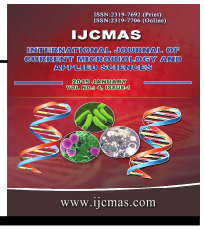
International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 4 Number 1 (2015) pp. 884-897**
http://www.ijcmas.com



Original Research Article

The Relationship among Body Composition and Body Mass index in a Population of Adolescents in Enugu State, Nigeria

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Keywords

Body Mass index, Relationship Among Body Composition, fat-free mass (FFM), Body fat percentage

A B S T R A C T

Methodological differences among indirect body composition techniques are a source of variability that can affect estimations of fat-free mass (FFM) or Body fat percentage (BF %) especially for different sex and age groups. The aim of this cross-sectional study was to ascertain the relationship among body Composition and Body mass index (BMI) in adolescents in Enugu State, Nigeria. 300 boys and 480 girls aged 10-20, from two places of domicile where studied. Their body compositions and BMI were measured using bioelectrical impedance analysis and anthropometry respectively. Measurements were reported according to age, sex and area of domicile. Mean BF% increased with age in all but one age group, with girls having a significantly ($p < 0.05$) higher BF% compared with boys. Mean BMI was found to increase with age in all the groups, however, the differences between BMI of boys and girls were not significant ($p>0.05$). The greatest discrepancies between mean BF% and BMI was observed in boys aged 16-18, who had a significantly ($p<0.05$) lower BF% compared to those aged 13-15 (13.45 vs 18.28 in Urban and 13.90 vs 17.38 in rural areas). BF% and BMI were significantly positively correlated ($p<0.01$) and negatively correlated with body muscle and body water ($p<0.01$). However, while BMI had positive correlation with age in all the subjects, BF% on the other hand was positively correlated with age only in girls. BMI was positively correlated with BF% measured with BIA. However, the relationship was influenced by age, sex, body muscle and body water. Therefore, we recommend the need to take other body composition into consideration when using BMI to predict BF% / obesity in a population

Introduction

During adolescence, body size and composition markedly change. These changes are strongly associated with the development of various physical performance characteristics[1]. The assessment of body composition in children and adolescent is of great importance, as it expresses the life, and health status of the population[2] and its influence on the morbimortality risks.[3-7] Human body is composed of fat mass and fat free mass which consists of muscle, water, bone and organ.

However, recently, high emphasis has been placed on only body fat due to the increasing prevalence[8-11] and adverse medical[12-18], economic[19] and psychosocial[16, 20, 21] consequences of obesity. Most of the methods used to measure body fat rely on anthropometric variables. This is because height and weight are variables readily available and easy to measure[22]. Many research works have proven this method to be an ineffective method of estimating body fat percentage since it fails to differentiate between fat mass and fat free mass[2, 16, 23-29].

Body muscle affects the amount of fat stored in the body. Excess calories are stored as fat only during periods of positive energy balance[30]. Muscle tissue requires a lot of calories to maintain, so masculine individuals (eg athletes) burn a lot of calories thereby storing less calories as fat. As the muscle mass increases, energy expenditure also increases due to rise in basal metabolic rate (BMR) [31]. Miyatake*et. al.,* [32] reported that aerobic exercise should be encouraged to increase muscle strength which helps for reducing body fat mass. Skeletal tissue holds a large amount of water that is partitioned into intracellular and extracellular fractions[33]. This implies that increase in skeletal muscle mass also helps in retaining more water in the body. Body muscle, body water and body calorie assessment in children and adolescents is important for the development of obesity intervention programmes since obese adolescents have the highest risk of becoming obese adults[29,31.34]. Since obesity in adult's life remains difficult to treat, preventing adolescents from becoming obese adults is important for their future health and may reduce health care cost[1, 35, 36] Though a lot of studies have been done on the effect of age, sex and ethnicity on BF % and BMI,[22,37], to the best of our knowledge, no work has been done in Southeast Nigeria, to determine the effects of body muscle, body water and body calories on BF% and BMI of adolescents even though such data is vital since body composition variables such as fat mass vary significantly among ethnic groups. [38] Hence, this work studied: (i) the effects of age and sex on body fat % and BMI, (ii) the effects of body muscle, body water and body calories on . Body fat % and BMI and (iii) the relationship among all the parameters.

