Body Circumference Parameter as Predictor of Percent Body Fat for Female Undergraduates in a Nigeria University Community

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Abstract

Background

Obesity was reported to be of high prevalence in all part of Nigeria affecting more women than men. In order to combat the menace of excess body fat in Nigeria, the accurate measurement of body fat plays an important role. The study was designed to derive simple equation using body circumference that predicts percent body fat for female undergraduates in a Nigeria University.

Material and Method

One hundred and seventy five apparently healthy females undergraduates from a Nigeria University were consecutively selected to participate in the study after obtaining their consent and ethical approval from appropriate authority. The body circumference was measured at the hip, waist, arm, forearm, wrist, thigh and calf using standard protocol. Participants percent body fat (PBF) was measured using Hydrostatic weighing equipment (HSW). Descriptive and inferential statistics were used to analyze the data. The result revealed that there was positive relationship between PBF and each of weight ($r= 0.714$, $p < 0.001$), BMI $r = 0.741$, $p < 0.001$) wrist circumference ($r = 0.297$ $p < 0.05$) and frame size ($r = 0.297$ $p < 0.05$). Three equations were obtained for prediction of PBF

Equation 1 =15.54 + 0.47(weight/kg) – 1.446 (wrist cir./cm); equation 2 = 1.113 (BMI) + 0.141(weight) – 12.507 and equation 3 = 1.456 (BMI) – 11.668. The relationship between the equations shows a positive correlation between equation 1 and 2 ($r= 0.914$ $p < 0.001$), 1and 3 ($r =0.870$, $p< 0.001$) and equation 2 and 3 ($r = 0.993$ $p = 0.001$). More so, our equations had a strong relationship (r= 0.773, 0.893, and 0.905 at $p< 0.000$) with prediction equation by Ejike and Ijeh.

Conclusion. Weight and BMI were found to be predictors of percent body fat with the derived equations.

It is suggested that the equations are put to use both in the clinical setting and for research for more validation.

Key words: Body mass index, Percent body mass, Frame size, Body circumference, Women

I. Introduction

World Health Organization reported that the number of disability adjusted life years that is lost to CVD in sub-Saharan Africa was increasing from 5.3 million for men and 6.3 million for women in 1990 to 6.5 million and 6.9 million in 2000, and could have risen to 8.1 million and 7.9 million in 2010 [1]. Cardiovascular disease has higher mortality in developing countries including Nigeria than in developed ones [2] and affects younger people and women disproportionately. It is responsible for the death of 17 million people, about one third of all deaths worldwide annually [3]. If no action is taken to improve cardiovascular health and current trends continue, WHO estimated that 25 per cent more healthy life years will be lost to cardiovascular disease globally by 2020. The brunts of this increase were borne by developing countries [1]. Obesity has been identified as an independent risk factors for CVD [4,5]. In the West African countries of Ghana and Republic of Benin, obesity was found in 13.6% and 18% respectively among adults[6,7] while Abubakari et al,[8] reported a prevalence of 10% in the West African sub-region with the odd of being obese being 3.2 among urban women compared to men. There is a general misconception in Nigeria that obesity is a sign of affluence, which may be a major reason for increase in CVD in Nigeria Ojofeitimi et al [9]. Wahab et al., affirmed in their study that there is a high prevalence of obesity in the northern part of Nigeria and the high prevalence is independently associated with female sex, hypercholesterolaemia and hyperuricaemia [10]. In a cross-sectional study in South western Nigeria, Ojofeitimi et al found that 21.2% of their respondents were obese while Kadiri & Salako found obesity in 21% and 28% of males and females respectively in a study of 146 middle-aged Nigerians [9,11]. Therefore there is urgent need for more intervention in order to reduce this burden and prevent other non-communicable obesity - related disorders.

