Keywords
Craniofacial anthropometry, Facial index, Sexual dimorphism, 3D Slicer, Iraqi population.

Authors
Ayman Hameed Uraibi[1*]
[1*] Department of Oral and Maxillofacial Surgery, College of Dentistry, University of Babylon, Al-Hilla, Babylon, Iraq.
E-mail:dent.ayman.hameed@uobabylon.edu.iq
ORCID: 0009-0001-1946-3799

Wahab Razaq Jassim[2]
[2]Department of Oral and Maxillofacial Surgery, College of Dentistry, University of Babylon, Al-Hilla, Babylon, Iraq.
E-mail:den251.whab.razak@uobabylon.edu.iq,
ORCID: 0000-0001-9296-0946

Hibah Ezzat Rashid Berum[3]
[3]Department of Oral and Maxillofacial Surgery, College of Dentistry, University of Babylon, Al-Hilla, Babylon, Iraq.
Department of Oral and Craniofacial Sciences, Faculty of Dentistry, Universiti Malaya, Kuala Lumpur, Malaysia.
E-mail: hibah.berum@uobabylon.edu.iq,
ORCID: 0009-0004-4144-0419

Israa Hussein Ali[4]
[4]Department of Pediatric Dentistry, Orthodontics and Preventive Dentistry, College of Dentistry, University of Babylon, Al-Hilla, Babylon, Iraq.
E-mail: dent.israa.ali@uobabylon.edu.iq,
ORCID: 0000-0002-5796-7365

Correspondence to:
Ayman Hameed Uraibi[1*]
[1*] Department of Oral and Maxillofacial Surgery, College of Dentistry, University of Babylon, Al-Hilla, Babylon, Iraq.
E-mail:dent.ayman.hameed@uobabylon.edu.iq
ORCID: 0009-0001-1946-3799

Received-18-05-2026
Revised-20-06-2026
Accepted-25-06-20.26
Doi:10.1922/ejprd.v34i4s.1500

European Journal of Prosthodontics and Restorative Dentistry (2026) 34(4s), 594-600

Anthropometric Analysis of CT Images Using 3D Slicer Software and Establishment of Facial Index Norms Among Iraqi Adults: A Cross-Sectional Study

Abstract
Background: Understanding craniofacial anthropometry is an important approach in respect of sexual dimorphism and population specific features. Facial index (ratio of facial height to width) is widely used to classify distinct facial types and assess morphological differences between populations.
Objective: The present study aims to implement the traditional anthropometric methods for assessing facial height, facial width and facial index among Iraqi adults. It also aims to delineate normative facial types according to Banister's classification.
Materials and Methods: A cross-sectional study included of 200 Iraqi adults (100 male, 100 female) aged 18-30 years. Standard anthropometric techniques were used to measure facial height (N– Me) and facial width (Zy–Zy) using CT images and 3D Slicer Software and then the facial index was calculated based on Banister's classification. Descriptive statistics, normality tests, independent samples t-test, Pearson correlation and Chi-square tests employed for data analysis.
Results: Males mean facial height, width and facial index were significantly greater than females ($p < 0.001$), suggesting robust sexual dimorphism. Correlation analysis showed that in both sexes, facial height was positively correlated with facial index ($P < 0.001$), whereas the relationship of width to the index was negative. Males showed long facial types and females round facial types as shown in the crosstabulation.
Conclusion: Significant sexual dimorphism was observed in craniofacial parameters among Iraqi population, with the facial index and facial type being accurate measures for sex estimation. The results provide valuable population-specific reference data and support the use of craniofacial measurements in forensic and anthropological applications.