Methods

A total of 300 boys and 480 girls aged 10-20 residing in urban and rural settings of Enugu State were studied. Weight was measured (in kilograms) using a portable digital scale with a 0.1kg precision. Height was measured (in meters) using a vertical stadiometer with a 0.1cm precision. Based on these measurements, body mass index was obtained by dividing weight in kilogram by height (in meters) squared.

Hand held body composition monitor (Tanita,Japan) was used to measure body fat (%), body muscle (%), body water (%) and body calories.

Statistical Analysis

Subjects were grouped into boys and girls. Each gender was further grouped into four (10-12, 13-15, 16-18 and $\geq$ 19 years) and also according to area of domicile (urban and rural), the results were expressed as mean $\pm$ SD and tests of statistical significance were carried out using one-way analysis of various (ANOVA) and t –test. The means were separated using Duncan multiple range test and differences with $p<0.05$ were considered significant and pearson correlation coefficients were calculated to investigate the relations between anthropometric and body composition variables.

Result and Discussion

Body composition for urban and rural Boys and Girls

Figure 1 shows that body fat % of boys and girls increased with age in all but one group, with group 4 recording highest mean values of body fat % irrespective of sex and area of domicile. However, boys in group 3 had a significantly ($p<0.05$) lower body fat % compared to those in group 2 . Boys were found to have significantly ($p<0.05$) lower body fat % than their female counterpart from the two places of domicile**.**

Body muscle was found to decrease with increasing age in all but in group 3 boys where a significant ($p<0.05$) higher mean body muscle compared to group 2 was observed. In all age bracket, boys had significantly ($p<0.05$) higher % body muscle than girls (Figure 2).

Body water percentage of boys and girls were found to decrease with age except in group 3 boys were a significant ($p<0.05$) increase in body water percentage was observed. It was also observed that boys had significantly ($p<0.05$) higher body water than girls (Figure 3).

The mean body calories of both boys and girls increased with age irrespective of areas of domicile.

The mean height of the boys and girls increased with age in all but one of the groups (group 4 rural girls). Group 3 girls had higher mean height compared with group 4 though the difference was not statistically significant ($p.>0.5$). The boys were significantly taller than girls in most of the groups studied (Figure 5).

The mean weight of both boys and girls also significantly ($p<0.05$) increased with age with girls being heavier than boys except in the urban area, however, in the rural area, boys were heavier than girls except in those aged 13-15 (group 2) where girls had significantly ($p<0.5$) heavier weight than the boys (Figure 6).

Figure 7 shows that BMI also increased with increasing age irrespective of sex and area of domicile. However, in the same age bracket, girls had higher mean BMI than boys though the differences seen in some groups were not statistically significant ($p>0.05$)

Pearson correlation coefficients for urban boys

Body fat % of urban boys had significant ($p<0.01$) positive correlation with weight and BMI and a significantly ($p<0.01$) negative correlation with body water and body muscle and a weak negative correlation ($r=0.226$, $p=0.13$) with age. BMI followed similar trend with body fat% except that it had in addition significant ($p<0.01$) positive correlation with age and height (Table 1).

Pearson correlation coefficients for rural boys

Table 2 shows that in rural boys, BF% had a similar trend as that observed in urban boys except that it significantly ($p<0.00$) correlated with height negatively ($p = -0.172$). The BMI of rural boys had similar correlation as that of urban boys except that it had a significantly ($p<0,05$) positive correlation with body calories

Pearson correlation coefficient of urban girls

The mean BF % and BMI of urban girls

were found to be significantly ($p<0.01$) correlated with each other positively and also with age, weight and body calories. However, only BMI was positively correlated with height. Also, both BF% and BMI had negative correlation with body water and body muscles.

Pearson correlation coefficient of rural girls

Table 4 also shows that BF% and BMI of rural girls were also positively correlated significantly with each other and with age, weight and body calories but negatively correlated with body muscle and body waters. Both BF% and BMI were not significantly correlated with height for rural girls.

Adolescence is an important time of physical development because of hormonal changes, sexual maturation and linear growth, all of which may potentially affect body composition[39]. Bioelectrical impedance analysis (BIA) is a simple, easy-to-use method of estimating body composition in large-scale epidemiologic studies, and is frequently used in combination with anthropometry to predict body composition.[2,33] We analyzed data from a group of South East Nigerian adolescents. We hope that the results obtained from this different ethnic group, would further add strength to the current pool of evidence regarding body composition of adolescents previously studied[40,41,42]

The mean body fat percentage from this study agreed with previous research work done by Jackson *et. al.* [22]who compared Caucasians with blacks and more recently, work done by Ranasinghe*et. al.* [43] who studied a large population of South Asian adults from Sri Lanka. The increase in body fat with age is as a result of significant decline in muscle strength and mass and enlargement of adipose compartment.

