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Sex Variation in Thumbprint Minutiae Among Hausa Lineage

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ABSTRACT
Fingerprint minutiae show great individuality in different populations and also been considered as a basic feature used for identification in the field of Human Biology. The aim of the study is to determine the frequency distribution, sexual dimorphism and sex discriminating features using thumbprints minutiae. A total of 283 subjects comprising 147 males and 136 females (18-25 years) participated. Minutiae count was carried out within a circle with a diameter that passes through the nucleus. Independent sample t-test was used to test for sex differences. Steps wise binary logistic regression was applied to obtain a predicting equation that discriminates the sex of the individual. Significant sex differences were observed only in ridge end, break, enclosure, and bridges and opposite bifurcation. The higher mean value was only in break and bridges in the female participants. The single best sex discriminator in the minutiae was break and ridge ending with an accuracy of 66.5% and 65.4% for the right and left thumb. In conclusion, the thumbprint minutiae proved to be useful in sex discrimination among Hausa population. However, different sides (left and right) have varying degrees of discriminating accuracy.

Keywords: Population data, sex discrimination, identification, Hausa ethnic group

INTRODUCTION
Determination of individual variations using fingerprints features has long been considered as a useful marker within the domain of biological anthropology. [1, 2, 3] The individuality can be determined by ridge flow pattern called fingerprint minutiae, a term coined by Galton, referred to the small distinguishing features associated with the individual ridge. This shows great variability in different populations and also been considered as a basic feature used for identification in the field of Human Biology [4] It has already been reported that the density of the minutiae varies in accordance with their location on the fingerprint. [5, 6, 7] This was confirmed in some studies which found that greater density of minutiae in the nucleus and in the delta than in the periphery of the fingerprint impression. [8] The variability of the minutiae among different areas of the finger remains the motivating factor for its utility across different populations. This also gives basis for determination of population-specific minutiae across the globe.

Dermatoglyphics in developing countries such as Nigeria had focused on dermatoglyphic patterns and ridge count [9, 10, 11, 12, 13] but not so much on other features such as ridge minutiae which is useful in personal identification or forensic science. Hence, there is a lack of data to support the existence of sexual variability in minutiae among Hausas. There is also need of reference anthropological data among Hausas especially with respect to thumbprints minutiae. These may provide an additional way of human characterization and identification. It was evident that the nature and variability of epidermal ridge minutiae are of direct scientific significance in the evaluation and comparison of fingerprints, particularly of partial fingerprints. The idea is to explore its usefulness in order to improve its application, as much in the field of Human Biology. Hence, this identification may also be a useful requirement in some cases of medico-legal investigations as mistaken identity may pose problems in delivering justice. The aim of this study was to discriminate sex using thumbprint minutiae types among Hausas of Nigeria.

MATERIALS AND METHODS

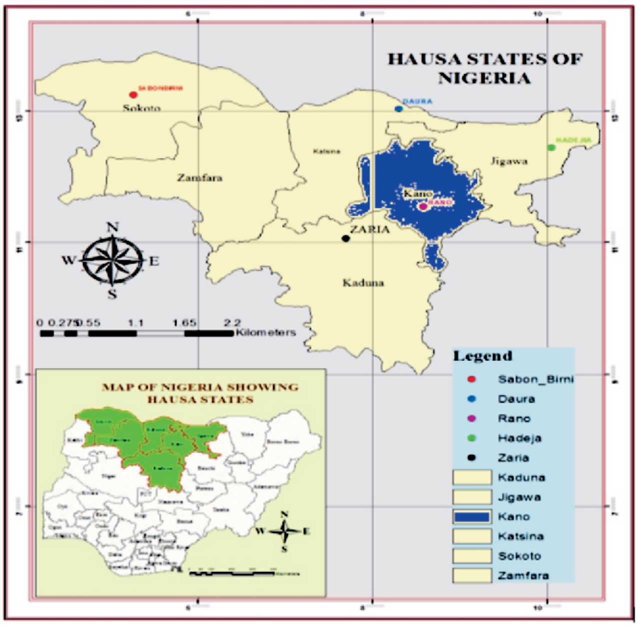

Figure 1: Map of Nigeria showing the location of study (Kano state)

