Annals of Human Biology
Journal of the Society for the Study of Human Biology

http://informahealthcare.com/ahb
ISSN: 0301-4460 (print), 1464-5033 (electronic)

Ann Hum Biol, 2014; 41(6): 568–578
 DOI: 10.3109/03014460.2014.885082

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HUMAN BIOLOGICAL SURVEY

Diversity of human lip prints: a collaborative study of ethnically distinct world populations

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Abstract

Background: Cheiloscopy is a comparatively recent counterpart to the long established dactyloscopic studies. Ethnic variability of these lip groove patterns has not yet been explored. *Aim*: This study was a collaborative effort aimed at establishing cheiloscopic variations amongst modern human populations from four geographically and culturally far removed nations: India, Saudi Arabia, Spain and Nigeria.
Subjects and methods: Lip prints from a total of 754 subjects were collected and each was divided into four equal quadrants. The patterns were classified into six regular types (A–F), while some patterns which could not be fitted into the regular ones were segregated into G groups (G-0, G-1, G-2). Furthermore, co-dominance of more than one pattern type in a single quadrant forced us to identify the combination (COM, G-COM) patterns.
Results and conclusion: The remarkable feature noted after compilation of the data included pattern C (a bifurcate/branched prototype extending the entire height of the lip) being a frequent feature of the lips of all the populations studied, save for the Nigerian population in which it was completely absent and which showed a tendency for pattern A (a vertical linear groove) and a significantly higher susceptibility for combination (COM) patterns. Chi-square test and correspondence analysis applied to the frequency of patterns appearing in the defined topographical areas indicated a significant variation for the populations studied.

Keywords

Cheiloscopy, ethnic variations, gender variations, human populations, lip dimensions, lip prints

History

Received 11 September 2013
Revised 4 December 2013
Accepted 6 January 2014
Published online 24 February 2014

Introduction

Friction ridges, serving the obvious purpose of improving grip, are commonly seen on the palms, soles and volar aspect of the fingers. The distinctive patterns made by these ridges, being unique to the individual, are a well-established phenomenon and, apart from generating scientific curiosity, have long been a successful tool for criminal investigation. The earliest reference to the fingerprinting of criminals for the purpose of establishing an identification record was during the reign of Hanimurabi (1792–1750 B.C.) in Babylon (Ashbaugh, 1991).

Similar ridges and grooves are present on the vermilion zone of the human lips, a particularly well developed organ in concurrence with the vocal abilities of man. We feel it would be justified to functionally categorize these ridges as frictional as they serve to provide suitable roughness assisting grasping for the subsequent ingestion of food. Unlike the well-entrenched dactyloscopic studies, patterns formed by the grooves on the lips were noted as recently as the beginning of the 20th century by Fischer (Caldas et al., 2007). Subsequent decades witnessed no further study as to the individuality or permanence of these patterns, their genesis in the pre-natal period or their practical application. In 1932, Edmond Locard, the famous French criminologist, recognized the important role cheiloscopy, the scientific study of lip prints, could play in nailing the perpetrator of a crime (Spencer, 2004). Later, Snyder (1950) reiterated the potential significance of lip prints as a tool for individual identification.

An exhaustive study of the developing lip by Soliman (1996) gives an interesting insight into the histo-genesis of lip wrinkles. The study revealed the commencement of these wrinkles as surface epidermal depressions and corresponding basal projections by the 16th week of intra-uterine life. These increase in number and depth by the 20th week and are transformed into fissures and furrows by the 28th week of intra-uterine life.

In order to establish the distinctive nature of groove patterns on human lips, further extensive research was done by Suzuki & Tsuchihashi (1971), Renaud (1973) and

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Tsuchihashi (1974). In recent times, a spate of studies pertaining to these patterns, confirming their age-related stability (Coward, 2007; Patel et al., 2010), uniqueness (Domiaty et al., 2010; Ragab et al., 2013; Sharma et al., 2009) and ability to weather minor trauma or inflammatory lesions, barring cases where the injury is major and distorts the lip morphology (Rajendran & Sivapathasundharam, 2006), has nudged cheiloscopy into the same league as dactyloscopy. However, despite numerous researches within individual population groups, studies dealing with the variability of these patterns amongst ethnically distinct human populations are surprisingly non-existent.

Basic classification of labial wrinkles and grooves into simple and compound types was done by Santos in 1966 (Soliman, 1996). Later, Suzuki & Tsuchihashi (1971) categorized them into five fundamental patterns including vertical grooves spanning the entire width of the lip, partial length vertical grooves, intersected, reticular and branched grooves. Subsequent workers sought to add greater details to the above classification; Fahmy and Hassan (1977) specified the direction of branching and further defined a pattern that could not fit with any of the regular groups; Afaf and El-Sharawy described the primary and secondary branches of the grooves, while Afify et al. (1989) differentiated the bifurcate from the branched type and added the X type, K type and braid shaped sutures (Soliman, 1996).

Interestingly, non-syndromic clefts of the lip and palate have been noted to be significantly associated with particular types of lip groove patterns (Neiswanger et al., 2009) giving credence to a genetic factor determining the type of pattern we may expect on our lips, thus inviting the interest of the geneticist and clinician alike.

The main purpose of this study is to establish whether any significant inter-ethnic variation related to these patterns exists amongst the populations of India, Saudi Arabia, Spain and Nigeria. Further, gender variations have been analysed by suitable statistical methods for any positive correlation. Apart from the forensic interest such a study might evoke, the pure scientific importance of such inter-ethnic variation, whether significantly present or not, is profound to the anthropologist.

Materials and methods

This was a collaborative study of ethnically distinct populations from India, Saudi Arabia, Spain and Nigeria representing the South Asian, Near East, European and the Sub-Saharan peoples, respectively. By convenience sampling, a total of 754 subjects were included in the study. The details of the country of origin, age range and gender distribution are given in Table 1. No volunteer of mixed racial parentage was included in the study. While the Indian study population represented subjects hailing from all parts of the country, the European sample was from Central and Southern Spain and the Nigerian prints were of the people from South West and South East regions of the country and comprised mostly of tribes such as the Yorubas and Igbos along with a few subjects from Edo and Delta, both of whom are minority ethnic groups in this geographical location.

