

Sexual Dimorphism and Age-Related Changes in Facial, Nasal, and Cranial Indices: A Review

Abdul Malik¹, Chinwe Jemimah Ukpai², Bushra^{*3}, Samreen Ansari⁴, Saba Parveen⁵, Shivani Verma⁵,
Insha Ali⁵, Priyanka Jaiswar⁵

^{*1}Associate Professor, Department of Human Anatomy, State Takmil-ut-Tib College & Hospital,
Lucknow, U.P. India

² Assistant Lecturer, Department of Human Anatomy, College of Medicine, Veritas University Abuja,
Nigeria

³Final Year Student, B.Sc. (Hons.) Anthropology, Indira Gandhi National Open University, New Delhi,
India

⁴Postgraduate Scholar, Department of Human Anatomy, State Takmil-ut-Tib College & Hospital,
Lucknow, U.P. India

⁵Medical Student, B.U.M.S., State Takmil-ut-Tib College & Hospital, Lucknow, U.P. India

***Corresponding Author**

DOI: <https://doi.org/10.47772/IJRISS.2026.100800994>

Received: 11 September 2026; Accepted: 16 September 2026; Published: 22 September 2026

ABSTRACT

Cephalic (cranial) index, facial index and nasal index are among the most commonly cited ratios in physical anthropology, forensic science and clinical anatomy, and many studies have been conducted on the variations in these ratios between males and females as well as between age groups throughout the human life span. This review brings together that literature to provide answers to two interrelated questions: the differences in these indices between male and female, and the differences in these indices as a function of age ranging from infancy to old age. In all three indices, there are sex differences that are consistent across populations; and the direction of the sex difference is sometimes different across populations, but not yet fully understood. It also discovers that the craniofacial skeleton isn't merely static after growth ceases, but is still in a state of continuous, slow change throughout adulthood and old age, as a result of ongoing bone remodelling, soft tissue laxity and tooth loss in the case of the jaws. The review examines the implications of this variation for forensic sex and age estimation, for craniofacial surgery, and for the interpretation of population reference data, and suggests that single ratios should be used as one piece of information among many to be used to determine sex, rather than as fixed lifelong sex markers.

Keywords: Sexual Dimorphism, Facial Index, Nasal Index, Cranial Index, Facial Morphology, Craniofacial Anthropometry

INTRODUCTION

Anthropometric indices reduce the complex three-dimensional shape of the head, face, and nose to a small number of simple ratios: head breadth relative to head length for the cephalic index, facial height relative to facial breadth for the facial index, and nasal width relative to nasal height for the nasal index. [1, 2] These ratios have long been used to describe population variation, but two further sources of variation complicate their interpretation and are the focus of this review: sex and age.

Sexual dimorphism refers to the systematic differences in size and shape that exist, on average, between males and females of the same population. In the craniofacial skeleton, this dimorphism arises from a mixture of

genetic, hormonal, and developmental factors that act throughout growth and, to a lesser extent, throughout adult life. [2] Age-related change, meanwhile, refers to the fact that the head and face are not fixed structures once adolescent growth ends; they continue to remodel gradually across the decades of adulthood, and this remodelling is not identical in men and women. [3, 4]

Both forms of variation matter well beyond simple description. In forensic anthropology, an accurate understanding of sex- and age-related variation in craniofacial indices underpins the estimation of a biological profile from skeletal or radiographic remains. [5, 6, 7] In clinical and surgical practice, understanding how the nose, face, and skull normally change with age is essential for planning reconstructive and aesthetic procedures and for interpreting what is 'normal' ageing as opposed to pathological change. [8, 9, 10] This review brings together evidence on sexual dimorphism and age-related change for each of the three indices in turn, before drawing out shared themes and practical implications.

Objective

This narrative review aimed to:

- i. Investigate sex differences in the cephalic, facial, and nasal indices among different populations and geographical regions.
- ii. Describe the changes in the cephalic, facial, and nasal indices throughout the lifespan, highlighting the effects of human growth, development, aging, and craniofacial remodelling.
- iii. Assess the value of these indices for physical and forensic anthropology, clinical anatomy, and craniofacial assessment, highlighting their applicability, limitations, and potential for use as sex and age indicators.

