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Sexual Dimorphism and Regional Variation in Fingerprint Pattern Indices among Hausa Populations of Kano and Zaria, Nigeria

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ABSTRACT
Dermatoglyphics, the study of dermal ridge patterns, remains a valuable tool for understanding genetic variation and population-specific characteristics. This study investigates the frequency distribution and sexual dimorphism of fingerprint pattern indices among Hausa populations in Kano and Zaria, Nigeria. Fingerprints from 600 participants (300 males and 300 females) were collected using systematic random sampling and analyzed for Dankmeijer's Index (DI), Furuhata's Index (FI), and the Pattern Intensity Index (PII). Statistical analysis was conducted using SPSS version 22, with chi-square tests applied to assess associations ($p<0.05$ significant). Findings revealed notable sexual dimorphism and regional variation. Among males, participants from Zaria demonstrated significantly higher mean FI (367 vs. 276, $p<0.05$) and PII (12.9 vs. 12.2, $p=0.03$) than those from Kano, whereas Kano males exhibited higher DI (143 vs. 129, $p=0.04$). In females, Zaria participants showed significantly higher FI (418 vs. 250, $p<0.01$) and PII (13.0 vs. 11.4, $p<0.01$), while Kano females had higher DI (254 vs. 122, $p=0.02$). Overall, females from Zaria displayed statistically higher mean DI values compared to their Kano counterparts ($p<0.05$). Across all groups, loop and whorl patterns predominated, with PII values ranging from 11 to 15, consistent with earlier reports on Nigerian populations. These findings highlight the interplay of genetic and environmental influences on fingerprint patterns and underscore the relevance of dermatoglyphic indices in understanding ethnic differentiation. The study contributes new data on the Hausa ethnic group and provides a basis for further research into genetic, evolutionary, and forensic implications of these biometric traits.
Keywords: Sexual Dimorphism, Fingerprints, Pattern Indices, Hausa, Kano, Zaria

INTRODUCTION

Fingerprint patterns have long been a subject of scientific inquiry, valued for their permanence, individuality, and significance in various disciplines, including forensic science, anthropology, and biomedicine[1,2,3]. The dermal ridges that form fingerprint patterns are established during the 10th to 16th weeks of fetal development and remain unchanged throughout life, making them an exceptional biometric trait[4,5]. Beyond their utility in individual identification, fingerprint patterns also reveal insights into genetic, developmental, and environmental influences, positioning them as valuable markers for anthropological and forensic studies[3].

The primary fingerprint patterns-arches, loops, and whorls-are distributed in a manner that exhibits significant sexual dimorphism across populations. Males are often associated with a higher frequency of whorls, while females more commonly display loops, suggesting the influence of genetic and hormonal factors during dermal ridge development[6,2]. These variations are thought to result from complex interactions of genes such as TGFβ2 and HOXC13, which are critical in ridge pattern formation during embryogenesis[7]. Furthermore, environmental influences, including intrauterine conditions, may also play a role in shaping these differences[8].

Current research into fingerprint pattern distribution and sexual dimorphism continues to expand, particularly in the context of forensic anthropology and population genetics[9,10,11,12, 13]. Forensic applications benefit significantly from understanding these differences, as they can enhance sex estimation models in cases where skeletal remains are unavailable[1]. Additionally, fingerprint studies contribute to population-level analyses, uncovering evolutionary and environmental influences shaping human biometric diversity[14].

Several studies have reported population genetics, forensics, anthropological and medical aspects of dermatoglyphics in Nigeria[15,16,17,18,13]. This study examines the frequency distribution and sexual dimorphism of fingerprint pattern indices in males and females. By analysing these differences, the article aims to contribute to the growing body of literature on biometric sexual dimorphism, highlighting its implications for forensic, anthropological, and medical research

MATERIALS AND METHODS

Geography of the study area

The Hausa people are concentrated mainly in northwest Nigeria and in adjoining Southern Niger. This area is mostly semiarid grassland or savanna, dotted with cities surrounded by farming communities. The cities of the region-Kano, Sokoto, Zaria, and Katsina, for example, are among the greatest commercial centres of sub-Saharan Africa (Africa south of the Sahara Desert). Hausa people are also found in other countries of West Africa, like Cameroon, Togo, Chad, Benin, Burkina Faso, and Ghana.

