BAJOPAS Volume 10 Number 1 June, 2017

http://dx.doi.org/10.4314/bajopas.v10i1.5

Bayero Journal of Pure and Applied Sciences, 10(1): 39 - 46
Received: December, 2016
Accepted: March, 2017
ISSN 2006 – 6996

EVALUATION OF ASYMMETRY USING THUMBPRINT MINUTIAE AMONG HAUSA POPULATION OF KANO STATE, NIGERIA

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ABSTRACT
The present study was aimed at determining the existence of FA in Hausa populations using thumbprint minutiae. The participants included 112 males and 105 females of Hausa Ethnic descent, aged between 18-25 years. The minutiae of the plain thumbprints were determined from a circle with radius that cut across the nucleus of the fingerprints. The result showed that in signed asymmetry bifurcation, crossbar, break, point/dot into ridges and point/dot between ridges exhibited sexual dimorphism. The left ward asymmetry in male was exhibited in bifurcation, cross bar, trifurcation bifurcation, break, bridge, opposite bifurcation, in "M" convergence, in "M" bifurcation and Point/Dot into ridges. Similarly, in female bifurcation, trifurcation bifurcation, enclosure big, opposite bifurcation, convergence, in "M" bifurcation and return exhibit left ward asymmetry. For absolute and composite asymmetry the significant differences was observed in end, enclosure (small), bridge and return. In the entire minutiae types only ridge bifurcation exhibited directional asymmetry in males and six other minutiae types in females. In conclusion, the presence of sexual dimorphism in thumbprint ridge minutiae was demonstrated in the present study. The leftward asymmetry was observed in both sexes in different types minutiae. Females were observed to exhibit directional type of asymmetry more than the males in this population.
Keywords: Asymmetry, Environmental stress, Hausa population, Ridge minutiae, Sexual dimorphism,

INTRODUCTION

Different types of asymmetry exist in nature, these include directional asymmetry when one side of a bilateral structure is consistently larger than the other, antisymmetry when sides are consistently unequal in size, but neither side is more likely to be the largest (Graham *et al.*, 1993). The third variety of asymmetry is fluctuating asymmetry (FA) which refers to random, subtle departures from perfect symmetry (Palmer and Strobeck, 1986). FA has become one of the useful tools in measuring developmental stability in structures that are normally symmetrical (Møller and Shykoff, 1999; Nijhout and Davidowitz, 2003). Of the three types of asymmetry, FA (Van Valen, 1962; Parsons 1990; Møller and Swaddle, 1997) and, under particular circumstances, directional asymmetry (Graham *et al.*, 1998; Graham *et al.*, 2003), are typically thought to be indicative of developmental instability and exposure to environmental stress during development.

Interestingly genetic factors may also have a weak relation to FA in fingerprints features (Martin *et al.*, 1982; Arrieta *et al.*, 1993). The genetic basis of differences in the small random variation usually found between the sides of the body of bilateral trait continues to be a subject of considerable interest in the literature. This can be applied to FA, a ubiquitous type of asymmetry that was reported to be one of those rare inheritable traits (Palmer *et al.*, 1994). Thus the level of FA is expected to increase in group of individuals subjected to any of a variety of stressors. Based on the comparison of FA in stressed and non-stressed population it was suggested that direct genetic effects on FA itself are not responsible for any observed differences (Palmer *et al.*, 1994). There is paucity of data regarding assessment of indicators of developmental instability in Hausa population. This may help in searching for possible factors that may lead to induction of stress and developmental instability *in utero*. It is now clear that the level of developmental instability and environmental stress may be assessed using FA in a given population (Palmer *et al.*, 1994; Møller and Swaddle, 1997). The present study aimed at determining the existence of FA in Hausa populations using thumbprint minutiae.

MATERIALS AND METHODS

Study location and population

The study was conducted among one of the original Hausa States; Kano state of Nigeria. Kano is the most populous state in Nigeria (Barau, 2007). The urban area of the state covers 137 km^2 and comprises of six local government areas (LGAs); Kano Municipal, Fagge, Dala, Gwale, Tarauni and Nassarawa (Figure 1).

