Original Research

Anthropometric Analysis of Lip Parameters Among Indian Population Using 2D Photogrammetry and Direct Methods

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ABSTRACT:
Background: Lip morphology plays a crucial role in facial aesthetics and functional reconstruction, yet limited normative data exist for the diverse Indian population. This study aimed to assess sexual dimorphism in lip parameters among Indian adults and evaluate the reliability of 2D photogrammetry compared to direct anthropometry. **Material and Methods:** A descriptive cross-sectional study was conducted on 640 healthy individuals (320 males, 320 females) aged 18–25 years from six geographic zones of India. Lip measurements—including mouth width, philtrum width, upper and lower lip height, vermilion dimensions, and derived indices—were obtained using both direct caliper-based anthropometry and 2D photogrammetry with DSLR imaging and Digimizer software. Statistical analysis was performed to determine gender differences and method agreement. **Results:** Males exhibited significantly larger mouth width, philtrum width, lip thickness, and lower vermilion height compared to females ($p < 0.05$), indicating sexual dimorphism in several horizontal and soft tissue lip dimensions. However, cutaneous lip heights and vermilion arch indices showed minimal gender differences. Total lip height showed significance only in direct measurements. The 2D photogrammetric method demonstrated high reliability and consistency with direct anthropometry for most parameters. **Conclusion:** This study confirms the presence of sexual dimorphism in specific lip dimensions among the Indian population and supports the use of 2D photogrammetry as a valid, non-invasive alternative for facial anthropometric assessment. These findings provide valuable normative references for clinical, forensic, and aesthetic applications.
Keywords: Lip anthropometry, 2D anthropometry, Direct anthropometry, facial measurements

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INTRODUCTION

Facial anthropometry is a scientific approach to measuring the dimensions of the face and its components, providing valuable data for various applications in medicine, forensic science, and aesthetic practices.[1] Among the many facial features, the lips play a crucial role in both function and appearance.[2] As a central element of the lower third of the face, the lips contribute to speech, expression, eating, and, significantly, to facial aesthetics.[3] The morphology of lips—including dimensions such as width, height, philtrum depth, and vermilion shape—varies greatly based on sex, ethnicity, genetic makeup, and regional demographics.[4]

In recent years, the demand for region-specific anthropometric data has grown due to the increasing emphasis on personalized medicine and cultural sensitivity in cosmetic and reconstructive surgery.[5] In India—a country with immense ethnic and geographical diversity—standardized lip measurements for various regional populations remain underexplored.[6] The lack of normative data for lip parameters limits the accuracy of procedures such as lip reconstruction following trauma or congenital anomalies, cleft lip surgeries, prosthodontic design, and aesthetic lip augmentations.[7]

Traditionally, **direct anthropometry** using tools like calipers has been the gold standard for facial measurements. However, it is often labor-intensive, intrusive, and less feasible in clinical settings. With advancements in technology, **indirect methods** such as **2D photogrammetry**—which involves image-

based analysis—have emerged as a non-invasive and efficient alternative.[8,9] These methods offer promising benefits including reduced measurement variability, digital record keeping, and increased patient comfort. Despite this, their reliability—especially for soft tissue structures like the lips—requires thorough validation against direct techniques.[10]

This study addresses key gaps: the absence of normative lip anthropometric data across different Indian regions, and the need to evaluate the accuracy and reliability of 2D image-based methods compared to direct measurement. By focusing on parameters such as mouth width, philtrum width, upper and lower lip heights, vermilion contours, and related indices, this study aims to generate a robust data set that can inform surgical planning, prosthetic design, and anthropological studies. The analysis of sexual dimorphism further enhances the clinical utility of these findings, supporting gender-specific assessments in both reconstructive and aesthetic domains.Ultimately, this work contributes to the growing body of evidence in facial morphometry and demonstrates the applicability of cost-effective digital imaging tools for large-scale anthropometric research in diverse populations.