METHODOLOGY

Design and Approach

The objective of this study was to collate and critically evaluate the existing evidence on sexual dimorphism and aging patterns of the three craniofacial anthropometric indices. A narrative review was chosen as the most appropriate design, given the nature and scope of the research question. The search strategy used was designed to identify publications that included sex differences, sexual dimorphism, or age-related differences and variations in the cephalic, facial, and nasal indices. The use of a narrative review was justified by the fact that the literature base for this review comprised studies that differed in terms of populations, age groups, geographical regions, methodologies, anatomical landmarks, measurement protocols, index calculations, and research goals. Therefore, a meta-analysis of the quantitative data was not considered an appropriate strategy.

Literature Search Strategy

A systematic search of the literature was undertaken using PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and the reference lists of articles and reviews identified in the search. The search terms used were selected to identify literature that reported on the anthropometric indices, sex differences, sexual dimorphism, age differences, and craniofacial anthropometry. The search strategy included combining the terms related to the three anatomical indices described above with terms related to sex, sexual dimorphism, age, growth, development, aging, and the craniofacial anthropometry. The combination of terms was selected according to the requirements of the databases.

Some of the search strategies used in the databases are provided below:

("cephalic index" OR "cranial index" OR "cranial anthropometry") AND ("sex differences" OR "sexual dimorphism" OR male OR female OR gender)

("facial index" OR "facial anthropometry" OR "facial morphology") AND ("sex differences" OR "sexual dimorphism" OR age OR ageing OR growth)

("nasal index" OR "nose anthropometry" OR "nasal morphology") AND ("sex differences" OR "sexual dimorphism" OR age OR ageing OR growth)

("craniofacial anthropometry" OR "craniofacial morphology") AND (age OR ageing OR aging OR growth OR development OR "age-related changes")

Other combinations of the terms used included anthropometric indices, cranial dimensions, facial dimensions, nasal dimensions, craniofacial growth, skeletal ageing, bone remodelling, forensic anthropology, sex estimation, and age estimation.

Sexual Dimorphism in the Cephalic (Cranial) Index

Cephalic Index is the ratio of maximum head breadth to maximum head length times 100. The ratio has been found to be significantly different in males and females in various population surveys, although not always the same in different countries. A few Indian and Sri Lankan studies have found a higher mean cephalic index for females compared to males, which is generally attributed to the fact that females have a relatively greater cephalic breadth, and not otherwise, as this is not found in all other indices. A recent 3-D computed tomography study of adult Turkish skulls also showed that there was a significant difference in cephalic index between males and females, with females having a higher index, yet a higher index on the nasal index in males and a higher orbital index in females, showing that the direction of sexual dimorphism can vary from one craniofacial index to another even among the same cranial population. On the other hand, other population studies show the opposite pattern; males have the higher mean cephalic index, suggesting that the underlying biological basis for this dimorphism is influenced by population specific factors including ancestry, nutrition and perhaps even cranial growth pattern.

A study of adults from the Wayanad and Thrissur districts of Kerala illustrates how this dimorphism can also vary regionally within a single country: in one district, both sexes were classified as dolichocephalic with only a small difference between them, while in the other, males remained dolichocephalic but females shifted into the mesocephalic category, indicating that the size of the sex difference, and not only its presence, is population-specific. [13] Because of this variability, cephalic index alone tends to be a relatively weak standalone predictor of sex in forensic contexts and performs best when combined with other cranial measurements in a multivariate discriminant model. [5]

Age-Related Changes in the Cephalic (Cranial) Index

The cephalic index is not fixed even after adolescent growth is complete. During infancy, the shape of the skull is especially vulnerable to outside pressures. Studies have shown that the average cephalic index in populations has changed over the twentieth and twenty-first centuries, and part of this shift appears to be related to updates in advice on infant sleep positions. Because babies' skulls grow most rapidly in the first months after birth, spending long periods lying on their backs can gradually flatten and widen the back of the head, leading to measurable changes in cranial proportions at the population level. [11] Because infant skull shape is so plastic, cephalic index reference values derived from adults cannot be applied to infants, and clinical classification of positional skull deformities requires its own age-specific norms. [11]