Accurate measurement of body composition plays an important role in order to combat the menace of body fat in Nigeria. There are several methods for studying human body composition, one of them is laboratory technique which involves weighing the individual underwater, and this is known as hydrostatic weighing. Dividing the body mass or weight by the body volume provides an accurate estimate of the density of the body, [12, 13, 14], from which the body fat could be calculated. From the perspective of public health screening for individuals at risk for metabolic disease, estimation of body fat distribution using the available methods to accurately determine body composition, especially hydrostatic weighing are generally impractical for field use. It is therefore desirable to have available simple methods that can accurately estimate body composition [15]. Many researchers [16,17,18,19,20,21], have published regression equations obtained from skinfold measurements with functions to estimate body density for women. The equations that estimate the various body compositions, fat-free weight, fat weight and relative fat are population -specific. Therefore the use of these equations can only produce accurate result if subjects are drawn from populations similar to the population from which the equations were originally derived[19]. Recently, Ojoawo et al., derived a regression equation using skin fold measurement for the estimation of body density for Nigerian female undergraduates[20]. However, skinfold measurement requires accuracy, precision and great care which is not to the advantage of many researchers and clinicians in Nigeria [21]. More so, the use of hydrostatic weighing equipment which was accepted as one of the accurate method of estimating body composition is time consuming, requires considerable space and equipment and must be conducted by someone who is highly trained in body composition assessment [13, 14]. As a result, most body composition evaluations, particularly in non research clinical settings are derived through anthropometrics techniques, using skin fold thickness measurements, girths, and diameters, either singly or a combination of these [19]

The use of body circumferences using tape rules though easy to measure, in terms of waist circumference, (WC), waist to height ratio (WHtR), waist to hip ratio (WHR) and even body mass index (BMI), however they were not a direct measures of body adiposity [22] but a prediction of health risk [22,23,24,25]. In spites of the fact that WC, WHR and BMI were significantly correlated to percent body fat using hydrostatic weighing, none of them can be used to determine the ratio of fat mass and fat free mass of the body [27,28]. Ejire and Ijeh used Bioelectric Impedance to obtained a regression equation using waist circumference, body mass index and age among young adult Nigerians [29]. There is paucity of data on derived equation using hydrostatic weighing technique and body circumference in any part of Nigeria to estimate body fat for women. More so, non availability of reliable and avoidable equipment for adequate estimation of percent body fat in Nigeria requires a concern. The present study was designed to obtain prediction equation using hydrostatic weighing equipment and circumference measurements among female undergraduates in a Nigerian university.

