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Estimation of Body Mass Index from Toe Length of Adult Yoruba Populace in Nigeria

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ABSTRACT

Anthropometric measurements are quick and relatively easy to obtain and require inexpensive equipment. Body Mass Index (BMI) is a simple index of weight-for-height that is commonly used to classify underweight, overweight and obesity in adults. Determination of BMI will help in early detection of some related diseases and could also aid forensic investigation when unraveling the identity of an unknown person is essential. 490 adults Yoruba traced to their grandparents, with equal percentage of males and females with age $\geqslant$ 18years and consented were involved in the study. Toe length (1T big toe - 5T little toe) was measured using digital vernier caliper, foot length was measured using steel meter rule, height was taking using stadiometer and weight using weighing scale and BMI was calculated in. SPSS (IBM®) t-test was to compare gender difference in the measured dimensions; while Automatic & Generalized Linear Modeling were used to determine the predictability of BMI from the toe lengths. The significance level was set at 95% as $P \leqslant 0.05$ was considered significant. Results of t-test revealed a significant higher value in all the toe lengths in males compared to females ($P<0.05$). The automatic regression analysis of the females displayed significantly higher prediction of BMI for R.2T, R.5T and L.5T ($P<0.001$). While the toe length of the males showed no prediction of BMI. Concurrently, the foot length did not predict BMI ($P>0.05$). Therefore this provides alternative method of BMI estimation and could serve as complement in forensic anthropometry. However this is gender specific thus require caution in its usage.

Keywords: Yoruba, BMI, Toe length, Foot length, Regression.

INTRODUCTION

Anthropometry is often viewed as a traditional and perhaps the basic tool of biological anthropology. It has a long tradition of use in forensic sciences and it is finding increased use in medical sciences [1]. The main aim of an anthropometrist employed in the forensic medicine and medical sciences, working with unknown variables, is to describe the human remains in such terms so that one can achieve the goal of estimating age at the time of death, sex, stock or race or ancestry or ethnicity, stature or height, body weight or body build, details of individualizing characteristics [2,1]. All human beings inhabiting this earth are of the same species the "***Homo sapiens***". Nevertheless, no two individuals are exactly alike in all measurable traits, even genetically identical twins (monozygotic) differ in some respects [1]. These traits tend to undergo change of varying degrees from birth to death, in health and disease, and since skeletal development is influenced by a number of factors producing differences in skeletal proportions between different geographical areas, quantitative expression to variations which such traits exhibit cannot be over emphasized. Anthropometry constitutes that means, as it is the technique of expressing quantitatively the form of the human body. In other words, anthropometry means the measurement of human beings, whether living or dead or on skeletal material [3].

In adults and children anthropometric measurements can be used to estimate body fat and lean body mass, and assess their distribution and change over time [4]. Anthropometric measurements are quick and relatively easy to obtain and require inexpensive equipment [4].

Body Mass Index (BMI) is a simple index of weight-for-height that is commonly used to classify underweight, overweight and obesity in adults. It is defined as the weight in kilograms divided by the square of the height in meters (kg/m^2). For example, an adult who weighs 70kg and whose height is 1.75m will have a BMI of 22.9 kg/m^2 [5]. Using a measure such as BMI allows for a person's weight to be standardized for their height, thus enabling individuals of different heights to be compared. BMI is the most commonly used measure for monitoring the prevalence of

overweight and obesity at population level [5]. It is also the most commonly used way of estimating whether an individual person is overweight or obese. The recommended BMI cut-off point for evaluating individuals as overweight and obese is 25 kg/m2, and 30 kg/m2, respectively [6]. The WHO classifies overweight or obesity as the fifth leading risk factors for death, responsible for 7% of death globally [7]. It is estimated that at 40 years of age, an obese person will live up to seven years less than someone of normal weight. Obesity is associated with a range of comorbidities called metabolic syndrome. There is increase in the risks of diabetes, hypertension and dyslipidemia with increasing body weight [7]. Excess body fatness is convincingly associated with a range of cancers and reducing obesity was one of the key recommendations of the 2007 World Cancer Research Fund report on cancer prevention [8].

To the best of our knowledge, there has been no parallel study of the relative lengths of the toes of humans and its forensic implication. Hence there are few works done and or reported on the anthropometry of toes in humans [9]. Few research works described toe length to be sexually dimorphic [9, 10, 11, 12] but there is however paucity of data on its relationship with height, body weight or BMI. Therefore this work is probably the first documented research on the relationship of the toe length with BMI in Nigeria.

