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The Development of Reference Values for Waist Circumference and Waist Height Ratios in Nigerian Youths 10-18 Years of Age

Anumah FO*[1], Mshelia-Reng R[1], Omonua OS[1], Shuaibu RA[2], Odumodu KC[2], Adelaiye RB[3] and Onuoha KN[4]

[1]Department of Medicine, University of Abuja Teaching Hospital, Abuja, Nigeria
[2]Department of Medicine, National Hospital Abuja, Nigeria
[3]Department of Community Medicine, University of Abuja Teaching Hospital, Abuja, Nigeria
[4]Centre for Integrated Health Programs (CIHP), Abuja, Nigeria

***Corresponding author:** Anumah FO, Department of Medicine, University of Abuja Teaching Hospital, Abuja, Nigeria, Tel: +2348033109028, E-mail: anumahnene@gmail.com

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Abstract

In Nigeria, indices predictive of adolescent central adiposity are lacking. This study aimed to develop age- and gender- specific cut-offs for WC and WHtR for Nigerian adolescents.

Methods: Cross-sectional study involving 2,995 students aged 9-19 years (1,187 boys and 1,808 girls) in 20 schools in the Federal Capital Territory Abuja, Nigeria, using a multistage cluster sampling design. Weight, height, Waist circumference (WC), body mass index (BMI), waist to height ratio was measured and Percentiles calculated using the LMS method. The receiver operating characteristic (ROC) curves and areas under the curves (AUCs) were employed to derive optimal age- and sex-specific WC and WHtR references for predicting abdominal obesity.

Results: At age 13 and 14, the mean WC, WHtR and BMI were significantly higher in girls than boys while the mean WHtR was significantly higher in girls at ages 13 through 18 years. The WC increased with age in both genders from the 5th through the 50th percentile with a significant fall thereafter. The WHtR in girls increased with age up to 15 years and plateaued across other percentiles. In boys, WHtR values decreased continuously.
The WC cut-offs according to WHO criteria for obesity ranged from 73.99 cm - 84.00 cm and 67.99 cm - 82.98 cm among girls and boys respectively. The WHtR cut-offs ranged from 0.461 to 0.506 and 0.438-0.488 for girls and boys across all ages. Identifying central obesity in girls, the AUC for WHtR and WC were 0.9396 (95% CI, 0.9207 - 0.9585) and 0.9297 (95% CI, 0.9100 - 0.9494) and in boys, 0.9638 (95% CI, 0.9463 - 0.9814) and 0.9169 (95% CI, 0.8880 - 0.9459) respectively. .

Conclusion: The age- and gender-specific cut-offs from this study may be used as surrogate markers to identify central obesity and also for further research to evaluate their relationship to adverse metabolic outcomes in Nigerian adolescents.

Keywords: Waist Circumference; Waist Height Ratio; Reference Values; Abdominal obesity

Introduction

Overweight and obesity in children and adolescents has become one of the most important public health problems in many nations of the world [1-3]. Obesity is associated with a less favorable cardiovascular risk factor status in children and adolescents. Studies have demonstrated a close relationship between increased excess of adipose tissue in the abdominal region and increased risk of cardiovascular disease [4,5].

In the past two decades, the rates of overweight and obesity have tripled in developing countries that have been adopting a western lifestyle involving decreased physical activity and the over-consumption of high fat, high sugar, high salt, energy dense and micronutrient - poor foods. Such lifestyle changes are also affecting children in these countries [6-8].

In many developing countries, the prevalence of obesity is increasing rapidly. A survey in seven African countries showed that school students in Egypt had the highest rates of overweight and obesity (31.4% and 9.3%) [9]. According to WHO report, in Africa, the prevalence of overweight and obesity among children and adolescents aged 5-19 has risen dramatically from just 4%

in 1975 to over 18% in 2016 [10]. In Nigeria, reports from different regions of the country showed a prevalence ranging from 1% to 18% [11-13]. It has been estimated that 11% of African children will be overweight by the year 2025 [14] thus diet-related chronic diseases such as diabetes, hypertension, cardiovascular diseases and cancer, known from older adults are now observed in children and adolescents. Using the body mass index (BMI) alone to assess adiposity is inaccurate and non-indicative of body fat distribution [15]. In addition, there are some problems associated with the application of BMI in the assessment of childhood obesity. Children are in a continuous growth phase, therefore fixed categories cannot be obtained as in adults, instead, BMI needs to be adjusted for age in childhood. It is also now clear form studies that in children, as in adults, an upper body or centralized deposition of excess fat carries an increased risk for coronary artery disease during childhood, adulthood obesity and an increased risk of adulthood morbidity and mortality [16,17].