In adulthood, cranial shape continues to change, albeit far more slowly. High-resolution three-dimensional computed tomography data from Turkish adults found that, as age increased, skull shape shifted measurably toward the dolichocephalic (relatively narrower, longer) category, while orbital proportions decreased and the nasal aperture widened, indicating that the whole facial skeleton, not only the soft tissue envelope, continues to remodel throughout adult life. [12] This kind of continuous adult cranial remodelling is consistent with older histological work showing ongoing, though slow, bone resorption and deposition across the craniofacial skeleton with advancing age, a process that appears more pronounced in women than in men. [14]

Sexual Dimorphism in the Facial Index

The facial (or prosopic) index — facial height divided by facial breadth, multiplied by 100 — is classified using the scheme introduced by Martin and Saller, which divides faces into hypereuryprosopic, euryprosopic, mesoprosopic, leptoprosopic, and hyperleptoprosopic categories. [15] Across the population literature, males tend to show a somewhat higher mean facial index than females, consistent with a generally longer and narrower facial pattern in men, though as with the cephalic index; the specific facial-type distribution differs considerably between populations and even between neighbouring regions. The Kerala study referenced above, for instance, found that males in one district were classified as hypereuryprosopic (very broad) while females in the same district were euryprosopic (broad), whereas in a second district only around fifty kilometres away, males were mesoprosopic and females were leptoprosopic, an inversion that underlines how sensitive facial-type classification is to sampling and regional variation even when the underlying sex difference in absolute facial index value is consistent. [13]

Supportive evidence comes from three-dimensional geometric morphometric studies, that instead of using only one index, are used to describe the three-dimensional pattern of sexual dimorphism in the face. These methods allow for the capture of multiple landmarks, and have the benefit of revealing, for example, that male faces tend to be wider both across the jaw and the mid-face, and have a more prominent lower third, a characteristic that is partially obscured by the facial index alone. This may account for the relatively low predictive ability of facial index alone when it comes to sex, as with the cephalic index. [5]

Age-Related Changes in the Facial Index

The shape of the face varies significantly in childhood, adulthood and old age. In growth the face grows longer than it is broad, and this is reflected in the secular growth studies of children and adolescents, but, when the growth period is over, the facial skeleton is not static. Longitudinal cephalometric studies of normal occlusion children and adults from 17 to 61 years of age revealed that the maxilla and the mandible continue to move forward, facial height increases, the ramus increases in height and that the mandible rotates forward more in males and backward more in females. A similar longitudinal study from late adolescence to late adulthood also reported continuous growth in midfacial length and lower facial height, as well as significant changes in soft-tissue which included thinning and elongation of the upper lip and the sagging of the nasal tip, again with distinct sex differences in the pattern of mandible movement recorded. [14]

The facial index changes in old age, usually becoming smaller due to the progressive loss of alveolar bones after tooth loss, while the overall facial index remains increasingly larger due to a progressive soft-tissue laxity, thus suggesting that the facial index in elderly adults is modulated by a combination of progressive soft-tissue laxity and alveolar bone remodelling, as well as dental status. A study of the skeletal population of a medieval population from Europe, which had no access to modern dental treatment, revealed that fully edentulous males and females had shorter heights of both the maxilla and mandible, and wider orbits than the dentate of the same age, leading to the conclusion that much of the difference in lower face height in older adults is due to the loss of teeth and not to the aging process. A three-dimensional analysis of facial surface models across age fourteen to eighty-three also revealed that some sexually dimorphic facial measures had a strong difference between youth and women, but this difference tended to diminish, and for some measures, even reverse, over the lifespan, suggesting that facial sexual dimorphism is not a stable quantity across the lifespan. [20, 21, 22]

Sexual Dimorphism in the Nasal Index

The nasal index (nose width/nose height x 100) is used to categorise noses into leptorrhine, mesorrhine or platyrrhine.[23,24] The nasal index of the nose appears to demonstrate some of the best consistency in terms of sex difference of any of the three indices examined here, with males on average having a higher index than females across a broad spectrum of populations, and, in many populations, a greater absolute nasal width and, in many cases, nasal height as well.[25] A retrospective computed tomography study of the Kosovar population yielded a combined nasal width and nasal height of both being statistically significant and independent of sex, with nasal height by itself giving a good separation of sex in around sixty-five per cent of cases. A retrospective computed tomography study of a Kosovar population showed that both nasal width and nasal height were

significant and independent predictors of sex, and that nasal height alone correctly classified sex in approximately sixty-five per cent of cases, which is statistically significant. [26] The Turkish three dimensional study, cited above, showed similarly that males had significantly higher nasal index values, as is reported in most of the literature, although it showed the opposite (higher values in females) for the cephalic and orbital indices, reinforcing the fact that different craniofacial ratios can not be assumed to be dimorphic in the same direction. [12]