The principal inhabitants of the city are the Hausa people (Barau, 2007). A total of 217 subjects comprising 112 males and 105 females within the 18-25 years of age participated in the study. Any subject who is Hausa up to level of grandfather**,** apparently healthy subject whose thumbs were free from any deformities or pathological changes were eligible for the study. Before the commencement of the research, Ethical approval was obtained from Ethical Committee of Ahmadu Bello University, Teaching Hospital, Zaria, Faculty of Medicine (ABUTHZ/HREC/506/2015) and Kano State Hospitals Management Board.

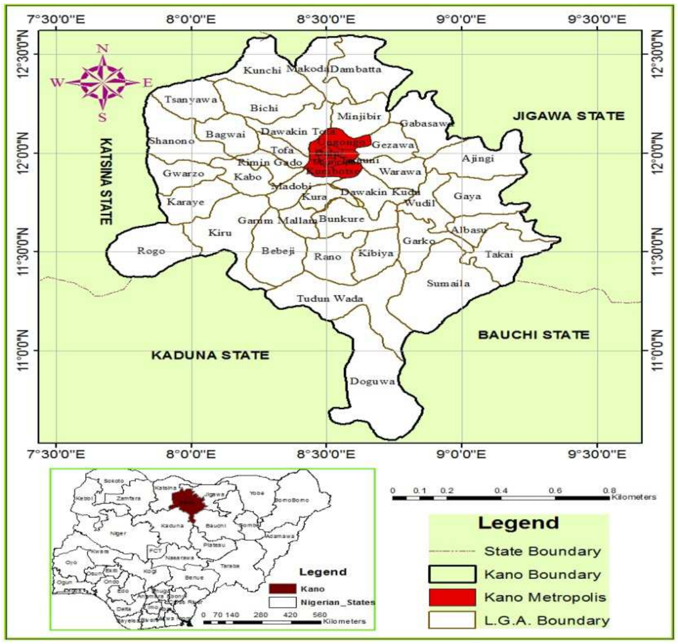

Figure 1: Map of the study area (Kano State).

Fingerprints Collection and Minutiae counts

Direct sensing fingerprints capturing method (Jain *et al.,* 2007) was used to capture the plain fingerprints. For each thumbprint, two versions; the original size image (used for scaling) and amplified image (at ratio of 7.74); were captured using Bioanalyser (Microsoft visual basic version 6.0 programming language). These images were saved in jpeg format for variables reading in personal computer. The amplified thumbprint images were used for the thumbprint minutiae count.

The fingerprints were classified into any of the three basic patterns namely; arches, loops, whorls (Cummins and Midlo, 1943). The minutiae count was designed according to the method described by Okajima (1970), and the count were made using magnified images of 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 (Figure 2). Sixteen different types (some with subtype) of minutiae (Table 1) were used **(**Champod and Margot, 1996; Gutierrez-Redomero *et al.*, 2007).