MATERIALS AND METHODS

The present study was carried out in Ogbomoso,Oyo State, on 490 (245 males and 245 females) Adults (⩾ 18years) belonging to Yoruba ethnicity in Nigeria. Samples were drawn from the different state representing the enthic groups with indiginicity traced to 2nd generation. Sample size was determined by proportion using Fisher's formula for large population (>10,000) or infinite population; [13]. Multistage stratified sampling technique was used and bio data of the subjects were gotten using semi structured questionnaire from respondents who gave their consent. Ethical clearance was gotten from the University of Port Harcourt.

Anthropometric measurement

With the knwoledge of the international agreement for paired measurements at Geneva (1912) [14], the toe lengths of both feet were measured during dorsi flexion (at well seated posittion) using a digital venier caliper (in mm) ; defined by the distance between the tip of the toe to the proximal metatarsophalangeal crease of that toe when fully extended for both feet.The toe length tagged 1T-5T from the great toe (1st toe) to the little toe (5th toe) for both right (R) and left (L) feet (Fig.1). Foot length was also measured for possible prediction of BMI, (right foot length, RFL and left foot length, LFL) is the distance from the tip of the big toe to the heel using a steel meter rule (in mm) (Fig.2). While the height was taken in standing position using a standiometer (in m). Weight was taken using Weighing scale (in Kg). Measurements were taken based on standard anthropometric principles. Subject(s) with any disease of the foot/toe or deformity, and/or statural deformity were excluded from this study.

BMI: The body mass index for a person is defined as their body mass divided by the square of their height. The weight (kg) and height (m) of each subject is used for the calculation [4,5].

Figure 1: Measurement of toe length using a digital venier caliper

Figure 2: Measurement of foot length using a steel meter rule

Statistical analysis

The data obtained were computed using EXCEL (2007) and analyzed using Statistical Package for Social Sciences, version 23.0 (SPSS, IBM®) and XLSTAT (2015; version 4.0.1). *t-test* analysis of mean differences between the sexes. Automatic & Generalized Linear Modeling (Regression analysis) were used to determine the predictability of BMI from the toe lengths; P values ⩽ 0.05 were taken to be statistically significant.

RESULTS

In the presented result, population distribution of the contributing states from which the Yoruba ethnic group were drawn includes Oyo State which had the highest population of 34.7%, followed in the decreasing order, Osun State, Ekiti State, Ogun State, Ondo State and Lagos State with the following percentages, 25.3%,13.7%,11.4%,9.4% and 5.7% respectively.

Descriptive statistics of the toe lengths in males and females are shown in Table 1.

All the foot dimentions (toe length and foot length) were significantly longer in males when compared to females (P>0.05) (Table 1).

The automatic and manual linear models were used to determine the strength of the contributing predictor variables. To determine the single variable prediction as the gender-specific regression model; thus, only those that showed satistically significance had their regresssion equation stated for single variable regression analysis (Tables 2&3).

From the univariable regression model in Tables 2&3, the estimation of BMI of the Yoruba populations was observed to correlate negatively with foot measurements with a very low accuracy (R-sq=0.00-7.50). Prediction of the BMI of the Yoruba male population was observed to be statistically inaccurate and unreliable as no variable was a significant predictor (P>0.05). All variables except for L.1T (R-sq=0.38; *P*=0.096), RFL (R-sq=0.37; *P*=0.098) and LFL (R-sq=0.17; *P*=0.258) were significant predictors of the BMI of Yoruba female population (P<0.05). R.2T, R.5T and L.5T in females were strongly significant predictors of BMI (P<0.001).

Table 1: Descriptive characteristics of measured parameters

TRIBE	Yoruba Male (N=245) Mean±S.D	Yoruba Female (N=245) Mean±S.D
AGE(Yrs)	23.04±6.07	26.44±10.75
HEIGHT(m)	1.72±1.54	1.61±0.07
WEIGHT(kg)	64.42±10.01	60.89±12.01
BMI (kgm-2)	21.82±3.07	23.43±4.55
R.1T(mm)	47.36±3.76	43.25±3.59
R.2T(mm)	35.81±4.67	31.29±4.27
R.3T(mm)	29.47±3.97	26.04±0.24
R.4T(mm)	25.28±3.69	22.12±3.21
R.5T(mm)	22.02±2.84	18.97±2.04
L.1T(mm)	46.07±3.70	42.48±3.19
L.2T(mm)	35.33±4.56	31.11±4.26
L.3T(mm)	29.32±3.83	25.55±3.75
L.4T(mm)	25.07±3.62	22.00±3.02
L.5T(mm)	21.47±2.40	18.74±2.10
RFL(mm)	269.20±13.12	245.73±11.80
LFL(mm)	269.86±12.68	246.71±11.86

