

ANTHROPOMETRIC PREDICTIVE EQUATIONS FOR PERCENTAGE BODY FAT IN NIGERIAN WOMEN USING BIOELECTRICAL IMPEDANCE AS REFERENCE

Oketayo, O.O. and Ojo, J.O.

Department of Physics, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

Corresponding author's e-mail address:

jojo@oauife.edu.ng

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ABSTRACT

The objective of this research was to develop improved predictive regression equations specific for Nigerian women for body fat estimation derived from common anthropometric measurements. Eighty-one healthy Nigerian female subjects between the ages 18 and 52 years were recruited. Height, weight, chin, biceps, triceps, scapular, subscapular, abdominal and suprailiac skinfolds; neck, forearm, wrist, abdominal, waist and hip circumferences for these subjects were measured. Height was measured by a centimeter rule, skinfolds were measured using a Lange skinfold caliper, circumferences were measured using a soft-tape rule and body weight was obtained using an electronic weighing scale. In this preliminary work, body fat was measured for each subject using a commercial bio-impedance-based device used as the reference. Statistical analysis on data obtained was carried out using SPSS 15.0. Predictive regression equations (with $r^2 = 0.931$ and 0.945 respectively) that worked better for Nigerian women compared to other existing equations such as Durnin and Wormersley, Siri, Vogel *et al.*, (1984) for the estimation of body fat were obtained. These equations could be validly used for mass screening exercise in epidemiological studies, nutrition/clinical studies, and in lieu of the bioelectrical impedance method.

Keywords: Anthropometry, Predictive Equations, Percentage Body Fat, Nigerian Women, Bioelectric Impedance

INTRODUCTION

The importance of appropriate body fat in health and diseases is well established. Obesity and overweight are associated with the on set of clinical diseases such as coronary heart diseases, stroke, hypertension, high blood pressure, respiratory problem and diabetics. Underweight on the other hand is associated with conditions such as muscle weakness, irregular heartbeats, heart failure, irregular menstrual period and difficulty in getting pregnant (Dae, 2003; Mary *et al.*, 2001). Such simplified assessments of body fat as obese/overweight and underweight have been shown to have significant correlations with these important clinical conditions (Arora *et al.*, 2007; Chadha *et al.*, 2006).

Sophisticated 'direct' methods such as Under Water Weighing (UWW), Dual Energy X-Ray Absorptiometry (DEXA), Near Infrared Intereactance, Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Air Displacement and Isotope dilution have been established for human body composition (Ada *et al.*, 2006 ; Kenneth, 2001). However, they are expensive, time-consuming and also require that the subjects perform complex procedures with fixed dedicated equipment in a laboratory setting.

Fortunately, a good correlation exists between the total body fat and those fractions of body fat distributed superficially on various regions of the body such as hip, abdomen, forearm, wrist, scapulum and

subscapulum (Akinjide and Ojo, 2007). A convenient and very inexpensive method for assessing body fat therefore, is by carrying out multivariate regression analyses resulting in mathematical equations linking body fat with anthropometric parameters. Anthropometric predictive equations are invaluable for mass screening, epidemiological or field studies. It is a non invasive method and very easy to use once the skills have been mastered (Doyle, 2009).

Military institutions for instance assess the physical fitness of their personnel usually by anthropometry-based equations. Military personnel are required to comply with body weight or body fat standards. The military applicants who do not meet these standards are denied entry into the military while serving military personnel who do not meet these standards are classified as non-compliant and may be denied promotions or made to face other disciplinary actions (Babcock *et al.*, 2006).

Several body fat estimation equations exist in the literature but they were derived for other races such as Asians and Indians (Pranav *et al.*, 2009), Caucasian and African -American girls (Wong *et al.*, 2000), Mexicans (Naycli *et al.*, 2007) etc. The use of these equations for Nigerian subjects is obviously fraught with errors since body build and anthropometric parameters do vary very significantly from one race to another.

The primary objective of this research therefore is to make use of anthropometry to develop predictive regression equations for Percentage body fat in Nigerian female subjects.