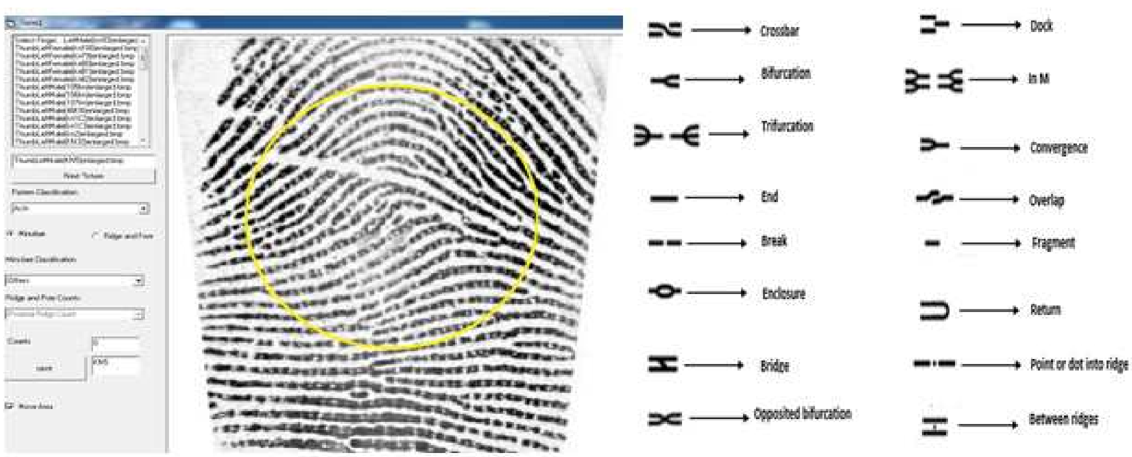

Figure 2: A Thumbprint Divided into Two Areas by a Circle for Determination of Different Types Of Minutiae

Table 1: Different Types of Fingerprints Minutiae and Their Description

Minutiae type	Description
Bifurcation	Minutiae form ridges to the right
Crossbar	Ridge that separates from its direction crossing between two others
Trifurcation	The minutiae form three ridges
End	Termination of a ridge
Break	Break in the ridge
Enclosure	The ridge path divides and then comes together again
Bridge	A short ridge crosses from one ridge to join the next
Opposite Bifurcation	Two ridges that join at one point
Dock	Crest end that enters between two other end ridges
In "M" convergence or bifurcation	Two converged/ bifurcated ridges develop next to each other on the same ridge
Convergence	Minutiae form ridges to the left
Overlap	Two ridge ends meet and overlap on a bias
Fragment	Short ridge with length equal or less ten times its width,
Return	The turning around of a ridge without being part of the nucleus
Point or dot into ridge	One ridge unit which contain only one sweat gland pores into ridge
Point or between ridges	One ridge unit which contain only one sweat gland pores between ridges

To determine systematic error in the minutiae counting the student paired t-test was performed to compare the means of the first and second counting using 30 randomly selected individuals. This allowed assessment of systematic error (bias error). Three indices of asymmetry, differences between left (L) and right (R) used included signed asymmetry (SA), absolute asymmetry (AA) and composite asymmetry (CA). These were determined by the following formulae; $SA = R-L$, $AA = \sqrt{(R-L)^2}$, $CA = \sum\sqrt{(R-L)^2}/n$, where n is the sample size. The existence of directional asymmetry was detected by subjecting the mean value of signed asymmetry to one sample t-test (Manning, 1995; Palmer and Strobeck, 2003). An asymmetry was considered to be directional if mean value of signed symmetry differed significantly from zero, otherwise it was considered as FA. The data were expressed as mean ± SD. ANOVA and Independent sample t test was used to test for differences between the areas of the thumb and sexual dimorphism respectively. SPSS version 20.0 statistical software was used for the statistical analysis and $P \leq 0.05$ was set as level of significance

RESULTS

From Table 2 the mean minutiae count showed variation between males and females. The significant differences were observed in ridge ending, enclosure, break, bridge, opposite bifurcation, in the right thumbprints. In the right thumbprints, the females had higher minutiae count only in break and bridge. With regards to the left thumbprints, the females had higher mean minutiae counts in the convergence and return. For males, significantly higher minutiae counts were observed in the bifurcation, cross bar, end, enclosure small and point or dot between ridges.

Table 2: Mean and Standard Deviation of Minutiae Count of Males and Females of both Left and Right Thumbs