According to Basu*et. al*. [44]reduction in muscle strength with age could be as a result of decrease in mitochondrial and nuclear gene transcription in skeletal muscles which will result in reduction in synthesis rates of muscle mitochondrial proteins, myosin heavy chain and actin, and because muscles burn a greater number of calories, decrease in muscle strength will result in accumulation of calories which is stored in the body as fat. However, in advanced old age, fat depot size decline, decreased fat depot size is related to reduce fat cell size, function, and impaired differentiation of preadipocyctes into fat cells[45].

Surprisingly, it was observed that in group 3, a different scenario for the increase in body fat percentage with age emerged for all the boys studied in both areas. The mean body fat (%) of boys in urban and rural areas in this group were 13.45 and 13.90 respectively which were significantly lower ($p<0.05$) compared with group 2 irrespective of area of domicile. This deviation from the normal increase in body fat (%) with age seen in all the other groups studied was as a result of high body muscle and water found in this group compared with other groups (Figures 2 and 3). The Level of adiposity is affected by body muscle and body water. In children and adults, low mean body water reflects the greater level of adiposity while high level reflects low adiposity [46].

Interestingly, it was observed that girls had significantly ($p<0.05$) lower body waters and body muscle and a higher body fat (%) compared with boys. Similar results have also been reported by other authors[6,26,28,46,47]. These differences reflect physiological development, as girls gain more body fat,

while boys gain more muscle mass during puberty because of the drastic hormonal changes that induce important modifications in growth bone mass, and body composition[28]. There modifications are associated with certain biochemical parameters-true "markers"- which regulate bone 'turnover' and lepton levels, reflecting changes in bone growth and fat mass rspectively[28]. From this study, sex difference in body composition is more pronounced at adolescents aged 16-18 (group 3).

Similarly, the mean BMI obtained for all the groups studied shows that BMI increased significantly ($p<0.05$) with age irrespective of sex and area of residence, with boys and girls in group 4 having the highest mean BMI values. Also, the mean BMI of group 3 boys were found to be significantly ($p<0.05$) higher compared with that of groups 1 and 2 in the two areas studied. It is noteworthy, to recall that group 3 boys from both areas had significant ($p<0.05$) lower mean body fat percent when compared with group 2 due to the presence of high muscle and body water found in this group as shown in Figures 2 and 3.

So, the high mean BMI found in this group when compared with groups 1 and 2 reinforces the statement made by Goodman *et al*[24]that error in BMI is significant due to its inability to differentiate between body fat and lean mass, thereby overestimating adiposity on those with high musculature while underestimating adiposity on those with less lean mass (e.g. elderly).

Even though, the mean BMI of all the subjects increased with age, it was realized from Table 2 that in the same age bracket, girls had non - significantly ($p>0.05$) higher mean BMI values compared with boys irrespective of area of domicile. This finding was in accordance with an earlier report by Jackson *et al* [22] that sex and age are major source of variation in BMI.

In this study, the overall correlations of BF% and BMI were significant notwithstanding sex and area of domicile. The finding therefore, confirms the conclusion of some earlier reports done by Widhalm*et. al.* [34] who studied 204 obese children and adolescents from white Austrians, Jackson *et. al.*[22] who compared Caucasians with blacks, Rush *et. al.*[40] who studied European and more recently work done by Ranasinghe*et. al.*[42] who studied Asian adults from Sri Lanka. However, our report differed from work done by Meeuwsen*et .al.*[48] who studied UK adults and found that the association is not especially good.

Although, some prior works have shown a positive correlation between age and BMI[34] and also between age and BF% [42] in both males and females. our work only showed positive correlation between age and BMI in both sexes, and between age and BF% only on girls studied while a negative correlation was observed between age and BF% in boys.

A potential explanation for this deviation is due to the sharp decrease in BF% in boys aged 16-18 compared with those aged 10-12 and 13-15. This was reported earlier to be due to high BM% found in this group which leads to increase in basal metabolic rate [31]

However, both BF% and BMI were found to have significant ($P<0.01$) negative correlation with body muscle and body water though BF% had stronger correlation compared with BMI in all the groups studied.