Indices predictive of adolescent central adiposity which are inexpensive and non-invasive include waist circumference (WC) and waist-to-height ratio (WHtR). WC in the detection of trunk fat mass has demonstrated high sensitivity and specificity compared to dual- energy X-ray absorptiometry [18]. WHtR is being increasingly used to detect the risk of diseases related to central fatness. The rational being that for a given height, there is an acceptable degree of fat stored on the upper body [19,20]. Research by Savva *et al* has also shown that waist circumference and WHtR are better predictors of cardiovascular disease risk factors than BMI in Greek-Cypriot children aged 10-14 years [21]. Such reference data are lacking for Nigerian youths. WC and WHtR cut-offs differ from country to country due to genetic and environmental factors. Each country must have its own reference values to identify abdominal obesity within the country and also allow comparison with world-wide curves generated for other adolescent populations. The objective of this study therefore was to develop age- and gender- specific definition of central obesity and possible cut-offs for WC and WHtR for Nigerian youths.

Materials and Methods

A cross-sectional study was conducted involving 2,995 students aged 9-19 years (1,187 boys and 1,808 girls) in 20 secondary schools in the Federal Capital Territory Abuja, Nigeria. The Federal Capital Territory has citizens from every part of Nigeria; the three major ethnic groups (Yourba, Ibo, and Hausa) and the minorities are all resident there, with their children in schools. Thus we consider this representative and the study could provide WC and WHtR reference data representative of Nigeria.

Sampling Technique

A multistage cluster sampling design was used. Sample was stratified according to school types (government and private) the schools randomly selected from the list obtained from the School's Board and the Ministry of Education. In the second stage, inside each school, students were randomly selected from each class (Junior Secondary 1-3, Senior Secondary 1-3). Subjects represented socio-economic and urban/rural groups.

Anthropometric Measurements

All measurements were performed by well-trained health professionals: Weight was measured in minimal clothing and recorded to the nearest 0.1kg on calibrated scales and height in bare feet to the nearest millimeter. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2) [22]. Waist circumference (WC) was measured at the point of noticeable waist narrowing to the nearest millimeter and waist-to-height ratio (WHtR) calculated as waist circumference (in cm) divided by height (in cm) [23].

Statistical Methods

SAS software (SAS Institute, Cary, North Carolina, USA) version 9.4 was used for database management and analyses. The data was not normally distributed so a non-parametric analysis was done. A total of 2,995 students (1,187 boys and 1,808 girls) enrolled in the study but outliers, those aged 9 and 19 years were removed thus 2, 879 1,137 (39.4%) boys and 1,745 (60.6%) girls were subjected to analysis.

Mean ± Standard Deviation (SD) were calculated for continuous variables (weight, height, BMI, WC and WHtR) while categorical variables were given as percentages. Smoothed age- and gender- specific percentiles (5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th}) were constructed for WC and WHtR with the use of LMS Chart Maker Pro, version 2.54. The LMS method assumes that data at each age can be normalized by using Box-Cox power transformation. The percentile curves were the result of smoothing the age specific curves: L for skewness, M for median and S for coefficient of variation.

The receiver operating characteristic (ROC) curves and areas under the curves (AUCs) were employed to derive optimal age- and gender-specific WC and WHtR cutoffs for predicting abdominal obesity (BMI > 97^{th} percentile) according to BMI classification based on WHO criteria 2007 [24]. Goulding *et al*, in his study found a curvilinear relationship between BMI and waist-to-height ratio with 90% of children and adolescents with BMI >97th percentile having WHtR > 0.5 [25]. Mann-Whitney and Kruskal-Wallis tests were used for comparing continuous variables between males and females. A value of $P< 0.05$ was considered as significant.