Introduction

Facial morphology is one of the most distinctive aspects of human biological variation and occupies a central position in anthropological, clinical and forensic investigations (Jaiswal, 2024; Richmond et al., 2018). One of the main strategies employed in characterizing facial morphology is identification of face types on the basis of facial index obtained through ratio between the height and width of face (Mohan et al., 2024). An index that lets a person be classified into multiple very broad, broad, round, long and very long face types, for comparing craniofacial proportions to populations using standardized indices (Mohan et al., 2024; Vezzetti & Marcolin, 2012).
Sexual dimorphism is the term for systematic differences in anatomical features between males and females of the same species. Craniofacial anthropology usually measures sexual dimorphism as facial height, width and overall proportion (da Silva et al., 2023). Facially, males often have larger and longer facial structures while females seem to have relatively shorter and wider facial shapes (Windhager et al., 2011). These differences are driven by

ejprd.org- Published by Riset Publishing Services LLC.

genetic,
hormonal and developmental factors, particularly the influence of androgens in growth and puberty (Berum et al., 2026; Ledergerber et al., 2026).

The association between face type and sexual dimorphism is critical since facial index trends usually correlate with specific morphological features of sexes (Da Silva et al., 2025). Therefore, face type classification has emerged as a practical application of forensic identification, particularly in estimated sex with the utilization of either skeletal remains or partial facial data (Lavrukova & Antipov, 2025). The recognition of male and female facial features increases the reliability of forensic reconstruction and personal identification (Das et al., 2025).

Studying facial types is essential for the Iraqi population due to ethnic diversity and limited anthropometric reference data. Facial morphology is already known to have population variation due to geographic and genetic diversity (Hopman et al., 2014). Understanding the distribution frequency of facial types and their relation to sex in Iraq would not only enhance the reliability of various forensic identification methods but also support an anthropological database as well.

The utilization of 3D Slicer software in conjunction with computed tomography (CT) images provides accurate and reliable methodology for performing craniofacial anthropometric assessments (Simmons-Ehrhardt et al., 2021). In contrast to traditional two-dimensional techniques, 3D Slicer permits accurate visual representation, segmentation, and measurement of anatomical points in a three-dimension, thereby minimizing measurement inaccuracies and variations among observers (Chae et al., 2019). The software facilitates facial morphology analysis and permits the reliable linear and angular measurements crucial for the determination of facial indices (Duangsuwan et al., 2023). Moreover, its open-source design supports a standardized and financially accessible analysis of wide-ranging datasets contributes to advancements in clinical, forensic, and anthropological research (Duangsuwan et al., 2023; Simmons-Ehrhardt et al., 2021).

Accordingly, study facial types based on the facial index in Iraqi sample and their relationship with sexual dimorphism. So, the integration of 3D Slicer with CT imaging offers a robust tool for generating an important reference data applicable to forensic science, clinical evaluation, and anthropological research in Iraqi population.

Methodology:

Study Design and Setting

A cross-sectional retrospective CT data designates to assess craniofacial anthropometric parameters and establish facial index norms among Iraqi adults using CT images obtained from radiology departments across multiple Iraqi hospitals then analyzed by open-source 3D Slicer software.

Study Sample

A total of 200 craniofacial CT scans (100 males and 100 females) to ensure balanced sex representation with age ranging 18 and 30 years selected to ensure full completion of craniofacial growth and to minimize age-related morphological variations. High-resolution CT images were utilized, and all DICOM datasets were imported into the open-source 3D Slicer software for detailed image processing, reconstruction, and anthropometric analysis.

Ethical Considerations

Ethical approval for this cross-sectional study was obtained from the Scientific Research Ethical Committee, College of Dentistry, University of Babylon, Republic of Iraq, Ministry of Higher Education and Scientific Research, Ref. No. (116), dated 28/06/2026.

Inclusion Criteria:

Iraqi adults aged 18–30 years with high-quality craniofacial CT scans. Participants must have no history of craniofacial deformities or facial trauma, and the sample will ensure equal representation of both sexes (100 males and 100 females) to maintain sex balance in the analysis.