MATERIALS AND METHODS

Ethical clearance for the study was obtained from the Ethics and Research Committee of the Obafemi Awolowo University Teaching Hospital Complex and a written consent was obtained from each subject before their recruitment into the study. Data obtained from the first 50 subjects were used to develop the predictive equations while those from the remaining 31 subjects were used for cross validation (age: 18–52 years, Mean age \pm SD = 29 \pm 9 years). According to Guo and Chumlea (1996), the sampling size (n) of at least 30 is adjudged as sufficient for the development of predictive equation for a given population. For each subject, the height was measured to the nearest 0.1cm by having the subject stand erect, looking straight ahead, against a calibrated wall. Body weight (with minimal clothing and without foot wears) was obtained to the nearest 0.1kg using an electronic weighing balance. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m). The neck, forearm, wrist, abdominal, waist and hip circumferences were measured with a standard tape rule to the nearest 0.1cm. Waist measurement were consistently taken at the level of the natural waist the narrowest part of the torso, while hip circumferences were measured at the maximum circumference of the buttocks posteriorly and the symphysis pubis anteriorly, in a horizontal plane. Skinfold thicknesses were also measured in triplicates at the chin, biceps, triceps, scapular, sub scapular abdomen and suprillium using Lange calipers (Beta Technology Incorporated Cambridge Maryland) to the nearest 0.1mm in accordance with World Health Organization (WHO) anthropometric guideline and operation manual. All measurements were carried out by trained female research Assistants. The Percentage body fat (% BF) obtained to the nearest 0.1% using a Tanita body composition analyzer (BF-350) which works by bioelectric impedance analysis (BIA) was used as reference.

Statistical analysis

The correct choice of statistical methods is essential for the development of predictive equation that will be accurate when applied to independent samples. In this study, SPSS 15 statistical package was employed to develop the predictive equations using selected anthropometric data obtained from the first 50 subjects as predictor variables. The reference % BF was obtained using bioelectrical impedance method.

The predictor variables were chosen using a forward selection regression procedure. This procedure involves the selection of predictor variable that has the highest correlation with the response variable to formulate a one-predictor variable equation. A second predictor variable that has the highest R^2 value with the response variable is then selected among the remaining predictor variables (to have a two-predictor variable equation). R^2 is the coefficient of determination and it represents the total variance in the response variable that is explained in the predictor variables in the equation. The larger the R^2 value, the better the equation fits the data. The significance of contribution to the equation is evaluated by the R^2 value, partial F-test and Standard error (SE). The procedure is continued until the inclusion of any of the remaining predictor variables does not significantly improve the equation (Guo and Chumlea, 1993).

The pure error (PE) measures the performance of a predictive equation on cross validation. It is the square root of the sum of the squared difference between the observed and predicted values divided by the number of subjects in the cross validation.

The smaller the pure error, the greater the accuracy of the equation when applied to the independent samples. The Root Mean Square Error (RMSE) is a measure of the precision of the predictive equation. When the equations are compared, the one with the smallest RMSE value has the highest precision. RMSE is calculated as

$$RMSE = \sqrt{\frac{\sum (observed - predicted)^2}{n - p - 1}} \dots\dots\dots(1)$$

where n is the no of observation and p is the no of predictor variables.

The residual plot is determined as

$$Residual\ plot = \frac{(Y - Y_{fitted})}{SD} \dots\dots\dots(2)$$

where Y = observed % BF and SD = standard deviation

To cross-validate the obtained equations, further thirty-one female Nigerian subjects were recruited from the same population. Anthropometric measurements were also carried out on them by the same field assistants using the same procedures and equipment.

The derived equations in this study were applied to these group with the pure error determined using the expression

$$PE = \sqrt{\frac{\sum (Y - \bar{Y})^2}{N}} \quad (3)$$

where \bar{Y} = predicted % BF and N = no of subjects.