Approval for the study was obtained from the Federal Capital Territory Education Secretariat, Secondary Education Board and the Federal Ministry of Education. Written and oral consent was obtained from the school authorities, students and their parents

Results

In this study, the attrition rate was 118 (3.9%) consisting of incomplete data, age <10 and > 18, and outliers as shown in Figure 1.

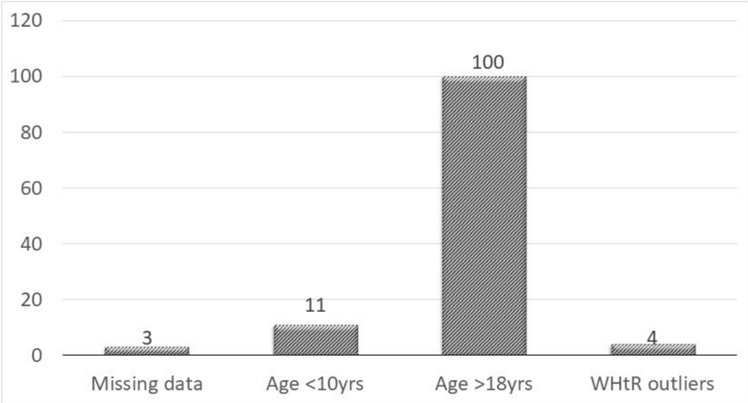

Figure 1: Attrition Analysis of Study subjects

Table 1 presents the means and standard deviations for the anthropometric data of the secondary school adolescents by age and sex. At age 13 and 14, the mean WC, WHtR and BMI were significantly higher in girls than boys while the mean WHtR was significantly higher in girls at ages 13 through 18 years.

Age** (years)	Girls 1,745 (60.6%)						Boys 1,134 (39.4%)					
	n (%)	WC (cm)	BMI (kg/m²)	WHtR	Ht (m)	Wt (kg)	n (%)	WC (cm)	BMI (kg/m²)	WHtR	Ht (m)	Wt (kg)
10	51 (2.9)	70.32	21.69	0.462	1.52†	50.47†	41 (3.6)	66.39	20.62	0.456	1.46	44.15
11	146 (8.4)	67.66	20.78	0.438	1.54†	50.03†	108 (9.5)	66.75	20.12	0.442	1.51	46.25
12	228 (13.1)	68.61	20.91	0.440	1.56	51.23†	146 (12.9)	69.26	20.60	0.447	1.55	49.96
13	274 (15.7)	70.24†	21.89†	0.439†	1.60	56.35†	162 (14.3)	66.99	19.64	0.422	1.59	49.82
14	283 (16.2)	70.32†	21.92†	0.439†	1.60	56.33†	176 (15.5)	68.13	20.02	0.420	1.62†	53.29
15	311 (17.8)	69.43	22.01†	0.432†	1.61	56.96	188 (16.6)	69.72	20.64	0.418	1.67†	57.80
16	244 (14.0)	69.85	22.02	0.436†	1.60	56.66	141 (12.4)	71.29†	21.54	0.420	1.70†	62.30†
17	137 (7.9)	69.89	22.18†	0.438†	1.60	56.48	112 (9.9)	70.63	21.38	0.416	1.70†	62.01†
18	71 (4.1)	70.25	22.79†	0.448†	1.57	56.32	60 (5.3)	69.48	21.34	0.410	1.70†	61.42†

Table 1: Mean Values for Weight, Height, Body Mass Index, Waist Circumference, Waist-To-Height Ratio by Age and Sex
**Age Indicates the Whole Age Group e.g. 10 = 10.0-10.11 years, †: Significant Difference between Male and Female Subjects, N Is Number of Subjects per Sex Category, Wc; Waist Circumference, Whtr: Waist Height Ratio, Ht: Height, Wt: Weight.