Exclusion Criteria

CT scans with poor quality or significant artifacts will be excluded to ensure measurement accuracy. Cases with a history of trauma, congenital craniofacial anomalies or pathological conditions: neoplasms, infections or fractures, and surgical interventions should also be excluded. Moreover, any CT datasets that are not complete or lack important anatomical regions required for comprehensive analysis should be excluded from the study.

Anthropometric Measurements:

As expressed in figure 1, CT images will be reconstructed into 3D models using open-source 3D Slicer software. Standard anatomical landmarks will be identified, and linear facial measurements (facial height, facial width) will be obtained. Each measurement was repeated 2–3 times and the mean value were used for analysis in order to minimize intra-observer error.

Measured Parameters:

1. Facial Height (N–Me): Measured as the linear distance between:
- Nasion (N): The midpoint at the junction of the frontal and nasal bones.
- Menton (Me): The lowest point on the mandible in the mid-sagittal plane

2. Facial Width (Zy–Zy): The maximum distance between the most lateral points on the zygomatic arches:
- Zygion (Zy) – right and left

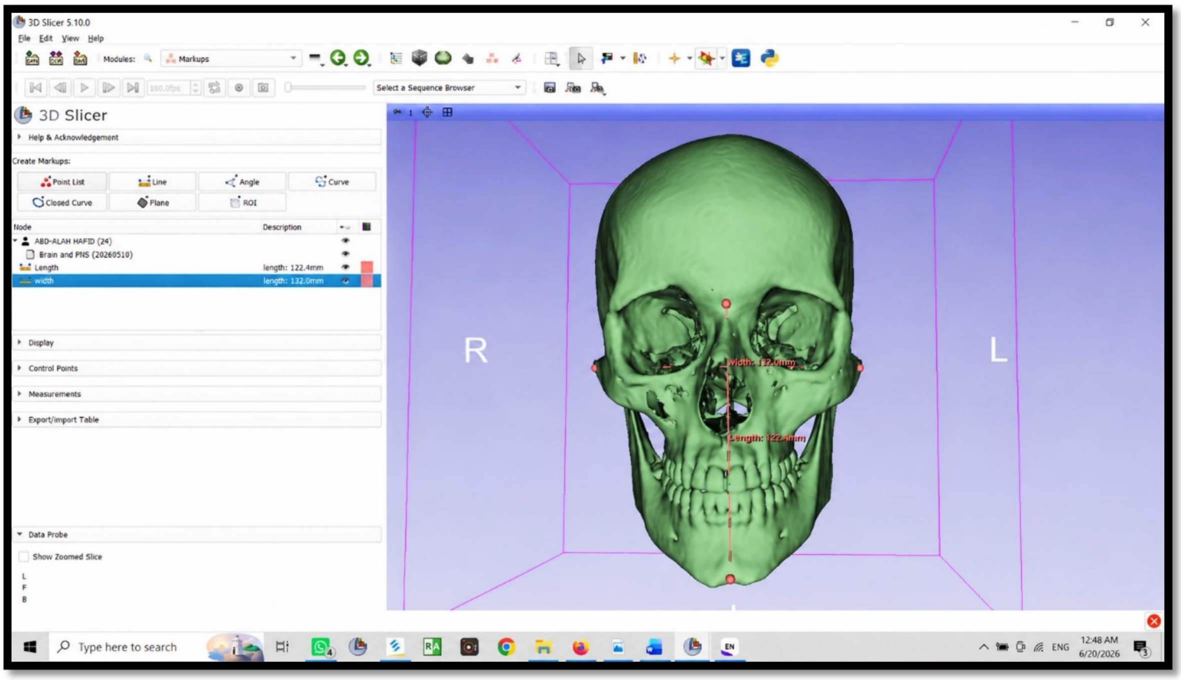


Figure1: Utilizing 3D Slicer software for linear measurements (facial height, facial width).

