The Potential of Thumbprint Profiles in Prediction of Body Mass Index among Hausa Ethnic Group of Nigeria

*[1]Adamu LH, [2]Ojo SA, [3]Danborno B, [3]Adebisi SS, [4]Taura MG

[1]Department of Anatomy, Faculty of Basic Medical Sciences, Bayero University, Kano, Nigeria
[2]Department of Veterinary Anatomy, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria, Nigeria
[3]Department of Human Anatomy, Faculty of Medicine, Ahmadu Bello University, Zaria, Nigeria
[4]Department of Anatomy College of Medicine University of Bisha Saudi Arabia

** Corresponding Author:Adamu LH, Department of Anatomy, Faculty of Basic Medical Sciences, Bayero University, Kano Nigeria, Email: alhassan.ana@buk.edu.ng*

Abstract
The need for prediction of body mass index can be seen in individuals whose height and/ or weight are difficult to measure especially in those with cerebral palsy, neuromuscular disorders, spinal deformity, and lower limb deformity among others. The study was designed to determine the correlation between body mass indexes with thumbprint profiles. It also developed equations for prediction of body mass index from thumbprints profiles. A total of 271 subjects within the age of 18-25 years participated. Plain thumbprints were captured using live scanner. The ridge count and thickness were determined from ulnar, radial and proximal areas of each thumbprint. Minutiae were determined with a circle with a diameter that cuts across the nucleus of the thumbprints. Pearson's correlation and stepwise multiple regression analysis were used for the relationship and predict analyses respectively. The results showed that BMI correlates with ridge crossbar ($r=0.27$, $p < 0.05$), ulnar ridge thickness ($r=0.22$, $p < 0.05$) and fragment big ($r=0.30$, $p < 0.05$) in males. For females the correlation was observed only in enclosure small ($r=0.19$, $p < 0.05$) and opposite bifurcation ($r=0.27$, $p < 0.05$). The best BMI predictor in the males was crossbar ($R^2= 0.0876$) and fragment big ($R^2= 0.0651$) for right and left thumb prints respectively. In the female participants, only enclosure small ($R^2= 0.0765$) of the left was the best predictor. In conclusion, BMI may be predicted from thumbprint profiles. However, thumb prints minutiae showing more potential compared to the ridge density.

Keywords: Body Mass Index, Thumbprint Minutiae, Thumbprint Ridge Density, Prediction, Hausa Ethnic Group.

Introduction
Body mass index (BMI), which is ratio of weight to height (kg/m^2), is commonly used in practice as simple measure of body size, and as an estimator of obesity in different populations across the globe.[1] Several studies have examined correlations between fingerprint measurements with some health related conditions such as obesity,[2] chromosomal disorders,[3] schizophrenia,[4] male pattern baldness,[5] and blood groups,[6] among a host of other condition. It was also reported that expression of an obesity-related gene is likely to predetermine *in utero* the pattern of fingerprint formation in obese patients.[7] The high percentage of the arch pattern on the first right digits of the patients was suggested to be peculiar to obese Ibibios compared to normal groups.[2]

Despite the well-established correlations between dermatoglyphics and obesity, [2] the correlations between fingerprints features like ridge counts, thickness and minutiae with obesity estimator (BMI) received less attention among Hausa population. It is noted that conventional methods of measuring individual's height and weight in order to compute his or her BMI may not always be possible. This is

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due to the fact that height and/ or weight are difficult to measure especially in those individuals with cerebral palsy, neuromuscular disorders, spinal deformity, and lower limb amputation or deformity among others. [8] In addition, prediction of BMI from thumbprint features is relatively simple and non-invasive. This prediction also gives room in assessing the health status of a given population without real contact with the population. For instance, latent fingerprint can be obtained in the absence of owner of print. The ridge characteristics (ridge minutiae and density) may be used to predict body fat distribution using BMI resulting in classifying an individual as normal or otherwise. Like any other population, there is need for population-specific formulae for prediction of BMI from thumbprint features. Hence, this will help in health assessment especially in situations were the individual is unconscious where BMI can be considered as one of the assessment tool of the health condition of the individual. The objectives of the study were to determine the correlation between BMI with thumbprint, ridge density, and thickness, and predict BMI from thumbprint features.

