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Original Article

Measuring body fat percentage using anthropometric skinfolds with different methods and investigating the outcomes of the methods: a case study of secondary school students in Lagos State

[1]Omotayo H.A., [2]Omotayo M.T., [3]Saibu L.K.

ABSTRACT

Background and aim: Individuals of upcoming age might experience a rapid body growth which can include excessive body fat, and this must be put on check because body composition of every individual is as important as health, wellness and fitness. This study aim to estimate body fat percentage of secondary school students in Lagos State using two different methods and subject the difference to a significance test.
Methodology: A cross-sectional study of 640 students (302 Males and 338 Females) of voluntary participation was carried out in secondary schools in Lagos State. Multistage Sampling with Simple Random Sampling deployed at each stage. All body measurements follow the recommendation of International Society for the Advancement of Kinanthropometry (ISAK) and SLIMGUIDE® calliper was used in taking the body skinfolds measurements for the study. The data was analysed for descriptive analysis and Body Fat Percentage. In addition, t-test statistics was performed on methods to check for significance and statistical significance set at $p<0.05$.
Results: The results shows variations in anthropometric indices of students in secondary schools across age and sex. Furthermore, it shows fluctuation in the body fat percentage based on age and sex. In addition there is a significance in the mean difference between the two methods used in measuring the body fat percentage.
Conclusion: This study have establish that there will be variation in estimates of body fat percentage for every different methods applied for an individual leading to different categorization of body fat. Therefore a need uniform and generally acceptable model is required.

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Body Composition; Body Fat Percentage; Skinfolds thickness

INTRODUCTION

In order to detect health risks as early as possible among growing population, the measurement of body fat (BF) is fundamental and adiposity can be evaluated by several field and laboratory-based methods (Duarte *et al*. 2014). Body Composition (BC) of every individual is as important as health, wellness and fitness of such individual. Accumulation of unnecessary fats in the body might lead to various health implications and at sometimes be severe (overweight and obese) and likely death. Individuals of upcoming age might experience rapid body growth while growing due to various reasons, and if not checked, such individual might fall into overweight and obese categories. The examination of body composition (BC) is an important element in determining the health of the body, both in healthy people and in those with diseases (Pawlak *et al*. 2021).
Body Fat Percentage (BF%) is the proportion of total body weight that is made up of fat tissue and it is expressed as a percentage. Body Fat Percentage (BF%) may vary based on age, gender, ethnicity, geographical location as well as other factors and measuring this body fat percentage is of various techniques. Body Fat Percentage (BF%) is a better predictor of visceral fat mass and an independent risk factor for cardiovascular disease, diabetes, and metabolic disorders (Rai *et al*. 2023). Under normal conditions, the body fat percentage for adolescence is 15-20% of body weight, and the mean body fat percentage will increase as age (Laras *et al*. 2023). Also, best body fat percentages averaged between 12% and 20% for men and 20% and 30% for women (Abernathy and Black 1996). Monitoring of the level of adiposity in children is important in establishing measures to control and prevent health risks associated with excess or low body fatness (Goon *et al*. 2007).

There are various methods in estimating the BF%

[1]*Department of Anatomy, Faculty of Basic Medical Sciences, Lagos State University College of Medicine, Ikeja, Lagos;*
[2]*Department of Community Health, Lagos University Teaching Hospital, Idi-Araba, Lagos;*
[3]*Helping Hands Royal Hospital, Ikorodu, Lagos.*

Address for Correspondence:
Omotayo H.A.
Department of Anatomy, Faculty of Basic Medical Sciences, Lagos State University College of Medicine, Ikeja, Lagos.
hameed.omotayo@lasucom.edu.ng

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for adult, children and adolescent. These methods include; Jackson & Pollock (1985), Durnin Womersley (1974), Siri method, Slaughter *et al*. (1988), Weststrate & Deurenberg (1989), Johnston *et al*. (1988), Deurenberg *et al*. (1990), Sloan *et al*. (1962), Wilmore & Behnke (1970), Brook (1971), Lohman *et al*. (1984) etc. All these methods use body measurements in estimation of BF%.

Measurement of body composition is an important part of any assessment of health or fitness (Maughan 1993). Three methods commonly used in field and clinical settings are Skinfolds, Bioelectrical Impedance Analysis (BIA), and Anthropometry.