Table 1: Pearson correlation coefficient for urban boys (n=121)

	Group (Age)	**Height**	**Weight**	**Body Fat**	**Body Water**	**Body Calorie**	**Body Muscle**	**BMI**
Group (Age)	-							
Height	xx .597	-						
Weight	xx .529	xx .819	-					
Body Fat	x -.226	-.012	xX .429	-				
Body Water	x -.200	-.002	xx -.428	xx -.987	-			
Body Calories	x .233	x .233	x .191	xx .101	.103	-		
Body muscles	x .223	.007	xx -.431	xx -.999	xx .987	.102	-	
BMI	xx .264	xx .301	xx .777	xx .752	xx -.755	.076	xx -.752	-

xxCorrelation is significant at the 0.01 level (2-tailed)
xCorrelation is significant at the 0.05 level (2-tailed)

Table 2: Pearson correlation coefficient for boys in rural area (n=179).

	Group (Age)	**Height**	**Weight**	**Body Fat**	**Body Water**	**Body Calorie**	**Body Muscle**	**BMI**
Group (Age)	-							
Height	xx .605	-						
Weight	xx .654	xx .823	-					
Body Fat	xx -.292	x -.172	xx .218	-				
Body Water	xx .283	xx .192	xx -.233	xx -.965	-			
Body Calories	xx ·740	xx .883	xx .972	.017	-.031	-		
Body muscles	xx .284	x .187	xx -.237	xx -.965	xx .996	-.032	-	
BMI	xx .471	xx .375	xx .820	xx .564	xx -608	xx .719	xx -.610	-

xx Correlation is significant at the 0.01 level (2-tailed)
x Correlation is significant at the 0.05 level (2-tailed)

Table 3: Pearson correlation coefficient for the girls in urban area (n=309).

	Group (Age)	**Height**	**Weight**	**Body Fat**	**Body Water**	**Body Calorie**	**Body Muscle**	**BMI**
Group (Age)	-							
Height	.334[xx]	-						
Weight	.362[xx]	.545[xx]	-					
Body Fat	.185[xX]	.087	.812[xX]	-				
Body Water	-.177[xX]	-.088	-.802[xx]	-.989[xx]	-			
Body Calories	.320[xx]	.631[xx]	.830[xx]	.587[xx]	-.577[xx]	-		
Body muscles	-.184[xx]	-.088	-.813[xx]	-.999[xx]	.990[xx]	-.588[xx]	-	
BMI	.267[xx]	.114[xx]	.862[xx]	.946[xx]	-.933[xx]	.658[xx]	-.947[xx]	-

[xx] Correlation is significant at the 0.01 level (2-tailed)

[x] Correlation is significant at the 0.05 level (2-tailed)

Table 4: Pearson correlation coefficient for rural girls (n=171).

	Group (Age)	**Height**	**Weight**	**Body Fat**	**Body Water**	**Body Calorie**	**Body Muscle**	**BMI**
Group (Age)	-							
Height	.364[xx]	-						
Weight	.353[xx]	.545[xx]	-					
Body Fat	.189[xx]	.100	.826[xx]	-				
Body Water	-.165[xx]	-.076	-.696[xx]	-.836[xx]	-			
Body Calories	.322[xx]	.748[xx]	.910[xx]	.614[xx]	-.522[xx]	-		
Body muscles	-.169[xx]	-.100	-.826[xx]	-.999[xx]	.836[xx]	-.614[xx]	-	
BMI	.268[xx]	.139	.885[xx]	.952[xx]	-.809[xx]	.708[xx]	-.953[xx]	-

[xx] Correlation is significant at the 0.01 level (2-tailed)

[x] Correlation is significant at the 0.05 level (2-tailed)