Materials and Methods

Study population

The subjects of this study were recruited from Hausa population of Kano State Nigeria (Figure 1). Using random sampling methods, a total of 271 subjects comprising 135 males and 136 females participated in this study. Only subjects that were Hausas, apparently healthy and whose thumbs were free from any deformity or pathological changes and within the age range of 18-25 years were considered, this was to minimize the effect of age on thumbprint profile. 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 Ahmadu Bello University, Teaching Hospital, Zaria, Faculty of Medicine (ABUTHZ/HREC/506/2015) and Kano State Hospital Management Board. Informed consent was sought from the participants

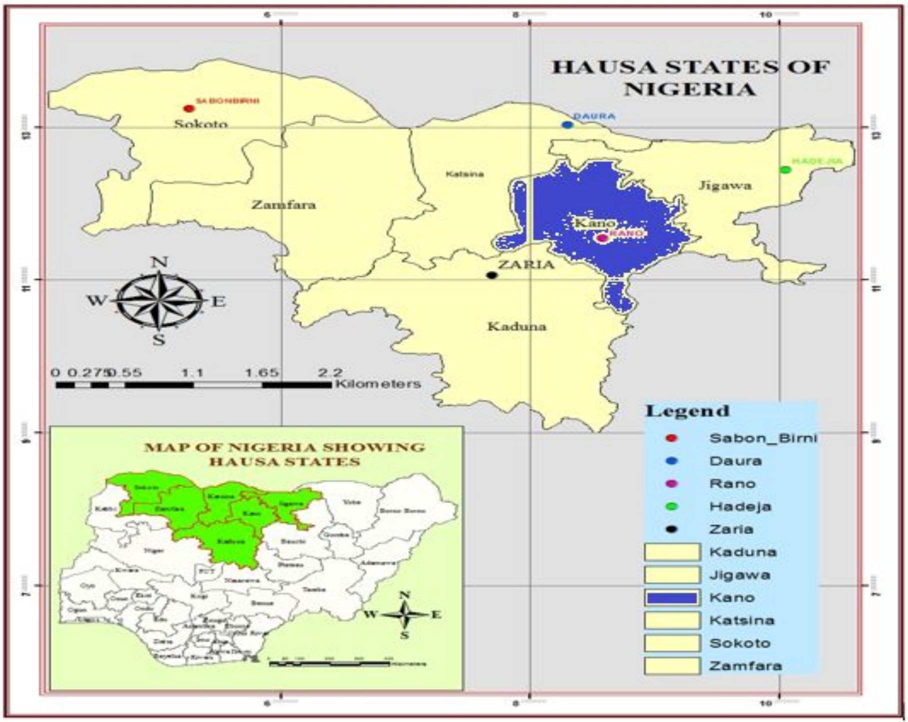


Figure 1: Map of Nigeria state showing the study location

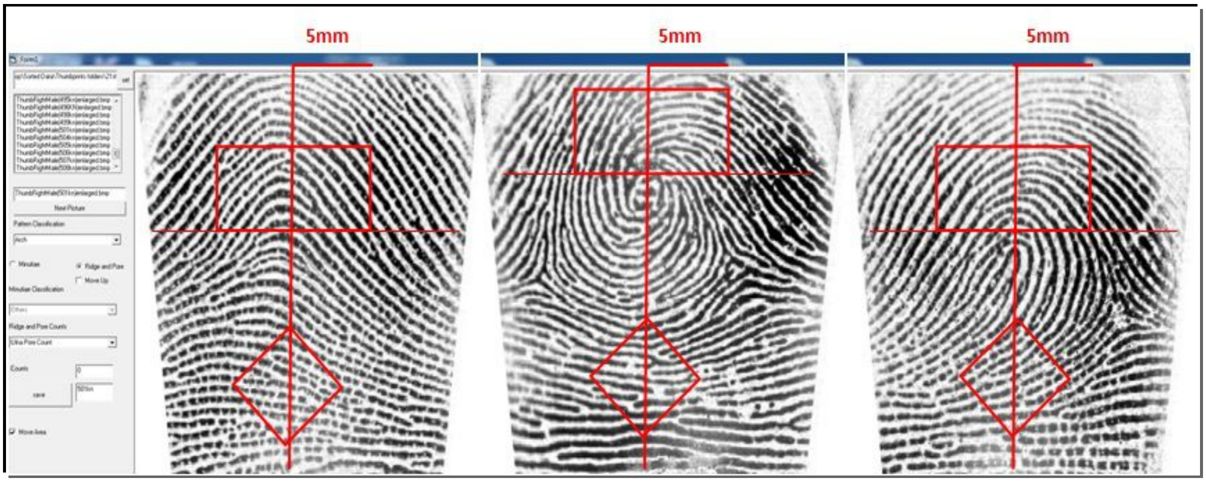
Anthropometry of Height, Weight and Body Mass Index

The height was measured as a vertical distance between the standing surface and the vertex of the head using a stadiometer (RGZ, 160). Body weight of the subjects was measured using digital weighing scale and BMI; calculated as weight in kg divided by height in m^2. [2]

Anthropometry of Thumbprint Profiles

The thumbprint was captured using a live scanner (digital persona, China). Each thumbprint was classified into any of the three basic patterns; arches whorls and loops (Figure 2). [7]

For ridged density, the method described by Acree [9] and Gutiérrez-Redomero et al. [10] was adopted (Figure 2). Indirect method of the ridge thickness measurement was used as proposed by Cummins. [11]



Arch pattern **Whorl pattern** **Loop**

Figure 2: Spaces (5mm x 5mm) on ulnar, radial and proximal of fingerprint for ridge density and thickness determination for three classes of fingerprint

The minutiae count was made according to the method described by Okajima, [12] using magnified images (at 7.74 ratios) of the thumbprint. The minutiae were classified into any of the sixteen types (Figure 3) as proposed by previous works. [13, 14]