The mean ages of the various populations studied were between 18.00–26.24 years. A uniform methodology of sample collection and pattern analysis was formatted and was strictly adhered to by the investigators from each of the four countries.

Table 1. Age and ethnic distribution of subjects.

	Males		Females	
Country	Sample size	Age, years; Range (mean)	Sample size	Age, years; Range (mean)
India	66	16–37 (18.22)	125	17–32 (18)
Saudi Arabia	114	17–20 (19.34)	120	14–40 (20.41)
Spain	111	18–31 (21.82)	118	18–32 (21.31)
Nigeria	46	21–60 (25.65)	54	20–54 (26.24)

Prior to sample collection, the subjects were explained the relevant details of the study and informed consent obtained. Those subjects with any obvious deformity (congenital or post-surgical), a pathological lesion on the lips or a known allergy to lipstick were excluded.

The subjects were requested to wash their lips with soap and water and pat dry with face tissues provided for the purpose. They were then required to wear lipstick and the application was done using a single stroke (to and fro rubbing of the lipstick was avoided) from one angle of the oral fissure to the other for the upper lip and in a similar manner for the lower lip, thus returning to the first angle. The lipstick used for the purpose was red or brown non-persistent, non-glossy, non-metallic and of good quality, as recommended by Domiaty et al. (2010).

The application was allowed to stand for a couple of moments, during which time A-4 papers (white; 210×297 mm; 75 GSM) were distributed to the participants and general information pertaining to their name, gender, age and the ethnic origin of both parents was recorded on the top right hand corner of the paper.

The paper was then folded and each participant was asked to in-fold their lips and gently lip-bite the folded portion of the paper. The process was repeated till the recording material was exhausted. This ensured the procurement of multiple prints which was invaluable during the process of reading the pattern-type as repetitive prints helped in diffusing any doubts as to the categorization of the patterns and, thus, decreased the chances of error.

The prints were serially numbered and filed gender-wise. They were scanned by a digital scanner (HP Scanjet 2400) and studied with the aid of Microsoft Office Picture Manager. Alternatively, some workers preferred to transfer the digital pictures of the prints into the computer for further analysis.

The lip prints were divided into four quadrants (UR = upper right; UL = upper left; LR = lower right, LL = lower left) (Figure 1).

The classification of the patterns was done as indicated in Table 2. These have been diagrammatically represented in Figure 2. Patterns A–F were the regular patterns as have been noted in previous studies. Indeterminate types which could not be fitted amongst the regular patterns were labelled as G patterns. Patterns C and D, as defined by us in this study, included a bifurcate or branched variety with no distinction made between patterns in which the branched ends were directed towards the peripheral edge of the lip or towards the

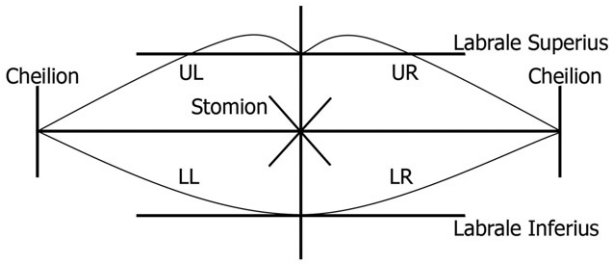

Figure 1. Four quadrants of the lips. Reference points while measuring lip dimensions.

Table 2. Classification of lip groove patterns.

Pattern type	Description
A	Vertical Complete
B	Vertical Incomplete
C	Branched Complete
D	Branched Incomplete
E	Intersected (horizontal grooves intersected by any other grooves which may be vertical/oblique/branched, etc.)
F	Reticular (diamond patterned)
G-0	Area devoid of any prints
G-1	X type pattern
G-2	Indeterminate (which could not be categorized in any of the above including whorls, short and long stemmed bouquet, H-type pattern)
COM	Equal representation of more than one pattern in a single quadrant
G-COM	Equal representation of more than one pattern in a single quadrant including an indeterminate G type

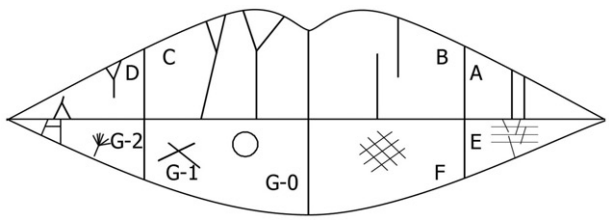

Figure 2. Diagrammatic representation of lip groove patterns.

oral orifice. A specific sub-type of the branched pattern, which incorporated a vertical linear fissure of variable length with several grooves originating and fanning out from a common point at the end of this fissure, akin to a crowded bouquet (Figure 2), was included in the G-2 group. The reticular pattern (F) was clearly defined as one in which there were a network of grooves enclosing multiple diamond shaped areas and was differentiated from pattern E in which clear horizontal lines intersected any other pattern type (Figure 2). Images of some of the patterns have been included in Figures 3–8.

The pre-dominant pattern present in each quadrant was recorded; however, if more than one pattern was noted to be co-dominant in a single quadrant, then these were separately classified as combination (COM) patterns. In case such combinations included an indeterminate (G-type) pattern, these were segregated into the G-COM group.

In case of any doubt as to the pattern type, the principal collaborators of all the four countries were consulted and the results compared and accepted only in the case of concurrence.

The dimensions of the lips were measured from the prints using a digital caliper of precision 0.01 mm. The width of the oral fissure was recorded as extending between the right and left cheilions and the height of the upper and lower lips were measured in the mid-sagittal plane extending from the

Figure 3. Spanish female print showing vertical (A, B) type pattern in the encircled area.

Figure 4. Spanish female print showing branched (C, D) type pattern in the encircled area.

Figure 5. Indian male print showing intersected (E) type pattern in the encircled area.