The following curves show the smoothed age- and sex-specific percentile values at the 5th, 10th, 25th, 50th, 75th, 90th 95th and 97th percentiles which were developed and smoothed by the LMS method for WC (Figure 2) and for WHtR (Figure 3). The WC increased with age among the girls and the boys from the 5th through the 50th percentile. Among the girls, at the 75th and 80th percentiles the values were constant across ages 10-14 years with a decrease afterwards and tended to plateau from 16-18 years across all estimated percentiles. Boys tended to plateau between the 75th and 90th percentiles from ages 10-14 years, then increased between 15-16 years and then decreased continuously. There is a significant rise at about 16 years from the 75th through the 95th percentile. The WHtR among the girls increased with age at the 5th and 10th percentiles. At the 25th and 50th percentiles the values were constant across ages 10-14 years with a slight increase afterwards. Between ages 15-17 years the values seemed to plateau across all other percentiles, whereas among the boys WHtR values decreased continuously.

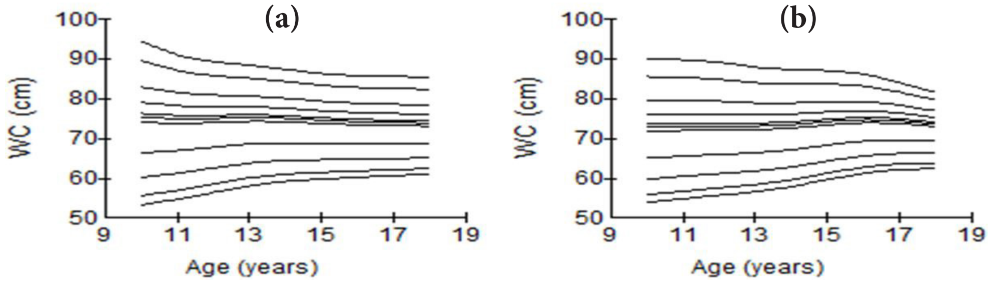

Figure 2: (**a**) Percentile for Girls; (**b**) Percentile for Boys

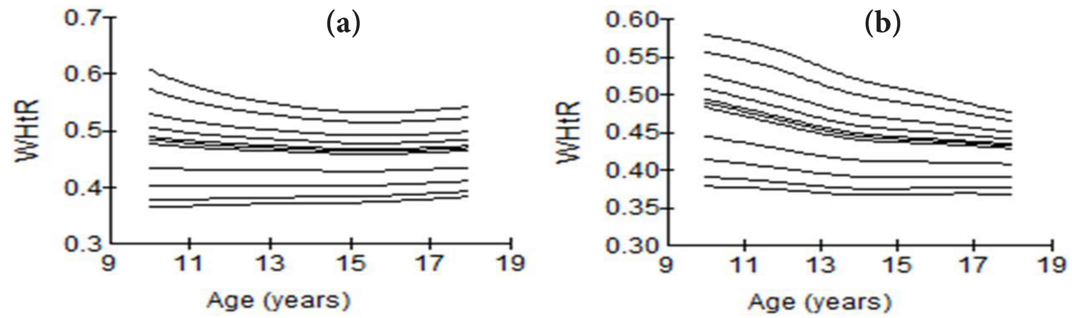

Figure 3: (a) Percentile for Girls**; (b)** Percentile for Boys

Using ROC analysis (Table 2 and 3), the WC cut-offs according to WHO criteria for overweight ranged from 66.00 cm-74.01 cm and 63.01 cm-78.00 cm among girls and boys respectively, while for obesity it ranged from 73.99 cm-84.00 cm and 67.99 cm-82.98 cm among girls and boys respectively. The WHtR cut-offs ranged from 0.461 to 0.506 and 0.438-0.488 for girls and boys respectively.