Research later on has investigated if sex can be directly identified from nasal images, instead of using manually computed ratios, through deep-learning techniques. A large radiographic study of sex and age classification based on a convolutional neural network achieved around seventy-four per cent accuracy overall, with a lower rate of accuracy in younger individuals than in older, interpreted by the authors to be indicative of the lower level of sexually dimorphic nasal characteristics found in younger individuals, making them less able to be sexed and aged.[27] It is also important to remember that, regardless of the type of index employed – either manually computed or an automated image classification system – the biological signal of sexual dimorphism of the nose becomes more significant as the subject grows older.

Age-Related Changes in the Nasal Index

The impression of the nose as one of the facial features that continuously grows is also echoed in the anthropometric literature, albeit informally. A comparative study of nasal parameters in various age groups showed that the nasal height, width, and total nasal dimensions increased with age from childhood to old age; the nasal tip angle decreased with age corresponding to the nasal tip drifting downwards and forwards over the years. [28] A forensic anthropometric study of soft tissue analyses also suggests a similar result as nasal volume, surface area, and linear dimensions were all found to increase significantly from childhood to old age, the angle of the nasal tip decreased, and not surprisingly, the size and rate of these changes varied with sex, with males exhibiting larger absolute changes than females. [14]

The skeletal level of the piriform aperture—the bony opening at the base of the nose—has been shown many times to enlarge with age and not just cartilage. [8] Other studies corroborate this finding of widening of skeletons. In a three dimensional imaging study, Turkey researchers discovered that width of the nostrils increased with age. Also, in a medieval European sample of skeletons, the surface area of the piriform aperture increased significantly with age but only in males. [18] This enlargement at the bony level is exacerbated by soft-tissue laxity of the nasal tip and columella and would be expected to result in a higher external nasal index in the elderly person compared to his youth; this is of practical significance to the surgeon, who uses external nasal index as one factor in rhinoplasty planning. [23]