Table 1: Descriptive Statistics of Skinfolts, Circumferences and other parameters

Group	Parameters	Range	Mean \pm SD
Physical/ Biophysical	Age (yrs)	18.0 – 52.0	28.2 \pm 8.4
	Height (cm)	146.0 – 173.0	159.8 \pm 5.9
	Weight (Kg)	39.2 – 105.8	59.8 \pm 14.1
	% Body fat	4.9 – 56.5	27.1 \pm 10.5
	BMI (kg/m ²)	16.7 – 40.3	23.3 \pm 4.8
Skinfolts (mm)	Chin SF	6.0 – 20.0	10.7 \pm 2.3
	Biceps	4.0 – 40.3	14.0 \pm 7.5
	Triceps	4.33 – 44.0	19.6 \pm 8.5
	Scapular	7.0 – 40.6	16.5 \pm 7.0
	Subscapular	7.0 – 45.3	17.8 \pm 8.9
	Abdominal SF	8.33 – 49.3	19.3 \pm 7.6
	Suprailiac	5.3 – 44.6	14.5 \pm 8.0
Circumferences (cm)	Neck CF	13.0 – 39.0	31.4 \pm 3.4
	Forearm CF	20.5 – 39.5	26.8 \pm 4.1
	Wrist	13.0 – 21.0	15.4 \pm 1.3
	Abdominal CF	60.0 – 116.0	79.0 \pm 13.5
	Waist CF	63.6 – 113.5	82.1 \pm 11.3
	Hip CF	78.2 – 123.0	96.3 \pm 10.7

Table 2: The Correlation Coefficients and Coefficients of Determination between the Anthropometric Parameters and Percentage Body Fat by Bioelectrical Impedance Technique

Parameters	R-Value	R ² Value
Hip CF	0.94689	0.89661
Weight	0.92978	0.86448
Forearm CF	0.85890	0.73771
Abdominal CF	0.77912	0.60703
Subscapular SF	0.73846	0.54533
Scapular SF	0.72703	0.52864
Wrist CF	0.70818	0.50151
Waist CF	0.67923	0.46135
Abdominal SF	0.67263	0.45243
Triceps	0.63175	0.39911
Biceps	0.62623	0.39228
Suprailiac SF	0.54767	0.29995
Neck CF	0.47673	0.22723
Chin SF	0.47470	0.23630

Table 3: The Model Summary for Predictive Equation 1

Source of variation	Sum of the squares	DF	Mean square	F-Statistics	P-value
Model	5562.989	2	2781.494	318.941	<0.0001
Residual	409.889	47	8.721		
Total	5972.878	49			

Table 4: The Model Summary for Predictive Equation 2

Source of variation	Sum of the squares	DF	Mean square	F statistics	P value
Model	5643.272	5	1128.654	150.667	<0.0001
Residual	329.606	44	7.491		
Total	5972.878	49			

Table 5: Comparison of the Developed Predictive Equations with Other Existing Ones

	Predictive equation 1	Predictive equation 2	Vogel <i>et al</i> (1984)	Durnin & Womersley (1971)	Akinjide & Ojo (2007)
Pure Error	2.2226	2.2618	7.1918	8.3029	2.3007
Correlation with BIA	0.9650	0.9720	0.6474	0.7199	0.9511