Age* (years)	Overweight					Obese				
	AUC	95% CI	Cutoff (≥)	Sen (%)	Spe (%)	AUC	95% CI	Cutoff (≥)	Sen (%)	Spe (%)
Girls										
10	0.759	0.5877-0.9308	(%)	55.6	81.0	(%)	0.9385-1.0000	73.99	85.7	93.3
11	0.853	0.7628-0.9426	66.00	71.4	82.7	0.935	0.8759-0.9937	73.01	84.8	96.0
12	0.907	0.8551-0.9582	68.00	84.5	85.8	0.952	0.9271-0.9769	74.00	87.0	87.9
13	0.906	0.8612-0.9513	71.00	79.7	87.7	0.922	0.8684-0.9755	75.99	86.7	88.2
14	0.861	0.8124-0.9096	72.01	72.7	83.5	0.954	0.9228-0.9849	80.00	82.1	95.7
15	0.895	0.8538-0.9367	72.00	71.9	88.0	0.970	0.9396-1.0000	77.01	90.5	92.8
16	0.862	0.7993-0.9239	72.00	75.0	80.5	0.995	0.9882-1.0000	82.00	90.9	98.3
17	0.821	0.7199-0.9215	74.01	65.0	84.7	0.988	0.9692-1.0000	84.00	80.0	97.7
18	0.853	0.7162-0.9895	74.01	77.8	88.9	0.973	0.9362.1.0000	79.99	83.3	96.9
Boys										
10	0.792	0.6033-0.9801	63.01	75.0	78.6	0.962	0.8879-1.0000	67.99	92.9	96.3
11	0.816	0.7141-0.9172	66.01	73.9	82.0	0.938	0.8789-0.9974	71.00	87.5	92.1
12	0.863	0.7887-0.9372	68.99	70.0	87.1	0.972	0.9497-0.9946	74.01	90.0	94.0
13	0.817	0.7234-0.9104	69.99	74.2	85.1	0.911	0.7990-1.0000	73.99	85.7	90.5
14	0.872	0.7732-0.9714	71.00	79.2	86.3	0.976	0.9548-0.9976	75.99	85.7	92.0
15	0.921	0.8647-0.9764	75.01	73.7	92.7	0.980	0.9611-0.9991	78.00	92.9	93.7
16	0.853	0.7199-0.9852	76.01	61.5	92.1	0.992	0.9770-1.0000	80.00	90.0	94.7
17	0.958	0.9177-0.9972	75.00	83.3	91.7	1.000	1.0000-1.0000	82.98	100.0	97.3
18	0.965	0.8991-1.0000	78.00	75.0	98.2	0.924	0.8575-0.9900	77.00	100.0	91.5

Table 2: Sensitivity and Specificity of Waist Circumference Cutoffs by Age and Sex According To the Receiver Operating Characteristic (ROC) Curve Analysis for Obesity Based On the World Health Organization (WHO) Criteria
AUC: Area Under the Curve, CI: Confidence Interval, Spe: Specificity, Sen: Sensitivity

Age* (years)	AUC	95% CI	Cutoff (≥)	Sensitivity (%)	Specificity (%)
Girls					
10	0.968	0.9277-1.0000	0.486	85.7	96.7
11	0.934	0.8745-0.9940	0.461	87.0	94.0
12	0.967	0.9475-0.9871	0.467	89.1	91.2
13	0.920	0.8613-0.9785	0.469	86.7	89.5
14	0.953	0.9139-0.9924	0.493	89.3	93.3
15	0.966	0.9410-0.9906	0.473	85.7	91.0
16	0.988	0.9720-1.0000	0.494	90.9	94.4
17	0.985	0.9538-1.0000	0.500	80.0	93.9
18	0.982	0.9548-1.0000	0.506	83.3	95.4

Boys					
10	0.988	0.9665-1.0000	0.471	92.9	96.3
11	0.941	0.8771-1.0000	0.465	87.5	96.1
12	0.945	0.9078-0.9827	0.477	76.7	94.8
13	0.952	0.9033-1.0000	0.458	85.7	92.6
14	0.975	0.9506-1.0000	0.465	92.9	94.4
15	0.982	0.9641-1.0000	0.455	92.9	93.1
16	0.979	0.9384-1.0000	0.488	90.0	100.0
17	1.000	1.0000-1.0000	0.470	100	97.3
18	0.814	0.7133-0.9138	0.438	100	81.4

Table 3: Sensitivity and Specificity of Waist -To-Height Cutoffs by Age and Sex According To the Receiver Operating Characteristic
AUC: Area Under The Curve, Ci: Confidence Interval, Spe: Specificity, Sen: Sensitivity

Cut-off for all age groups combined using WC: overweight for Girls, 70.50cm (AUC 0.846 CI 0.8230-0.8697), sensitivity 71.3%, specificity 81.0%. Boys, 69.99cm (AUC 0.748 CI 0.7041-0.7915) sensitivity 67.3%, specificity 72.2%. Obesity cut-off for girls, 75.99cm (AUC 0.930 CI 0.9100-0.9494), sensitivity 83.0%, specificity 88.9% while for boys 74.01cm (AUC 0.917 CI 0.8880-0.9459) sensitivity 81.5%, specificity 87.0%. The WHtR cut-off for Girls: 0.469 (AUC 0.940 CI 0.9207-0.9585), sensitivity 83.3%, specificity 88.5%, Boys: 0.465 (AUC 0.964 CI 0.9463-0.9814), sensitivity 85.4%, specificity 94.8%.