Figure 6. Spanish male print showing reticular (F) type pattern in the encircled area.

stomion to the edge of each lip; labrale superius or inferius as the case may be (Figure 1).

The data was statistically analysed using SPSS package (Version 11.5, Chicago, IL). Chi square test was performed for qualitative data comparison, while for quantitative data comparison, Student's *t*-test and ANOVA were used. The level of significance was set at 0.05. Correspondence analysis was performed to provide a graphical representation of the association of the various pattern types to the different ethnic groups under study.

Results

Out of the total 191 Indian prints, three prints (one male and two female) of the UR, LR and the LL quadrants each and two prints (one of each gender) of the UL region could not be deciphered. In a similar manner, of the total 229 Spanish prints, two prints (both male) were not clear of the UR and UL quadrants each and needed to be disregarded.

Figure 7. Saudi female print showing X (G-1) type pattern in the encircled area and indeterminate (G-2) type pattern in the rectangular area.

Figure 8. Indian female print showing whorl (G-2) type pattern in the encircled area.

Pattern frequency in each quadrant of each population (Table 3; Figure 9)

Pattern-type prevalence was noted in each quadrant and the frequency was analysed between the populations wherever plausible to test any significant difference. Gender distribution was not done at this stage as the focus was on inter-ethnic pattern variability.

The Indian prints revealed an almost equal propensity for patterns B and C (with a combined frequency of almost 60%) in each of the four quadrants, while the remaining patterns (of the regular types A–F) were sporadically present. In the Saudi population, pattern C was again a frequent feature. However, although this pattern was noted in ~30% of the upper quadrants (akin to the Indian people), in the lower lip the incidence was increased to nearly 50% of the prints. Such distinction in the frequency of pattern types between the upper and lower lips was repeated in the Saudi as well as the Spanish populations for pattern E; present in nearly 30% of the upper quadrants and in only ~7% of the lower ones for the former population, while in the case of the Spanish prints it was noted in nearly 15% of the upper quadrants while the lower quadrants favoured this pattern in only 0.4% of cases. The predominant pattern noted in the Spanish people was C (with 63% of the upper lip and nearly 70% of the lower lip quadrants having this type).

From amongst the regular patterns (A–F), the principal pattern noted amongst the Nigerians was type A, which was noted in ~50% of each quadrant, while it was an infrequent occurrence amongst the Indian and Spanish peoples and was noted with moderate frequency amongst the Saudis. Apart from type A, the only other patterns noted in the Nigerian prints were B (varying between 9–12% in the various quadrants), E (which showed up in 1–3% of the four quadrants) and F (which was observed in 1% of cases and only in the LL region). Patterns C and D were completely absent amongst the Nigerians. The Nigerian prints, however, exhibited susceptibility for COM type of patterns in which there was equal representation of more than one pattern in a

Table 3. Frequency (%) of patterns noted in the four quadrants of each population; significance of chi-square test when applicable.

	UR (%)					UL (%)					LR (%)					LL (%)				
Ptns	In	SA	Sp	Ni	*p*	In	SA	Sp	Ni	*p*	In	SA	Sp	Ni	*p*	In	SA	Sp	Ni	*p*
A	4.8	15.8	6.6	54	*	4.8	11.1	5.3	55	*	6.9	16.2	10.5	48	*	4.8	11.1	10.0	48	*
B	28.2	2.1	2.2	12	*	24.3	1.3	1.3	10	*	29.8	1.3	3.1	9	*	30.9	0	2.6	12	*
C	27.1	27.8	63.9	0	*	30.2	30.8	63.4	0	*	32.4	47.4	70.3	0	*	29.3	48.7	69.0	0	*
D	3.2	1.7	1.8	0	NA	3.7	3.0	2.2	0	NA	7.4	1.3	1.7	0	NA	9	5.1	1.3	0	*
E	1.1	29.9	14.1	3	*	0.5	29.5	15.0	1	*	1.6	6.0	0.4	2	NA	2.7	7.7	0.4	1	NA
F	14.9	4.3	7.9	0	*	14.2	6.0	8.3	0	*	6.4	6.0	5.7	0	NS	8.5	3.8	7	1	NS
G-0	0	2.1	0	0	NA	0	3.4	0	0	NA	0	4.7	0	0	NA	0	2.1	0	0	NA
G-1	2.1	2.1	0	0	NA	3.7	1.3	0.4	0	NA	1.6	1.3	0	0	NA	2.1	1.7	0.4	0	NA
G-2	5.3	0	0.4	0	NA	4.2	0	0.4	0	NA	4.3	0	0.4	0	NA	5.3	0	0.4	0	NA
COM	11.2	6.4	3.1	31	*	12.7	8.1	3.5	34	*	9	10.7	7.4	41	*	6.9	11.1	7.9	38	*
G-COM	2.1	7.7	0	0	NA	1.6	5.6	0	0	NA	0.5	5.1	0.4	0	NA	0.5	8.5	0.9	0	NA

Ptns, patterns; UR, upper right quadrant; UL, upper left quadrant; LR, lower right quadrant; LL, lower left quadrant; In, India; SA, Saudi Arabia; Sp, Spain; Ni, Nigeria; *p*, *p* value; NS, not significant; NA, no analysis.
*$p < 0.001$ highly significant.