	Right Thumb						Left Thumb					
	Male		Female				Male		Female			
Variables	Mean	SD	Mean	SD	t	P	Mean	SD	Mean	SD	t	P
Bifurcation	2.97	2.21	3.10	2.10	-0.45	0.654	3.94	2.85	3.13	2.47	2.21	0.0279
Cross bar	0.05	0.23	0.08	0.30	-0.63	0.530	0.15	0.51	0.03	0.17	2.38	0.0184
Trifurcation convergence	0.04	0.19	0.04	0.24	-0.08	0.934	0.03	0.16	0.02	0.14	0.38	0.7058
Trifurcation bifurcation	0.01	0.09	0.03	0.17	-1.06	0.289	0.06	0.24	0.05	0.26	0.42	0.6716
End	5.08	3.61	3.17	2.53	4.48	0.001	4.88	3.45	2.65	2.21	5.64	0.0001
Break	0.56	1.30	1.46	1.86	-4.13	0.001	0.71	1.31	0.74	1.29	-0.20	0.8433
Enclosure(big)	1.31	1.43	0.88	1.14	2.42	0.016	1.12	1.33	1.05	1.07	0.42	0.6772
Enclosure(small)	0.88	1.41	0.63	0.88	1.59	0.113	0.68	1.01	0.30	0.86	2.98	0.0032
Bridge	0.15	0.41	0.46	0.94	-3.14	0.002	0.21	0.54	0.39	0.89	-1.86	0.0641
Opposite bifurcation	0.17	0.44	0.04	0.19	2.81	0.005	0.20	0.44	0.19	0.44	0.13	0.8980
Dock	0.06	0.34	0.06	0.23	0.14	0.892	0.02	0.13	0.05	0.25	-1.09	0.2780
In "M" convergence	0.00	0.00	0.09	0.52	-1.74	0.083	0.04	0.19	0.05	0.21	-0.42	0.6720
In "M" bifurcation	0.04	0.19	0.02	0.14	0.73	0.464	0.08	0.27	0.05	0.21	0.98	0.3289
Convergence	1.39	1.34	1.76	1.61	-1.84	0.067	1.24	1.38	2.00	2.02	-3.25	0.0014
Overlap	0.29	0.62	0.19	0.42	1.43	0.153	0.15	0.38	0.17	0.47	-0.34	0.7356
Fragment Big	0.35	0.72	0.53	1.25	-1.35	0.179	0.31	0.67	0.54	1.10	-1.89	0.0608
Fragment Small	0.63	1.40	0.59	1.24	0.24	0.809	0.50	1.05	0.33	1.17	1.07	0.2839
Return	0.02	0.13	0.08	0.36	-1.60	0.112	0.001	0.001	0.09	0.31	-2.89	0.0042
Point or dot into ridge	0.08	0.38	0.15	0.50	-1.20	0.231	0.21	1.15	0.001	0.01	1.83	0.0682
Point or between ridges	2.56	3.81	1.86	3.15	1.48	0.140	2.10	3.22	0.49	1.60	4.69	0.0001

Sexual dimorphism assessments in the three indices of minutiae showed that in signed asymmetry bifurcation, crossbar, break, point/dot into ridges and point/dot between ridges exhibited sexual dimorphism (Table 2). For absolute asymmetry the significant sex differences was observed in cross bar, end, enclosure (small), bridge and return. Where significant sexual differences were observed the female had higher mean value ridge bridge and return only (Table 3). For composite asymmetry the significant sexual dimorphism in minutiae asymmetry was similar to what was observed in absolute asymmetry except for cross bar which also approaches significant (Table 4). The left ward asymmetry in male was exhibited in bifurcation, cross bar, trifurcation bifurcation, break, bridge, opposite bifurcation, in "M" convergence, in "M" bifurcation and Point/Dot into ridges. Similarly, in female bifurcation, trifurcation bifurcation, enclosure big, opposite bifurcation, convergence, in "M" bifurcation and return exhibit left ward asymmetry (Table 2).