Skinfold thickness (SFT) measurement is a reliable, cheap, simple, noninvasive method of body fat estimation at all ages including the newborn period and It measures the thickness of subcutaneous fat at various sites of the body from which total body fat and hence contribution of fat to body mass can be estimated (Olutekunbi *et al*. 2018). The skinfold method is appropriate for estimating body fat of children (6-17 years) and body density of adults (18-60 years) from diverse ethnic groups (Heyward V.H. 1998). Data on skinfold thickness can be utilized in a number of ways. They can be directly compared with reference values in an attempt to determine adequacy, deficiency, or excess (Olutekunbi *et al*. 2018).

Anthropometric measurements are used to assess the size, proportions and composition of the human body. Also, anthropometry is a simple reliable method for quantifying body size and proportions by measuring body length, width, circumference, and skinfold thickness (Wang J. *et al* 2000).

Furthermore, Anthropometric measurements can be combined with each other or with other information to calculate anthropometric indices. These indices can be used to make inferences about body composition, growth and development. Anthropometric indices have been used for different purposes becoming indicators for risk identification, intervention, or impact assessment on nutritional status or health (Piqueras *et al*. 2021).

For comparison, any method of estimating BF% mentioned above can be used and compared with other established values for reference purpose. However, different BF% estimate would be arrived at, this could make an individual falls into different category of BF% and give rise to various conclusion on category BF% of individuals.

The study aimed is to generate the average values of body fat percentage (BF%) for secondary schools students' in Lagos State using the anthropometry skinfolds based on age and genders with two different methods (Slaughter *et al*. (1988) and Weststrate & Deurenberg (1989)), then subject the difference to significance test. Additionally, it is also aimed to make it as a reference case for Lagos State, Nigeria.

MATERIALS AND METHODS

Study Setting, design and participants

The study was carried out on selected secondary schools students in Lagos State after necessary approval was gotten from the state ministry with approval number MB&SE/PPR&S/R&S-EMIS/01/34/VI/300.

Sample Size

Multistage Sampling with Simple Random Sampling without replacement deployed at each stage for the selection of schools and students. Stage one involve the selection of one educational district from the six educational districts in Lagos State. Stage two is the selection of one local government area from the district selected. Stage three is the selection of schools that participated in the study from the local government. It was a cross-sectional research and a total of 640 students (302 males and 338 females) aged 10-17 years participated voluntarily in the study across the selected secondary schools.

Data collection methods

In taking the skinfolds measurements, all practices follows the recommendation of International Society for the Advancement of Kinanthropometry (ISAK). The skinfold thickness was measured in millimetres using special calliper, SLIMGUIDE® calliper (BODYCARE, Northfield Road, Southam, Warwickshire, CV33 OFG, England) as the reliability of anthropometric measurement depends on standardizing the caliper and site of measurement, and upon the measuring skill of the anthropometrist (Wang *et al* 2000).

Data Analysis

The data was analysed for descriptive analysis and Body Fat Percentage (Weststrate and Deurenberg (1989) and Slaughter et al. (1988)). In addition, t-test statistics was performed on the outcome of the body fat percentage method to check for significant difference in the mean of both method with statistical significance set at $p<0.05$.

Slaughter et al. (1988) Method

The Slaughter et al. (1988), which is internationally accepted for use in children and adolescents from different ethnic groups was used to derive the body density, it is the most widely used and acceptable method for children from pre-pubescent to post-pubescent and aged 8 to 18. The equation is of two part (male and female).

Body Fat Percentage using Slaughter et al. (1988):

$$\text{Male BF\%} = 0.735 \times (\text{Triceps} + \text{Calf}) + 1 \quad \text{(i)}$$

$$\text{Female BF\%} = 0.610 \times (\text{Triceps} + \text{Calf}) + 5.1 \quad \text{(ii)}$$

Triceps Skinfold: The point on the posterior surface of the arm, in the midline, at the level of the Mid-Acromiale-Radiale landmark.

Calf Skinfold: A vertical fold taken at the widest point of the calf at the medial (inner) aspect of the calf.

Weststrate and Deurenberg (1989) Method

The Weststrate and Deurenberg (1989) is a modification of Siri's Method which is used for calculating the body fat percentage, it is specifically design for individuals for age 10-18 for both gender. Unlike Slaughter et al. (1988), Weststrate and Deurenberg (1989) uses body density in calculating the body fat percentage.