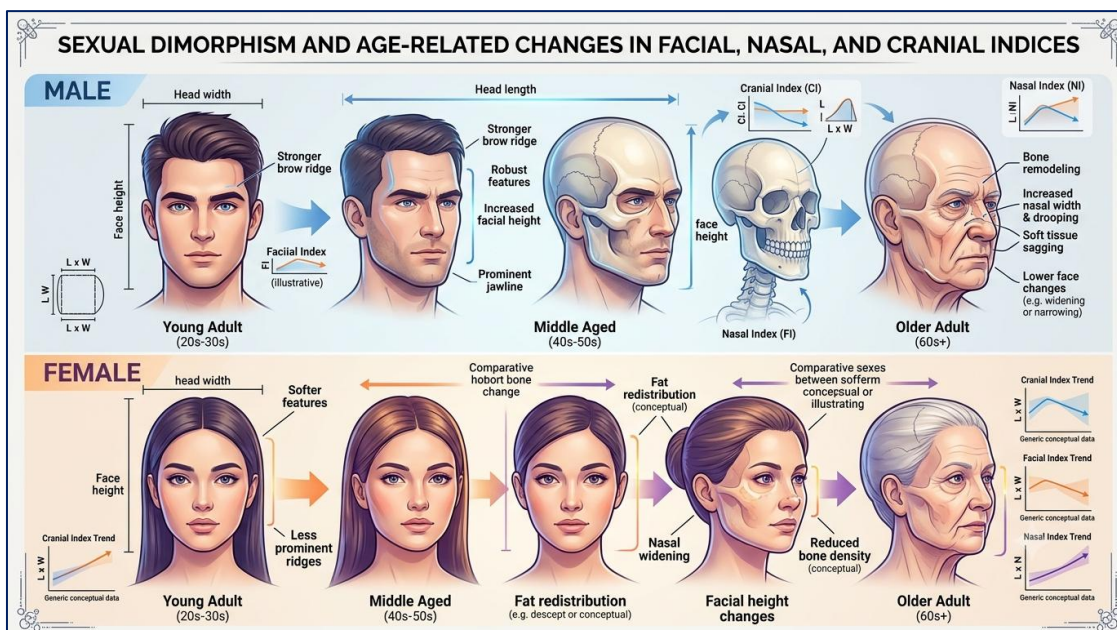


Figure 1 Morphometric analysis of age-related changes in male and female facial, nasal, and cranial indices across adult age cohorts. Image generated using Google Gemini.

Cross-Cutting Themes

Sexual dimorphism is index-specific, not uniform

What has become clear from this review is that the direction and intensity of sexual dimorphism may not be the same in the cephalic, facial and nasal indices in any given population, and is certainly not the same across the three indices. The Turkish three dimensional study is illustrative: The cephalic and orbital indices were higher in females, and the nasal index was higher, in the same sample, in the males. This is because no single index can be used as an overall indicator of 'craniofacial masculinity' or 'femininity', and each of the indices reflects a slightly different, and not fully overlapping, aspect of shape.

Age interacts with sex

A second theme is that sexual dimorphism itself is not constant across the lifespan. Several studies reviewed here found that sex differences in specific facial measurements were most pronounced in youth and early adulthood and diminished, sometimes to the point of disappearing, in old age. [20] Similarly, automated sex classification from nasal images performed distinctly worse in younger individuals, suggesting that dimorphic traits are still developing and are therefore less reliable markers of sex before or around the time of skeletal maturity. [27] Any forensic or clinical use of these indices for sex estimation should therefore take the subject's approximate age into account rather than applying a single set of thresholds across the whole lifespan.

Bone remodelling and soft-tissue change act together

Age-related change in all three indices reflects the combined effect of skeletal remodelling and soft-tissue change, and these two processes do not always move in the same direction. Facial height, for example, tends to increase through early and middle adulthood but can decrease again in old age following tooth loss and alveolar resorption, while facial width and nasal dimensions tend to increase more continuously across the same period. [8] Any interpretation of age-related change in a single index therefore needs to account for dental status, since edentulous and dentate individuals of the same chronological age can show quite different facial proportions. [18]

Single indices versus multivariate and geometric approaches

Across the cephalic, facial, and nasal literature, single-ratio indices consistently show statistically significant but only moderate accuracy when used alone to predict sex, typically in the range of the mid-fifties to mid-seventies per cent. [26] Combining several measurements in a discriminant function, or moving to full three-dimensional geometric morphometric or machine-learning-based classification, generally improves accuracy considerably. [5] This does not make the classical indices redundant — they remain quick, interpretable, and useful for population-level description and initial screening — but it does mean that where an accurate individual sex or age estimate is required, for example in forensic casework, single indices are best treated as one contributing measurement rather than a stand-alone diagnostic tool.

Practical Implications

These findings carry several practical implications. In forensic anthropology, sex and age estimation protocols that rely on cephalic, facial, or nasal index values should ideally be calibrated to the specific population under investigation and, where possible, to an appropriate age band, given how much both sex differences and age-related trends vary between populations. [5] In reconstructive and aesthetic surgery, understanding the normal trajectory of age-related widening of the nasal aperture and lengthening, then shortening, of facial height allows clinicians to distinguish expected ageing change from pathology and to set realistic expectations for surgical outcomes. [8] In physical anthropology and human biology more broadly, the population- and sex-specific nature of these indices reinforces the point made in the wider anthropometric literature that reference values generated in one population, sex, or age group should not be assumed to transfer directly to another. [11]

CONCLUSION

Sexual dimorphism and age-related change are not minor complications to be adjusted for once and then set aside; they are central features of how the cephalic, facial, and nasal indices behave. All three indices show statistically detectable, though population-specific and sometimes index-specific, sex differences, and all three continue to change gradually throughout adult life as bone remodelling, tooth loss, and soft-tissue laxity accumulate with age. Because sexual dimorphism itself appears to strengthen through early adulthood and then weaken again in old age, and because different indices within the same individual can be dimorphic in opposite directions, no single ratio should be relied upon in isolation for sex or age estimation. The most defensible use of these classical indices going forward is as part of a broader toolkit that combines population-specific reference data, multivariate statistical models, and, where resources allow, three-dimensional geometric morphometric or machine-learning-based shape analysis.