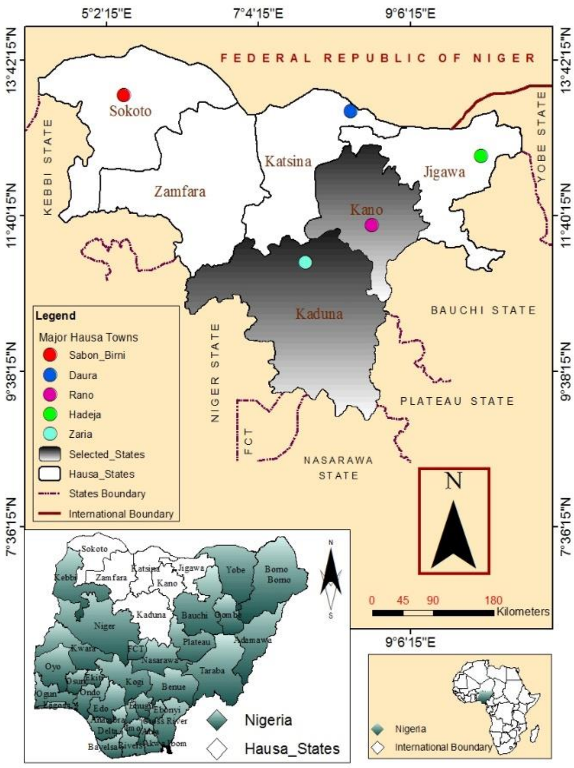

Figure 1: Map of Hausa states showing the two study areas (above): Map of Nigeria showing the Hausa states (below). **Source:** Geographic and information systems (GIS)

Study location and population

This study was conducted in two Hausa-majority cities: Kano and Zaria, because of the large population of Hausas found in the two cities, located in northwestern Nigeria. These regions are characterized by semi-arid grasslands and savannas, with densely populated urban centers surrounded by farming communities. The study focused on the Hausa ethnic group, which is one of Nigeria's largest ethnic groups and is also found in other West African countries.

Sampling and participants

A total of 600 participants (300 males and 300 females) were selected using systematic random sampling, considering the minimum sample size of 384, which was calculated using a formula below:

$$n = \frac{Z^2 \; pq}{d^2}$$

Where n = desired sample size

Z = standard normal deviation 1.96 at 95% confidence level

q = 1 – p,

d = degree of precision usually set at 0.05, p= proportion = 0.5 (50%)

Participants were recruited from the general population of Kano and Zaria, utilizing some randomly selected higher institutions, whereby both students and staff were involved. Inclusion criteria required participants to be Hausa by ethnicity and aged between 18 and 50 years. Informed verbal consent was obtained from all participants before data collection. Ethical approval was secured from the Research Ethics Committee of Ahmadu Bello University Teaching Hospital, Zaria. Batch number ABUTH/HREC/M22/2014.

Fingerprint collection

Fingerprints were collected using traditional methods. Participants were instructed to wash and dry their hands to ensure clear prints. Printer's duplicating ink and stamp pads were used to ink the fingertips, and impressions were made on clean white sheets of paper. Each fingerprint was carefully examined and categorized into patterns: arches, loops, and whorls, using established dermatoglyphic methods[19].

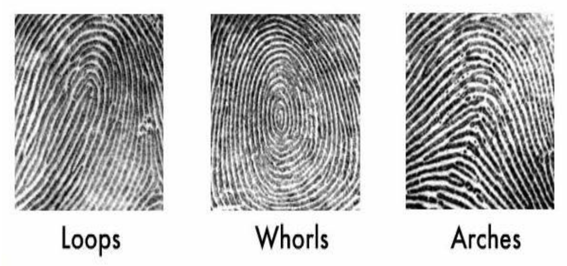

Figure 2: The main types of fingerprint patterns.

Indices computation

Three indices were calculated for each participant:

1. **Dankmeijer's index (DI):** Calculated as the percentage frequency of arches divided by the percentage frequency of whorls, multiplied by 100.

$$DI = \left(\frac{\%Arches}{\%Whorls}\right) \times 100$$

2. **Furuhata's index (FI):** Computed by dividing the percentage frequency of whorls by loops, multiplied by 100.

$$FI = \left(\frac{\%Whorls}{\%Loops}\right) \times 100$$

3. **Pattern intensity index (PII):** Derived by counting the triradii in each fingerprint. The value was expressed as the average number of triradii per finger or individual.

$$PII = \left(\frac{2 \times \%Whorls + \%Loops}{n}\right)$$

Ethical clearance

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Data analysis
Data were analyzed using SPSS version 22 (IBM Corp., New York). Descriptive statistics, including frequencies and percentages, were used to summarize fingerprint patterns. Chi-square tests were performed to evaluate associations between categorical variables. Differences between means of fingerprint indices across regions and sexes were tested for statistical significance, with a p-value of <0.05 considered significant.