Calculation of Facial Index:

The **Facial Index (FI)** was calculated using the formula:

$$\text{Facial Index} = \frac{\text{Facial Height (N–Me)}}{\text{Facial Width (Zy–Zy)}} \times 100$$

Classification of Facial Types:

Based on the Facial Index, participants were classified according to Banister's classification as explained in table1 and figure2:

Table 1. Banister's classification, based on Facial Index (Mohan et al., 2024; Ozsahın et al., 2016).

Facial Index Range	**Facial Type**	**Description**
< 79.9	Hypereuryprosopic	Very broad face
80 – 84.9	Euryprosopic	Broad face
85 – 89.9	Mesoprosopic	Round face
90 – 94.9	Leptoprosopic	Long face
> 95	Hyperleptoprosopic	Very long face

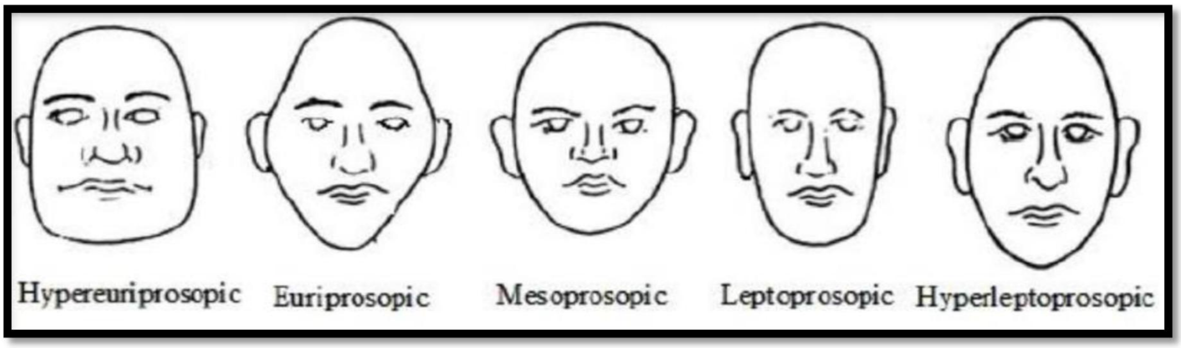


Figure2: Morphological classification of facial form (Mohan et al., 2024).

Statistical Analysis:

Data were analyzed using IBM SPSS Statistics.

The following statistical procedures were applied:

- Descriptive statistics (mean, standard deviation, frequencies, percentages)
- Normality tests (Kolmogorov–Smirnov and Shapiro–Wilk)
- Independent samples t-test or Mann–Whitney U test for comparison between sexes
- Pearson or Spearman correlation to assess relationships between variables
- Chi-square test to examine the association between sex and facial index categories

A **p-value < 0.05** was considered statistically significant.

Results

The Present Study on 200 Iraqies (100 Males and 100 Females). The Craniofacial Parameters were assessed among the males and females of present study. Descriptive Statistics of (facial height, facial width and facial index) including (mean, SD, min, and max) as expressed in table2 significantly had higher mean values in males relative to females. As shown in table3, normality tests indicated that all variables were normally distributed ($p > 0.05$), thus allowing the presentation of parametric analyses, while table4 expressed Levene's Test for homogeneity and Independent Samples t-Tests demonstrated that males and females varied significantly in height and width ($p < 0.05$). Strong positive correlations were seen between facial height and facial index in both sexes; however, facial width had an inverse relationship with the index explained in table5. Crosstabulation and relative frequencies results in tables 6 and 7 and figure 2, indicated that the male faces were primarily long and very long, whereas female faces were mostly round and broad in types.

Discussion:

The findings explore craniofacial dimorphism in an Iraqi population based on sex to establish their own standards. Facial height and width were greater in males than females, consistent with guidelines on sexually dimorphic anthropometric measures previously applied to sampled populations across several regions. This dimorphism can be explained in terms of genetic, hormonal and rudimentary environment factors, especially the effects of the androgens on craniofacial growth. The independent samples t-test showed facial height has a strongly significant sexual dimorphism ($t= 13.787$, $p < 0.001$) with mean male facial height exceeding females by +8.27 mm (95% CI: 7.08–9.45). Facial width also revealed a significant difference ($t= 12.192$, $p < 0.001$), where male facial width larger than females by an average of 3.91 mm (95% CI: 3.28–4.54).