Conflict of Interest

The authors declare that there are no conflicts of interest to disclose in relation to the publication of this manuscript.

Funding

No funding source is reported for this study.

Ethical Considerations

As this is a literature-based study, no human or animal subjects were involved, and thus no ethical clearance was required. However, due academic integrity was maintained through proper citation and referencing practices.

REFERENCES

1. Farkas, L.G. (1994) *Anthropometry of the Head and Face*. 2nd edn. New York: Raven Press.
2. Farkas, L.G., Katic, M.J. and Forrest, C.R. (2005) 'International anthropometric study of facial morphology in various ethnic groups/races', *Journal of Craniofacial Surgery*, 16(4), pp.615–646. <https://doi.org/10.1097/01.scs.0000171847.58031.9e>
3. Behrents, R.G. (1984) *Growth in the Aging Craniofacial Skeleton*. Craniofacial Growth Series, Monograph 17. Ann Arbor: Center for Human Growth and Development, University of Michigan.
4. Le, T.T., Farkas, L.G., Ngim, R.C.K., Levin, L.S. and Forrest, C.R. (2002) 'Proportionality in Asian and North American Caucasian faces using neoclassical facial canons as criteria', *Aesthetic Plastic Surgery*, 26(1), pp.64–69. <https://doi.org/10.1007/s00266-001-0033-7>
5. Farkas, L.G. (1994) *Anthropometry of the Head and Face*. 2nd edn. New York: Raven Press.
6. Musilová, B., Dupej, J., Velemínská, J., Chaumoitre, K. and Bruzek, J. (2016) 'Exocranial surfaces for sex assessment of the human cranium', *Forensic Science International*, 269, pp.70–77. <https://doi.org/10.1016/j.forsciint.2016.11.006>
7. Bejdová, Š., Dupej, J., Křajčůček, V., Velemínská, J. and Velemínský, P. (2018) 'Stability of upper face sexual dimorphism in central European populations (Czech Republic) during the modern age', *International Journal of Legal Medicine*, 132(1), pp.321–330. <https://doi.org/10.1007/s00414-017-1625-3>
8. Fish, D., Hinton, C. and Barrios, A. (2024) 'Revisiting the cephalic index: the origin, purpose, and current applicability — a narrative review', *JPO: Journal of Prosthetics and Orthotics*, 36, pp.e35–e48. <https://doi.org/10.1097/JPO.0000000000000478>
9. Mydlová, M., Dupej, J., Koudelová, J. and Velemínská, J. (2015) 'Sexual dimorphism of facial appearance in ageing human adults: a cross-sectional study', *Forensic Science International*, 257, pp.519.e1–519.e9. <https://doi.org/10.1016/j.forsciint.2015.09.008>
10. Cunha, E., Baccino, E., Martrille, L., Ramsthaler, F., Prieto, J., Schuliar, Y., Lynnerup, N. and Cattaneo, C. (2009) 'The problem of aging human remains and living individuals: a review', *Forensic Science International*, 193(1–3), pp.1–13. <https://doi.org/10.1016/j.forsciint.2009.09.008>

