Sexual dimorphism through lip print analysis: a study on pattern variations among Indonesian adolescents

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SUMMARY

The analysis of lip print patterns has been recognized as a supplementary method for forensic identification. This study examines sex-based variations in lip print patterns among Indonesian adolescents to explore potential forensic applicability. Ninety-six lip prints were collected from subjects (40 males and 56 females) aged 16–20 years. Lip prints were obtained through a standardized procedure involving the application of lipstick, transfer onto cellophane tape, and placement on white paper. Patterns were analyzed using ImageJ software, and statistical analysis was conducted using IBM® SPSS® Statistics version 29.0. The results indicate that Type I is most common among males, whereas Type II predominates among females. Significant differences were observed between the upper left and lower right quadrants ($p<0.05$). Although these findings reveal sexual dimorphism in certain quadrants, they remain preliminary and specific to Indonesian adolescents. Further studies with broader age ranges and predictive modeling are needed to evaluate forensic utility.

Key words: Forensic odontology – Identification – Legal identity – Lip prints – Sexual dimorphism

INTRODUCTION

Crime remains a significant global concern, including in Indonesia, where criminal incidents reached 239,481 in 2021 (Direktorat Statistik Ketahanan Sosial 2024). In response, law enforcement authorities, including the police, judiciary, and correctional institutions, play a critical role in maintaining justice and public safety. The resolution of criminal cases requires comprehensive investigative measures to gather reliable evidence, reconstruct events, determine offenses, and identify those involved. Investigators are essential in identifying individuals, whether as perpetrators or victims, necessitating a scientific approach that integrates advanced technology and forensic methodologies to enhance the accuracy and effec-

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tiveness of criminal investigations (Salado Puerto et al., 2021).

Rapid technological advancements have enabled criminals to adopt increasingly sophisticated methods, making it easier to commit crimes while posing greater challenges for investigators. When primary identification methods are unavailable, alternative techniques are essential in forensic investigations. Cheiloscopy, the study of lip prints, is one such method that can serve as a valuable tool in criminal identification (Venkatesh and David, 2011; Remya et al., 2016). Lip prints and fingerprints share key forensic characteristics, including uniqueness, permanence, and the ability to persist despite minor trauma. Given that lip prints may be present at crime scenes, their analysis can be instrumental when fingerprint identification is not feasible, offering an additional avenue for forensic examination (Maheswari and Gnanasundaram, 2011; Krishnan, 2022).

Sex estimation is a fundamental aspect of forensic identification. Although lip prints have been proposed as a potential tool for sex identification, their reliability remains a topic of debate. Several studies have suggested significant differences in lip print patterns between males and females, supporting their use in forensic sex estimation (Gondivkar et al., 2009; Sharma et al., 2009; Krishnan et al., 2016). However, other research findings indicate no statistically significant variations, raising questions about their efficacy as a reliable identification method. These conflicting results highlight the need for further investigation into the potential relationship between lip print characteristics and sex. This study examines lip print patterns in Indonesian adolescents, thereby providing new insights into the forensic applicability of lip prints in sex identification.

MATERIALS AND METHODS

This study was approved by the Health Research Ethical Clearance Commission of the Faculty of Dental Medicine, Universitas Airlangga (approval number: 790/HRECC.FODM/VII/2023). Ninety-six subjects (40 males and 56 females, aged 16-20 years) voluntarily participated in this study. Subjects with healthy lip conditions were included, while exclusion criteria were made for individuals with lip lesions, injuries, congenital abnormalities, or inflammation. Adolescents were chosen to explore early developmental patterns due to practical accessibility and considerations; hence, the findings of this study can be applied to the studied age group and limit the extrapolation to adults.

Pre-impression preparation

Participants were instructed to avoid eating, drinking, or applying lip cosmetics for at least 30 minutes before sampling. Lips were cleaned and allowed to rest for 5 minutes before lipstick application. Red colored lipstick was applied uniformly using a disposable applicator. Participants were instructed to rub their lips together to spread the lipstick evenly. The lip print patterns were duplicated by pressing cellophane tape onto the relaxed, closed lips with minimal pressure. The tape was then placed on a piece of white paper for digitization. The choice of cellophane tape and lipstick was based on prior studies demonstrating their ability to produce clear and reproducible prints (Costa and Caldas, 2012).