Body Fat Percentage using Weststrate and Deurenberg (1989):

$$\text{Male: Body Fat (\%)} = \frac{[562-4.2\ (\text{Age}-2)]}{\text{BD} - [525-4.7\ (\text{Age}-2)]} \quad \text{(iii)}$$

$$\text{Female: Body Fat (\%)} = \frac{[553\text{-}7.3\ (\text{Age-}10)]}{\text{BD} - [514\text{-}8\ (\text{Age-}10)]} \quad \text{(iv)}$$

Where BD is the Body Density.

Furthermore, to get the Body Density as required by Weststrate and Deurenberg (1989), the Siri Method was be reversed.

The Siri Method is

$$\text{BF\%} = \frac{495}{BD} - 450 \quad \text{(v)}$$

Reversing the method by making BD the subject of the formula

$$\text{BD} = \frac{495}{BF\%+450} \quad \text{(vi)}$$

Statistical Package

All data and statistical analysis was carried out using MS-Excel and SPSS v25.0.

RESULTS

Table 1 shows the composition of the students' participants in age and sex. From the table, it was shown that female students' participants were 338 (52.8%) while their male counterparts were 302 (47.2%). In addition, the frequency of the age varies, while students' of age 13 has the highest count (88) which has 13.8%, students' of age 12 has the lowest count (72) which also have 11.3%.

Table 2 highlight the descriptive statistics of the students' participant according to their sex. It was shown on the table that the mean weight for male was slightly more than their female counterpart. While they share thin superiority in height in advantage for female, all other anthropometry measurement mean value are slightly higher in males than female. Also, the statistics show the difference in mean between the sexes, however, no there was no statistical significance.

Table 3 highlight the descriptive statistics of variables based on age and sex of the participants. It describe the statistics of the parameters of each age category.

Table 4a shows the descriptive statistics of both method based on age and sex. The t-test statistics between sex for same age and method shows no significance.

Table 4b show the mean and standard deviation of students' participant body fat percentages based on age and gender for two methods used. It shows the diversity in mean according to different ages for both sex. From the table, it was shown that each mean value of slaughter et al. (1988) is greater than Weststrate and Deurenberg (1989) across all ages investigated. The table also show that as the age increases the BF% increases as well in both gender regardless of method used as both method show almost the same trend. The t-Test statistics within same age and sex for different method shows a statistical significance.

Table 5 highlight the t-test statistics of the methods investigated. The mean and standard deviation of slaughter et al. (1988) and W & D (1989) were 27.28 (± 5.80) and (± 7.70) respectively. The mean difference between the two methods is 3.98. Also, the t value was 10.45 and degree of freedom (df) was 1187.76. The p-value is 0.00 which very well lesser than the set point 0.05. This indicated a significant in the mean difference of both methods.

Table 1: Composition of the students' participants in Age and Sex

		Frequency	*Percent (%)*
Sex	Male	302	47.2
	Female	338	52.8
	Total	640	100.0
Age	10	78	12.2
	11	82	12.8
	12	72	11.3
	13	88	13.8
	14	81	12.7
	15	79	12.3
	16	85	13.3
	17	75	11.7
	Total	640	100.0

Table 2: Descriptive statistics of students' participant anthropometry data based on sex with t-Test

	Descriptive Statistics						t-Test
	Male			Female			
	Mean ± SD	*Min.*	*Max.*	*Mean ± SD*	*Min.*	*Max.*	*p-value*
Age (*yrs*)	13.51 ± 2.32	10	17	13.50 ± 2.23	10	17	0.969
Weight (*kg*)	41.22 ± 12.69	20.2	59.91	40.77 ± 12.44	20	59.94	0.648
Height (*cm*)	133.00 ± 8.86	110.1	149.8	133.05 ± 7.9	111.2	149.9	0.946
Triceps Skinfold (*mm*)	14.66 ± 2.66	10.02	19.93	14.56 ± 2.72	10.03	19.9	0.617
Calf Skinfold (*mm*)	20.07 ± 2.88	15.13	24.96	20.04 ± 2.94	15	24.96	0.400
Slaughter *et al*. Method	27.41 ± 5.92	16.22	40.55	27.16 ± 5.70	16.40	40.92	0.053
W&D Method	23.31 ± 7.93	8.76	40.01	23.27 ± 7.50	9.09	40.21	0.452