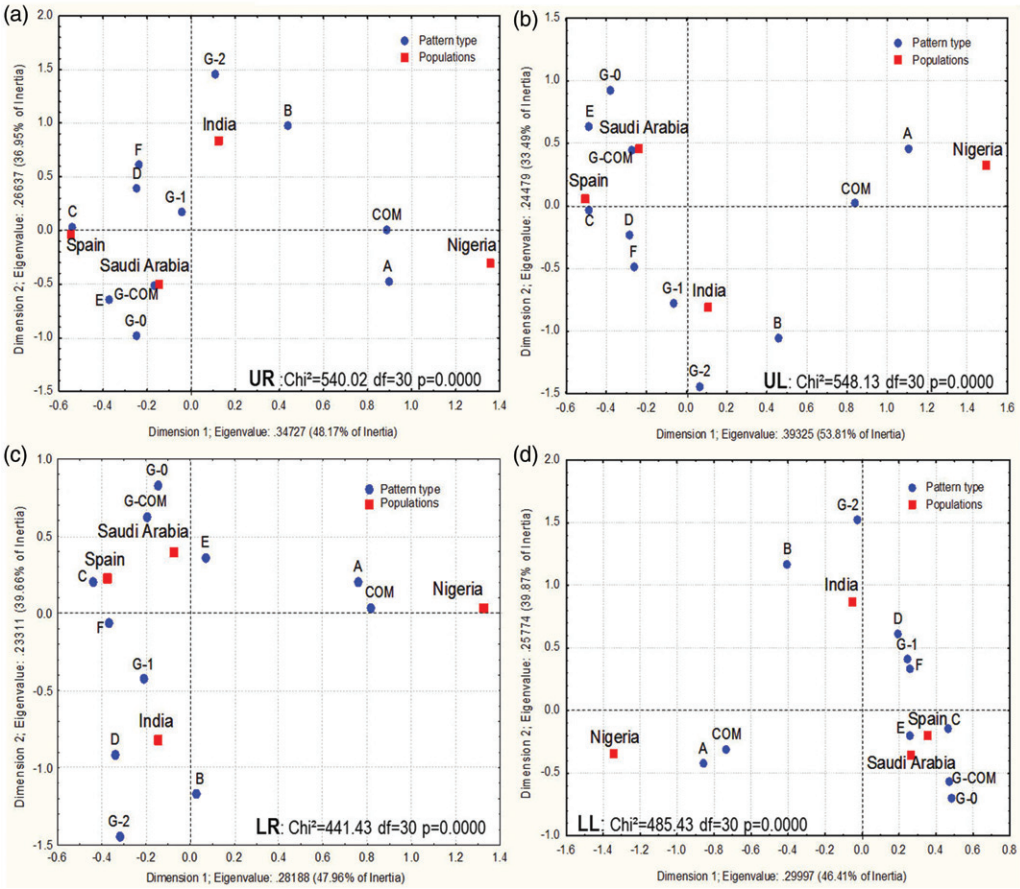

Figure 9. Correspondence analysis between the types of lip patterns and populations in the four quadrants. (a) UR: upper right. (b) UL: upper left. (c) LR: lower right. (d) LL: lower left.

Table 4. Patterns (from amongst the regular types A–F) encountered most and least frequently in all four quadrants of the lip prints of the various populations studied.

Country	Pattern(s) most frequently encountered (%)	Pattern(s) least frequently encountered (%)
India	B (28.3); C (29.75)	E (1.48)
Saudi Arabia	C (38.68)	B (1.18); D (2.78)
Spain	C (66.65)	B (2.3); D (1.75)
Nigeria	A (51.25)	C (0); D (0); F (0.25)

single quadrant. This was noted to be significantly higher than the other populations studied.

Briefly, from amongst the regular patterns, the predominant types for each of the populations studied were B and C for the Indians, C and E for the Saudis, C for the Spanish and A for the Nigerians. The least prevalent pattern types amongst the Indians were E and for Saudis were B and D. Amongst the Spanish prints, akin to the Saudis, while B and D were rarely observed in all four quadrants, E was least noted in the lower lip. A synopsis of the most and least frequently noted patterns (from amongst the regular types A–F) for each population group, summing up their prevalence in all the four quadrants of the print, has been indicated in Table 4.

Other interesting observations included every type of G pattern (as defined in this study) being completely lacking from the Nigerian prints and the complete absence of G-0 pattern in all quadrants of all populations except for the Saudi prints, in which it was uniformly present in all the quadrants, albeit with low frequency. The slightly higher occurrence of G-2, as noted amongst the Indian population, was primarily due to the frequent appearance of a bouquet type of pattern (both short and long stemmed) which was not noted in any other population studied.

Chi-square test applied to the frequency of patterns appearing in the defined topographical areas indicated a significant variation for the populations studied (Table 3). Application of correspondence analysis to study the association between the predominant patterns in each population revealed the dimensions accounted for over 85% of the inertia in each quadrant (Figures 9a–d).

Gender variability in pattern prevalence for each quadrant (Tables 5–8)

Inter-gender variability (related to the frequency of pattern prevalence) was noted in each quadrant for each of the populations studied. Chi-square test was applied wherever applicable.

Pattern B was noted to be present with a significantly higher frequency in both the upper quadrants of the Indian male prints, while the female prints showed a predilection for pattern F in only the UR quadrant. There was no variability in the quadrants of the lower lip pertaining to any of the pattern types.

Table 5. Inter-gender variability in the UR quadrant within each population; significance of chi-square test when applicable.

a	India			Saudi Arabia			Spain			Nigeria		
	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value
A	3.1	5.7	NA	19.3	12.5	NS	2.7	10.2	*	58.7	50	NS
B	38.5	22.8	*	0.9	3.3	NA	0.9	3.4	NA	8.7	14.8	NS
C	30.8	25.2	NS	33.3	22.5	NS	67	61	NS	0	0	NA
D	0	4.9	NA	0	3.3	NA	1.8	1.7	NA	0	0	NA
E	0	1.6	NA	21.9	37.5	*	14.7	13.6	NS	0	5.6	NA
F	7.7	18.7	*	7	1.7	NA	9.2	6.8	NS	0	0	NA
G-0	0	0	NA	1.8	2.5	NA	0	0	NA	0	0	NA
G-1	1.5	2.4	NA	0.9	3.3	NA	0	0	NA	0	0	NA
G-2	4.6	5.7	NA	0	0	NA	0	0.8	NA	0	0	NA
COM	12.3	10.6	NS	7	5.8	NS	3.7	2.5	NA	32.6	29.6	NS
G-COM	1.5	2.4	NA	7.9	7.5	NS	0	0	NA	0	0	NA

*$p < 0.05$ = significant.
NS, not significant; NA, not applied; M, male; F, female.