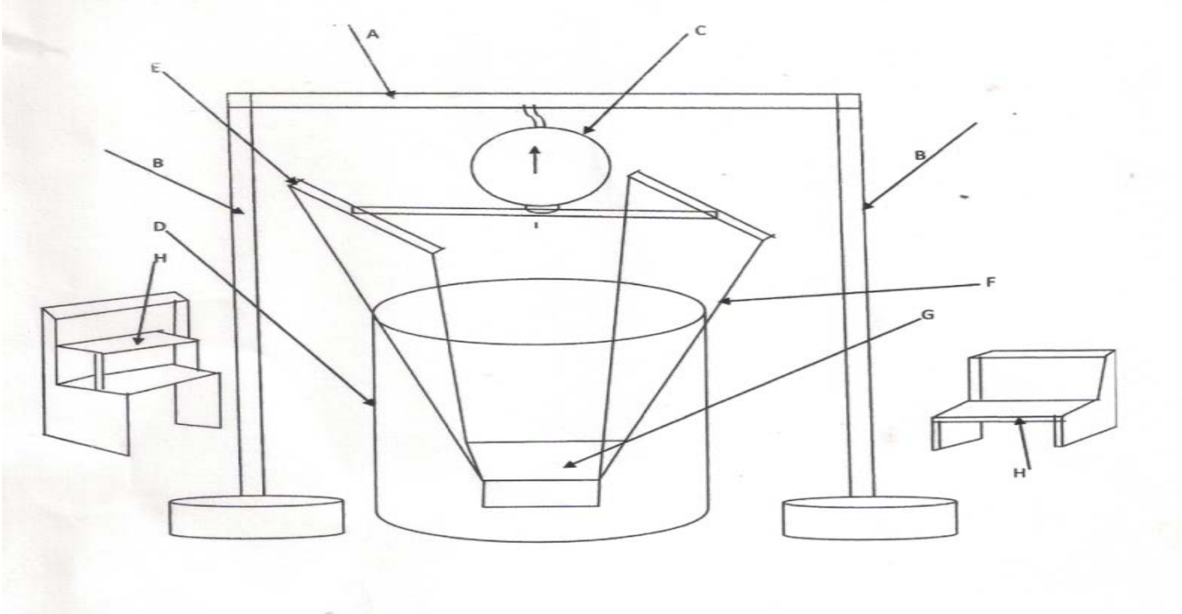
II. Material and Method

One hundred and Seventy five female undergraduates of Obafemi Awolwo University Ile Ife Nigeria participated in the study. Apparently healthy female students who were not within their menstruation period were included in the study. Among 353 female students consulted 232 students volunteered but 175 students were qualified to participate in the study.

Inclusion criteria

Each participant prior to HSW avoided vigorous activity, caffeine and other non-essential stimulants such as pop, candy and chocolate for 8 to 12 hours. They fasted for at least 4 hours before the test by not eating, however they drank adequate water to ensure they were well hydrated. Foods that can produce gas in the course of metabolism (e.g beans, walnut, eggs, and pounded yam) at least two days prior to test date were also avoided.

The restrictions were necessary in order to minimize the accumulation of gastrointestinal gases which can affect the buoyancy of participants in water.



KEY:

A = Galvanized metal pipe of 1.83m. , B = Galvanized metal pipe with U-shape top and heavy base of 2.1m high. C = Weighing scale (Hanson) with a capacity of 200 kg. D = Plastic water container (Geepee) with a volume of 2000 liter capacity. E = .02m diameter iron rod of .10m long. F = Metal chain of 1.12 meter long. G = A small metal seat with footrest. H = A stand

Research design: A cross sectional descriptive survey design was used in the study.

Sampling technique: The participants were non athlete female students who were consecutively selected as they volunteered.

Procedure: The HSW apparatus used was a plastic water container (GEEPEE) with a volume of 2000 liter capacity. Apparatus was arranged such that the container was accessible. The tank was filled up with water with two uprights of metal of 2.1m height on each side of the container and joined at the top by a galvanized metal pipe of 1.83m. There were 2 stands, one outside the container and the other inside for the purpose of entering and exiting. A weighing scale (Hanson) with a capacity of 200 kg consisting of 2 hooks one at the upper end of the scale and the other at the bottom was used. The upper one was used to hang the scale on the horizontal bar which joined the two uprights while the lower one was used to hang the seat. The seat was hung to the weighing scale by 4 hooks with 4 metal chain one to each hook giving a distance of 0.60 meter from the foot rest to the floor of the container so that the subject can sit under the water with legs slightly bent and the water at neck level. (Fig 1)

Fig 1 Sketch of Hydrostatic Weighing Equipment

Procedure

The procedures of Salem et al were adopted in this study [16]. The weight of the chair in air and in water was measured before the subject entered into the water container.

The participants were asked to urinate and expel any gas or feces from the bowels prior to testing if there was such urge [12]. Swim attire was worn which reduced the possibility of air traps. Long hair was cleansed of oil and tied back with a non metallic hair tie. Participants were asked to remove any jewelry on them. They were asked to comfortably seat in the weighing chair in water and were instructed to exhale as fully as possible while slowly leaning forward until the head was completely submerged underwater. Participants were to remain motionless in the water for 5 to 7 seconds before coming up for air. While in water, participants were instructed not to move deliberately in order to prevent water turbulence that could make the scale reading difficult. Five trials were done before the final reading was taken. The last 3 readings were recorded and the average calculated [14]. This was the weight in water. The water temperature was recorded with a thermometer. The weight of subject outside the water was then measured. This was the combined weight of chair, chains and the subject. The underwater weight was then subtracted from the air weight; the result was the net underwater weight of the subject (WW).