Most importantly, the correlation analyses revealed that facial height among males was very strongly positively correlation ($r=0.911$; $p<0.05$). Similar patterns in female facial heights that correlated highly positively ($r=0.877$, $p<0.05$), while facial width demonstrated a significant negative correlation with the index ($r= -0.461$, $p < 0.01$); though height was weakly and non-significantly correlated with width ($r= -0.053$, $p > 0.05$), significant negative correlations between facial width and the index were found among females ($r= -0.373$, $p<0.05$). The correlation between height and width in females was weak and non-significant ($r= 0.118$, $p > 0.05$). Overall, the results indicate that cranial height is the main contributor to variation in the height–width index in both sexes.

Sexual dimorphism in craniofacial growth and development is the main contributory factor to sex differences seen in facial index distribution. In men, androgen (testosterone) is known to have a protracted and more potent effect on skeletal growth which results in increased vertical development of cranio-facial structures with higher facial index values (long and very long faces).

By contrast, females are influenced less by testosterone and more so by estrogen; where the latter tends to limit excessive vertical growth and favor relatively wider and rounder facial proportions. The genetic basis and population-specific traits likely further explain these patterns, with environmental exposures (e.g. nutrition and growth conditions) potentially modulating craniofacial morphology.

A number of regional and international studies highlight important differences in facial index as well as craniofacial morphology between populations largely affected by genetic, environmental or ethnic factors. In nearby populations, such as the Kurdish sample from Sulaimani show a predominance of leptoprosopic long facial type (Amin et al., 2016) , while mixed distributions were evident from Iranian and Turkish studies (Ozsahın et al., 2016), with euryprosopic and mesoprosopic types demonstrating higher frequencies. Asian populations also exhibit substantial diversity (Shetti et al., 2011; Yesmin et al., 2014) with clear sexual dimorphism and generally broader facial types compared to elongated forms.

Although in East Asian populations (Ishii, 2002; Samizadeh, 2022) mesocephalic and brachycephalic facial patterns characterized by a relatively low facial index, whereas South Asian populations (Raveendran, 2019) have wider varieties of craniofacial forms due to broad ethnic heterogeneity. In contrast, Caucasian populations (Maskey et al., 2020) tend to exhibit relatively long facial forms with a larger proportion of mesocephalic and dolichocephalic types. All these global variations underscored the need for population specific anthropometry standards.

The similarities and unique features in the present Iraqi study compared to these findings are noticeable. The high frequencies of long and very long facial types in Iraqi males correspond to patterns seen among regional populations, especially Kurdish groups but shows a stronger preference for elongated facial features. On the other hand, more round facial types could be seen among Iraqi females indicating unambiguous sexual dimorphism similar to international data.

In summary, these comparisons show that although sexual dimorphisms are evident globally, this study again demonstrates unique craniofacial characteristics within the Iraqi population compared to those from other regions of the world and reinforces that population-specific normative data is needed to accurately use such measurements in forensic and anthropological contexts.

Conclusion

The study confirms sexual dimorphism in craniofacial parameters among Iraqi population using CT images analyzed by open-source 3D Slicer. Males having higher facial height, width and facial index compared to females. Index distributions indicated that males are mostly long and very long facial types, while females are low round and broad face type.

In both sexes, facial height was the primarily associated with facial index whereas an inverse relation of effect exists for facial width. The differences in facial type distribution among male and female faces represented a reliable identity tool among forensic identification modalities.