A total of 283 subjects comprising 147 males and 136 females participated in the study. The simple random sampling method was adopted. Any apparently healthy (no inflammation or scar on the thumb) subject who was Hausas up to the level of grandfather and within the age range of 18-25 years was considered. This is to avoid effect of age on the ridge density and/or thickness. Any subjects outside these inclusion criteria were also excluded from the study. Before the commencement of the research, ethical approval was sought from ethical committee of Kano state Hospitals Management Board. Informed consent was obtained from the participants.

Fingerprints Capturing and Minutiae count

After using brief questionnaire was completed for all individuals, this captured questionnaire code, date of birth, the location of birth, tribes of parents and grandparents. A software (Printnalyser version 1) was designed using Microsoft visual basic (version 6.0) programming language in order to save each thumbprint with the participants bio data in two different sizes (original and enlarge size). After capturing a thumbprint using fingerprint sensor (digital persona), the type of finger, sex, side of the finger and unique code of the participants were saved with each thumbprint. For each thumbprint two versions were captured, the original size image (used for scaling) and amplified image (at ratio of 7.74) used for minutiae counting.

The fingerprints were classified into any of the three basic patterns (arches, whorls, and loops). The minutiae counts, designed according to the method described by Okajima [15], were made using magnified images of a thumbprint. The thumbprints were divided into two areas (center and periphery) by a circle with a diameter covering about 18 ridges. Only minutiae within the circle were counted. The minutiae were classified into any of the following types (Figure 2). Ridge ending; a termination of a ridge, bifurcation; when the minutiae form ridges to the right, convergence; when the minutiae form ridges to the left, trifurcation (convergence and bifurcation); when the minutiae form three ridges, fragment (big or small); short ridge with length equal or less ten times its width, point or dot; one ridge unit which contains only one sweat gland pore, break; two ends of ridge very near and opposite, enclosure (big or small); where the ridge path divides and then comes together again, overlap; where two ridge ends meet and overlap on a bias, crossbar; ridge that separates from its direction crossing between two others, bridge or crossover; where a short ridge crosses from one ridge to join the next, opposite Bifurcations; two ridges that join at one point, Y o M (convergence and Bifurcation); when two bifurcations develop next to each other on the same ridge a unique formation, dock; crest end that enters between two other end ridges, and return; the turning around of a ridge without being part of the nucleus. [4,16]

Figure 2: A thumbprint divided into two areas for determination of different types of minutiae

Strength and Systematic Error of Measurements

The intra class correlation (ICC) was used to demonstrate the strength of the relationship (similarities) between first and second measurements. The values for the reliability coefficient (r) ranged from 0 to 1, where ICC < 0 indicated "no reliability", ⩾ 0 but <0.2 "slight reliability", 0.2 to < 0.4 "fair reliability", 0.4 to < 0.6 "moderate reliability", 0.6 to < 0.8 "substantial reliability" [17]. To determine the systematic error in the minutiae counting the student paired t-test was performed to compare the means of the first and second counting (Table 1). This allowed assessment of systematic error (bias error). This was considered as a substitute of method error since in minutiae count there is always a possibility of zero counts (absent of particular type of minutiae). The interval between two measurements will be at least one week and 30 randomly selected records were used for this evaluation.

Data Analyses

Independent sample t-test was used to test for gender differences in the variables. Steps wise binary logistic regression was applied to obtain a predicting equation (BLR model) that discriminate the sex of the individual. The predicted probabilities of BLR were analyzed using receiver operating characteristic (ROC) curve. SPSS version 20 statistical software was used for the statistical analysis and P < 0.05 was set as the level of significance.

RESULTS

From Table 1 systemic assessment of measurement error shows that there are no statistically significant differences (P> 0.05) between first and second minutiae counts of the thumbprints. Higher interclass correlation (ICC) was observed in bifurcation and least in fragment small.