The weight of participant was measured with bathroom weighing scale (Hanson, Ireland) and height with calibrated height meter. The following body circumferences - waist, hip, thigh, calf, arm, forearm and wrist- were measured using inextensible tape rule of 150 cm long (Butterfly Brand, China) according to several authors [30,31,32,33]. Body mass index= Weight / Height^2, Waist to Hip Ratio = waist circumference / Hip Circumference and waist circumference to height ratio were calculated.

The Net Weight was calculated:

Net Weight (Nw) = Weight in Air (Wa) – Weight in water (Ww)

Nw= Wa – Ww

and Body density (BD) by hydrostatic weighing was calculated as follows:

$$BD = \frac{Wa}{\frac{Wa - Ww - Rv + 100}{DW}}$$

Dw = Density of water, Rv = Residual lung volume (RLV): = 0.009 (age, years) + 0.032 (height, cm) – 3.9 [14]

Data Analysis: The data collected was analyzed using Statistical Package for Social Sciences (SPSS) version 16. Descriptive and inferential statistics were used to summarize the data. Pearson moment correlation coefficient was used to determine the relationship between percent body fat by underwater weighing and each of weight, height, BMI, and body circumferences at waist, hip, arm, forearm, wrist, thigh and calf. Stepwise Regression analysis was used to derive the predictive variables for the percent body fat.

III. Result

Presented in table 1 is the physical characteristic of the participants. The mean age was 22.91± 3.01 years while the mean BMI, waist circumference and percent body fat underwater weighing were 22.29 ± 3.37 kg/m2, 74.74 ± 8.33 cm and 20.79 ± 6.45 respectively.

Table 1 Physical Characteristic of Participants

Variables	Min	Max	Mean ±STD
Age/Yrs	18.00	30.00	29.91 ±3.01
Height/m	1.49	1.79	1.64 ± 0.06
Weight/kg	36.00	80.00	60.30± 9.40
BMI/Kgm^{-2}	14.61	30.48	22.29± 3.37
WaistCir/cm	59.00	91.00	74.74± 8.33
WHR	0.68	0.98	0.80±0.06
WHtR	0.13	0.56	0.44±0.08
PBFUW	5.06	37.05	20.79±6.45

Key: Cir = Circumference, WHR = Waist to hip ratio, WHtR = Waist to height ratio, PBFUW = percent body fat underwater

Presented in table 2 is the summary of correlation matrix of percent body fat by underwater weighing (pbfuw) and body circumferences. There was significant correlation between pbfuw with the followings parameters: weight (r = -.714, p< 0.001); BMI (r = .741, p< 0.001), wrist circumference (r = -.297, p < .05), frame size (r= 0.292, p< 0.05) and wait to height ratio (r = 0.297, p < 0.05)

Table 2: Correlation between Percent Body Fat by underwater weighing and Body Circumference

Variables	r-values	p-values
Age/Yrs	0.084	0.565
Height	-0.029	0.841
Weight/Kg	0.714**	0.000
BMI/Kg^{-2}	0.741**	0.000
Waist Cir/cm	-0.172	0.236
Hip Cir/cm	0.073	0.616
WHR	-0.180	0.216
Arm Cir/cm	-0.004	0.977
Forearm cir/cm	-0.054	0.713
Thigh Cir/cm	-0.226	0.118
Calf Cir/cm	0.211	0.145
Wrist Cir/cm	-0.297*	0.038
Frame size	-0.292*	0.042
WHtR	0.297	0.038

Key: *=Correlation is significant at 0.05 level, **=Correlation is significant at 0.001 level, BMI = Body Mass Index Cir. = Circumference, WHR= Waist Hip Ratio

Presented in table 3 is the stepwise regression analysis between pbfuw and body circumference. Weight and wrist circumference were found to have contribution to the prediction of percent body fat underwater with standard error of 4.228. The Analysis of variance among these variables showed a significant difference between the variables (f = 27.999, p < 0.001) indicating that the relationship between weight, wrist circumference and percent body fat underwater did not occur by chance.

