F	11.71±2.563	
F (51–60)	M	12.85±2.943	0.355
	F	11.52±0.782	

Middle Nasal Cavity Dimensions

Both RMMW and LMMW parameters reached their peak within age group D, which spans from 31 to 40 years. The highest RMMW measurements were found in males at 5.05±1.653 mm, whereas the lowest values were observed among females in group C at 2.80±0.471 mm. For the LMMW dimension, males also exhibited the highest measurements at 4.39±1.639 mm, while females in group C demonstrated the lowest values at 2.38±0.502 mm. Statistical evaluation revealed significant differences between sexes specifically within group D, with a p-value of 0.007 for RMMW and a p-value of 0.047 for LMMW

No significant differences were found in other groups (Table 2).

Posterior Nasal Cavity Dimensions

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

Bilateral Symmetry

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

Discussion

This study provides the first comprehensive set of ethnic-specific normative data for bony and mucosal nasal cavity dimensions in a Nigerian population mostly Hausa, Fulani, Ibra, Yoruba and Igbo ethnic groups using CT imaging. Our findings confirm that nasal morphology is not only influenced by age and sex but also exhibits distinct patterns that differ from those reported in non-African populations.

Ethnic-Specific Nasal Morphology

One of the most significant contributions of this study is the establishment of baseline morphometric values for a Nigerian population. These data are essential for evidence-based clinical practice and forensic identification in West Africa.

The mean Anterior Bony Width (ABW) in adult males ranged from 11.39 mm to 12.85 mm, peaking in the 51–60 years group. This is narrower than values reported in Caucasian populations (e.g.: 32.54 mm for piriform aperture height), but comparable to other African studies. The relatively narrower nasal aperture in this population may reflect climatic adaptation, as narrower noses are more efficient at warming and humidifying air in hot, humid environments, a phenomenon known as Allen's Rule (Marechal et al., 2023).

The middle nasal cavity, particularly the nasal valve, showed the most dynamic variation. RMMW and LMMW reached their maximum in the 31–40 years group, coinciding with peak physical activity and metabolic demand. The fact that over 90% of subjects had a nasal valve width < 4 mm explains the clinical need for topical decongestants to facilitate diagnostic endoscopy, as noted by Mohammad et al. (2017).

Age-Related Changes

Nasal dimensions increased with age, peaking in mid-adulthood before declining in the elderly. This pattern aligns with known principles of craniofacial growth. According to Moore and Lavelle (1974), the midface undergoes active growth until the third decade, after which remodeling continues under mechanical and hormonal influences.

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—a phenomenon observed in geriatric patients with nasal valve collapse.

Sexual Dimorphism: Population-Specific Patterns

While males tended to have larger nasal dimensions, consistent sexual dimorphism were absent across all age groups. Significant differences were observed only in the 31–40 years group for RMMW and LMMW, 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

This study establishes the first comprehensive set of ethnic-specific normative data for nasal cavity dimensions in a Nigerian population. Nasal dimensions increase with age, peak in middle adulthood, and exhibit variable sexual dimorphism. Bilateral symmetry is preserved. These findings have important implications for surgical planning, forensic anthropology, and craniofacial research in African populations.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments

The authors express their gratitude to the radiology department staff and hospital administration of Usmanu Danfodiyo University teaching Hospital for providing access to the imaging databases and support during data collection.

Conflict of Interest

The authors declare that they have no competing financial interests or personal relationships that could have influenced the work reported in this paper.

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