Table 6. Inter-gender variability in the UL quadrant within each population; significance of chi-square test when applicable.

	India			Saudi Arabia			Spain			Nigeria		
	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value
A	7.7	3.2	NA	12.3	10	NS	3	9	NS	69.6	42.6	*
B	35.4	18.5	*	0.9	1.7	NA	0	3	NA	8.7	11.1	NA
C	26.2	32.3	NS	35.1	26.7	NS	67	77	NS	0	0	NA
D	0	5.6	NA	0.9	5	NA	3	2	NA	0	0	NA
E	0	0.8	NA	21.9	36.7	*	18	16	NS	0	1.8	NA
F	15.4	13.7	NS	10.5	1.7	*	12	7	NS	0	0	NA
G-0	0	0	NA	4.4	2.5	NA	0	0	NA	0	0	NA
G-1	0	5.6	NA	0	2.5	NA	1	0	NA	0	0	NA
G-2	3.1	4.8	NA	0	0	NA	0	1	NA	0	0	NA
COM	12.3	12.9	NS	9.6	6.7	NS	5	3	NA	21.7	44.4	*
G-COM	0	2.4	NA	4.4	6.7	NS	0	0	NA	0	0	NA

*$p < 0.05$ = significant.
NS, not significant; NA, not applied; M, male; F, female.

Table 7. Inter-gender variability in the LR quadrant within each population; significance of chi-square test when applicable.

	India			Saudi Arabia			Spain			Nigeria		
	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value
A	6.2	7.3	NA	18.4	14.2	NS	6.3	14.4	NS	41.3	53.7	NS
B	26.2	31.7	NS	0	2.5	NA	2.7	3.4	NA	13	5.6	NA
C	36.9	30.1	NS	47.4	47.5	NS	72	68.6	NS	0	0	NA
D	6.2	8.1	NA	0.9	1.7	NA	0.9	2.5	NA	0	0	NA
E	3.1	0.8	NA	8.8	3.3	NS	0.9	0	NA	4.3	0	NA
F	7.7	5.7	NA	7	5	NS	9.9	1.7	*	0	0	NA
G-0	0	0	NA	2.6	6.7	NA	0	0	NA	0	0	NA
G-1	1.5	1.6	NA	0.9	1.7	NA	0	0	NA	0	0	NA
G-2	6.1	3.3	NA	0	0	NA	0.9	0	NA	0	0	NA
COM	6.1	10.6	NS	7.9	13.3	NS	6.3	8.5	NS	41.3	40.7	NS
G-COM	0	0.81	NA	6.1	4.2	NS	0	0.8	NA	0	0	NA

*$p < 0.05$ = significant.
NS, not significant; NA, not applied; M, male; F, female.

Amongst the Saudi people, pattern E was noted to be significantly more in the female population in both the upper quadrants, while pattern F was noted to be more commonly present in the UL and G-COM in the LL quadrants of the male prints.

Spanish females showed a significant predilection for pattern A (UR quadrant) and the males for pattern F (LR quadrant). In the Nigerian people, gender differentiation was only noted in the UL quadrant for patterns A (more in males) and COM (more in females).

Pattern repetition in all four quadrants (Table 9)

The same pattern prevailing in all four quadrants was noted in 6%, 11.1%, 22.3% and 46.7% of the Nigerian, Saudi, Indian and Spanish populations, respectively.

Table 8. Inter-gender variability in the LL quadrant within each population; significance of chi-square test when applicable.

	India			Saudi Arabia			Spain			Nigeria		
	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* value	M (%)	F (%)	*p* Value	M (%)	F (%)	*p* Value
A	3.1	5.7	NA	12.3	10	NS	6.3	13.6	NS	52.2	44.4	NS
B	26.2	33.3	NS	0	0	NA	2.7	2.5	NA	8.7	14.8	NS
C	33.8	26.8	NS	44.7	52.5	NS	70.3	67.8	NS	0	0	NA
D	10.8	8.1	NS	3.5	6.7	NS	0.9	1.7	NA	0	0	NA
E	4.6	1.6	NA	10.5	5	NS	0.9	0	NA	0	1.8	NA
F	7.7	8.9	NS	3.5	4.2	NA	10.8	3.4	NS	2.2	0	NA
G-0	0	0	NA	0.9	3.3	NA	0	0	NA	0	0	NA
G-1	1.5	2.4	NA	1.8	1.7	NA	0.9	0	NA	0	0	NA
G-2	6.2	4.9	NA	0	0	NA	0.9	0	NA	0	0	NA
COM	6.2	7.3	NA	8.8	13.3	NS	6.3	9.3	NS	37	38.9	NS
G-COM	0	0.8	NA	14	3.3	*	0	1.7	NA	0	0	NA

*$p < 0.05$ = significant.
NS, not significant; NA, not applied; M, male; F, female.

Table 9. Prevalence (*n*) of the same pattern in all four quadrants: gender-wise distribution and significance.

Country	Sex	A	B	C	D	E	F	G-2	*n* (%)	*p* Value (inter-gender)	% (for each population)	*p* Value (inter-ethnic, male)	*p* Value (inter-ethnic, female)
India	M = 65	0	11	9	0	0	1	1	22 (33.84)	*	22.3	**	**
	F = 123	0	8	8	1	0	2	1	20 (16.26)				
Saudi Arabia	M = 114	1	0	9	0	1	1	0	12 (10.53)	NS	11.1		
	F = 120	0	2	9	3	0	0	0	14 (11.67)				
Spain	M = 109	2	0	47	0	1	2	0	52 (47.7)	NS	46.7		
	F = 118	0	5	47	0	0	2	0	54 (45.76)				
Nigeria	M = 46	3	0	0	0	0	0	0	3 (6.52)	NS	6		
	F = 54	3	0	0	0	0	0	0	3 (5.56)				

**$p < 0.001$: highly significant; *$p < 0.05$ = significant.
NS, not significant; M, male; F, female.

Intra-ethnic gender variation pertaining to this parameter was significant only in the Indian population, wherein 33.84% of males exhibited this feature as against 16.26% females. For the remaining populations studied, although gender variation was not significant, in both the Spanish as well as the Nigerian populations males showed a marginally higher tendency to display four quadrant pattern symmetry.