Table 3. Stepwise Regression Analysis between Percent Body Fat Underwater (PBFUW) and Body Circumference

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error Est	Beta	ANOVA	P-value
1	(Constant)	15.540				
	Weight	.470	4.2228	.685	27.999	.000
	Wrist cir	-1.446		-.201		

a. Dependent Variable: PBFUW

b. PBFUW= 15.54 + 0.47 (weight) – 1.446 (wrist Circumference) 1

Shown in table 4 is the stepwise regression analysis between pbfuw, weight and BMI Weight and BMI were found to have contribution to the prediction of percent body fat underwater with standard error of 4.228. The Analysis of variance among these variables showed a significant difference between the variables (f = 32.88, p < 0.001) indicating that the relationship between weight, BMI and percent body fat underwater did not occur by chance.

Table 4 Stepwise Regression Analysis between Percent Body Fat Underwater and weight and BMI

Model		Unstandardized Coefficients		Standardized Coefficients	ANOVA	P value
		B	Std. Error Est	Beta		
1	(Constant)	-12.507				
	Weight	.141	4.2285	.205	32.88	0.000
	Bmi	1.113		.582		

a. Dependent Variable: pfuw

b.PBFUW = 1.113 (BMI) + 0.141 (weight) – 12.507 2

Table 5 is the stepwise regression analysis between pbfuw and BMI. Body mass index was found to have contribution to the prediction of percent body fat underwater with standard error of 4.2279. The Analysis of variance among these variables showed a significant difference between the variables (f = 64.723, p < 0.001) indicating that the relationship between BMI and percent body fat underwater did not occur by chance.

Table 5. Stepwise Regression Analysis between Percent Body Fat Underwater and BMI

Model		Unstandardized Coefficients		Standardized Coefficients	ANOVA	p-value
		B	Std. Error Est	Beta		
1	(Constant)	-11.668	4.2279		64.723	0.000
	Bmi	1.456		.761		

a. Dependent Variable: pfuw

b. PBFUW = 1.456 (BMI) – 11.668 3

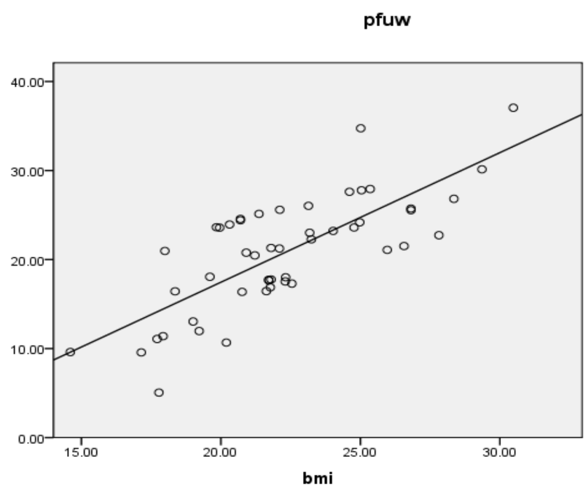


Fig 2: Scatter plot of pfuw with BMI

Presented in table 6 is the summary of correlation matrix showing the relationship among pfuw, body fat derived equation (BFDE) 1, 2, 3, and equations by Ejike and Ijeh (2012), 1 and 2. There was a significant relationship between Pfuw and each of BFDE 1, 2, and 3 (r=0.660, 0.672 and 0.638) at p < 0.001. Also, there was significant relationship between pfuw and each of NDE 1 and 2 (r=0.511 and 0.450) at p < 0.001). Body fat from derived equation 1 also had a significant relationship with BFDE 2 and 3 (r = 0.914 and 0.870) indicating that values obtain from one equation may not be too different from value obtain from other equation.