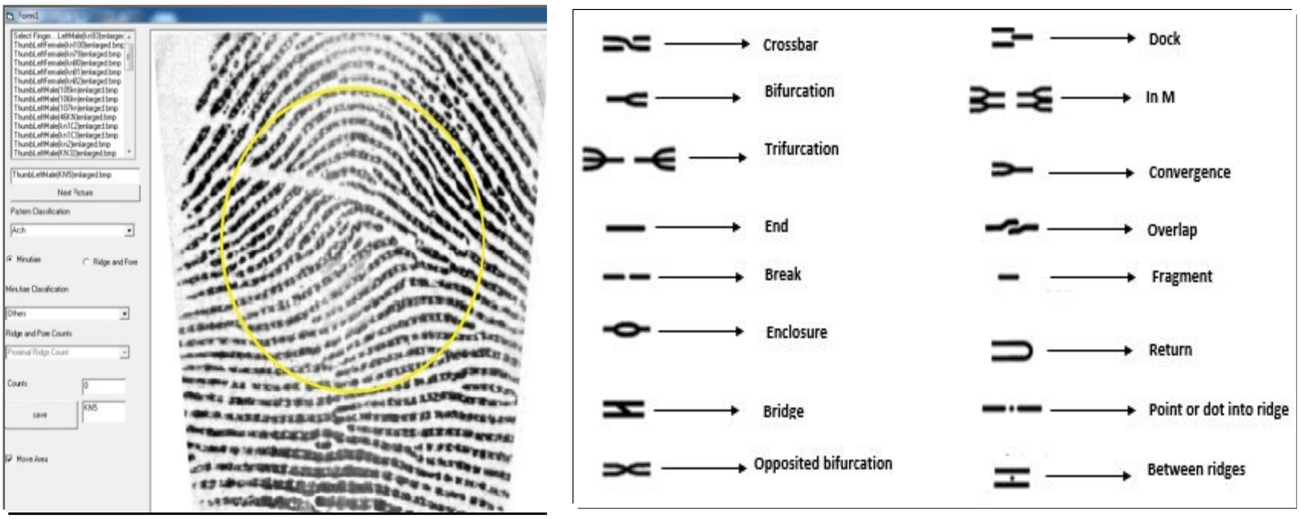


Figure 3: Thumbprint divided into minutiae counting area (within the circle) and on counting area (outside the circle), and minutiae classification

Measurement Error

Precision of Measurements

To quantify precision, two sets of measurements taken were compared using technical error of measurement (TEM). [15] This allowed assessment of random error.

Absolute TEM = $di^2/2n$, where: Σd^2 = summation of deviations (The difference between the 1st and 2nd measurements) raised to the second power; n = number of volunteers measured i = the number of deviations. The absolute TEM was expressed as percentages as follows;

Relative TEM = × 100, Where, VAV= Variable average value, this is the arithmetic mean of the mean between both measurements obtained (1st and 2nd measurements) of each volunteer for the same variable. The percentage scores exceeding 10% were deemed poor. [16]

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", 0.6 to < 0.8 "substantial reliability". [17] 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. This allowed assessment of systematic error (bias error). This was considered as substitute of method error since in minutiae count there is always a possibility of zero count (absence of particular type of minutiae).

Data Analysis

The data was expressed as mean ± standard deviation. After normality test (Shapiro-Wilk test, $p < 0.05$) Mann-Whitney test was used to assess the differences between the sexes. Pearson's correlation analysis was used for relationship between thumbprint profile and BMI with facial profiles. Stepwise multiple regression analysis was used to predict BMI from thumbprint profiles. SPSS version 20 statistical software was used for the statistical analysis and $P < 0.05$ was set as level of significance

Results and Discussion

The descriptive statistics showed that significant mean differences in minutiae were only observed in ridge end, break, bridge, opposite bifurcation and point or dot between ridges in the right thumb. For the left thumb different variables exhibit sex differences. Ridge bifurcation, cross bar, end, enclosure small, convergence, fragment small, return, point or dot into ridges and point or dot between ridges. In most of the minutiae, males tend to have higher count compared to female counterparts (Table 1). There were no significant mean differences in ridge count and thickness in all the areas except for ulnar and proximal for right and left thumbs respectively. Males had higher ridge count in the left proximal and females for the right ulnar count (Table 2).

It was suggested that the difference between males and females in a given ridge characteristics such as thumbprint features may be linked to sexual dimorphism in body proportions in which on average males have larger body frame than females. [18, 19] It was noticed that in minutiae counts male tend to have higher count in minutiae that may form as a result of division of an existence ridges like ridge enclosure, ridge bifurcation, not minutiae that form as a result of relationship between two ridges as seen in cross bar. Hence, this supports the evidence that the males have coarser ridges than the females by approximately 10%. [20] However, the reverse of this phenomenon in some areas (proximal areas) of the fingerprint may further suggest additional factors such as differences in genetic make-up between the sexes as well differences in developmental instruction of different areas of fingerprints. [21]

Table 1: The Mean and Standard Deviation of Minutiae Count of Males and Females of Both Left and Right Thumbs