Table 3: Sexual Dimorphism in Signed Asymmetry of Thumbprint Minutiae

Minutiae Types	Male Mean ± SD	Female Mean ± SD	T	P value
Bifurcation	-0.96 ± 3.02	-0.03 ± 2.94	-2.31	0.022
Cross bar	-0.10 ± 0.57	0.05 ± 0.32	-2.3	0.022
Trifurcation convergence	0.01 ± 0.21	0.02 ± 0.24	-0.33	0.742
Trifurcation bifurcation	-0.05 ± 0.26	-0.02 ± 0.31	-0.89	0.376
End	0.20 ±4.65	0.52 ± 2.60	-0.64	0.526
Break	-0.14 ± 2.00	0.72 ±1.88	-3.28	0.001
Enclosure (big)	0.20 ± 1.73	-0.17 ± 1.36	1.73	0.084
Enclosure (small)	0.21 ± 1.75	0.33 ± 1.13	-0.64	0.525
Bridge	-0.05 ± 0.58	0.07 ± 1.11	-1.01	0.315
Opposite bifurcation.	-0.03 ± 0.68	-0.15 ± 0.50	1.55	0.123
Dock	0.04 ± 0.37	0.01 ± 0.35	0.72	0.473
in "M" convergence	-0.04 ± 0.19	0.04 ± 0.57	-1.3	0.196
in "M" bifurcation	-0.04 ± 0.34	-0.03 ± 0.26	-0.39	0.696
Convergence	0.15 ±1.89	-0.24 ±2.35	1.35	0.178
Over lap	0.14 ±0.70	0.02 ±0.60	1.40	0.164
Fragment big	0.04 ± 1.01	0.00 ± 1.43	0.27	0.789
Fragment small	0.14 ± 1.35	0.26 ± 1.69	-0.55	0.582
Return	0.02 ± 0.13	-0.01 ± 0.45	0.62	0.538
Point/Dot into ridges	-0.13 ± 1.22	0.15 ± 0.50	-2.16	0.032
Point/Dot between ridges	0.48 ± 3.39	1.39 ± 3.38	-1.98	0.049

Table 4: Sexual Dimorphism in Absolute Asymmetry of Thumbprint Minutiae

Minutiae Types	Male Mean ± SD	Female Mean ± SD	t	P value
Bifurcation	2.29 ± 2.18	2.26 ± 1.88	0.10	0.918
Cross bar	0.21 ± 0.54	0.09 ± 0.31	1.98	0.049
Trifurcation convergence	0.04 ± 0.21	0.04 ± 0.24	0.22	0.829
Trifurcation bifurcation	0.07 ± 0.26	0.08 ± 0.30	-0.13	0.90
End	3.55 ± 2.98	1.95 ± 1.78	4.76	0.001
Break	1.18 ± 1.62	1.35 ± 1.49	-0.82	0.413
Enclosure (big)	1.21 ± 1.24	0.95 ± 0.98	1.72	0.088
Enclosure (small)	1.17 ± 1.31	0.66 ± 0.98	3.25	0.001
Bridge	0.27 ± 0.52	0.60 ± 0.94	-3.26	0.001
Opposite bifurcation.	0.37 ± 0.57	0.23 ± 0.47	1.94	0.054
Dock	0.08 ± 0.36	0.10 ± 0.34	-0.52	0.607
in "M" convergence	0.04 ± 0.19	0.13 ± 0.56	-1.77	0.08
in "M" bifurcation	0.12 ± 0.32	0.07 ± 0.25	1.26	0.21
Convergence	1.44 ±1.23	1.74 ±1.58	-1.59	0.112
Over lap	0.36 ±0.61	0.27 ±0.54	1.15	0.252
Fragment big	0.53 ± 0.86	0.76 ± 1.21	-1.66	0.098
Fragment small	0.68 ± 1.17	0.81 ± 1.51	-0.72	0.474
Return	0.02 ± 0.13	0.12 ± 0.43	-2.48	0.014
Point/Dot into ridges	0.29 ± 1.20	0.15 ± 0.50	1.06	0.29
Point/Dot between ridges	2.25 ± 2.57	1.94 ± 3.09	0.8	0.425