Table 1: Assessment of measurement error in thumbprint ridge minutiae

	Paired samples t -test							
	1st Measurements		2nd Measurements				Intra class correlation	
Minutiae Types	Mean	SD	Mean	SD	t	P value	SA	AM
Bifurcation	3.18	2.83	2.9	2.68	1.48	0.147	0.91	0.95
Cross Bar	0.03	0.16	0	0	1	0.323	0	0
Trifurcation convergence	0	0	0	0	0	1	0	0
Trifurcation bifurcation	0	0	0	0	0	1	0	0
End	2.1	1.45	2.13	1.09	-0.13	0.9	0.52	0.69
Break	1.03	1.33	1.25	1.19	-1.07	0.291	0.45	0.62
Enclosure (Big)	0.93	1.14	1.15	1.23	-1.36	0.183	0.61	0.76
Enclosure (Small)	0.65	0.89	0.43	0.78	1.5	0.141	0.36	0.53
Bridge	0.18	0.45	0.35	0.8	-1.55	0.128	0.4	0.57
Opposite bifurcation	0.1	0.3	0.1	0.3	0	1	0.72	0.84
Dock	0.13	0.34	0.05	0.22	1.36	0.183	0.24	0.39
in "M" convergence	0.03	0.16	0.03	0.16	0	1	1	1
in "M" bifurcation	0.05	0.32	0.03	0.16	1	0.323	0.8	0.89
Convergence	2.78	1.61	2.95	1.8	-0.66	0.513	0.52	0.68
Over lap	0.18	0.45	0.28	0.51	-1.07	0.291	0.23	0.38
Fragment Big	0.9	1.46	1.28	1.88	-1.32	0.194	0.43	0.61
Fragment Small	0.85	1.39	0.43	0.93	1.47	0.149	0.2	0.48
Return	0.08	0.35	0	0	1.38	0.183	0	0
Point/Dot into Ridge	0	0	0	0	0	1	0	0
Point/Dot between Ridge	0.2	0.99	0.28	1.26	-0.65	0.52	0.79	0.885

A statistically significance differences were observed between minutiae type and right thumbprint pattern. In the male, the association of the pattern was noticed in convergence and fragment small, for female in overlap and point or dot into the ridge. However, for bridge and point or dot between ridges the association was observed in the total sample (irrespective of sex) and female only, and in total sample and male only respectively (Table 2). The total minutiae count of the right thumbprints was 1464 with Bifurcation (226) account for higher count followed by ridge end (221) and the least was trifurcation B (4). In all this female tend to have a higher count in whorl pattern only (Table 2). For the left thumbprints with an overall frequency of 1228, the same pattern was observed with bifurcation (212) and end (210) having highest, however, the least was dock (6) and point/dot within the ridges (6). The female tend to have higher frequency compared to the male counterpart in whorl pattern only. Moreover, in bifurcation association with the pattern was observed in the both sexes combine and in female only (Table 3).

Table 2: Frequency distribution of different type of minutiae of the right thumbprints

Right Thumbprint Minutiae	Female			Male			Total
	Arch	Whorl	Loop	Arch	Whorl	Loop	
Bifurcation	4	38	69	7	48	60	226
Cross Bar	0	4	4	0	1	5	14
Trifurcation convergence	0	1	3	1	1	2	8
Trifurcation bifurcation	0	1	2	0	0	1	4
End	5	38	65	7	45	61	221
Break	4	22	42	0	14	15	97
Enclosure big	2	21	39	5	38	34	139
Enclosure small	3	20	35	2	28	59	147
Bridge*, f	2	8	25	0	8	9	52
Opposite bifurcation	0	2	3	0	8	11	24
Dock	0	5	3	1	3	1	13
in "M" convergence	0	3	2	0	0	0	5
in "M" bifurcation	0	0	2	1	1	3	7
Convergence m	4	29	55	6	41	41	176
Overlap f	1	8	13	2	11	13	48
Fragment big	2	11	14	2	13	16	58
Fragment small m	2	13	15	2	13	19	64
Return	0	2	4	0	0	2	8
Point or dot into ridge f	0	2	10	0	5	2	19
Point or dot between ridge *, m	3	17	33	5	34	42	134
Total	32	245	438	41	312	396	1464