Figure 1: Body fat percentage of urban and rural boys and girls

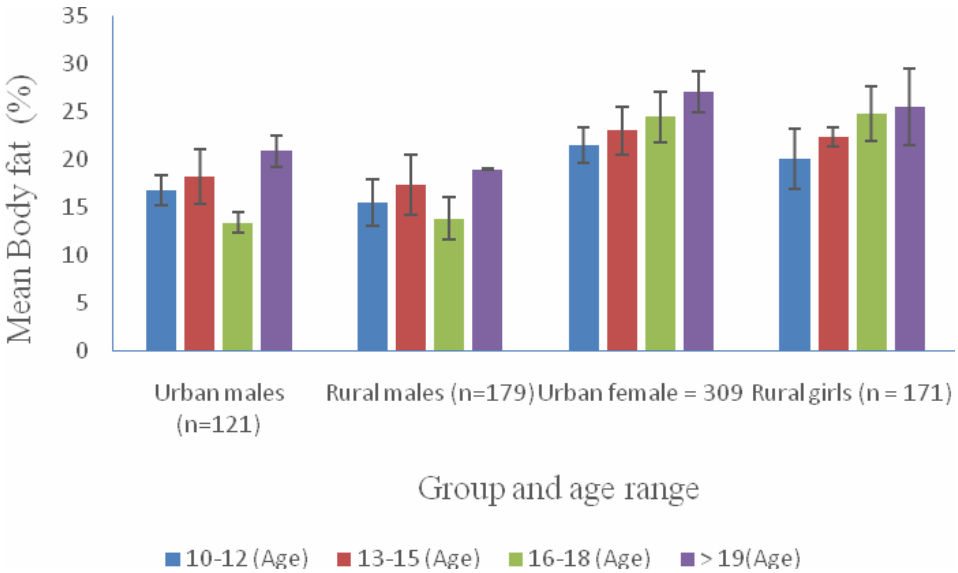


Figure 2: Body muscle percentage of urban and rural boys and girls

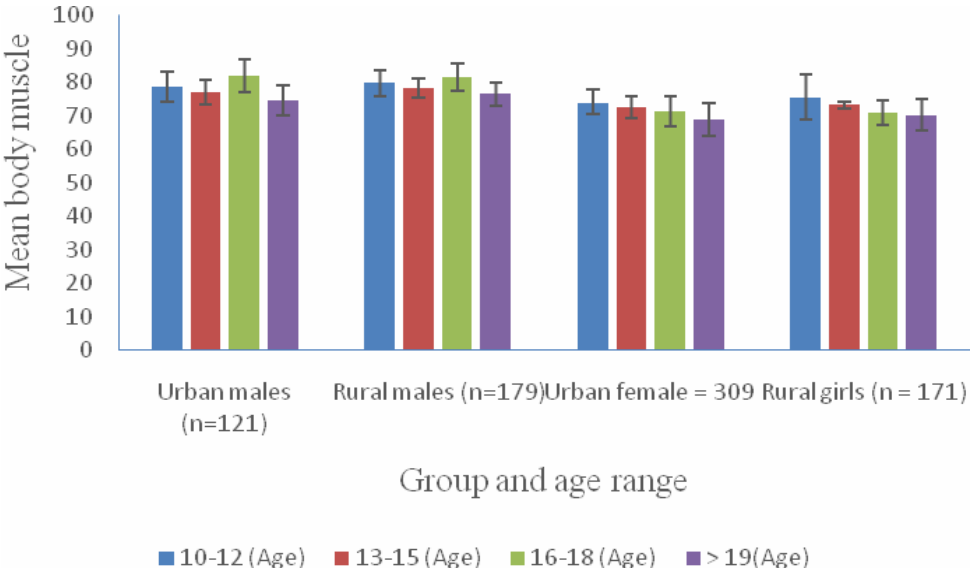


Figure 3: Body water percentage of urban and rural boys and girls

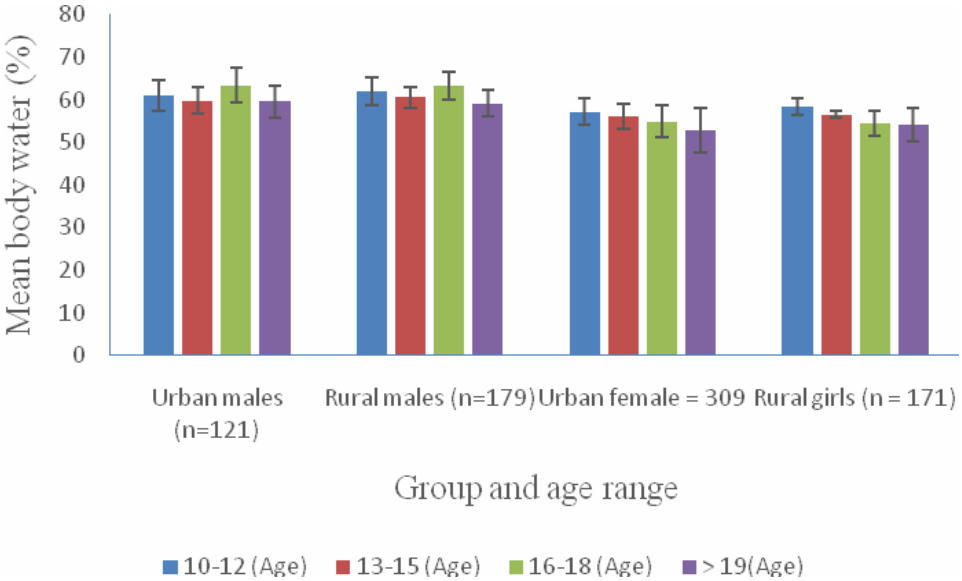


Figure 4: Body calories of boys and girls in urban and rural areas

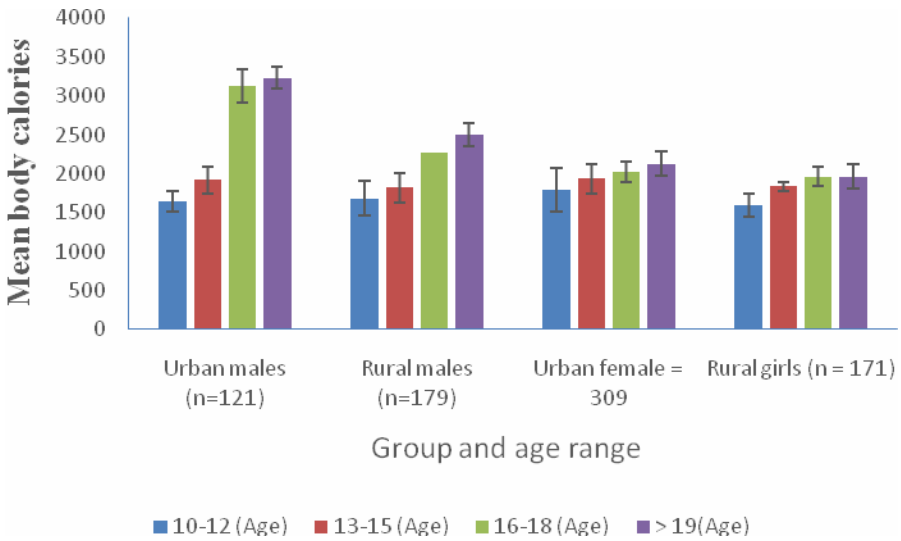


Figure 5: mean Height of urban and rural boys and girls

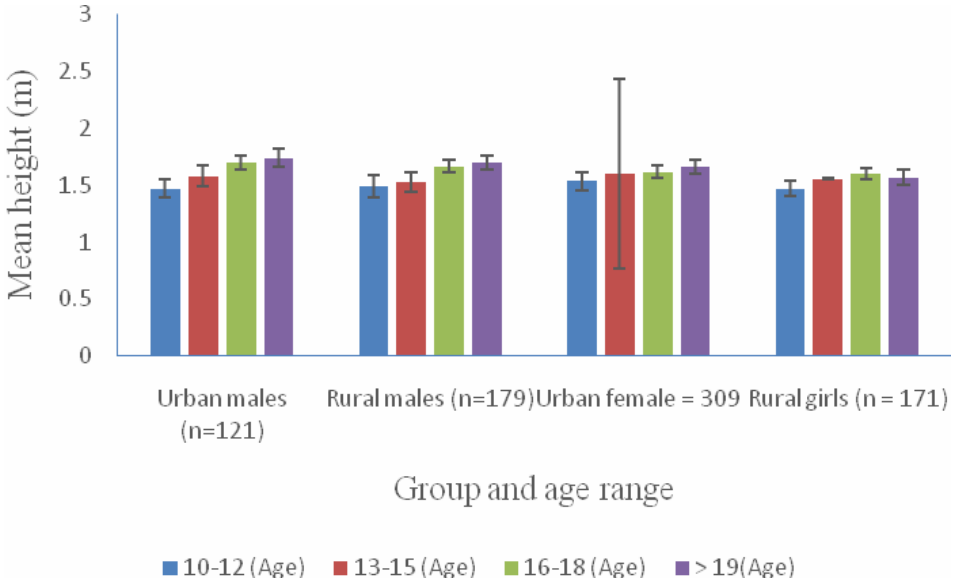