Analysis of lip print patterns

The lip prints were then digitized using an Epson L3110 scanner and analyzed in ImageJ software to enhance image quality, apply magnification, and demarcate quadrants. Each lip print was divided into the following six quadrants: upper left (UL), upper middle (UM), upper right (UR), lower left (LL), lower middle (LM), and lower right (LR). Lip print patterns were classified based on the Suzuki and Tsuchihashi system, as described in Table 1 (Suzuki and Tsuchiahashi, 1971).

The statistical analysis of sex-based differences in lip print patterns was conducted for each quadrant using the Chi-Square test in IBM® SPSS® Statistics version 29.0 (IBM, Armonk, NY, USA). In cases where significant differences were detected, Cramér's V test was performed to assess the strength of the association. To ensure the reliability of the findings and minimize bias, intra-observer reliability was evaluated using Cohen's Kappa coefficient. The interpretation of Kappa values followed that of Landis and Koch (1977): ≤0.20 slight, 0.21–0.40 fair, 0.41–0.60 moderate,

Table 1. Lip print classification according to the method of Suzuki and Tsuchiahashi (1971)

Type	Lip print pattern	Description
Type I	Straight grooves	A clear-cut line or groove running vertically across the lip
Type I'	Partial straight grooves	A partial-length groove of Type I
Type II	Branched grooves	Grooves that fork in their course or a branched groove
Type III	Intersected grooves	An intersected groove
Type IV	Reticular grooves	A reticular groove pattern
Type V	Undifferentiated grooves	Grooves that do not fall into any of the above categories and cannot be differentiated morphologically

0.61–0.80 substantial, and 0.81–1.00, almost perfect agreement (Landis and Koch 1977).

RESULTS

Intra-observer reliability in this study was assessed by analyzing lip print patterns across the entire sample twice at different time points during the study period. Intra-observer reliability showed Cohen's Kappa values exceeded 0.8 for all quadrants, indicating almost perfect agreement.

Table 2 presents the frequency and percentage distribution of lip print patterns across the six lip quadrants for each sex. The most predominant lip print pattern in the UL quadrant among males was Type V (27.5%), while in females, Type II was the most prevalent (35.7%). In the UM quadrant, Type I' is the most common pattern in males (22.5%), whereas Type II dominates in females (26.8%). In the UR quadrant, Type I was the most frequent lip print pattern among males, representing 25%, whereas Type II was the most dominant in females at 33.9%.

In the LL quadrant, Type III is the most prevalent among males (25%), whereas in females, both Type II and Type III occur with equal frequency (23.2%). For the LM quadrant, Type I was the most dominant pattern in both sexes, with a prevalence of 22.5% in males and 26.8% in females. Finally, in the LR quadrant, Types I and II are equally dominant in males, each accounting for 22.5%, while Type II is the most frequent in females, constituting 30.4%.

The most predominant lip print pattern among males is Type I, accounting for 20.4%, particularly in the UR, LM, and LR quadrants, followed by Type IV (17.1%), Types I' and II (16.3%), Type III (15.4%), and Type V (14.6%). The most dominant lip print pattern in females is Type II, comprising 26.5%, primarily in the UL, UR, LL, and LR quadrants, followed by Type III (21.1%), Type IV (14.6%), Type V (14.3%), Type I (13.4%), and Type I' (10.1%). Overall, Type I' is the least frequently

Table 2. Distribution of lip print patterns among males and females in this study

Sex	n	Quad rant	Lip Print Pattern					
			Type I	Type I'	Type II	Type III	Type IV	Type V
Male	40	UL	7 (17,5%)	4 (10%)	5 (12,5%)	4 (10%)	9 (22,5%)	11 (27,5%)
		UM	5 (12,5%)	9 (22,5%)	8 (20%)	6 (15%)	8 (20%)	4 (10%)
		UR	10 (25%)	6 (15%)	5 (12,5%)	7 (17,5%)	6 (15%)	6 (15%)
		LL	9 (22,5%)	5 (12,5%)	5 (12,5%)	10 (25%)	5 (12,5%)	6 (15%)
		LM	9 (22,5%)	8 (20%)	7 (17,5%)	5 (12,5%)	8 (20%)	6 (15%)
		LR	9 (22,5%)	7 (17,5%)	9 (22,5%)	8 (20%)	5 (12,5%)	5 (12,5%)
Female	56	UL	6 (10,7%)	8 (14,3%)	20 (35,7%)	16 (28,6%)	4 (7,1%)	2 (3,6%)
		UM	9 (16,1%)	5 (8,9%)	15 (26,8%)	9 (16,1%)	10 (17,9%)	8 (14,3%)
		UR	4 (7,1%)	7 (12,5%)	19 (33,9%)	9 (14,3%)	7 (12,5%)	11 (19,6%)
		LL	8 (14,3%)	5 (8,9%)	13 (23,2%)	13 (23,2%)	7 (12,5%)	10 (17,9%)
		LM	15 (26,8%)	4 (7,1%)	5 (8,9%)	12 (21,4%)	14 (25%)	6 (10,7%)
		LR	3 (5,4%)	5 (8,9%)	17 (30,4%)	13 (23,2%)	7 (12,5%)	11 (19,6%)

observed lip print pattern in both sexes.