RESULTS
Table 1 shows that Zaria males exhibited higher Furuhata's Index (FI) and Pattern Intensity Index (PII) values (RT = 102.91, 14.50; LT = 110.69, 14.52) compared with Kano males (RT = 47.77, 12.61; LT = 53.39, 12.63) in contrast, Dankmeijer's Index (DI) was higher in Kano males (RT = 15.20; LT = 19.34) than in Zaria males (RT = 7.77; LT = 9.66).

Among females (Table 2), Zaria subjects recorded higher FI and PII values (RT = 83.57, 13.84; LT = 89.82, 13.94) than those from Kano (RT = 63.94, 12.82; LT = 85.15, 12.83). Conversely, DI values were greater in Kano females (RT = 21.60; LT = 29.89) compared with Zaria females (RT = 11.38; LT = 12.00).

Analysis of the right-hand five digits (Table 3) revealed that Zaria males had higher FI (12.9) and PII (369) values compared with Kano males (12.2 and 276, respectively). However, DI values were higher among Kano males (143) than Zaria males (129)

Table 1: Comparison of fingerprint pattern indices (Pattern intensity index, Dankmeijer's index and Furuhata's index) in males of Kano and Zaria

Metropolis	Digits	% of whorl	% of loop	% of arch	Pattern intensity index	Dankmeijer's index	Furuhata's index
Kano	RT	30.81	64.50	4.68	12.61	15.20	47.77
	LT	32.61	61.08	6.31	12.63	19.34	53.39
Zaria	RT	48.79	47.41	3.79	14.50	7.77	102.91
	LT	50.00	45.17	4.83	14.52	9.66	110.69
Kano	RT+LT	31.71	62.79	5.50	12.62	17.33	50.50
Zaria	RT+LT	49.40	46.29	4.31	14.51	8.73	106.70

RT: Right thumb, LT: Left thumb

Table 2: Comparison of fingerprint pattern indices (Pattern intensity index, Dankmeijer's index and Furuhata's index) in females of Kano and Zaria

Metropolis	Digits	% of whorl	% of loop	% of arch	Pattern intensity index	Dankmeijer's index	Furuhata's index
Kano	RT	35.97	7.77	56.26	12.82	21.60	63.94
	LT	40.43	12.09	47.48	12.83	29.89	85.15
Zaria	RT	43.28	4.93	51.79	13.84	11.38	83.57
	LT	44.78	9.37	45.85	13.94	12.00	89.82
Kano	RT+LT	38.20	9.93	51.87	12.83	25.99	73.65
Zaria	RT+LT	44.03	5.15	50.82	13.89	11.69	86.64

RT: Right thumb, LT: Left thumb

Table 3: Distribution of fingerprint pattern indices in males of Kano and Zaria

	DI		FI		PII	
Digits	Kano	Zaria	Kano	Zaria	Kano	Zaria
I	17	16	117	125	2.8	2.9
II	38	37	57	78	2.4	2.5
III	44	47	30	42	2.2	2.3
IV	23	13	48	79	2.5	2.7
V	21	16	24	43	2.3	2.5
Total Frequency	143	129	276	367	12.2	12.9
Total Index	27	24	49	68	13	12

DI; Dankmeijer's index, FI; Furuhata's index, PII; pattern intensity index

No significant differences were observed in the mean Pattern Intensity Index (PII) of the five digits between males and females across both study locations (Figure 4). Among females, Zaria subjects recorded higher FI and PII values (418 and 13, respectively) compared with Kano females (250 and 11.4, respectively) (see Table 4). Conversely, Dankmeijer's Index (DI) was higher in Kano females (254) than in Zaria females (122) (see Table 4). The mean values of the indices were statistically significant, with Zaria females exhibiting higher overall means (Figure 3).