MATERIAL AND METHODS

This descriptive cross-sectional study was conducted in the Department of Anatomy at Teerthanker Mahaveer Medical College and Research Centre, Moradabad, Uttar Pradesh, India, over a one-year period from January 2023 to January 2024. A total of 640 healthy participants, comprising 320 males and 320 females. Eligible participants were healthy Indian adults aged between 18 and 25 years.[11] Individuals were excluded if they had a history of facial trauma or reconstructive surgery, congenital craniofacial anomalies, intellectual disabilities, or a mixed ethnic background.[12] The study received ethical approval from the Institutional Ethics Committee (Ref. No. TMU/IEC/20-21/103), and all participants provided informed consent in accordance with the ethical standards set by the Declaration of Helsinki (1975). To maintain anonymity and confidentiality, all identifiable features were masked during image capture, and no personal identifiers such as names or contact details were recorded. The images were stored on a secure, password-protected system and were used exclusively for research purposes under restricted access. Anthropometric evaluation focused on eight key nasal parameters—namely, Mouth width, philtrum width, Upper lip height, lower lip height,

total lip height, Cutaneous upper lip height, Cutaneous lower lip height, Upper and lower vermilion arc and Vermilion height. These dimensions were assessed using two distinct approaches: conventional direct anthropometry and 2D photogrammetric analysis.

Direct Anthropometric Method

Prior to initiating the measurements, informed written consent was obtained from all participants. Each subject was thoroughly briefed on the measurement procedure to alleviate any concerns and ensure full cooperation. During data collection, participants were instructed to adopt a neutral head position, aligned along the Frankfurt horizontal plane, and to maintain a relaxed, expressionless face.Key anatomical landmarks were identified and marked using a surgical skin marker. Linear measurements were then taken using a digital vernier caliper and spreading caliper with appropriate precision. To enhance reliability, each parameter was measured multiple times, and the mean of the readings was recorded as the final value.[6]

2D Indirect Photogrammetry Method

High-resolution facial images were obtained using a 24.2-megapixel DSLR camera under standardized, well-illuminated conditions. The camera was mounted on a tripod and positioned at a fixed distance, ensuring parallel alignment with the occlusal plane and maintaining the Frankfurt horizontal plane for head orientation. A millimeter reference scale was placed adjacent to the participant's face in each image to allow for precise calibration.[6,11]

Photographs were reviewed meticulously to identify and exclude any images with errors such as poor orientation, facial distortion, or visual artifacts. The selected JPEG files were imported into **Digimizer Image Analysis Software (Version 5.7.5)**, a user-friendly platform known for its precision in soft tissue measurement. Facial dimensions were then analyzed digitally, enabling a non-invasive yet highly accurate anthropometric assessment.[12]

RESULTS

Tables 1 and 2 present the descriptive statistics of linear and index-based lip parameters, expressed as mean ± standard deviation. These tables also illustrate the assessment of sexual dimorphism between Indian males and females using the unpaired t-test. A p-value < 0.05 was considered statistically significant, indicating notable gender-based differences in several lip measurements.

Table 1: Descriptive statistics of linear Lip Parameters

Parameters	Indian male (cm)	Indian female (cm)	t-value	p-value
Mouth Width 1	5.19±0.4	4.93±0.5	7.26	<0.05
Mouth Width 2	5.26±0.44	4.98±0.43	8.14	<0.05
Philtrum Width 1	1.03±0.18	0.97±0.21	3.88	<0.05
Philtrum Width 2	1.28±0.24	1.23±0.23	2.69	<0.05
Upper Lip Height 1	1.87±0.26	1.78±0.2	4.9	>0.05