Table 2 : Prediction model for BMI of male population (with regression equations)

Variables	YORUBA BMI PREDICTION (in Kgm^{-2})		
	R_E	R^2(%)	P-Value
R.1T(mm)	No Prediction	0.14	0.599
R.2T(mm)	No Prediction	0.02	0.840
R.3T(mm)	No Prediction	0.02	0.809
R.4T(mm)	No Prediction	0.85	0.149
R.5T(mm)	No Prediction	0.87	0.145
L.1T(mm)	No Prediction	0.09	0.649
L.2T(mm)	No Prediction	0.04	0.744
L.3T(mm)	No Prediction	0.01	0.888
L.4T(mm)	No Prediction	0.00	0.971
L.5T(mm)	No Prediction	0.94	0.130
RFL(mm)	No Prediction	1.25	0.080
LFL(mm)	No Prediction	0.79	0.166

Note: R^2- Coefficient of determination; R_E - Regression Equation, R - right, L - left, T - toe

Table 3: Prediction model for BMI of female population (with regression equations)

Variables	YORUBA BMI PREDICTION		(in Kgm^{-2})
	R_E	R^2(%)	P-Value
R.1T(mm)	26.71-0.0854 R1T	0.71	0.023
R.2T(mm)	27.56-0.1419 R2T	2.76	<0.001
R.3T(mm)	25.96-0.1124 R3T	1.27	0.002
R.4T(mm)	25.296-0.1033 R4T	0.83	0.014
R.5T(mm)	27.81-0.2457 R5T	2.59	<0.001
L.1T(mm)	No Prediction	0.38	0.096
L.2T(mm)	25.97 - 0.0943 L2T	1.17	0.003
L.3T(mm)	25.02 - 0.0791 L3T	0.62	0.033
L.4T(mm)	25.20 - 0.0998 L4T	0.71	0.022
L.5T(mm)	28.28 - 0.2738 L5T	2.78	<0.001
RFL(mm)	No Prediction	0.37	0.098
LFL(mm)	No Prediction	0.17	0.258

Note: R^2 -Coefficient of determination; R_E, Regression Equation; R - right; T - toe; L - left

DISCUSSION

The aim of the study is to develop a cheap, easily accessible and alternative method for determination of BMI, for the purposes of early detection of body mass index related diseases and forensic investigation when unraveling the identity of an unknown person is essential.

However, there is scarcity of data with respect to toe length anthropometry [9], and perhaps paucity of literature regarding correlation between the toe length and BMI.

McFadden and Shubel [9] discovered that the average toe length were in the following order from the longest to the shortest, which was the same for both sexes i.e. 1T,2T,3T,4T and 5T. This tallies with the order of toe length in this present study.

The significant longer toe length in males compared to females in this study agrees with the findings of McFadden and Shubel, in Texas [9], Voracek and Dressler, among Austrian adults [11], Abledu *et al*., [15] among Ghanians and Alabi *et al*., [12] among Igbos in Nigeria.

Various body structures; most especially volumetric components have been demonstrated to correlates with body size, fat mass and body mass index (BMI) [16]. Relatively few studies conducted have utilized linear measurements in predicting BMI; however, much research have utilized quantitative variables such as; cross-sectional properties [17, 18].

From this study, no determined foot dimension of males significantly contributed to the prediction model for estimating Body Mass Index. But in females, R.2T, R.5T, and L.5T were the strong, significant predictors of BMI; with negative contributions to the model from R.2T, R.5T and L.5T. However, the regression model developed had very low accuracy (R^2=2.78%, 2.76% and 2.59% for L.5T, R.2T and R.5T respectively). Subsequently other foot dimension in females except L.1T, RFL and LFL also predict BMI but of a weaker effect. The results of the univariate predictions of BMI from foot length showed that none of observed variables significantly predicted the BMI of males and females.

CONCLUSION

In conclusion, some of the toe length can accurately estimate BMI among Yoruba ethnicity in Nigeria. However this is gender specific, thus caution must be taking in its usage as alternate method of BMI determination in the clinical practice and as a complement in forensic investigations.

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