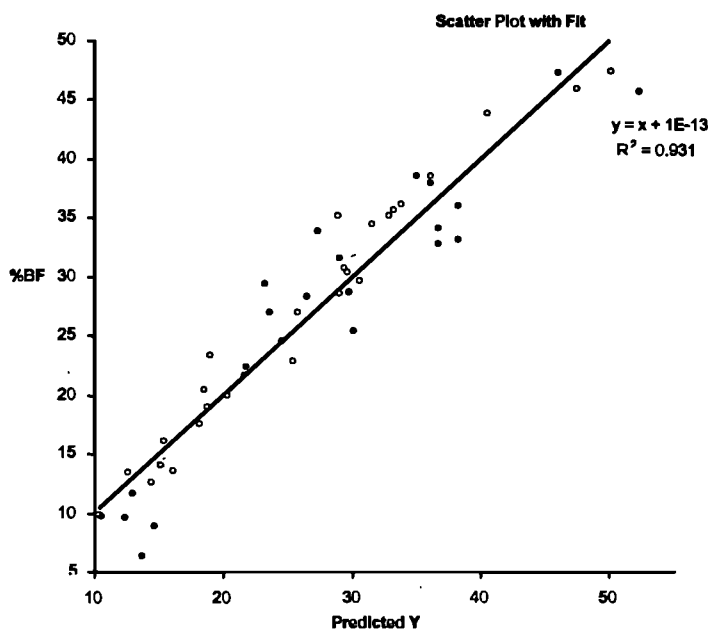


Figure 1a: Scatter Plot for Predictive Equation 1

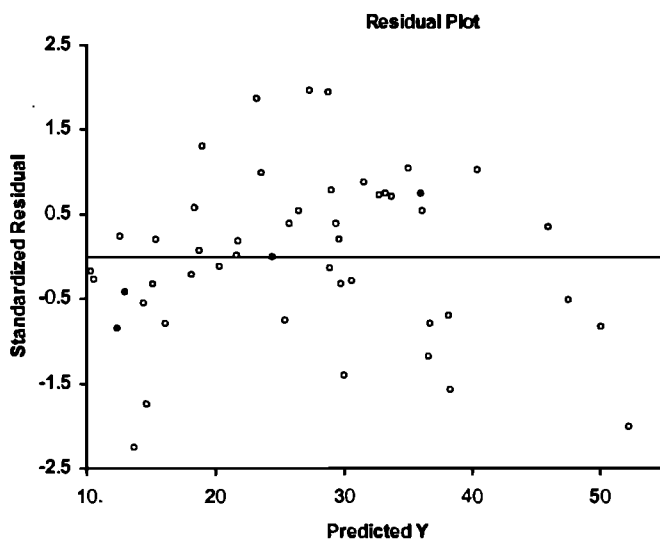


Figure 1b: Residual Plot for Predictive Equation 1

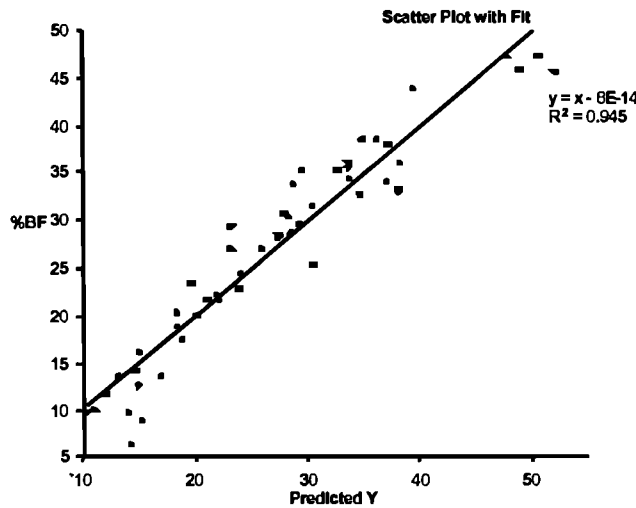


Figure 2a: Scatter Plot for Predictive Equation 2

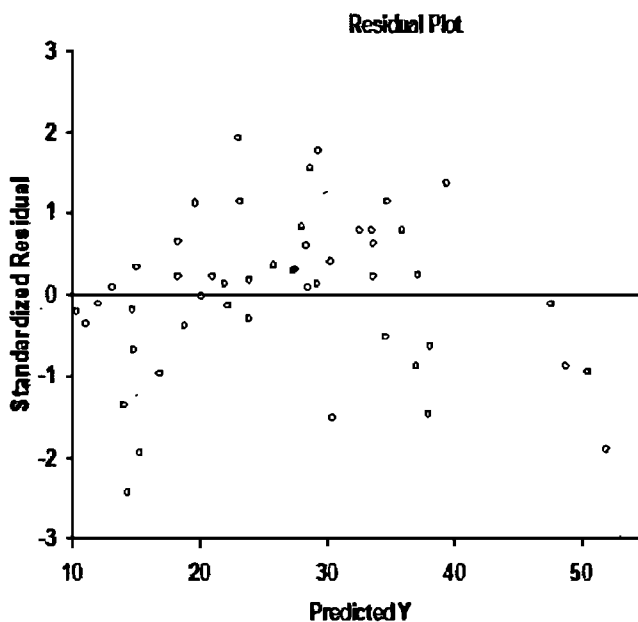


Figure 2b: Residual Plot for Predictive Equation 2

RESULTS

Table 1 shows the descriptive statistics of the parameters measured in this study while table 2 depicts the coefficients of determination (R^2) between the anthropometric parameters and the % BF by Bioelectrical Impedance Analysis.