* $p < 0.05$ for both sexes, f$p < 0.05$ for female only, m$p < 0.05$ for male only

Table 3: Frequency distribution of different types of minutiae of the left thumbprints

Left Thumbprint Minutiae	Frequency						Total
	Female			Male			
	Arch	Whorl	Loop	Arch	Whorl	Loop	
Bifurcation*, f	7	39	50	9	29	78	212
Cross Bar	0	3	0	2	3	7	15
Trifurcation convergence	0	1	1	0	3	4	9
Trifurcation bifurcation	0	3	1	0	2	5	11
End	6	35	55	9	29	76	210
Break	1	12	12	4	6	28	63
Enclosure big	2	29	39	6	19	45	140
Enclosure small	1	7	11	4	16	27	66
Bridge	2	20	11	2	3	16	54
Opposite bifurcation	0	10	9	3	5	13	40
Dock	0	2	2	1	0	1	6
in "M" convergence	0	1	4	0	3	1	9
in "M" bifurcation	1	2	2	0	2	8	15
Convergence	6	22	45	8	19	49	149
Over lap	1	4	10	2	2	15	34
Fragment Big	1	14	12	2	4	20	53
Fragment Small	0	6	6	3	10	22	47
Return	0	3	6	0	0	0	9
Point or Dot into Ridge	-	-	-	0	0	6	6
Point or Dot between Ridge	0	7	9	5	17	42	80
Total	28	220	285	60	172	463	1228

* $p < 0.05$ for both sexes, f$p < 0.05$ for female only,

For differences in the mean value of the right thumbprints minutiae, significance sex differences were observed only in ridge end, break, enclosure (big and small), and bridges and opposite bifurcation. The higher mean value was only in break and bridges in the female participants. In the left thumbprints, the significance was noticed only in a bifurcation, cross bar, end, enclosure (small), convergence, return, point/dot between the ridges. Only return and convergence have higher mean value in the female (Table 4).

Table 4: Sex differences in the mean minutiae count of the thumbprint

	Right					Left				
	Male		Female			Male		Female		
Minutiae Type	Mean	SD	Mean	SD	t	Mean ±	SD	Mean±	SD	t
Bifurcation	2.89	2.17	3.12	2.05	0.85	3.99	2.94	3.1	2.43	-2.53*
Crossbar	0.05	0.22	0.08	0.33	0.98	0.14	0.48	0.03	0.16	-2.30*
Trifurcation convergence	0.03	0.18	0.04	0.24	0.35	0.03	0.18	0.02	0.13	-0.7
Trifurcation bifurcation	0.01	0.09	0.03	0.16	1.03	0.06	0.23	0.05	0.25	-0.36
End	4.85	3.59	3.19	2.62	-4.13*	4.84	3.48	2.66	2.2	-5.67*
Break	0.55	1.29	1.55	2.15	4.40*	0.65	1.26	0.69	1.26	0.25
Enclosure(big)	1.39	1.47	0.87	1.11	-3.11*	1.1	1.35	1.15	1.16	0.29
Enclosure(small)	1	1.6	0.68	0.89	-1.95*	0.65	1.02	0.32	0.9	-2.67*
Bridge	0.15	0.4	0.47	0.92	3.58*	0.23	0.55	0.38	0.87	1.59
Opposite Bifurcation	0.18	0.44	0.04	0.2	-3.09*	0.19	0.43	0.19	0.44	0.01
Dock	0.06	0.32	0.07	0.25	0.26	0.02	0.13	0.04	0.25	1.13
in "M" convergence	0	0	0.08	0.49	1.71	0.03	0.18	0.04	0.21	0.48
in "M" bifurcation	0.04	0.2	0.02	0.13	-1.09	0.08	0.27	0.04	0.21	-1.13
Convergence	1.48	1.38	1.75	1.62	1.43	1.17	1.34	1.98	2	3.70*
Overlap	0.28	0.61	0.22	0.45	-0.96	0.17	0.42	0.17	0.46	0.01
Fragment Big	0.35	0.71	0.52	1.22	1.33	0.33	0.73	0.55	1.09	1.87
Fragment Small	0.58	1.34	0.53	1.18	-0.29	0.51	1.07	0.34	1.15	-1.22
Return	0.02	0.13	0.07	0.34	1.55	0	0	0.09	0.32	3.14*
Point or dot into ridge	0.08	0.37	0.18	0.59	1.5	0.19	1.1	0	0	-1.87
Point or between ridges	2.48	3.65	1.83	3.06	-1.51	2.05	3.19	0.49	1.6	-4.69*