SD = Standard Deviation

Table 3: Descriptive statistics of participants based on age and sex

	Variables							
	Weight (*kg*)		Height (*cm*)		Triceps Skinfold (*mm*)		Calf Skinfold (*mm*)	
	Male	Female	Male	Female	Male	Female	Male	Female
Age	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
10	25.97 ± 3.32	26.17 ± 3.01	129.29 ± 6.37	130.28 ± 5.37	14.09 ± 2.42	13.22 ± 2.43	14.14 ± 2.26	13.6 ± 2.09
11	25.85 ± 3.38	25.69 ± 3.52	130.95 ± 5.27	130.55 ± 5.35	14.46 ± 2.37	13.66 ± 2.17	13.78 ± 2.15	14.11 ± 2.35
12	33.78 ± 4.06	31.47 ± 4.36	130.24 ± 3.07	129.79 ± 2.67	13.77 ± 2.56	14.59 ± 2.93	13.79 ± 2.44	14.2 ± 2.27
13	32.83 ± 4.33	32.54 ± 4.85	130.36 ± 2.82	130.44 ± 2.71	15.24 ± 2.74	15.68 ± 2.83	14.64 ± 2.1	13.89 ± 2.43
14	50.82 ± 3.29	50.26 ± 2.71	127.61 ± 10.32	130.34 ± 9.59	15.06 ± 2.51	14.56 ± 2.67	15.53 ± 3.35	14.51 ± 2.67
15	50.23 ± 3.01	50.86 ± 2.78	127.8 ± 10.37	129.46 ± 9.38	14.85 ± 2.96	14.78 ± 2.78	15.09 ± 3.2	15.1 ± 3.06
16	55.22 ± 2.79	54.23 ± 2.62	143.53 ± 4.34	141.64 ± 4.1	15 ± 2.87	14.54 ± 2.48	14.71 ± 3.28	15.46 ± 2.44
17	55.47 ± 2.78	54.77 ± 2.71	142.79 ± 4.27	142.95 ± 4.01	14.67 ± 2.67	15.28 ± 2.79	15.01 ± 2.69	14.37 ± 2.75

SD = Standard Deviation

Table 4a: Descriptive statistics of both BF% methods based on age and sex with p-value within method

	Slaughter *et al*. Method			W&D Method		
	Male	Female	t-Test	Male	Female	t-Test
Age	*Mean ± SD*	*Mean ± SD*	p-value	*Mean ± SD*	*Mean ± SD*	p-value
10	21.79 ± 1.59	21.84 ± 2.44	0.917	13.54 ± 1.84	13.76 ± 2.89	0.700
11	21.75 ± 2.60	21.65 ± 1.99	0.848	16.33 ± 3.01	16.40 ± 2.16	0.898
12	23.22 ± 2.48	22.72 ± 2.01	0.344	17.28 ± 2.66	16.74 ± 2.34	0.365
13	22.28 ± 2.49	22.37 ± 3.02	0.885	17.59 ± 2.92	18.62 ± 3.23	0.124
14	32.38 ± 2.65	31.93 ± 2.73	0.464	28.86 ± 2.81	28.41 ± 2.88	0.482
15	32.90 ± 3.57	32.08 ± 3.30	0.294	30.54 ± 3.73	29.96 ± 3.40	0.477
16	31.19 ± 2.7	32.09 ± 2.24	0.100	29.41 ± 2.85	30.40 ± 2.35	0.087
17	34.03 ±3.36	32.57 ± 3.71	0.078	33.15 ± 3.40	31.65 ± 3.73	0.073

SD = Standard Deviation

Table 4b: Descriptive statistics of both methods based on age and sex with p-value between the methods

	SLAUGHTER ET AL. (1988)		W&D (1989)		t-Test	
	Male	Female	Male	Female	Male	Female
Age	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	*p-value*	*p-value*
10	21.79 ± 1.59	21.84 ± 2.44	13.54 ± 1.84	13.76 ± 2.89	0.000	0.000
11	21.75 ± 2.60	21.65 ± 1.99	16.33 ± 3.01	16.40 ± 2.16	0.000	0.000
12	23.22 ± 2.48	22.72 ± 2.01	17.28 ± 2.66	16.74 ± 2.34	0.000	0.000
13	22.28 ± 2.49	22.37 ± 3.02	17.59 ± 2.92	18.62 ± 3.23	0.000	0.000
14	32.38 ± 2.65	31.93 ± 2.73	28.86 ± 2.81	28.41 ± 2.88	0.000	0.000
15	32.90 ± 3.57	32.08 ± 3.30	30.54 ± 3.73	29.96 ± 3.40	0.000	0.000
16	31.19 ± 2.7	32.09 ± 2.24	29.41 ± 2.85	30.40 ± 2.35	0.000	0.000
17	34.03 ±3.36	32.57 ± 3.71	33.15 ± 3.40	31.65 ± 3.73	0.000	0.000