The chi-square test was used to analyze sex-based differences in lip print patterns (Table 3). The results revealed that most quadrants did not exhibit significant sex-based differences ($p > 0.05$). However, two quadrants—UL and LR—demonstrated statistically significant differences in lip print patterns between males and females ($p < 0.05$). The Chi-Square significance test can determine whether a relationship exists between two variables; however, it does not measure the strength of that relationship. Therefore, Cramér's V correlation test was employed to assess the strength of associations between variables, particularly when a significant difference is detected in the Chi-Square analysis. Cramér's V values range from 0 to +1, with the following interpretations: 0–0.1 indicates no meaningful association, 0.1–0.2 signifies a negligible association, 0.2–0.4 suggests a moderate association, 0.4–0.6 indicates a relatively strong association, 0.6–0.8 denotes a strong association, and 0.8–1 represents a very strong association.

As shown in Table 3, the UL quadrant exhibited a significant difference in lip print patterns between males and females, with a relatively strong association between lip print patterns and sex. In contrast, the UM, UR, and LM quadrants showed no significant differences in lip print patterns between sexes, with only a moderate relationship observed. No significant differences were detected in the LL quadrant, and the relationship between the two variables was weak. Although a significant difference was found in lip print patterns between males and females in the LR quadrant, the relationship strength was only moderate.

DISCUSSION

Lip prints serve as supplementary forensic evidence in criminal investigations and play a potential role in sex estimation. The pattern of lip prints can be recovered from various objects at crime scenes, including drinking glasses, cigarette butts, paper, adhesive tape, and clothing. Lips are often moistened by saliva, increasing the likelihood of leaving discernible lip prints on such surfaces. Identifying sex using lip print analysis is a simple, cost-effective, and efficient method. The distinct grooves and ridges on the lips form unique patterns, making lip print analysis a promising approach for sex estimation. While previous studies have drawn comparisons between lip prints and fingerprints, their reliability in sex identification remains a subject of debate (Negi and Negi, 2016; Krishnan et al., 2016). This study investigates the differences in lip print patterns between males and females in Indonesia, contributing to the ongoing discourse on the forensic applicability of lip prints.

The predominance of Type I in male lip prints in this study is consistent with the findings of Obosi et al. (2022), who examined 100 individuals (50 males and 50 females) from the Akwa Ibom Indigenous community in Nigeria. Their study reported that Type I was the most common lip print pattern in males across all quadrants, accounting for 29%, followed by Type II (25%), Type I' (17%), Type IV (13%), Type V (9%), and Type III (7%). Similarly, a study by Kapoor and Badiye (2017) on 100 males and 100 females in India also identified Type I as the most frequent pattern in males. Moreover, their findings align with the present study regarding the least common type, confirming that Type I' is the rarest lip print pattern in

Table 3. Chi-square and Cramér V test results and the strength of association between lip print patterns and sex

Quadrant	p-value (Chi-Square)	Cramér's V value	Strength of the Association
UL	<0.001*	0.475	Relatively Strong
UM	0.547	0.205	Moderate
UR	0.074	0.323	Moderate
LL	0.739	0.169	Weak
LM	0.089	0.315	Moderate
LR	0.048*	0.341	Moderate

*Indicates a significant difference between males and females

both males and females. In contrast, Moshfeghi et al. (2016), in their study of 96 lip prints from patients at the Dental School of Shahid Beheshti University of Medical Sciences in Iran (22 males and 74 females), reported that Type V was the most frequently observed pattern in males (39.3%), while Type III was the least common (5.3%).

Among females, the most prevalent lip print pattern in this study was Type II, followed by Types III, IV, V, I, and I'. The predominance of Type II in female lip prints in this study aligns with the findings of Hamzah et al., who examined the native Chinese population (203 males and 209 females) residing in the Klang Valley, Malaysia. Their study reported that Types II and IV were the most frequently observed patterns in both sexes. In females, Type II was most dominant in the lower left (55%) and lower right (56.5%) quadrants, whereas Type IV was prevalent across almost all quadrants, with a frequency range of 50.2%–78%, except in the lower right and lower left quadrants (Md Udin et al. 2019). Conversely, Moshfeghi et al. (2016) found that Type V was the most frequently observed pattern in females, comprising 31.3%, while Type III was the least common, occurring in only 1.8% of cases.