Considering sexual dimorphic variable only for discrimination, Table 5 showed that the best single sex discriminator in the minutiae of the right thumbprints was a break with an accuracy of 66.5% and 8-10% contribution to the prediction. However, when six minutiae types (break, end, enclosure big, enclosure small, bridges and opposite Bifurcation) were added to the model the accuracy will rise to 71.4% and 23-31% contribution to the prediction.

Table 5: Generated equations for sex discrimination minutiae types of the thumbprint

	Steps	Equations (y=mx + c)	Accuracy (%)	-2 Log likelihood	Cox & Snell R2	Nagelkerke R2	χ2
Right	1	SEX= -0.406x (Break) - 0.399	66.4	313.835	0.08	0.107	20.22*
	2	SEX= 0.165 x (End) + (-0.374) (Break) - 0.26	67.6	300.761	0.129	0.172	33.29*
	3	SEX= 0.184 x (End) + (-0.316) Break + 0.355 (Enclosure big) - 0.74	66.8	290.695	0.165	0.22	43.37*
	4	SEX= 0.171 x (End) + (-0.342) Break + 0.358 (Enclosure big) + (-0.67 x Bridge) - 0.525	68.9	282.861	0.191	0.255	51.20*
	5	SEX= (0.169 x End) + (-0.344 x Break) + (0.316 x Enclosure big) + (-0.716 x Bridge) + (1.346 x Opposite bifurcation) - 0.59	70.5	274.911	0.218	0.29	59.15*
	6	SEX= (0.178 x End) + (-0.348 x Break) + (0.316 x Enclosure big) + (0.25 x Enclosure small) + (-0.687 x Bridge) + (1.352 x Opposite bifurcation) - 0.845	71.4	269.986	0.233	0.311	64.07*
Left	1	SEX= (0.274xEnd) -0.878	65.4	293.723	0.121	0.161	30.05*
	2	SEX= (0.243xEnd) + (0.283 x Point between ridges) -1.047	70.1	278.875	0.175	0.233	44.90*
	3	SEX= (0.188 x Bifurcation) + (0.257xEnd) + (0.312 x Point between ridges) -1.811	70.1	266.853	0.216	0.288	56.92*
	4	SEX= (0.201 x Bifurcation) + (0.231xEnd) + (-24.16x Return) + (0.559x Point between ridges) - 1.792	73.5	244.137	0.288	0.385	79.6*
	5	SEX= (0.158 x Bifurcation) + (0.2281xEnd) + (-0.231 x convergence) +(-24.27x Return) + (0.54x Point between ridges) -1.256	74.4	238.325	0.306	0.408	85.45*
	6	SEX= (0.156 x Bifurcation) + (0.23xEnd) + (0.479 x enclosure small) + (-0.282 x convergence) +(-23.91x Return) + (0.506x Point between ridges) -1.377	75.6	230.848	0.328	0.437	92.93*

Cut value is 0.5 (negative value indicate female) *p<0.05

The predicted probabilities of BLR for the variables that contributed best to the prediction show that only break and bridges (Figure 3) were the best predictor with a higher area under the curve. The left thumbprint minutiae showed that end minutiae were the best with an accuracy of 65.4% and 12-16% contribution to the prediction. However, when six minutiae types (end, bifurcation enclosure small, convergence, return and point/dot between the ridges) were added to the model the accuracy raised to 75.6% and 32-43% contribution to the prediction. The predicted probabilities of BLR for the variables that contributed best to the prediction show that only return and convergence (Figure 3) were good predictor with an area under the curve above 0.5.