Table 5: Sexual Dimorphism in Composite Asymmetry of Thumbprint Minutiae

Minutiae Types	Male	Female		
	Mean ± SD	Mean ± SD	t	P value
Bifurcation	0.02 ± 0.02	0.02 ± 0.02	-0.43	0.669
Cross bar	0.002 ± 0.005	0.001 ± 0.003	1.86	0.065
Trifurcation convergence	0.0003 ± 0.00	0.0004 ± 0.002	-0.13	0.894
Trifurcation bifurcation	0.001 ± 0.002	0.001 ± 0.003	-0.25	0.803
End	0.03 ± 0.03	0.02 ± 0.02	4.30	<0.001
Break	0.01 ± 0.01	0.01 ± 0.01	-1.21	0.228
Enclosure (big)	0.01 ± 0.01	0.01 ± 0.01	1.27	0.206
Enclosure (small)	0.01 ± 0.01	0.01 ± 0.01	2.91	0.004
Bridge	0.002 ± 0.005	0.01 ± 0.01	-3.47	0.001
Opposite bifurcation.	0.00 ± 0.01	0.002 ± 0.004	1.68	0.094
Dock	0.00 ± 0.003	0.001 ± 0.003	-0.64	0.521
in "M" convergence	0.0003 ± 0.00	0.001 ± 0.01	-1.81	0.072
in "M" bifurcation	0.001 ±0.003	0.001 ±0.002	1.12	0.266
Convergence	0.01 ±0.01	0.02 ±0.02	-2.11	0.036
Over lap	0.003 ±0.01	0.003 ±0.01	0.90	0.37
Fragment big	0.005 ± 0.01	0.01 ± 0.01	-1.94	0.054
Fragment small	0.01 ± 0.01	0.01 ± 0.01	-0.97	0.332
Return	0.0002 ± 0.001	0.001 ± 0.004	-2.52	0.013
Point/Dot into ridges	0.00 ± 0.01	0.00 ± 0.00	0.97	0.333
Point/Dot between ridges	0.02 ± 0.02	0.02 ±0.03	0.45	0.657

Using one sample t test only bifurcation exhibit directional asymmetry ($p < 0.05$) in male and six different minutiae types; end, break, enclosure small, point/dot into ridges and point/dot between ridges, in female (Table 6).

Table 6: One Sample t-test in for Evaluation of Fluctuation Asymmetry

	Male				Female			
Minutiae Types	Mean	SEM	t	P value	Mean	SEM	t	P value
Bifurcation	-0.96	0.285	-3.383	0.001	-0.03	0.287	-0.099	0.921
Cross bar	-0.1	0.054	-1.827	0.07	0.05	0.031	1.517	0.132
Trifurcation C	0.01	0.02	0.446	0.657	0.02	0.023	0.815	0.417
Trifurcation B	-0.05	0.025	-2.156	0.033	-0.02	0.03	-0.631	0.53
End	0.2	0.439	0.447	0.656	0.52	0.253	2.069	0.041
Break	-0.14	0.189	-0.756	0.451	0.72	0.184	3.938	<0.001
Enclosure big	0.20	0.163	1.203	0.232	-0.17	0.133	-1.29	0.2
Enclosure small	0.21	0.165	1.245	0.216	0.33	0.11	3.017	0.003
Bridge	-0.05	0.055	-0.973	0.333	0.07	0.108	0.614	0.54
Opposite B	-0.03	0.064	-0.419	0.676	-0.15	0.048	-3.15	0.002
Dock	0.04	0.034	1.295	0.198	0.01	0.034	0.276	0.783
in "M" C	-0.04	0.018	-2.028	0.045	0.04	0.056	0.684	0.495
in "M" B	-0.04	0.032	-1.393	0.167	-0.03	0.025	-1.135	0.259
Convergence	0.15	0.179	0.85	0.397	-0.24	0.229	-1.039	0.301
Over lap	0.14	0.066	2.173	0.032	0.02	0.059	0.323	0.747
Fragment Big	0.04	0.095	0.469	0.64	0.001	0.139	0.001	1.00
Fragment Small	0.14	0.127	1.122	0.264	0.26	0.165	1.556	0.123
Return	0.02	0.013	1.421	0.158	-0.01	0.044	-0.217	0.828
Point/Dot into R.	-0.13	0.116	-1.081	0.282	0.15	0.048	3.15	0.002
Point/Dot between R.	0.48	0.32	1.507	0.135	1.39	0.329	4.221	<0.001

C; convergence, B; Bifurcation, R; ridge, SEM; standard error of mean

DISCUSSION

In population studies, thumb record higher bilateral asymmetry and large individual variation than any other finger (Malhotra *et al.*, 1991). It is to be mentioned here that the thumb is given particular importance in the evolutionary history of man (Kusuma *et al.*, 2001). Considering these advantages exhibited by thumb, this study assessed the asymmetry in ridge minutiae using thumbprints.