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Upper Lip Height 2	1.92±0.31	1.79±0.17	6.57	>0.05
Lower Lip Height 1	1.76±0.15	1.73±0.24	1.89	>0.05
Lower Lip Height 2	1.79±0.27	1.72±0.29	3.16	>0.05
Total Lip Height 1	1.82±0.32	1.77±0.25	2.2	<0.05
Total Lip Height 2	1.82±0.23	1.81±0.21	0.57	<0.05
Cutaneous Upper Lip Height 1	1.38±0.17	1.31±0.23	4.3	>0.05
Cutaneous Upper Lip Height 2	1.38±0.22	1.38±0.31	0.02	>0.05
Cutaneous Lower Lip Height 1	0.86±0.17	0.86±0.18	4.2	>0.05
Cutaneous Lower Lip Height 2	0.93±0.2	0.95±0.21	1.23	>0.05
Upper Vermilion arch 1	5.62±0.58	5.45±0.57	3.73	<0.05
Upper Vermilion arch 2	5.05±0.57	5.53±0.6	10.3	<0.05
Lower Vermilion arch 1	5.65±0.82	5.38±0.2	5.72	<0.05
Lower Vermilion Arch 2	5.66±0.59	5.48±0.72	3.45	<0.05
Upper Vermilion Height 1	0.91±0.11	0.86±0.16	4.6	>0.05
Upper Vermilion Height 2	1±0.17	0.94±0.15	4.73	>0.05
Lower Vermilion Height 1	1.12±0.2	1.07±0.25	2.79	<0.05
Lower Vermilion Height 2	1.19±0.16	1.11±0.25	4.82	<0.05
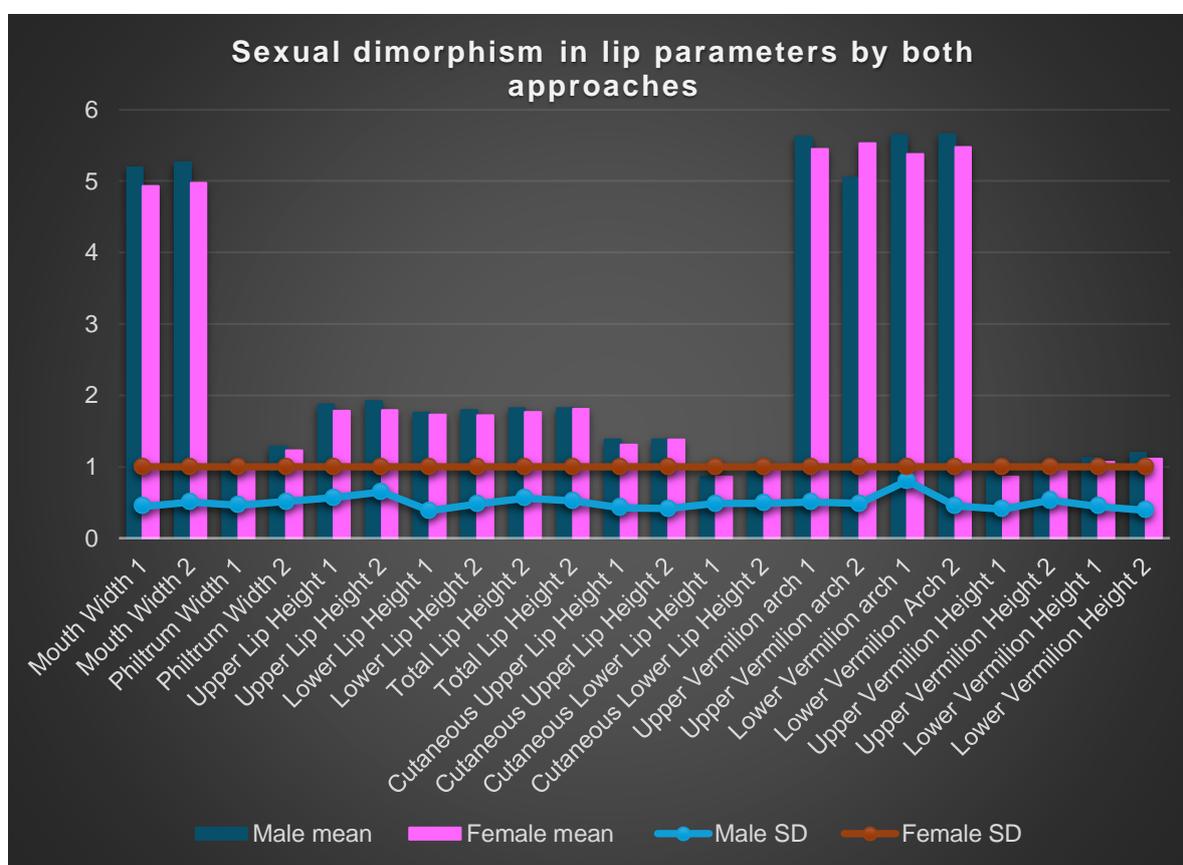
Figure 1: Sexual dimorphism in lip parameters by both approaches