This study identified significant differences in lip print patterns between males and females in the UL and LR quadrants. The significant differences observed in these quadrants are consistent with the findings of Pelin et al. (2019), who studied 434 individuals (143 males and 291 females) in Anatolia. Their study reported significant sex-based differences in lip print patterns across nearly all quadrants, including the UL and LR. Similarly, Ahmad et al. (2018) conducted a study in Malaysia with 360 participants (180 males and 180 females) and found significant differences between males and females across all six lip print quadrants (Ahmad et al., 2018).

The significant differences identified in the UL quadrant in the present study align with the findings of Obosi et al. (2022) and Hamzah et al. (Md Udin et al. 2019). Additionally, a study by Moshfeghi et al. (2016) concluded that only the LR quadrant demonstrated significant sex-based differences ($p < 0.05$), whereas the overall comparison of male and female lip print patterns did not yield statistically significant results. Conversely, studies that analyzed only four lip print quadrants have reported conflicting findings. Peeran et al. (2015) found no significant differences between male and female lip print patterns in the four quadrants analyzed (UR, LR, UL, and LL). Similarly, Chukwumeka et al. (2019), in their study of 212 males and 238 females in Nigeria, reported no significant differences in the upper right, lower left, and lower right quadrants ($p > 0.05$), with only the upper left quadrant exhibiting a significant variation, which they attributed to coincidence. In contrast, Kapoor and Badiye's (2017) study on the Marathi population in India found significant sex-based differences in lip print patterns across all quadrants.

In this study, Cramér's V correlation test results indicated a relatively strong relationship between lip print patterns and sex in the UL quadrant, whereas a moderate association was found in the LR quadrant. The differences observed in certain quadrants support prior findings on sexual dimorphism. The explanation involving genetic and hormonal influences should be grounded in craniofacial developmental biology. Sexual dimorphism in lip morphology arises from complex interactions among genetic determinants and sex hormones, influencing facial soft tissue growth and lip vermilion characteristics (Sforza et al., 2010; Ayuba et al., 2019; Davies et al., 2022).

Some of the findings in this study differ from those reported in previous research, especially regarding the predominant lip print patterns in each sex and the specific quadrants showing significant differences. Several factors may explain these discrepancies. First, lip print analysis is inherently subjective, relying heavily on the examiner's expertise and experience, which can introduce variability and inconsistencies in pattern classification across studies. Additionally, differences in methodological approaches to quadrant division contribute to divergent results; while some studies divide the lips into four, six, or even eight quadrants, others analyze the lip prints as a whole without subdivision. Moreover, population-specific genetic and environmental factors likely influence lip print distribution, resulting in distinct pattern variations among different eth-

nic groups and geographic regions (Ahmed et al., 2018; Brkić et al., 2021).

The quality of lip print impressions used in this study may influence the accuracy of pattern analysis. Poor-quality impressions may lead to misinterpretation of lip print patterns, potentially affecting the reliability of findings. Several factors contribute to lip print quality, including the pressure applied during impression collection, the lipstick layer's thickness, and the lips' cleanliness (Ortiz-Contreras et al., 2024). Excessive pressure when pressing the tape onto the lip surface can distort or obscure lip grooves, while insufficient pressure may result in incomplete or faint impressions. Similarly, lipstick thickness plays a crucial role in print clarity; an overly thick application can mask lip grooves, making the pattern indistinct, whereas insufficient lipstick may produce weak or barely visible impressions. Additionally, debris, moisture, or other substances on the lip surface can interfere with the formation of a clear lip print, further complicating pattern identification and analysis.

Notably, the study remains descriptive. Although quadrant-specific differences were identified, no predictive sex estimation models were developed or validated. Future studies should explore discriminant analysis or machine learning approaches to quantify classification accuracy, sensitivity, and specificity, thereby assessing forensic applicability more rigorously.

CONCLUSION

This study provides preliminary evidence of sex-based variation in lip print patterns among Indonesian adolescents, with significant differences in the upper-left and lower-right quadrants. Future studies are necessary to develop and validate sex estimation models incorporating lip print data and replicate findings across different age groups and populations.

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