	Right						Left					
	Male		Female				Male		Female			
Variables	Mean	SD	Mean	SD	Z value	P value	Mean	SD	Mean	SD	Z value	P value
Bifurcation	2.96	2.21	3.13	2.07	-0.825	0.409	4.11	3.01	3.10	2.41	-2.478	0.013
Crossbar	0.05	0.22	0.08	0.34	-0.512	0.608	0.15	0.50	0.03	0.16	-2.419	0.016
Trifurcation C	0.04	0.18	0.04	0.24	-0.037	0.97	0.02	0.13	0.02	0.13	0.00	1
Trifurcation B	0.01	0.09	0.03	0.16	-0.963	0.335	0.06	0.24	0.04	0.25	-0.891	0.373
End	4.60	3.17	3.18	2.61	-3.595	<0.001	4.98	3.51	2.67	2.19	-5.536	<0.001
Break	0.59	1.33	1.45	1.93	-4.785	<0.001	0.55	1.10	0.69	1.25	-0.761	0.446
Enclosure(big)	1.39	1.49	0.85	1.10	-2.795	0.005	1.08	1.33	1.14	1.15	-0.992	0.321
Enclosure(small)	1.04	1.65	0.68	0.90	-0.703	0.482	0.66	1.05	0.33	0.91	-3.24	0.001
Bridge	0.12	0.36	0.47	0.92	-3.597	<0.001	0.18	0.49	0.38	0.87	-1.758	0.079
Opposite Bifurcation	0.18	0.45	0.04	0.20	-2.818	0.005	0.18	0.43	0.19	0.44	-0.318	0.75
Dock	0.06	0.33	0.07	0.25	-0.755	0.45	0.01	0.09	0.04	0.24	-1.358	0.175
In "M" C	0.00	0.00	0.08	0.49	-2.217	0.027	0.04	0.19	0.04	0.21	-0.326	0.744
In "M" B	0.04	0.21	0.02	0.13	-1.184	0.236	0.08	0.27	0.04	0.21	-1.101	0.271
Convergence	1.53	1.38	1.74	1.61	-0.75	0.453	1.14	1.32	2.02	2.01	-2.962	0.003
Overlap	0.25	0.55	0.22	0.46	-0.106	0.915	0.15	0.40	0.17	0.46	-0.193	0.847
Fragment Big	0.33	0.71	0.53	1.23	-0.156	0.876	0.31	0.73	0.57	1.10	-1.212	0.225
Fragment Small	0.57	1.38	0.53	1.18	-0.39	0.697	0.49	1.00	0.33	1.14	-3.245	0.001
Return	0.02	0.13	0.07	0.34	-1.381	0.167	0.00	0.00	0.09	0.31	-3.054	0.002
Point or dot into ridge	0.08	0.38	0.14	0.48	-1.388	0.165	0.21	1.14	0.00	0.00	-2.681	0.007
Point or between ridges	2.40	3.30	1.86	3.08	-2.388	0.017	1.96	3.05	0.49	1.59	-5.888	<0.001

C; convergence, B; bifurcation, M; letter M shape

Table 2: The Mean and Standard Deviation of BMI, Ridge Count and Thickness of Males and Females of Both Left and Right Thumb

	Male		Female			
Variables	Mean	SD	Mean	SD	Z value	P value
BMI	20.00	2.40	20.35	4.56	-1.009	0.313
Right ulnar ridge count	10.06	1.30	10.91	1.62	-4.55	<0.001
Right ulnar ridge thickness	0.71	0.09	0.66	0.10	-4.55	<0.001
Right radial ridge count	10.48	1.52	10.18	1.90	-1.083	0.279
Right radial ridge thickness	0.68	0.10	0.71	0.15	-1.083	0.279
Right proximal ridge count	9.78	1.31	9.70	1.65	-0.272	0.786
Right proximal ridge thickness	0.73	0.10	0.74	0.14	-0.272	0.786
Left ulnar ridge count	10.42	1.48	10.70	1.51	-1.449	0.147
Left ulnar ridge thickness	0.69	0.11	0.67	0.11	-1.449	0.147
Left radial ridge count	10.65	1.46	10.31	1.70	-1.79	0.073
Left radial ridge thickness	0.67	0.10	0.70	0.13	-1.79	0.073
Left proximal ridge count	9.77	1.13	9.17	1.52	-2.961	0.003
Left proximal ridge thickness	0.73	0.08	0.79	0.15	-2.961	0.003

SD; Standard Deviation

Table 3: The Correlation between BMI with Minutiae Counts, Ridge Count and Thickness in Males and Females