Comparing WHtR and WC optimal cutoff points using ROC curves for identifying abdominal obesity in girls, the AUC for WHtR and WC were 0.9396 (95% CI, 0.9207-0.9585) and 0.9297 (95% CI, 0.9100-0.9494) respectively. Among the boys, the AUC for WHtR and WC were 0.9638 (95% CI, 0.9463-0.9814) and 0.9169 (95% CI, 0.8880-0.9459) respectively. The AUC for WHtR was significantly larger than that for WC in both genders $P<0.05$ (Figure 3).

The spearman's rank correlation between the anthropocentric data revealed strong relationship between measurements as shown in (Table 4, Figure 4, 5 and 6). The correlation coefficient (r) for WC & BMI = 0.79478, WHtR & BMI *r* =0.75219, WC & WHtR *r* = 0.8212).

	AGE	**WC**	**WHtR**	**BMI**
AGE	1	0.12995	-0.08317	0.16266
		*<.0001	<.0001	<.0001
WC	0.12995	1	0.8212	0.79478
	<.0001		<.0001	<.0001
WHtR	-0.08317	0.8212	1	0.75219
	<.0001	<.0001		<.0001
BMI	0.16266	0.79478	0.75219	1
	<.0001	<.0001	<.0001	

Table 4: Spearman's Correlation between Anthropometric Data

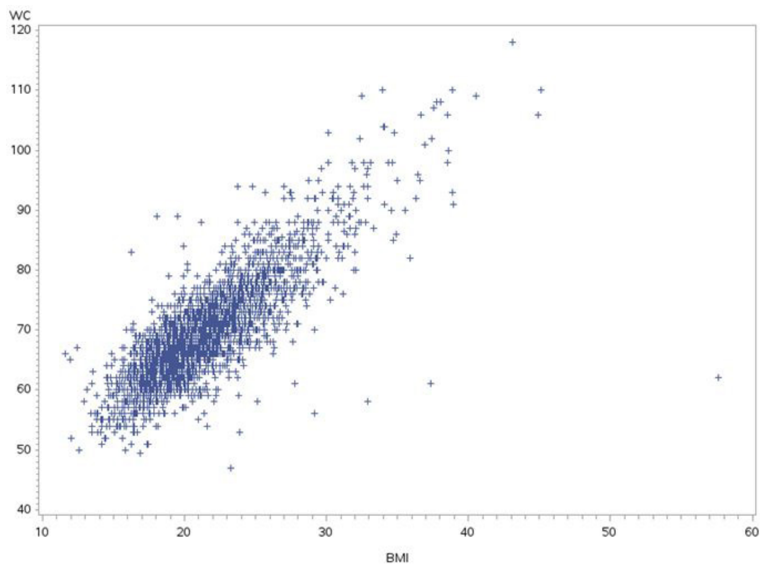

Figure 4: Correlation between Waist Circumference (Wc) And Body Mass Index (BMI)