SD = Standard Deviation

Table 5: t-Test Statistics of the two method

t-Test Statistics		
		Mean±Std.Deviation
Methods	Slaughter et al. (1988)	27.28 ± 5.80
	W & D (1989)	23.29 ± 7.70
		Value
t-Test Statistics	t	10.45
	df	1187.76
	p-value	0.00**
	Mean Difference	3.98

** Statistical significance

DISCUSSION

In measuring body composition and specifically body fat percentage, anthropometry plays an important role, although there are various ways of measuring body fat percentage. However, this study male students' participant in the study than their male counterpart. The table also show the distribution of the students' participant based on their age. Students' in age 13 has the highest percentage of participants followed by age 16, while students' at age 12 has the lowest participant.

In describing the anthropometry statistics, the minimum participant age is 10 while the maximum participant age is 17 for both male and female as stated earlier. The mean weight is 41.22 for male and 40.77 for female, while the mean height is 133.00 for male and 133.05 for female. Also, from table 2, the results show the mean triceps skinfold for male to be 14.66 and female 14.56, calf skinfold mean for male to be 20.07 and female 20.04. The minimum and maximum values of the anthropometry variables also computed and the estimates of BF%. Overall, there was slight increase in mean for male than female for all except for height and the mean difference is not statistically significance. The descriptive statistics of the anthropometry of the students according to their gender shows that male students are more built than their female counterpart, although the difference was little and not significant.

The descriptive statistics of variables based on age and sex of the participants was highlighted, as shown in table 3. It describe the statistics of the parameters of each age category.

Body Fat Percentage value varies from each other significantly, based on the methods used since there is no uniformity in method. There are various methods that can estimate body adiposity. The most commonly used method is the skinfold thickness measurement – which assesses body fatness through the use of callipers at particular body sites (Zin et al. 2014). As shown in table 4a, the mean value of BF% measured from slaughter et al. (1988) is different from the mean value of BF% measured from Weststrate and Deurenberg (1989) based on age and sex, the t-test statistics between sex for same age and method shows no significance. The mean value for both male and female is higher in Slaughter et al. (1988) than Weststrate and Deurenberg (1989). As shown table 4b, as the age increases the BF% increases as well in both gender regardless of method used as both method show almost the same trend. The t-Test statistics within same age and sex for different method shows a statistical significance. Furthermore, students' participants of older age had more BF% than students' participants of younger age across both sexes. The study observed a fluctuation in the mean of both methods across age and gender, this is in line with the findings of Njoku et al. (2024) which found out fluctuation of body fat percentages across age groups. This also conform to Omotayo et al. (2024) findings, that there were differences in the pattern of variation depending on the specific dimensions and indices being evaluated.

In measuring the BF%, following the standard practice in anthropometric measurement especially for the skinfolds is key and using the best method designed for that category of participants. Since there is no single method in measuring BF% and as stated by Zin *et al.* 2014 that, there was no consistency between the methods. This prompt further investigation in testing the significance of the difference in mean between the two methods as the summary is shown in table 5.

The two methods was subjected to t-Test statistics to check if the difference in mean between the two methods is insignificant, however, it was found that the mean difference between the two method is statistically significant (p=0.00). This indicated that for

any value arrived at in the measurement of BF% using one method there might be another value of BF% from another method for the same individual which can fall into any category of reference for BF%. This implies that, individual could fall in different categories of BF% and this could jeopardise the real estimate of an individual BF% further stressing the need for a standard, single and acceptable model.

CONCLUSION: This study has shown that estimates of Body Fat Percentage (BF%) will continue to vary in individuals for any method applied in measuring it. It has highlighted the significance in the usage of methods in measuring body fat percentage. This study has also generated a point reference on the measurement of body fat percentage. This study have also shown difference in anthropometrics of secondary school students in Lagos State. However, more research is needed to establish a uniform model acceptable in measuring and computation of body fat percentage.

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