Table 2: Descriptive statistics of indices of Lip Parameters

Parameters	Indian male (cm)	Indian female (cm)	t-value	p-value
Lip Index 1	35.9±5.8	36.4±6.8	1	>0.05
Lip Index 2	35.5±6.3	36.9±6.3	2.8	<0.05
Philtrum Mouth Width Index 1	24.4±5	24.7±5.3	0.73	>0.05
Philtrum Mouth Width Index 2	25.1±4.5	25.4±4.5	0.84	>0.05
Upper Lip Thickness Index 1	51±5	49±4.9	5.11	<0.05
Upper Lip Thickness Index 2	54.6±12	53.2±8.6	1.69	>0.05
Lower Lip Thickness Index 1	63.2±9	60.3±11.1	3.63	>0.05
Lower Lip Thickness Index 2	65.5±8.3	62.9±7.6	4.13	<0.05
Upper Lip Height Mouth Width Index 1	35.6±6.8	36.5±5.2	1.88	>0.05

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Upper Lip Height Mouth Width Index 2	38.3±7	36.2±5.2	4.3	<0.05
Upper Vermilion Contour Index 1	92.9±10	91±10.2	2.37	<0.05
Upper Vermilion Contour Index 2	93.5±9.1	91.5±12	2.37	<0.05
Lower Vermilion Contour Index 1	94±10	92.8±8.3	1.65	>0.05
Lower Vermilion Contour Index 2	94.7±10	92.1±12.6	2.89	<0.05
Vermilion Arch Index 1	99.3±9	98.6±3.6	1.29	>0.05
Vermilion Arch Index 2	98.9±6.3	99.5±9	0.97	>0.05
Cutaneous Total Upper Lip Height Index 1	75.5±13	75.2±15	0.27	>0.05
Cutaneous Total Upper Lip Height Index 2	75.2±18	80±12	3.96	<0.05
Cutaneous Total Lower Lip Height Index 1	48.9±9.1	50.8±9.8	2.54	<0.05
Cutaneous Total Lower Lip Height Index 2	42.8±11.7	56.8±9.8	16.4	<0.05
Vermilion Total Upper Lip Height Index 1	50±13	48.9±14	1.03	>0.05
Vermilion Total Upper Lip Height Index 2	53.4±12.9	54.4±12	1.01	>0.05
Vermilion Total Lower Lip Height Index 1	65.6±10.5	61.9±13	3.96	<0.05
Vermilion Total Lower Lip Height Index 2	68.2±11.4	65.6±11.9	2.82	<0.05
Vermilion Total Lower Lip Height Index 1	82.3±11	82.6±14	0.3	>0.05
Vermilion Total Lower Lip Height Index 2	84.5±13.2	82.1±14	2.23	<0.05