	Male		Female	
	BMI	BMI	BMI	BMI
Variables	Right	Left	Right	Left
Bifurcation	-0.05	-0.22*	-0.13	0.02
Crossbar	0.27**	-0.09	0.07	-0.02
Trifurcation C	-0.12	0.01	-0.03	-0.06
Trifurcation B	-0.05	-0.01	-0.05	-0.03
End	0.07	0.04	0.00	-0.03
Break	-0.12	-0.07	0.04	-0.04
Enclosure(big)	-0.08	0.00	0.03	0.03
Enclosure(small)	0.01	0.12	-0.01	0.30**
Bridge	-0.06	0.11	-0.11	-0.06
Opposite Bifurcation	-0.17	0.04	0.00	0.19*
Dock	0.07	-0.07	0.00	-0.06
In "M" C	0.00	0.07	-0.04	-0.12
In "M" B	-0.25**	0.12	0.12	-0.02
Convergence	-0.03	-0.02	0.01	0.05
Overlap	0.00	0.03	0.09	-0.04
Fragment Big	0.00	.252**	0.03	-0.09
Fragment Small	0.09	0.12	0.07	-0.10
Return	-0.17	0.00	0.15	-0.13
Point or dot into ridge	-0.10	0.03	-0.01	0.00
Point or between ridges	0.12	0.05	-0.06	0.01
Ulnar ridge count	-0.21*	0.04	0.07	-0.09
Ulnar ridge thickness	0.22*	-0.06	-0.07	0.09
Radial ridge count	-0.06	0.01	-0.10	-0.13
Radial ridge thickness	0.08	-0.01	0.10	0.06
Proximal ridge count	-0.16	0.10	0.02	0.08
Proximal ridge thickness	0.16	-0.11	-0.01	-0.10

C; convergence, B; bifurcation, M; letter M shape * $p < 0.05$, ** $p < 0.001$

The results showed that BMI correlates positively with crossbar (r=0.27, $p < 0.05$), ulnar ridge thickness (r=0.22, $p < 0.05$) and fragment big (r=0.30, $p < 0.05$) in males. For females the correlation was observed only in enclosure small (r=0.30, $p < 0.05$) and opposite bifurcation (r=0.19, $p < 0.05$) (Table 3). This is in agreement with study done on other populations. [22] For example, in a study of the influence of body size on the fingerprint ridges, it was suggested that weight and BMI correlated with ridge breadth. [22] The pattern of relationship of BMI and thumbprint profile may not be preserved across population. The fingerprints profile may likely be associated with variables that have more affinity to genetic factor compared to the environmental factors. Therefore population-specific study for establishment of relation may be useful in developing population-specific formulae for prediction of BMI from fingerprints.

The use of anthropometry in estimation of the main body components is common practice among scientists due to its simplicity and non-invasive nature. [23] Under certain conditions, medical practitioners use "best guess" estimate of body variables such as weight of patient or assign a conventional weight of 70 kg for a male or 60 kg for a female. [24] Similar scenario may occur with respect to body mass index which is a more powerful tool for assessing the fat composition of an individual than the weight alone. In the present study, the best single predictor of BMI in the male was crossbar (R^2= 0.08.76) and fragment big (R^2= 0.0651) for right and left thumbprints respectively. In the female participants, only enclosure small (R^2= 0.0765) of the left was the best predictor (Table 5). This supports the previous finding which established obesity-related gene and pattern of fingerprint formation, [7] and high arch pattern on the first right digits as peculiarity of obese individuals. [2] Obesity is well defined by BMI of the individuals; therefore, it is possible to compute the BMI of an individual using direct and / or indirect anthropometry.

From Table 5, it was observed that the analyses that combined left and right into a single factor, revealed that right crossbar (R^2= 0.1701) and left enclosure small (R^2= 0.1197) were the single best predictors of BMI in male and female respectively. However, considering other variables (such as ridge return) that were selected in subsequent steps in the equations, it can be seen that the variable alone has no correlation with BMI (Table 3) but when combined with other variables, they increase correlation potential as such contribute to the prediction. This may suggest that even variable that shows no correlation at bivariate (Pearson's correlation) level of analysis may be useful in subsequent multivariate analyses (stepwise analysis).