Statistical analysis of inter-ethnic gender distinction pertaining to this parameter indicated a significant difference for the males of all the studied populations, with such pattern recurrence noted in the range of 6.52% (Nigerian males) to 47.7% (Spanish males). A comparable significance was noted in the female populations, with the incidence ranging from 5.56% (Nigerian females) to 45.76% (Spanish females).

Bilateral symmetry of pattern type for upper and lower quadrants (Tables 10 and 11)

Bilateral symmetry of pattern type in the upper quadrants was noted to be highest for the Saudi and the Nigerian populations (51.3% and 51%, respectively) while for the lower lip quadrants it was mostly noted in the Indian prints (49.5%). Difference between all the populations was significant only for the upper lip.

Intra-ethnic gender variation for this parameter was noted to be significant only in Indians (for both the upper as well as for the lower quadrants) and in Saudis (only for the upper quadrants); in each of the above cited cases the predominance was noted for the female sample.

Dimensions of the lips (Tables 12 and 13)

Dimensions of the lips (in terms of both width of the oral fissure as well as the height of the two lips) were seen to be greatest for the Nigerian people, while for the Spanish population the height of the lips were least. Inter-ethnic variations for all these parameters were highly significant.

Intra-ethnic gender variability was noted to be significant, indeed in some populations highly so, for the width of the oral fissure (for all the studied populations), for the height of the upper lip (except for the Nigerian population) as well as for the height of the lower lip (for the Indian and Spanish populations).

Discussion

The main thrust of our research was to establish variability (or lack of the same) of lip print patterns amongst ethnically distinct populations as well as ascertaining cheiloscopic gender variability. We did not attempt to determine the individuality of lip prints as we feel that, apart from pattern type, to pronounce a set of grooves unique to the individual, it would be necessary to define a more detailed classification of lip groove patterns and further provide a groove count for each topographical area.

A comparison of the observations noted in the previous literature with those made in the present study exhibited a mixture of both similar as well as contradictory results.

Table 10. Bilateral symmetry of pattern type in upper quadrants: gender-wise distribution and significance.

Country	Sex	A	B	C	D	E	F	G	COM	*n* (%)	% (for each group)	*p* Value (inter-gender)	*p* Value (for all the populations studied, not considering individual genders)
India	M = 65	2	7	4	0	0	2	1	4	20 (30.77)	43.6	*	*
	F = 123	4	9	17	1	1	13	5	12	62 (50.41)			
Saudi Arabia	M = 114	8	1	17	0	15	3	1	3	48 (42.11)	51.3	*	
	F = 120	6	2	14	3	40	1	1	5	72 (60)			
Spain	M = 109	1	0	13	2	11	6	0	4	37 (33.94)	38.3	NS	
	F = 118	4	3	19	2	14	4	1	3	50 (42.37)			
Nigeria	M = 46	20	1	0	0	0	0	0	4	25 (54.35)	51	NS	
	F = 54	21	1	0	0	0	0	0	4	26 (48.15)			

*$p < 0.05$ = significant.
NS, not significant; M, male; F, female.

Table 11. Bilateral symmetry of pattern type in lower quadrants: gender-wise distribution and significance.

Country	Sex	A	B	C	D	E	F	G	COM	*n* (%)	% (for each group)	*p* Value (inter-gender)	*p* Value (for all the populations studied, not considering individual genders)
India	M = 65	2	4	7	4	1	1	3	1	23 (35.38)	49.5	*	NS
	F = 123	6	22	20	5	1	4	4	8	70 (56.91)			
Saudi Arabia	M = 114	8	0	24	1	6	2	0	4	45 (39.47)	41	NS	
	F = 120	4	0	32	1	1	3	2	8	51 (42.5)			
Spain	M = 111	5	2	26	1	0	9	1	6	50 (45.05)	43.7	NS	
	F = 118	8	3	26	2	0	0	0	11	50 (42.37)			
Nigeria	M = 46	11	3	0	0	0	0	0	3	17 (36.96)	34	NS	
	F = 54	11	3	0	0	0	0	0	3	17 (31.48)			

*$p < 0.05$ = significant.
NS, not significant; M, male; F, female.

Ethnic variations as noted in the present study

In the present study, we aimed at defining inter-ethnic variations based on the following parameters; quadrant-wise predilection for groove types, pattern repetition in all the four quadrants, bilateral symmetry of pattern type in the upper and lower quadrants and lip dimensions.

Statistical analysis of the various patterns noted in each of the quadrants indicated a healthy variation amongst the populations studied, providing proof for lip-print-pattern related ethnic diversity. While A and C were noted with significantly increased frequencies amongst the Nigerian and Spanish populations, respectively, frequency of pattern B was notably higher in the Indian people and E in the upper quadrants of the Saudis. It may be further noted that the COM type of pattern was appreciably a frequent feature amongst the Nigerians and least observed amongst the Spanish. Notably, the Nigerians failed to exhibit any of the defined varieties of indeterminate patterns, which, in any case, were a rare feature for the remaining populations too. In fact, G-0 was a pattern exclusively noted (although with low frequency) on the Saudi lips.

Ethnic diversity was further noted in case of a 4-quadrant-pattern-repetition wherein it ranged between 6% (Nigerian population) and 46.7% (Spanish population). Again, such inter-ethnic variation was noted in the predilection for bilateral symmetry of groove type in the upper quadrants of the lip, a feature which was observed to be maximally present amongst Saudi and Nigerian populations (51.3% and 51%, respectively) and least noted in the Spanish prints (38.3%). Interestingly, the lower quadrants of the lips did not exhibit similar variation.