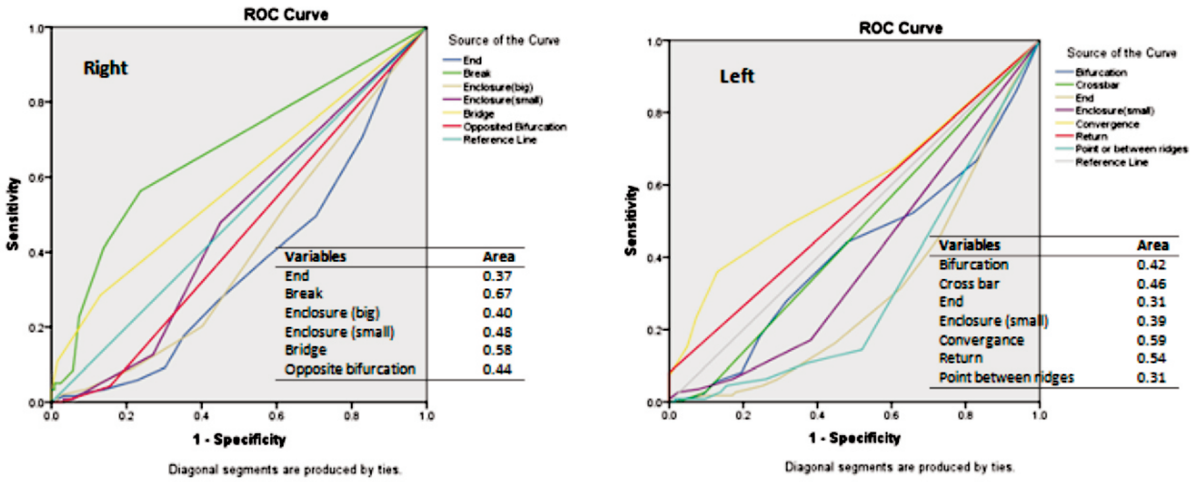

Figure 3: Receiver operating characteristics curve for determination of best model for sex discrimination u*sing minutiae types of the* thumbprint

DISCUSSION

One of the pillars of dactyloscopy identification is the used of fingerprint minutiae. Its study and analyses have long been considered as the scientific bases that determine the process of individualization in personal identification using fingerprints. [18, 19] The variability of the minutiae among the different area of the finger remain the motivating factor for the various study of it variability across the different population. The aim of the present study is to determine the frequency distribution and sex dimorphism in thumbprints minutiae. The study also used thumbprint ridge minutiae to predict sex among Hausa ethnic group of Nigeria. The study was conducted among one original Hausa states; Kano state of Nigeria.

A significance differences between minutiae type and thumbprint pattern was observed. This may depend on the gender of the individual and type of minutiae for examples, in the male the association with of the pattern was noticed in convergence and fragment small, for female in overlap and point or dot into the ridge. In the previous literature, it was reported that in Danish males a greater number of minutiae in are found in the whorls, followed by the loops and arches in the entire fingerprint. [20] However, in Japanese population the minutiae of the index finger for the same area (the inside of an 18 ridge radius circle), finding a greater number of minutiae in the arches and loops than in the whorls. [15] This may indicate population variability which may also depend on the pattern of fingerprints. In the case of the present study, the higher count in the loop is probably due to its higher frequency of its occurrence compared to the other patterns.

As far as sex is concerned, the number of minutiae in relation to the general fingerprint pattern (arches, loops and whorls) was significantly greater for the males than for the females in whole fingerprint and outside the circle, with the exception of the arches in the count of the whole fingerprint. [4, 21] It was reported that the differences between sexes with respect to pattern type could be due to few ridges outside the circle for female subjects, but not inside the circle. [4, 21] This may support an idea that there is a regional variation of the ridge within the same finger. This may be due nature of the ridge formation, which is not uniform all over the fingertips.