Following the procedures described, two equations have been obtained. The first equation incorporated only hip circumference and subject's weight while the other equation employs circumferences of hip, forearm, abdomen and wrist with the subject's weight. Natural logarithm was introduced to further improve the R^2 values. The two equations are:

$$\%BF = -269.164 + 43.300\text{Ln Hip CF (cm)} + 24.188\text{Ln Weight (kg)}$$

$$(R^2 = 0.931, SE = 2.95)$$

and

$$\%BF = -233.323 + 43.955\text{Ln Hip CF (cm)} + 27.735\text{Ln Weight (kg)} + 13.639\text{Ln Forearm (cm)} - 9.386\text{Ln Abdominal CF (cm)} - 20.903\text{Ln Wrist CF (cm)}$$

$$(R^2 = 0.945, SE = 2.73)$$

The two equations provide a sort of trade-off between ease of measurements (2 parameters in the first and 5 parameters for the second) and precision or goodness of fit. It is intended that the first equation

involving two variables, might be preferred in some situations involving mass screening.

Tables 3 and 4 show the model summary for the two developed equations while the scatter and standard residual plots for the two models are presented in figures 1a & b and Figures 2a & b respectively.

DISCUSSION

The sites for fat distribution vary for each race of people, gender and age (Vogel *et al.*, 1984). The most important sites in order of decreasing importance, peculiar for the Nigerian subjects studied here, are hip, forearm, scapular, subscapular, waist, wrist, tricep, bicep, supriliac, neck and chin (Table 2). This is the reason why predictive equations based on other races such as caucasians (Durnin and Womersley, 1974), Mexicans (Nayeli, 2007) and others (Kotler, 1996) are inappropriate for the blacks. Even among the blacks, body built differs with ethnicity, growth, sexual maturation and physical activity (Vogel *et al.*, 1984).

Table 5 shows the comparison of the equations developed in this work with the existing predictive equations. At 95% confidence interval, the regression sum of the squares (5562.989 and 5643.272) are significantly higher than the residual sum of the squares (409.889 and 329.606) for equations 1 and 2 respectively, which indicates that about 95% of the variation in percentage body fat is explained by the model (table 3 and 4). Residuals are estimates of the true errors in the model. For the two models, the regression standardized residual plots give a normal curve indicating that the error terms in the predicted values of % BF are normally distributed.

It is particularly remarkable that the hip circumference, in particular, has such a high correlation with % BF ($R = 0.9468$ at $p < 0.05$). This indicates that the hip circumference could be a strong predictor or a well validated measure of the body fat of women in this category. This shows the relevance of including hip circumferences in developing predictive equations for these subjects which has been adequately taken care of using forward selection stepwise regression procedure as against the predictive equation by Akinjide and Ojo (2007) for Nigerian female subjects within the same age bracket using backward elimination method of selecting predictor variables.

CONCLUSION

Two improved predictive equations based on anthropometric measurements have been obtained for Nigerian women in child bearing age. The equations, when applied to another set of 31 Nigerian female subjects for cross validation exhibited a lower pure error compared with other existing equations such as

Durnin/Womersley (1974) and Vogel *et al.*, (1984) used for the estimation of percentage body fat. This indicates that the equations could be validly used in lieu of the bioelectrical impedance method. They can therefore be found applicable for mass screening purpose in epidemiology, nutritional and clinical studies as well as other emerging applications including assessment of physical fitness.