The presence of sexual dimorphism in the three different types of thumbprint minutiae may indicate differences in the responses to environmental stress encounter by developing organisms. It was reported that dermatoglyphic asymmetries are related to adult testosterone (Jamison *et al.*, 1993). In another separate study pregnant Rhesus positive mothers exposed to testosterone tend to have offspring with fewer dermal ridges than controls (Jamison *et al.*, 1994). Since men have higher average ridge number than women it is generally suggested that higher levels of androgens may lead to an increased complexity in ridge patterns and a higher ridge count (Mustanski *et al.*, 2002). This may explain possible variation of the ridge minutiae between male and female in this population.

Number of studies reported that the ridges of right hand were found to be coarser than the left hand (Cummins *et al.*, 1994). It was evident that left hand have greater number of ridges than in the right (Gutie´rrez-Redomero *et al.*, 2007) and finer ridges than the right fingers (Mundorff *et al.,* 2014). But these observations may be influenced by sex (Gutie´rrez-Redomero *et al.*, 2007). It was suggested that if low asymmetry and sexual dimorphism in favor of male indicates the same aspects of mate quality then the ability to produce large traits in males should be correlated to the ability to produce symmetrical traits, leading to inverse relationship between asymmetry and trait size (Møller and Cuervo, 2003; Koehler *et al*, 2004). It was reported that male in the same (Hausa) population tend to have larger trait size compared to females including hands parameters (Umar *et al.*, 2016). Therefore, the low asymmetry observed in males in this study is supported. However, higher asymmetry in some of minutiae indices was also observed in males in this study. It may be hypothesized that only minutiae that depends on finger size and or/ masculinity respond to effect of testosterone. This is due to the fact that level of testosterone correlated positively with symmetry and fingerprint ridges (Jamison *et al.*, 1994). That leads to expression of low asymmetry in male compared to females.

During embryogenesis developing organism encounter different types of challenges from its environment. This led to manifestation of permanent signs in the adult body as a result of genetic and external perturbations in the environment. One of the manifestations includes small deviations from perfect symmetry in bilateral structure which correlates negatively with the amount of stress experienced during development (Siegel and Smookler, 1973; Siegel *et al.*, 1977; Mooney *et al.*, 1985). Many factors such as extreme temperatures, environmental pollution, population density, and inbreeding among others are reported to be potential stressors encountered by developing organisms (Parsons, 1992; Markow and Martin, 1993; Galeotti *et al.*, 2005; Velickovic, 2007; Lewis *et al.*, 2008). Therefore, this study highlighted the significance of thumbprints minutiae in assessing the level of developmental stress and instability among the Hausa population using FA. It was reported that fluctuating asymmetry is often used as a proxy to quantify developmental stressors and explore the effects of these developmental insults on individuals' health, fitness, and behavior (Benderlioglu, 2010). It may be recommended that this study be expanded to other digits and other populations in order to explore more about the pattern of the asymmetry in other digits and populations for better explanation of the phenomenon.

CONCLUSION

The presence of sexual dimorphism in thumbprint ridge minutiae was demonstrated in the present study. The leftward asymmetry was observed in both sexes in different types minutiae. Females were observed to exhibit directional type of asymmetry more than the males in this population.

Acknowledgements:

We thank all those who volunteered to participate in this research. Also to Sanusi Aminu who helped in the development of the software used as well as other technical assistance.

Funding:

This work is an extract of a Ph.D. dissertation which was sponsored by Bayero University Research Grant Unit and Tertiary Education Trust Fund (TETfund) of Nigeria.

Conflict of Interest:

The authors declare that there is no conflict of interest.

Authors' contributions: Adamu L .H: concepts, design, definition of intellectual content, literature search, data acquisition and analyses, manuscript preparation, editing and review. Ojo S.A: design, definition of intellectual content, manuscript preparation, editing and review. Danborno, B: design, data analyses, manuscript preparation, editing and review. Adebisi S. S: definition of intellectual content, manuscript preparation, editing and review. Taura M.G: definition of intellectual content, manuscript preparation, editing and review.

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