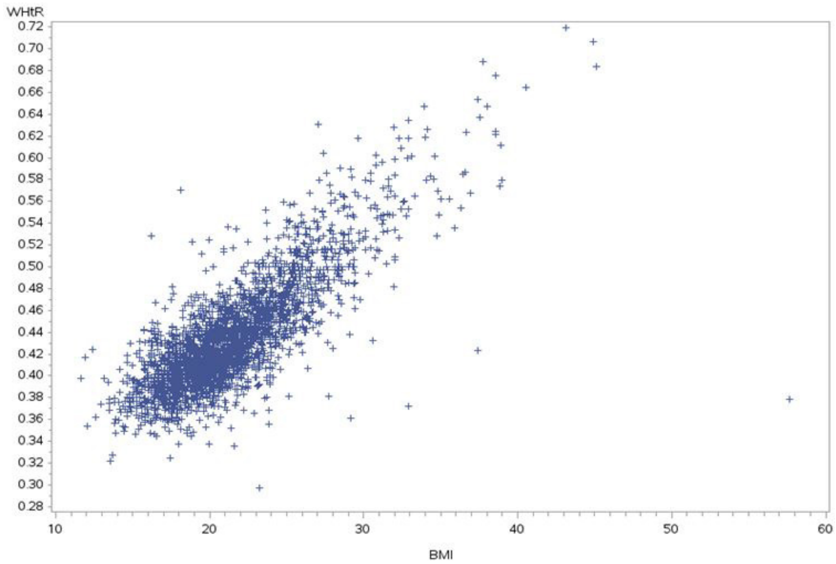

Figure 5: Correlation between Waist Height Ratio (WHtR) and Body Mass Index (BMI)

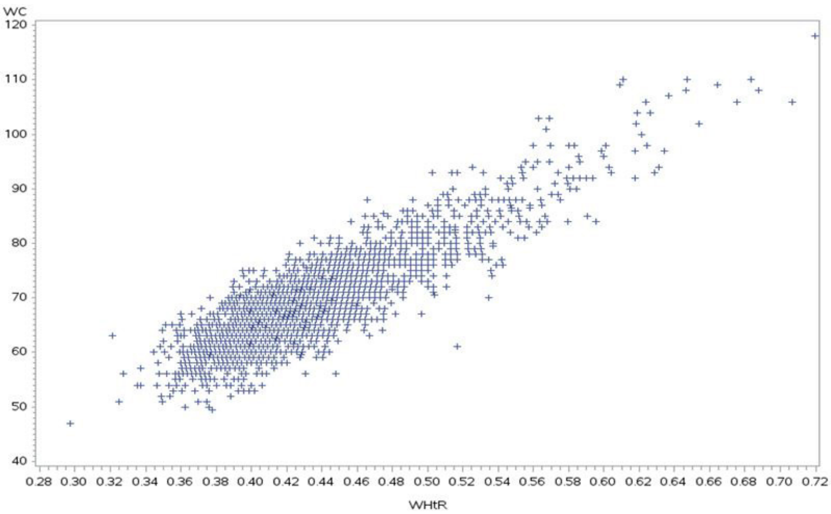

Figure 6: Correlation between Waist Circumference (Wc) and Waist Height Ratio (WHtR)

Discussion

Developing reference ranges, percentiles and cut-offs for WC and WHtR is needed to enable clinicians identify adiposity in Nigerian youths aged 10-18 years with the rising prevalence of overweight and obesity in this population [11-13]. Each country must have its own reference values to identify obesity within the country.

Research has shown that abdominal fat, irrespective of whether an individual is overweight or not is a major risk factor for cardiovascular and metabolic diseases [4,14,16,17].

Waist circumference is a highly sensitive and specific measure of upper body fat and is the simplest, easiest, cheapest, non-invasive and most widely accepted method for evaluation of body composition in children [18]. Consistent evidence has demonstrated significant correlation between waist circumference and cardiovascular and metabolic disease risk factor levels in children and adolescents [21,26,27]. In this study, the waist circumference was measured at the point of noticeable narrowing as done in some studies [28,29].

The WC and WHtR from the present study were significantly higher in girls at 13-14 years, while the WHtR remained significantly higher in girls from 13 through 18 years. Puberty is the critical period for body fat development and distribution in both boys and girls and there is a normal increase in WC throughout puberty [30,31]. Central fat distribution appears to be more predominant in the girls than the boys in in this study, in contrast to some other studies that have shown boys, having more adipose tissue distribution in the upper body [15,31].

Waist circumference cut-offs values are affected by ethnicity and environment, such data are not available for Nigerian adolescents, thus the need to provide population specific reference values for this age group. We have proposed from our data, for the girls, overweight and obesity cut-offs of 70.50cm (AUC 0.846) and 75.99cm (AUC 0.930) and for the boys 69.99cm (AUC 0.748) and 74.01cm (AUC 0.917) respectively. Based on the cut-offs for all the age groups proposed in this study, we found an overall prevalence of abdominal adiposity to be 19.6%. Among the girls, 20.6% and the boys 18.1%. The overall prevalence is higher than 14% found by Bacopoulou *et al*. in Greek adolescents aged 12-17 years [30].