Finally, these findings provide a key anthropometric reference dataset for the Iraqi adult population and added support to the non-invasive craniofacial measurements in forensic applications such as sex estimation. We propose that replication and generalizability of these findings be examined further in future studies of larger, more representative samples.

Limitations of the Study

While this research offers valuable anthropometric measurements for the Iraqi population, several limitations can be taken into account. Limitations include the small, single-derived sample limiting generalizability, as well as cross-sectional design not permitting change over time to be evaluated. Additionally, the sample is restricted to young Iraqi adults aged 18–30 years, which limits the generalizability of findings to other age groups or populations. Moreover, the analysis limited to height and width of the face without adjusting other craniofacial variables as gene-environment interaction or confounding nutritional influences, may have effects on their findings

Recommendations

In order to enhance representativity and external validity, future studies ought to be conducted with larger sample sizes from wider regions of Iraq using multicenter designs. Such longitudinal investigations using, for example, nasal/cephalic or mandibular indices will be required to understand how craniofacial morphology evolves according to individual characteristics over time.

Table2: Sex-Based Descriptive Statistics of Facial Height, Width, and Facial Index

Descriptive Statistics						
Sex		**Mean**	**Std. Deviation**	**Max**	**Min**	**N**
Male	Height (N-Me)	121.622	4.516	132.32	111.60	100
	Width (Zy-Zy)	130.587	2.257	135.41	125.32	100
	Height/Width*100	93.165	3.877	101.19	83.63	100
Female	Height (N-Me)	113.355	3.943	122.57	105.59	100
	Width (Zy-Zy)	126.676	2.278	131.79	120.74	100
	Height/Width*100	89.506	3.329	97.68	82.51	100

Table3: Statistical Assessment of Normality for Facial Dimensions and Index Stratified by Sex

Tests of Normality							
	Sex	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	df	Sig.
Height (N-Me)	Male	.063	100	.200*	.987	100	.450
	Female	.069	100	.200*	.984	100	.255
Width (Zy-Zy)	Male	.068	100	.200*	.985	100	.322
	Female	.071	100	.200*	.987	100	.463
Height/Width*100	Male	.066	100	.200*	.988	100	.538
	Female	.067	100	.200*	.988	100	.524

Table4: Independent Samples t-Test and Homogeneity of Variance for Height (N–Me) and Width (Zy-Zy) Stratified by Sex

Independent Samples Test									
	Levene's Test for Equality of Variances		**t-test for Equality of Means**						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	**95% Confidence Interval of the Difference**	
								Lower	**Upper**
Height (N-Me)	1.471	.227	13.787	198	.000	8.26670	.59961	7.08426	9.44914
Width (Zy-Zy)	.046	.830	12.192	198	.000	3.91110	.32079	3.27850	4.54370

Table5: Sex-Specific Correlation Analysis between Cranial Height (N–Me), Width (Zy–Zy), and Facial Index

Correlations					
Sex			Height (N-Me)	Width (Zy-Zy)	Height/Width*100
Male	Height (N-Me)	Pearson Correlation	1	-.053	.911**
		Sig. (2-tailed)		.597	.000
		N	100	100	100
	Width (Zy-Zy)	Pearson Correlation	-.053	1	-.461**
		Sig. (2-tailed)	.597		.000