Figure 6: mean weight of urban and rural boys and girls

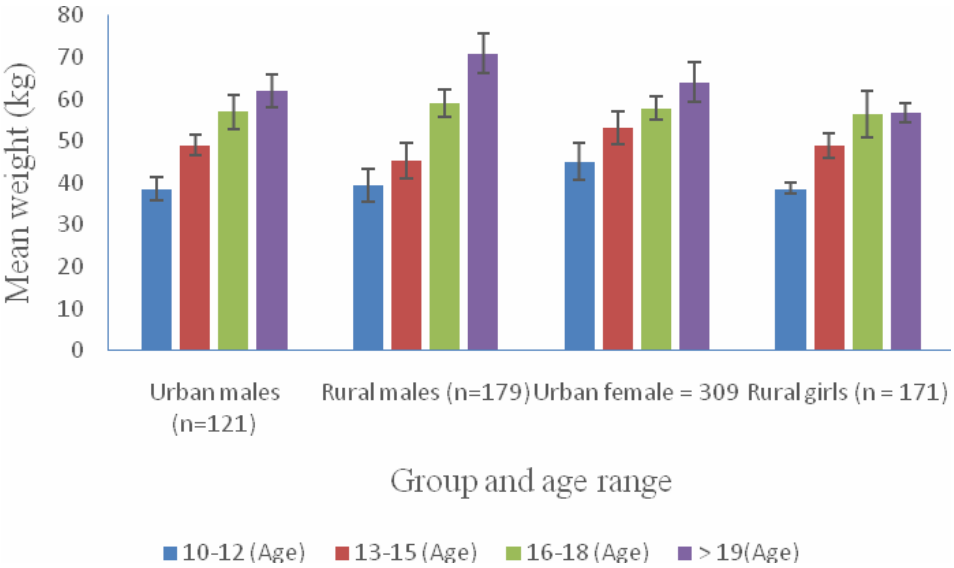
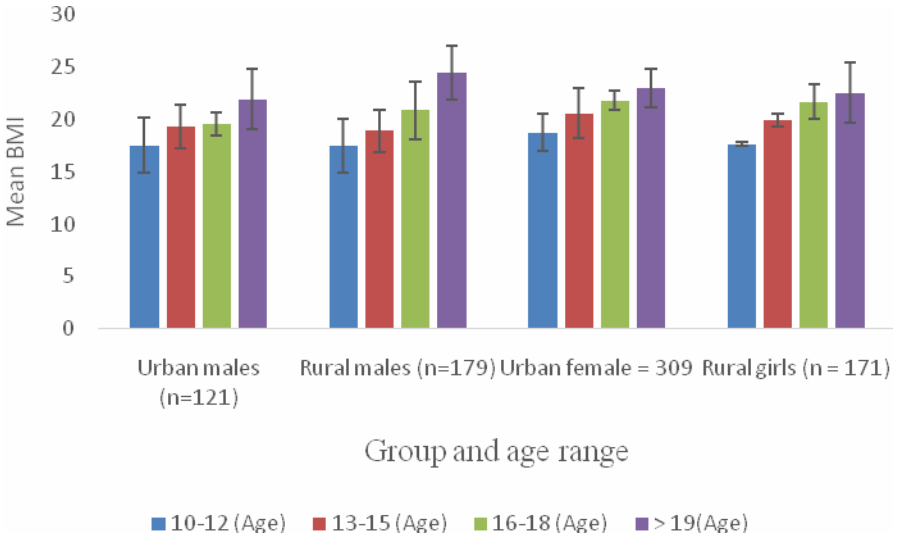


Figure 7: Mean BMI of urban and rural boys and girls



Conclusion

The results of this finding showed that body mass index significantly correlated with body fat percentage estimated by bioelectrical impedance analysis. The relationship was significantly influenced by age, gender, body muscle and body water, so when BMI is used as a measure of body fatness in research or clinical setting particularly when comparisms are made across age and gender .It is important to consider other body compositions like body muscle and body water in interpretation of results.

Acknowledgment

We thank Proff B .C. Nwangwuma for providing the bioelectrical impendence analysis machine (Tanita, Japan) used for the study and all the volunteers who participated in this study.

Competing interest

The authors declare that they have no competing interest.

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