For this study, we pay attention only on the minutiae count within the circle in order to avoid the influence of confounding factor, such fewer ridges outside the circle among females. This will also eliminate effects of size of the finger on the minutiae count. Despite all the consideration higher minutiae count was observed in male counterparts when the total count is considered. But zero down to specific pattern the female had a higher frequency in the whorls in both fingers. This may be linked to higher frequency of whorl in the female (as reported earlier). In line with this, the frequency of pattern may be a factor that influences the number (not type) of minutiae to be higher in a particular pattern.

However, it was documented that the type of the general pattern is not the one responsible for the gender differences at the interior of the circle but that there must be other factors that determine the significant differences between the sexes with respect to the total number of minutiae. [4] The frequency of pattern may be simple directly proportional to the minutiae count.

In thumbprints of both sides, bifurcation account for higher count followed by ridge end and the least was trifurcation B for right and dock and point/dot within the ridges for left. In several studies conducted it was reported that the most frequent minutiae of Spanish population were ridge endings, convergences, and bifurcations.[4] Moreover, across several population ridge ending recorded higher frequencies, followed by bifurcation [22, 21] and the least were opposite bifurcation and crossbar [23], return [24], enclosure [7], break [25], Trifurcation bifurcation [6], point/dot [22], fragment [15], dock (Spanish) [4], return (Puna-Quebrada), MC (Ramal) [26]. It can now be deducted that most of the population have the same most frequent minutiae indicating they are of little significance when it comes to the characterization of a different population. However, these findings may project the importance of the less frequent type of minutiae as indices of population variability. The fact that different methods and classification in minutiae analyses may reduce the magnitude and application of these findings should not be ignored in totality. In addition, a complete absence of minutiae type was reported in other population, for instance, absence of bridge in Indians [27] and return among Spanish population. [4] Although all the minutiae considered in this study are a presence in the study population, absence may be recorded when zero down to the level of pattern types.

For differences in the mean value of the right thumbprints minutiae, significance gender difference was observed. The female has higher mean value in break and bridges whereas male has higher values in ridge end, enclosure (small and big) and opposite bifurcation. In the left thumbprints, the significance was noticed only in a bifurcation, cross bar, end, enclosure (small), convergence, return, point/dot between the ridges. Sex wise analysed in the previous study show that ridge ending, convergences, bifurcations, and enclosures were more frequent in female.[4] In a further study by the same author, it was confirmed that males presented a statistically significant greater number of minutiae than the females. The differences between the sexes were significant for ridge endings, bifurcations, breaks, and crossbars, which were on average found less often in the females. [21]

This is in line with the present finding with respect to the type of minutiae that exhibited sexual dimorphism. However, the reverse is the case with respect to gender dominance in the minutiae types. This may highlight to us there could be a mechanism that operates in determining which minutiae type should be more common in a particular sex. Another possible extrapolation is that gene controlling this may not be associated with sex chromosome, rather may be in association with the autosomal gene, which expression may vary between sexes in a different population. In a given population this may be well expressed in male while in another population the expression may be in favor of females. Contrarily, differences in means for males and females were not found for Japanese in the earlier study, although among the German subjects counts were higher for males.

Further study on Japanese population (twins) shows the level of sexual dimorphism in mean minutiae counts.[28] This may portray the importance of methodology with respect to the analyses of the minutiae. It can be seen that only after more robust methodology, significant different was observed in Japan population. Hence, the need for universally accepted methodology for analyses of the minutiae for better and accurate comparison between individuals and population at large. Considering sexual dimorphic, the current study advance a little to find the minutiae that best discriminate the sex. It was observed not all the variables that exhibited sexual dimorphism were good discriminators. In the right, all the sexually dimorphic minutiae are included in the equation with a break as a single best discriminator. For the left, some sexually dimorphic trait was excluded from the equation with ridge end as a single best predictor. It was noticed that within side of the finger is also another factor that may influence the interpretation and prediction using minutiae types.

CONCLUSION

Population variability of the minutiae may be considered as one of the ways through which individual will be characterized. The thumbprint minutiae proved to be useful in sex discrimination. However, different sides of the body have varying degree of prediction accuracy in sex prediction among Hausas.

CONFLICT OF INTEREST

The authors have not declared conflict of interest

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