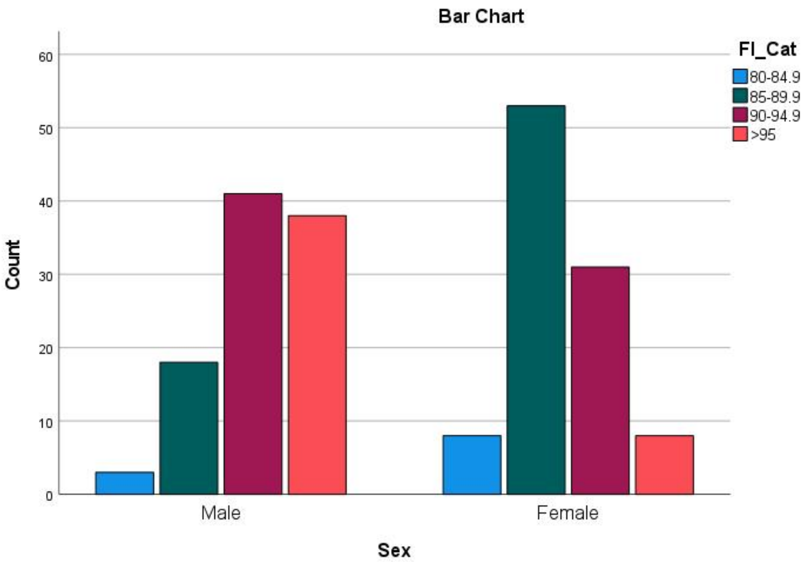
		N	100	100	100
	Height/Width*100	Pearson Correlation	.911**	-.461**	1
		Sig. (2-tailed)	.000	.000	
		N	100	100	100
Female	Height (N-Me)	Pearson Correlation	1	.118	.877**
		Sig. (2-tailed)		.242	.000
		N	100	100	100
	Width (Zy-Zy)	Pearson Correlation	.118	1	-.373**
		Sig. (2-tailed)	.242		.000
		N	100	100	100
	Height/Width*100	Pearson Correlation	.877**	-.373**	1
		Sig. (2-tailed)	.000	.000	
		N	100	100	100

Table6: Distribution of Facial Index Categories (FI_Cat) by Sex: Crosstabulation Analysis

Sex * FI_Cat Crosstabulation							
			FI_Cat				Total
			80-84.9 Broad face	85-89.9 Round face	90-94.9 Long face	>95 Very long face	
Sex	Male	% within Sex	3.0%	18.0%	41.0%	38.0%	100.0%
		% within FI_Cat	27.3%	25.4%	56.9%	82.6%	50.0%
	Female	% within Sex	8.0%	53.0%	31.0%	8.0%	100.0%
		% within FI_Cat	72.7%	74.6%	43.1%	17.4%	50.0%
Total		% within Sex	5.5%	35.5%	36.0%	23.0%	100.0%
		% within FI_Cat	100.0%	100.0%	100.0%	100.0%	100.0%

Table7: Comparative Distribution of Facial Types Between Males and Females

Category	**Male**	**Female**	**Meaning**
80–84.9 Broad face	27.3%	72.7%	Mostly females
85–89.9 Round face	25.4%	74.6%	Strongly females
90–94.9 Long face	56.9%	43.1%	More males
>95 Very long face	82.6%	17.4%	Strongly males



Reference:

1. Amin, A. A., Rashid, Z. J., & Noori, A. J. (2016). Study of facial index among kurdish population. *Int J Dent Res Dev*, *6*(4), 9-14.
2. Berum, H. E. R., Uraibi, A. H., Hasan, H. A., & Jawad, A. S. (2026). MIMICS-Based 3D CT Morphometrics of Mandibular Condyles. *Dentistry 3000*, *14*(1).
3. Chae, M. P., Hunter-Smith, D. J., & Rozen, W. M. (2019). Imaging and printing in plastic and reconstructive surgery part 1: established techniques. *Australasian Journal of Plastic Surgery*, *2*(1).
4. Da Silva, C., Hoskens, H., Aponte, J. D., Caine, K., Weinberg, S. M., Claes, P., & Hallgrímsson, B. (2025). Measuring sexual dimorphism in human faces. *Journal of Anatomy*.