11. Garib, D., Natsumeda, G.M., Massaro, C., Miranda, F., Naveda, R. and Janson, G. (2021) 'Cephalometric changes during aging in subjects with normal occlusion', *Journal of Applied Oral Science*, 29, e20210199. <https://doi.org/10.1590/1678-7757-2021-0199>
12. Kaur, M., Garg, R.K. and Singla, S. (2015) 'Analysis of facial soft tissue changes with aging and their effects on facial morphology: a forensic perspective', *Egyptian Journal of Forensic Sciences*, 5, pp.46–56. <https://doi.org/10.1016/j.ejfs.2014.07.006>
13. Kulkarni, M.M., Soni, J.S. and Hathila, S.B. (2019) 'An anthropometric study of nasal index with its clinical correlation', *International Journal of Anatomy and Research*, 7(2.1), pp.6377–6380. <https://doi.org/10.16965/ijar.2019.121>
14. Kaur, M., Garg, R.K. and Singla, S. (2015) 'Analysis of facial soft tissue changes with aging and their effects on facial morphology: a forensic perspective', *Egyptian Journal of Forensic Sciences*, 5, pp.46–56. <https://doi.org/10.1016/j.ejfs.2014.07.006>
15. Martin, R. and Saller, K. (1957) *Lehrbuch der Anthropologie*. Stuttgart: Gustav Fischer Verlag.
16. Mendelson, B.C. and Wong, C.H. (2012) 'Changes in the facial skeleton with aging: implications and clinical applications in facial rejuvenation', *Aesthetic Plastic Surgery*, 36(4), pp.753–760. <https://doi.org/10.1007/s00266-012-9904-3>
17. Mitteroecker, P., Gunz, P., Windhager, S. and Schaefer, K. (2013) 'A brief review of shape, form, and allometry in geometric morphometrics, with applications to human facial morphology', *Hystrix, the Italian Journal of Mammalogy*, 24(1), pp.59–66. <https://doi.org/10.4404/hystrix-24.1-6369>
18. Noback, M.L., Harvati, K. and Spoor, F. (2011) 'Climate-related variation of the human nasal cavity', *American Journal of Physical Anthropology*, 145(4), pp.599–614. <https://doi.org/10.1002/ajpa.21523>
19. Wen, Y.F., Wong, H.M., Lin, R., Yin, G. and McGrath, C. (2015) 'Inter-ethnic/racial facial variations: a systematic review and Bayesian meta-analysis of photogrammetric studies', *PLOS One*, 10(8), e0134525. <https://doi.org/10.1371/journal.pone.0134525>
20. Pawar, R. and Thorat, S. (2021) 'Study of nasal index', *Journal of Forensic and Legal Medicine* (published as *Journal of Forensic Medicine*), 12(9), p.476.
21. Bulygina, E., Mitteroecker, P. and Aiello, L. (2006) 'Ontogeny of facial dimorphism and patterns of individual development within one human population', *American Journal of Physical Anthropology*, 131(3), pp.432–443. <https://doi.org/10.1002/ajpa.20317>
22. Coleman, S.R. and Grover, R. (2006) 'The anatomy of the aging face: volume loss and changes in 3-dimensional topography', *Aesthetic Surgery Journal*, 26(1_Supplement), pp.S4–S9. <https://doi.org/10.1016/j.asj.2005.09.012>
23. Scavassini, L., Silva, R., Khan, A., Anees, W., Murray, J., Angelakopoulos, N., Arakelyan, M., Porto, L., Abade, A. and Franco, A. (2025) 'YOLO11m-cls applied to sex and age classification based on the radiographic analysis of the nasal aperture', *Scientific Reports*, 15, article 40784. <https://doi.org/10.1038/s41598-025-24593-5>
24. Hegazy, A.A. (2014) 'Anthropometric study of nasal index of Egyptians', *International Journal of Anatomy and Research*, 2(4), pp.761–767. <https://doi.org/10.16965/ijar.2014.544>
25. Scendoni, R., Kelmendi, J., Arrais Ribeiro, I.L., Cingolani, M., De Micco, F. and Cameriere, R. (2023) 'Anthropometric analysis of orbital and nasal parameters for sexual dimorphism: new anatomical evidences in the field of personal identification through a retrospective observational study', *PLOS One*, 18(5), e0284219. <https://doi.org/10.1371/journal.pone.0284219>
26. Shastri, D., Tandon, P. and Singh, A. (2021) 'Nasal changes in different age groups', *National Journal of Maxillofacial Surgery*, 12(3), pp.367–371.
27. Thomson, A. and Buxton, L.H.D. (1923) 'Man's nasal index in relation to certain climatic conditions', *Journal of the Royal Anthropological Institute of Great Britain and Ireland*, 53, pp.92–122. <https://doi.org/10.2307/2843753>
28. Velemínská, J., Dupej, J., Veleminsky, P., Bruzek, J., Cagaňová, V. and Krajíček, V. (2022) 'Three-dimensional analysis of modeled facial aging and sexual dimorphism from juvenile to elderly age', *Scientific Reports*, 12, article 21821. <https://doi.org/10.1038/s41598-022-26376-8>