Variable lip dimensions are an accepted fact. Thick lips are a Negroid characteristic, while Orientals exhibit mixed type and Western Eurasians thin lips (Datta et al., 2012). This was validated both in a study by Xu et al. (2012), who found significant racial variations while studying the thickness of the upper and the lower lips and by the observations made in the present study (Tables 12 and 13), thus indicating that the anatomy of a lip print could provide a clue as to the ethnicity of its owner.

It is an accepted fact that wrinkle lines or lines of expression on the face are caused by the contraction of the underlying muscles (Standring et al., 2005). Such lines, however, become permanent only as age advances due to loss of skin elasticity. It would be reasonable to assume a similar basis for the production of lip furrows; their early appearance by the 16th week of intra-uterine life (Soliman, 1996) and subsequent permanence could be attributed to the relatively thin epidermis that clothes the vermilion zone. The very thinness of this tissue would make it susceptible to easy crinkling. Such a hypothesis is well supported by the fact that there is a concomitant initiation of rhythmic lingual and mandibular movements from the 11th week of gestation which have been shown to increase as pregnancy advances

(Grassi et al., 2005); such peri-oral muscular activity might well be the pre-disposing factor for the formation of the lip wrinkles.

If such a hypothesis is acceptable, then it may well be imagined how the height and width of the organ, which is known to differ in the various populations of the world (Datta et al., 2012), and was noted to be so in the present study too, associated with the obvious and consequent variation in morphology of the underlying peri-oral musculature, would dictate the biomechanics of epidermal crinkling subsequent to oral movement. A significant inter-ethnic variation in pattern types could be partially attributed to this factor.

Pattern-type predilection of the various populations; comparing previous literature with the present study

Regarding the Indian population, a wealth of cheiloscopic research done in the last decade afforded plentiful data for a comparative analysis. Unfortunately, there seems to be no consensus in either the pattern type found in the Indian lips or a sexual dimorphism related to the same. The reason for such discord could possibly be attributed to the cultural and religious blend one encounters in the geographically vast subcontinent. While most previous research has focused on a particular region or state within the country, the Indian sample in the present study represented Indians from all parts of the country.

While most of the patterns were noted with varying frequencies in each population, the Indian prints, as noted in our study, indicated an almost equal predilection for the vertical incomplete (B) and branched/bifurcated (C) types. This was faithfully repeated in each quadrant with a combined (B and C type) frequency percentage ranging between 54.5–62.2% in the four quadrants and is consistent with the findings of Venkatesh & David (2011) and Nagasupriya et al. (2011). However, contrary to our noting, the latter authors, following a simplified classification for lip grooves into three broad groups, found the reticular pattern to be more frequent than the vertical linear type. This could possibly be due to them opting to discount the indeterminate G type pattern, many of which might have found their way in the reticular group and caused the numbers in this group to swell.

The intersected type pattern (E) was infrequently noted (0.5–2.7%) in our study of the Indian segment which conforms to the observations made on a study of the Indian people by Prabhu et al. (2012), but contradicts the findings of Saraswathi et al. (2009) who noted this pattern to be the most frequently encountered type.

Further, while incomplete vertical grooves (pattern B) were frequently observed in our Indian prints (ranging from 24.3–30.9%), the complete version of this type (pattern A) was rarely noted in either of the genders. This is in contrast with the studies by Vahanwala & Parekh (2000) and Karki (2012), both of whom noted the complete vertical groove to be significantly present in the Indian male population.

Regarding the Saudi population, as noted in the present study, patterns C and E were predominantly present, and with almost equal frequencies in the upper lip, while in the lower lip the frequency of pattern E decreased dramatically with a proportionate increase of pattern C. Such observations are in complete harmony with the earlier work of Domiaty et al. (2010) on the Saudi people. However, whereas in their earlier study Domiaty et al. (2010) had failed to record even a single print showing a D pattern type, in the present study this

Table 12. Width of oral fissure–inter-gender comparison within each ethnic group; inter-ethnic comparison and significance.

Country and gender	Width of oral fissure (cm), mean ± SD	p Value (inter-gender)	p Value (for all the populations studied, not considering individual genders)
India			
Male	5.205 ± 0.433	$t = 6.772$**	$F = 101.89$**
Female	4.65 ± 0.463		
Saudi Arabia			
Male	4.557 ± 0.602	$t = 2.425$*	
Female	4.788 ± 0.738		
Spain			
Male	4.964 ± 0.424	$t = 8.718$**	
Female	4.548 ± 0.303		
Nigeria			
Male	5.946 ± 0.531	$t = 2.481$*	
Female	5.679 ± 0.556		

**$p < 0.001$: highly significant; *$p < 0.05$: significant.

Table 13. Height of lips—inter-gender comparison within each ethnic group; inter-ethnic comparison and significance.

Country and gender	Height of upper lip (cm), mean ± SD	p Value (inter-gender)	p Value (for all the populations studied, not considering individual genders)	Height of lower lip (cm), mean ± SD	p Value (inter-gender)	p Value (for all the populations studied, not considering individual genders)
India						
Male	1.068 ± 0.177	$t = 4.049$**	$F = 201.56$**	1.088 ± 0.173	$t = 5.043$**	$F = 41.95$**
Female	0.952 ± 0.138			0.923 ± 0.184		
Saudi Arabia						
Male	1.053 ± 0.221	$t = 2.507$*		1.084 ± 0.257	$t = 2.058$ NS	
Female	0.987 ± 0.141			1.021 ± 0.165		
Spain						
Male	0.741 ± 0.164	$t = 3.767$**		0.997 ± 0.155	$t = 4.210$**	
Female	0.663 ± 0.147			0.921 ± 0.140		
Nigeria						
Male	1.209 ± 0.258	$t = 1.097$ NS		1.261 ± 0.265	$t = 1.126$ NS	
Female	1.155 ± 0.208			1.202 ± 0.237		

*$p < 0.05$: significant; **$p < 0.001$: highly significant; NS, not significant.

pattern was noted to be present in each quadrant, with frequencies ranging between 1.3–5.1%.