5. da Silva, J. C., Strazzi-Sahyon, H. B., Nunes, G. P., Andreo, J. C., Spin, M. D., & Shinohara, A. L. (2023). Cranial anatomical structures with high sexual dimorphism in metric and morphological evaluation: A systematic review. *Journal of Forensic and Legal Medicine*, *99*, 102592.
6. Das, S. R., Champatyray, S., & Panda, D. K. (2025). Anthropometric analysis of facial dimensions using 3D imaging for forensic identification and ethnicity-specific reference models. *Forensic Science International: Reports*, 100428.
7. Duangsuwan, J., Raocharernporn, S., Thiradilok, S., & Manopatanakul, S. (2023). Computerized three-dimensional cephalometric template for Thai adults. *Heliyon*, *9*(4).
8. Hopman, S. M., Merks, J. H., Suttie, M., Hennekam, R., & Hammond, P. (2014). Face shape differs in phylogenetically related populations. *European Journal of Human Genetics*, *22*(11), 1268-1271.
9. Ishii, N. (2002). *Morphological differences in craniofacial structure between Japanese and Caucasian subjects*. University of London, University College London (United Kingdom).
10. Jaiswal, S. (2024). Exploring Morphometry of Human Faces: A review of Anthropometric parameters.
11. Lavrukova, O. S., & Antipov, V. M. (2025). Forensic identification of personality: skull as a key element of person identification (a case report). *Russian Journal of Forensic Medicine*, *11*(1), 41.
12. Ledergerber, R., Schumann, M., & Roth, R. (2026). Development of the Muscular and Skeletal System During Adolescence. In *Enhancing Adolescent Health: The Contribution of Exercise to Growth and Metabolism* (pp. 17-45). Springer.
13. Maskey, S., Shrestha, P., Shrestha, A., Sharma, K., & Yadav, A. (2020). Measurement of cephalic and facial indices among students of KUSMS. *Journal of Chitwan Medical College*, *10*(1), 31-35.
14. Mohan, S. M., Leander, D., Roopesh, R., Abiraj, K., Ali Fathima, S., Pratheesh, A., & Krishna, A. (2024). Evaluation and establishment of norms for facial index in Kerala population-a cross sectional study.
15. Ozsahın, E., Kızılkanat, E., Boyan, N., Soames, R., Oguz, O., OZSAHIN, E., KIZILKANAT, E., BOYAN, N., SOAMES, R., & OGUZ, O. (2016). Evaluation of face shape in Turkish individuals. *Int. j. morphol*, *34*(3), 904-908.
16. Raveendran, M. (2019). The South Asian facial anthropometric profile: a systematic review. *Journal of Cranio-Maxillofacial Surgery*, *47*(2), 263-272.
17. Richmond, S., Howe, L. J., Lewis, S., Stergiakouli, E., & Zhurov, A. (2018). Facial genetics: a brief overview. *Frontiers in genetics*, *9*, 462.
18. Samizadeh, S. (2022). Characteristics of Asian Faces. In *Non-Surgical Rejuvenation of Asian Faces* (pp. 41-58). Springer.
19. Shetti, V. R., Pai, S. R., Sneha, G., Gupta, C., & Chethan, P. (2011). Study of Prosopic (Facial) Index of Indian and Malaysian Students. *International journal of Morphology*, *29*(3).
20. Simmons-Ehrhardt, T., Falsetti, C. R., & Falsetti, A. B. (2021). Using Computed Tomography (CT) data to build 3d resources for forensic craniofacial identification. In *Biomedical Visualisation: Volume 9* (pp. 53-74). Springer.
21. Vezzetti, E., & Marcolin, F. (2012). Geometrical descriptors for human face morphological analysis and recognition. *Robotics and Autonomous Systems*, *60*(6), 928-939.
22. Windhager, S., Schaefer, K., & Fink, B. (2011). Geometric morphometrics of male facial shape in relation to physical strength and perceived attractiveness, dominance, and masculinity. *American Journal of Human Biology*, *23*(6), 805-814.
23. Yesmin, T., Thwin, S. S., Afrin Urmi, S., Wai, M. M., Zaini, P. F., & Azwan, K. (2014). A study of facial index among Malay population. *Journal of Anthropology*, *2014*(1), 726974.