Table 6: Correlation matrix showing relationship among PBFUW , percent body fat by derived equations and percent body fat by equations of Ejike and Ijeh

	Pfuw	BFDE1	BFDE2	BFDE3	NDE1	NDE2
Pfuw	1					
BFDE1	.660** .000	1				
BFDE2	.672** .000	.914** .000	1			
BFDE3	.638** .000	.870** .000	.993** .000	1		
NDE1	.511** .000	.773** .000	.893** .000	.905** .000	1	
NDE2	.450** 001	.253 .077	.362** .010	.363** .010	.423** .002	1

Key: ** Sig. at p < 0.001. PFUW = Percent body fay underwater weighing.
BFDE1 = Body fat derived equation1. BFDE2= Body fat derived equation 2. BFDE3 = Body fat derived equation 3. NDE1 = Newly derived equation 1. NDE2 = Newly derived equation 2.

IV. Discussion

The purpose of this study was to determine the body circumference predictor of percent body fat for Nigerian female undergraduates. Assessment of body composition provides important information on the health status of an individual [34]. Methods such as underwater weighing are not widely available and estimation techniques based on circumferential measures have not been adopted as a method of evaluating percent body fat. The use of body circumferences is not a direct measures of body adiposity but a prediction of health risk [22,23,24,25,26]

therefore it is considered necessary to derive equations using body circumference for easy assessment of the percent of body adiposity. The test -retest reliability of the HSW equipment used in this study indicated a significant positive and high correlation with weight in air (r = 0.95 p< 0.01) ; weight in water (r = 0.94, p<0.01) and net weight, (r = 0.96 p< 0.01). This indicated that the constructed HSW equipment is reliable.

The mean BMI of participants in the study was 22.30 kg/m^2, showing that it was within the normal range of obesity according to WHO where range of 18.5 kg/m^2 to 24.9 km/m^2 was considered normal [35]. Other physical characteristics such as waist circumference, waist to hip ratio and percent body fat were also found to be within the normal values according to literatures [33,36]. This indicated that participants for the study were may not be at risk of obesity related diseases. The normal in the anthropometric values of the participants of this study might be due to the various activities within the campus undergoing by the participants, which might have raised the level of metabolism thereby reducing accumulation of body adiposity.

Our study observed that there was a significant relationship between BMI and percent body fat by underwater weighing. The study supported the reports of Key et al, and Bjorntorp, which concluded that body mass index showed the closest relationship with estimates of body fatness by skin fold and by underwater weighing [37,38]. In a recent study by Ranasinghe et al BMI was found to have a positive relationship with percent body fat by bioelectric impedance [39]. Body Mass Index has a positive correlation with estimate of body fatness and low estimate with stature [40,41]. Garrow and Webster showed that Body Mass Index has a relatively significant and positive correlation with estimate of body composition from three methods: body density, total body water and total body potassium. They therefore concluded that body mass index is a convenient and reliable indicator of obesity[42].

The result of the correlation of percent body fat with frame size especially in this study was in agreement with the study of Chumlea et al, [43]. They reported that frame size is a description of the supportive structure of the skeleton that is used to adjust for skeletal mass and size in measures of body composition and weight. In their study, they found that frame size measures were significantly and positively associated with all body-composition and bone mineral measures. Measures of frame size are significantly and positively correlated with fat-free mass (FFM), body fatness, and bone mass and with body weight at all ages [44,45].

The high correlation observed among the derived equations body fat derived equation (BFDE) 1, 2 and 3 at $p < 0.001$ is an indication that these equations can be used interchangeably. The values obtained from BFDE 1, 2 and 3 may not be too different from each other. Similarly one of the 2 equations derived by Ejike and Ijeh using Nigerian population showed a strong relationship with the BFDE 1, 2 and 3 indicating that this equation can be used for the measurement of percent body fat for Nigerian women [29].

Conclusion: The study concluded that each of BMI, body weight, and wrist circumference have a strong relationship with percent body fat by underwater weighing and can be used to predict percent body fat for undergraduate women.

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