Table 4: Count, and Thickness for both Left and Right Thumbprints Separately in Male and Female

Sex	Side	Model	R	R Square	SEE	F	P
Male	Right	1. BMI= 19.995 + 3.75 (cross bar)	0.296	0. 0876	2.33	9.98	0.002
		2. BMI= 20.11 + 3.64(cross bar) + In "M" bifurcation (-2.93)	0.375	0.1407	2.27	8.44	<0.001
		3. BMI= 15.97 + 3.51(cross bar) + In "M" bifurcation (-2.79) + 5.82 (ulnar ridge thickness)	0.428	0.1836	2.23	7.65	<0.001
		4. BMI= 14.96 + 3.39(cross bar) + In "M" bifurcation (-2.84) + 7.35 (ulnar ridge thickness) + return (-4.29)	0.489	0.2388	2.16	7.92	<0.001
	Left	1. BMI= 19.69 + 0.83 (fragment big)	0.255	0.0651	2.33	7.09	0.009
		2. BMI= 20.33 + 0.84(fragment big) + bifurcation (-0.16)	0.323	0.1042	2.30	5.88	0.004
Female	Right						
	Left	BMI= 19.84 + 1.27 (Ridge Enclosure small)	0.277	0.0765	4.241	7.95	0.006

Stepwise multiple regression analyses for prediction of BMI from minutiae count, ridge

Table 5: Stepwise Multiple Regression Analyses for Prediction of BMI from Minutiae Count, Ridge Count and Thickness for Both Left and Right Thumbprints Combined in Male and Female

Sex	Model	R	R Square	SEE	F	P value
Male	BMI= 19.95 + 1.69 (right cross bar)	0.41	0.1701	2.25	16.20	<0.0001
	BMI= 26.55 + 5.08 (right cross bar) + right ulnar ridge count (-0.67)	0.52	0.2741	2.12	14.73	<0.0001
	BMI= 27.69 + 4.97 (right cross bar) + right ulnar ridge count (-0.77) + right return (-5.52)	0.58	0.3335	2.05	12.84	<0.0001
	BMI= 27.60 + 4.83 (right cross bar) + right ulnar ridge count (-0.75) + right return (-5.62) + in "M" bifurcation	0.63	0.3940	1.96	12.35	<0.0001
Female	BMI= 19.73 + 1.69 (left enclosure small)	0.35	0.1197	4.33	11.01	0.001
	BMI= 20.18 + 2.04 (left enclosure small) + right bridge (-1.42)	0.43	0.1850	4.19	9.08	<0.0001
	BMI= 19.92 + 2.09 (left enclosure small) + right bridge (-1.33) + right return (2.83)	0.49	0.2382	4.08	8.23	<0.0001
	BMI= 20.13 + 2.17 (left enclosure small) + right bridge (-1.41) + right return (3.27) + Left return (-3.24)	0.53	0.2826	3.98	7.68	<0.0001
	BMI= 19.99 + 2.19 (left enclosure small) + right bridge (-1.36 + right return (3.32) + Left return (-3.16) + right in "M" bifurcation (8.38)	0.57	0.3227	3.89	7.34	<0.0001

In conclusion, the present study demonstrated that BMI can be predicted from thumbprint ridge minutiae count and thickness among Hausa ethnic group of Nigeria. However, the minutiae count showed more potential in the prediction compared to the ridge density and thickness. The single best predictors were ridge cross bar and enclosure small for male and female respectively. It was also revealed that some variables may not correlate significantly with BMI unless when in combination with other potential variables. Hence, this study further portrays the importance of multivariate analysis in the establishment of relationship between variables such BMI and thumbprints features.

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Conflict of Interest
The authors have declared that there is no conflict of interest

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