Vermilion Height Index 1	82.3±15.1	82.6±11	0.28	>0.05
Vermilion Height Index 2	84.5±14	82.1±18.1	1.876	>0.05
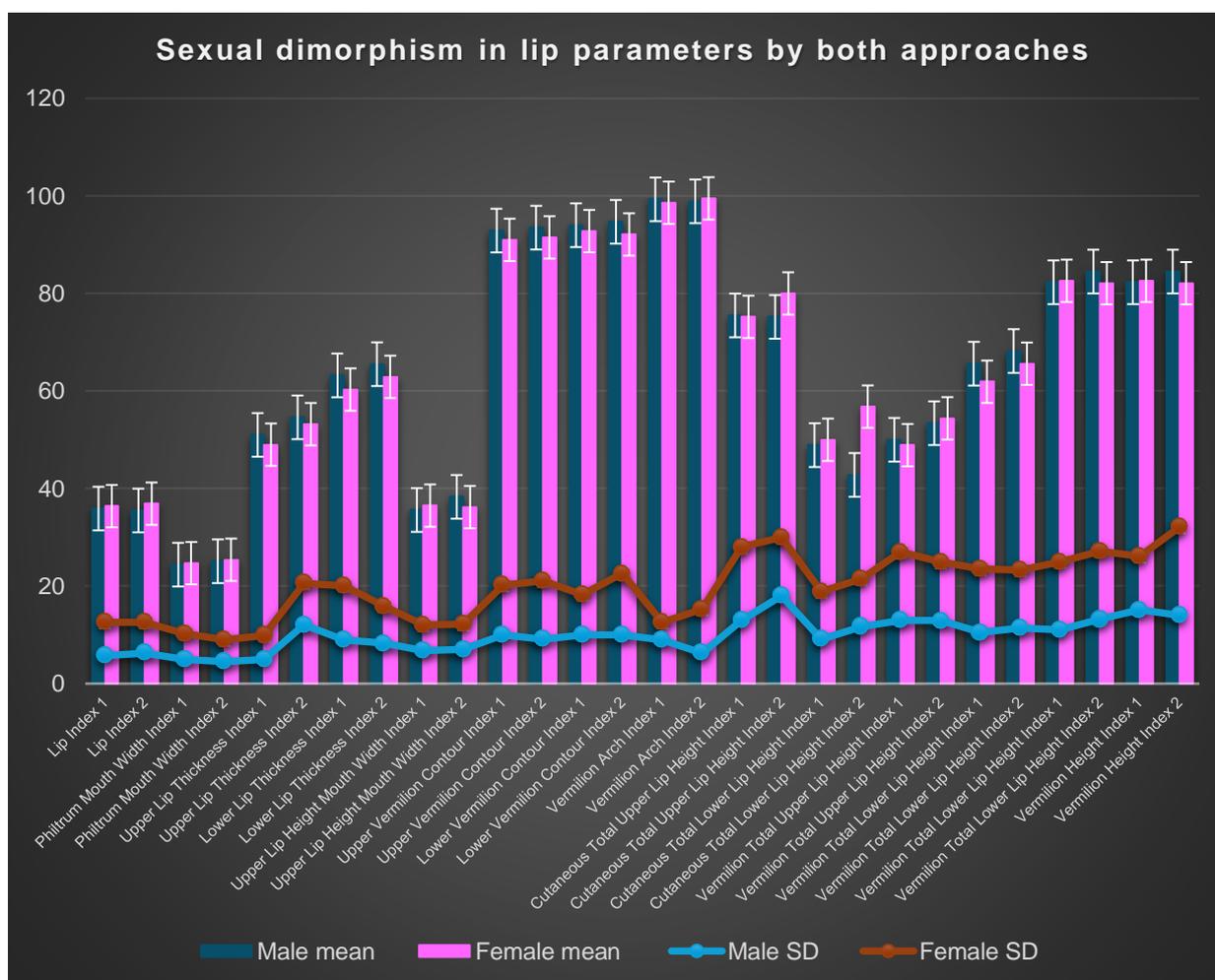
Figure 2: Sexual Dimorphism in lip parameters by both approaches

DISCUSSION

The present study comprehensively analyzed linear and index-based lip parameters in Indian males and females using both direct anthropometry and 2D photogrammetry. The aim was to explore sexual dimorphism and evaluate the reliability of photogrammetric methods. Our findings revealed several statistically significant differences between the sexes, though some parameters remained comparable across genders.

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Mouth and Philtrum Width
Significant sexual dimorphism was observed in both mouth width and philtrum width. Males consistently demonstrated greater mean values than females across both direct and indirect measurements. These results contrast with those of Hasibuan LY et al.[13,] who reported slightly higher mean mouth width in females and found no statistically significant sex differences. Likewise, Sharma RL et al.[14] observed wider philtrum dimensions in males but also reported no notable sexual dimorphism, suggesting regional or methodological variations may influence outcomes.

Upper and Lower Lip Height
Although males had marginally higher upper and lower lip height values, the differences were generally not statistically significant, indicating limited dimorphism. This contrasts with Goel A et al.[15], who found significant sexual dimorphism in upper lip height among North Indian populations. Similarly, Gulzar S et al.[16] noted a marked gender difference in lower lip height, with males showing significantly higher values than females—findings partially echoed in our lower lip data.