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REFERENCES

- Ada, L.G; Karen, W; Christiana E.; Ulrike, T.; Corrina K. and Hans-Joachim, F.Z. 2006. Evaluation of Body Fat Changes during Weight Loss by Using Improved Anthropometric Predictive Equations. *Annals of Nutrition and Metabolism*, 50, pp 297-304.
- Akintunde, R.A. and Ojo, J.O. 2007. Derivation of Anthropometry Based Body Fat Equation Specific for Nigerian Women. *Proceedings of the 30th Annual Conference of the Nigerian Institute of Physics* (August 15 -18, 2007) held at the Lagos State University, Ojo, Lagos State, Nigeria.
- Arora, M.; Koley, S.; Gripta, S.; and Sandhu, J.S. 2007. A Study on Lipid Profile and Body Fat in Patients with Diabetes Mellitus, *Anthropologist*, 9(4), pp. 295-298.
- Babcock, C.J.; Kirby, T.E.; McCarroll, M.L. and Devor, S.T. 2006. Comparison of Military Circumference Equations to Skinfold-Based Equations to Estimate Body Composition. *Military Medicine*. pp. 12-15.
- Chada, D.S.; Singh, G.P.; Vasdev, V. and Ganjoo, R.K. 2006. Anthropometry Correlation of Lipid Profile in Healthy Aviators. *Indian Journal of Aerospace Med.* 50 (2), pp. 32 - 36.
- Dae, J. 2003 . Bodyometryfutrex, <http://www.futrex.com/6100htm/>, pp 1-3.
- Durnin, JVGA and Womersley J. 1974. Body Fat Assessed from Total Body Density and its Estimation from Skinfold Thicknesses: Measurements in 481 Men and Women Aged from 16 to 72 years. *British Journal of Nutrition*, 32, pp. 77- 97.
- Guo, S.S. and Chumlea Wm-Cameron. 1996. Statistical Methods for the Development and Testing of Predictive Equations In: Human Body Composition- Methods and Findings. A.F. Roche, S.B. Heymsfield, Lohman TG Eds Champaign, IL: pp. 191-202.
- Kenneth, J.E. 2001. Innovative Non-or Minimally-Invasive Technologies for Monitoring Health

- and Nutritional Status in Mothers and Young Children In: Selected Body Composition Methods can be used in Field Studies. *J. Nutr.* 131, 1589S-1595S.
- Kotler, D.P.; Burastew S.; Wang, J. and Pierson, R.N. 1996. Prediction of Body Cell Mass, Fat-Free Mass and Fat-Free Mass and Total Body Water with Bioelectrical Impedance Analysis: Effects of Race, Sex, and Diseases. *Am. J. Clin. Nutri.* 64 (3 Suppl.) 489S-497S.
- Mary, E and Cogswell R.N.; Geraldine, S.P.; Laura, A.S and William, H.D. 2001. Obesity in Women of Child bearing Age: Risks, Prevention and Treatment. *Science Direct Primary Care Update for OB/GYNS*, 8(3), pp 89-105.
- Naycli, M.; Heliodoro, A.; Julian, E. and Mauro, E. 2007. Body Fat Measurement by Bioelectrical Impedance and Air Displacement Plethysmography: A Cross Validation Study to Design Bioelectrical Impedance Equations in Mexican Adults. *Nutrition Journal*, Vol.6, pp. 18-23.
- Pranav, C.Y. and Chittaranjan S. (2009). Predictive Equations for Body Fat in Asian Indians. *Obesity*, 17(5), pp. 935-936.
- Vogel, J.A.; Kirkpatrick, J.W.; Fitzgerald, P.I., Hodgdon, J.A. and Harman, E.A. 1984. Derivation of Anthropometry Based Body Fat Equations for the Army's Weight Control Program. *Technical report, Jun-Nov, Army Research Institute of Environmental Medicine, Natick, MA.* <http://handle.dtic.mil/100.2/ADA197706>.
- Wong, W.W.; Stuff, J.E.; Butte, N.F.; Smith, E.O and Ellis, K.J. 2000. Estimation of body fat in Caucasian and African-American Girls: Total Body Electrical Conductivity Methodology Versus a Four Compartment Model. *International Journal of Obesity*, 24(9), pp. 1200-1206.

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