Table 4: Distribution of fingerprint pattern indices in females of Kano and Zaria

	DI		FI		PII	
Digits	Kano	Zaria	Kano	Zaria	Kano	Zaria
I	28	18	98	126	2.6	2.8
II	52	32	56	117	2.3	2.6
III	87	38	26	52	2	2.4
IV	43	17	46	77	2.3	2.7
V	44	17	24	46	2.2	2.5
Total Frequency	254	122	250	418	11.4	13
Total Index	46	24	46	77	11	12

DI; Dankmeijer's index, FI; Furuhata's index, PII; pattern intensity index

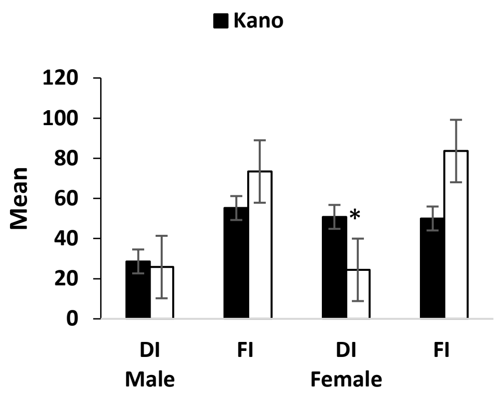

Figure 3: Differences in fingerprint pattern indices (DI and FI) of males and females of Kano and Zaria (DI; Dankmeijers index, FI; Furuhatas index), * $p < 0.05$

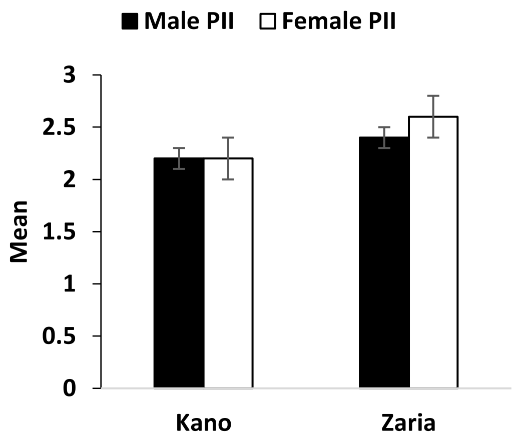

Figure 4: Differences in fingerprint pattern index (PII) of male and female of Kano and Zaria (PII; pattern intensity index)

DISCUSSION

The findings of this study highlight significant metropolis and gender-based differences in fingerprint pattern indices among Hausa populations in Kano and Zaria, Nigeria. These results align with the broader understanding of sexual dimorphism and geographic variation in dermatoglyphics as influenced by genetic, developmental, and environmental factors[4,5]. Males from Zaria exhibited higher Furuhata's Index and Pattern Intensity Index compared to their Kano counterparts, indicating a higher frequency of whorl and loop patterns. This is consistent with studies reporting regional variations in fingerprint patterns, likely influenced by genetic diversity and environmental conditions[3,6]. Similarly, females from Zaria had higher FI and PII than those from Kano, corroborating prior findings of sexual dimorphism in dermatoglyphics, where females often show distinct loop and whorl distributions compared to males[2].

Interestingly, DI was higher in Kano participants in both sexes, reflecting a greater prevalence of arches in this group. This regional variation may suggest underlying genetic differences or environmental influences such as temperature, humidity and sunlight unique to Kano's population, as previously suggested in studies of ethnic fingerprint variations[20,14]. On the contrary, a study conducted on the Bengali Hindu population of West Bengal has reported that Pattern Intensity and Furuhata's Index are higher for males; whereas Denkmeijer's and Poll's Index are higher in females[21]. Even the previous studies among Rajput[22], Toda of Tamil Nadu[23], Limbu of Sikkim[24], and Dhimal of North Bengal[25], also show PII and FI are higher in males. Also, the studies on Brahmins[22], Toda of Tamil Nadu[23], Muslims of central India[26], Dhimals of North Bengal[25], Rengma Nagas of Nagaland[27], and Tibetans of Tibet[28], show higher DI among females only.

The PII values in this study ranged from 11 to 15, consistent with values reported for other Nigerian populations, such as Yoruba and Igbo, as well as global populations[29,30]. These findings underscore the dominance of loop and whorl patterns across diverse ethnic groups, highlighting their evolutionary stability and genetic determinants[7].

The sexual dimorphism observed in this study aligns with global trends, where males typically exhibit higher PII values compared to females[31]. This difference has been linked to hormonal influences during embryogenesis, particularly the role of androgens in dermal ridge development[8,31].

This study contributes valuable data to the limited dermatoglyphic research on the Hausa ethnic group and supports the utility of fingerprint indices in understanding ethnic differentiation, forensic identification, and genetic research. Future studies should explore the molecular basis of these patterns to elucidate the genetic and environmental mechanisms driving such variations.

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