Costa & Caldas (2012), in their study of the Portuguese population, noted the branched pattern to be predominant. This would be comparable to the pattern C that was noted in an overwhelming majority in all the quadrants of the Spanish people; the two populations being ethnically related.

Other notable features as noted in our study of Spanish prints included the infrequent occurrence of co-dominance of patterns (COM/G-COM) when compared to the other populations studied, the difference being significant for each of the four quadrants and a similar rarity of any kind of indeterminate (G) pattern.

We could find only a single other related work done on the Nigerian population and the discrepancy in the observations between the two studies was startling. While in our study, the A pattern was a dominant feature in all the topographical areas of the lips and there was complete absence of any G pattern whether present alone or co-dominant with other pattern types, Adamu et al. (2012) noted the exact reverse for the same population. The possible explanation for such bewildering variation could be the fact that we deemed it fit to make additional COM/G-COM groups which have not been defined by previous workers and such co-dominance was seen within a range of 31–41% in the four quadrants of the Nigerian segment of our study. The modified classification style may be responsible for the skewed observations.

Gender differentiation within each ethnic group

While reviewing the results of previous studies, inconsistency appears in the observations related to the potential of cheiloscopy being a reliable tool for gender identification. While a number of investigators failed to find any statistical difference in the prints of males and females (Nagasupriya et al., 2011; Ragab et al., 2013) there are some who found a significant correlation between a particular pattern and the sex of the individual (Sharma et al., 2009). Some investigators have even claimed impressive success rates in the accurate detection of the gender of the subject based on the type of pattern noted in a gender-blind identification process of the lip prints (Gondivkar et al., 2009; Vahanwala & Parekh, 2000; Xu et al., 2012).

We attempted to determine inter-gender variability within each ethnic group by a three-pronged approach: related to the pattern type in each quadrant, frequency of pattern repetition in all four quadrants and the dimensions of the lips.

In our study, the uniformity with which all the investigators spanning different continents and working independently (although with uniform methodology) on four distinct races failed to find remarkable intra-ethnic gender variability in the pattern types was interesting. As noted in the present study, each country's investigator(s) did find particular pattern(s) to be significantly present in a particular gender in one or more of the quadrants. However, such inter-gender variability was sporadic and we do not feel justified in advocating the use of cheiloscopic patterns as an aid in identifying the sex of the individual.

None the less, it is noteworthy that Rastogi & Parida (2012) and Karki (2012), both working on Indian subjects, found pattern-related gender variability with results in concurrence with the Indian segment of our own study. While the former advocated the UL quadrant to be used for gender identification as this quadrant showed branched patterns predominant in females and vertical complete type in males, Karki (2012), with comparable results, found the vertical type patterns (A and B) to be common in males as compared to the branched types (C and D) which was noted more often in females. This is in partial harmony with our own observations wherein the branched types (C and D) were present with greater (although not significant) frequency in females in the UL quadrant and the incomplete vertical type pattern (B) was noted to be significantly more present in males in both the upper quadrants.

On the other hand, there is no consensus between our results (of the Indian segment) and those of either Sharma et al. (2009) or Vahanwala & Parekh (2000), both of whom also worked on the Indian population, regarding pattern type gender variability. With such inconsistencies, we were discouraged in claiming the viability of using lip print patterns for gender recognition.

The opinions of most authors in previous studies are harmonized as to the significantly greater frequency of a four-quadrant-pattern-repetition amongst the female prints (Amith et al., 2011; Karki, 2012; Rastogi & Parida, 2012; Vahanwala & Parekh, 2000) and feel justified in advocating the parameter to be used for gender identification. Here again, the results of our study, pertaining to each ethnic group, although consistent with each other are at variance with previous researchers. While the inter-gender variability for this parameter was significant only for the Indian segment of our study (and surprisingly in favour of the male subjects), in the other three populations, such pattern repetition was noted to be almost equally present in their respective male and female counterparts. Our results, thus, strongly refute any claim as to gender recognition on the basis of this particular criterion.

Finally, our observations and analyses regarding (intra-ethnic) gender-related variability of lip dimensions have thrown up some interesting results. The consistency with which all the populations studied indicated significant variation between the sexes for the width of the oral fissure was too remarkable to be ignored. While gender distinction pertaining to the heights of the upper and lower lips were noted to be highly significant in the case of the Indian and Spanish segments of the data, analysis of the Saudi prints showed significant inter-gender variation only for the height of the upper lip. Such distinction was notably completely absent for the Nigerian population.

In view of the above, we feel lip dimensions could serve as a potential tool for gender recognition for most ethnic groups.

Concluding remarks

Variability of anatomical features amongst ethnically distinct human populations has stimulated scientific curiosity for many decades and resulted in the origin of many hypotheses as to the genesis of such differences. Cheiloscopy *per se* is an evolving study and, as yet, ethnic variability of this feature has not been explored.

This study reveals significant inter-ethnic variance in the cheiloscopic study of four distinct world populations as well as in the dimensions of the lips. Further, significant intra-ethnic gender variations were observed in lip dimensions as can be deciphered from lip prints. However, on the basis of our study, for the purpose of gender recognition, we refrain from prescribing either the use of quadrant-based pattern prediliction or a four-quadrant-pattern-repetition.

We would like to present this as a pilot study and hope to validate the results presented here with a more extensive research on an expanded database in terms of number of ethnic populations involved and the datum size. More such collaborative researches exploring, recording and ultimately cementing cheiloscopic variations between different modern human populations would be an invaluable forensic asset in providing a clue as to the ethnicity of the criminal in a global scenario where migrant populations are increasingly widespread and most regions host people belonging to a medley of ethnicities.

Acknowledgements

The authors are grateful to S. Garad, Department of Preventive and Social Medicine, Bharati Vidyapeeth Medical College and Hospital, Pune, India for assistance in the statistical analysis of the data and Mairembam Khogen Singh, Head (IT) at Bharati Vidyapeeth Deemed University Medical College, Pune, for technical assistance.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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