Total Lip Height
In our study, total lip height showed statistically significant sexual dimorphism only in direct measurements. The photogrammetric method reflected a negligible difference between sexes. Sharma RL et al.[14] had earlier reported significant gender differences in this parameter, but our findings suggest a more uniform distribution of total lip height in younger adults.

Cutaneous Lip Heights
Both cutaneous upper and lower lip heights showed no significant gender differences across measurement methods. This indicates minimal sexual dimorphism in the skin portion of the lips. Interestingly, Sharma RL et al.[14] reported significant dimorphism in cutaneous upper lip height, possibly due to population or methodological differences.

Vermilion Arch and Height
The vermilion arch dimensions showed notable gender differences, with males exhibiting higher upper and lower vermilion arch values. In contrast, the photogrammetric method captured a slightly higher upper vermilion arch mean in females, possibly reflecting curvature nuances more precisely. Lower vermilion height was significantly greater in males in both methods, while upper vermilion height showed no significant sex differences—consistent with the findings of Gulzar S et al.[16], who also reported higher lower vermilion height in males.

Lip Index and Philtrum Mouth Width Index
The lip index showed a statistically significant difference in the 2D method, with females exhibiting slightly higher values, reflecting proportionally taller lips relative to mouth width. The philtrum-mouth width index, however, showed no significant gender variation across either method. This is supported by studies from Bahsi I et al.[17] and Farkas LG et al.[18], both of whom observed minimal or no dimorphism in similar populations.

Lip Thickness Indices
Significant sexual dimorphism was observed in both upper and lower lip thickness indices. Males had notably thicker lips, especially in the lower region, across both measurement methods. These findings reflect a greater accumulation of soft tissue mass in the male lip structure.

Upper Lip Height to Mouth Width Index
This index was significantly higher in males using the 2D method, indicating a taller upper lip relative to mouth width. However, the direct method did not show significant differences, likely due to the sensitivity of measuring vertical dimensions manually. Kalra S et al.[19] also observed statistically insignificant differences, aligning with our direct measurement results.

Vermilion Contour and Arch Indices
The upper vermilion contour index was significantly greater in males across both methods, indicating a more pronounced upper lip curvature. Lower vermilion contour index reached significance only in the 2D method. Vermilion arch index showed no significant gender variation, a finding consistent with Farkas LG et al.[20], who also reported similar mean values across sexes.

Cutaneous and Vermilion Height Indices
The cutaneous lower lip height index was significantly greater in females, especially in 2D assessments, suggesting longer skin coverage in the lower lip. Males showed slightly higher, though non-significant, values in upper cutaneous lip height. The vermilion total lower lip height index was consistently higher in males across both methods, reinforcing the observation of more prominent soft tissue components in males. However, the overall vermilion height index did not vary significantly by gender, reflecting a relatively balanced contribution from upper and lower vermilion segments across sexes. Despite its comprehensive scope, the study has several limitations: The sample was limited to adults aged 18–25 years, which may not reflect age-related changes in lip morphology. Both direct and 2D approaches relied on precise anatomical landmark identification, which may introduce inter-observer variability despite standardization. The study presumed binary gender identity based on physical appearance or documentation, without accounting for intersex or non-binary individuals, which may be relevant in future anthropometric research.

CONCLUSION

This study presents a comprehensive anthropometric analysis of lip dimensions and indices among Indian males and females using both direct and 2D photogrammetric methods. Significant sexual dimorphism was observed in various lip parameters—particularly in mouth width, philtrum width, lip thickness, and lower vermilion height—highlighting measurable differences between male and female lip morphology. While some parameters such as cutaneous lip heights and vermilion arch indices showed minimal gender variation, others demonstrated consistent trends across both measurement techniques.

The findings confirm that 2D photogrammetry is a reliable and non-invasive alternative to traditional direct anthropometry, particularly for linear and index-based lip measurements. Its ease of use and accuracy support its application in large-scale facial analysis, aesthetic surgery planning, and forensic identification. The regional and gender-specific data generated by this study contribute valuable normative benchmarks for future clinical and anthropological research in the Indian population.

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