The waist height ratio (WHtR) is an index of the amount of upper body fat accumulation in relation to height thus useful in children. This ratio starts to increase when extra fat would start to accumulate on the upper body [15]. The mean WHtR was significantly higher among the girls from age 13 through 18 years in this study. This finding is in contrast to that of McCarthy HD and Ashwell M, where the girls had lower WC values than the boys at any given height in two surveys (children aged 5-16years and 11-16 years) [15]. This difference could be due to genetics and environment. In the Nigerian environment, the girls about this age stay more at home and join their mothers to do the cooking and are exposed to more food environment with little physical activity, while the boys are outgoing and more likely to be involved in physical activity.

In this study, the proposed cut-offs based on BMI percentiles associated with body adiposity for WHtR ranged from 0.461-0.506 and 0.438-0.488, and overall 0.469 and 0.465 for Girls and Boys respectively with high sensitivity and specificity. The overall prevalence of abdominal obesity was 18.7%. However, the prevalence was higher in adolescent girls 21.5% than boys 14.4%. When the universal cut-off of 0.5 suggested by McCarthy and Ashwell was used, abdominal adiposity was found in only 10.0% and 7.1% of the girls and boys respectively. The cut-offs in this study is close to the age specific cut-offs of 0.467-0.506 used by Cintra et al., in the Brazilian study and they reported excess body weight in 28.15% of their adolescents [32].

Other authors such as Panjikkaran have also reported different WHtR cut-offs for identifying their own school children in Kerala, India with excess weight. He found that the area under the ROC curve (AUC) was 0.827 at WHtR cutoff of 0.48 compared to 0.673 at WHtR 0.50, showing that 0.48 is an optimal cut-off for their population [33]. In the present study, the AUC was 0.940 at WHtR 0.469 for girls and AUC 0.964 at WHtR 0.465 for boys. This finding suggests that our adolescents with these WHtRs may be at risk of abdominal adiposity.

Research has shown that abdominal adiposity starts in childhood, progresses through adolescence to adulthood [4,17,34]. In this study, the AUC for WHtR for Girls (0.9396) and boys (0.9638) respectively were found to be significantly larger than the AUC for WC (0.9297) and (0.9169) for girls and boys respectively. Therefore WHtR which is a simple straightforward indicator of abdominal obesity appears to be a better screening tool than WC and can be used for assessing increased health risk in children. Freedman *et al*., studied 2,498 children and adolescents aged 5 to 17 years and found a strong correlation between WHtR and visceral fat and risk factors of cardiovascular disease [35]. Also Mokha et al., in his own work in adolescents aged 4-18 years reported that WHtR is not only an important indicator of central obesity and adverse cardio metabolic risk for obese children but also for normal-weight children with WHtR > 0.5 [36].

In this study, a strong correlation was found between WC and BMI r = 0.79478, WHtR and BMI r =0.75219, WC and WHtR r = 0.8212. This finding corroborates with Goulding *et al*., in his study who found a curvilinear relationship between BMI and waist-to-height ratio with 90% of children and adolescents with BMI >97th percentile having WHtR > 0.5 [25]. Freeman *et al*., also in the Bogalusa Heart Study concluded that BMI-for-age and WHtR do not differ in their abilities to identify children with adverse risk factors [37].

Conclusion

Our findings show that abdominal adiposity was more prevalent in our adolescent girls than boys using both WC and WHtR. Overall, with WC, 19.6% and with WHtR 18.7% had abdominal adiposity. Our cut-off values showed high sensitivity and specificity. We propose that these percentiles could be used for now in clinical practice to identify children with excessive accumulation of fat on the upper body. Early detection of abdominal obesity in Nigerian youths is urgent considering the associated elevated risk factors for cardiovascular disease, future adulthood morbidity and mortality.

Limitation

In this study, anthropometric measurements were taken only once by trained healthcare professionals. There were no repeat measurements therefore; we could not estimate the error margin of the measurements.

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