

Predictive capacity of anthropometric indicators of body fat in identifying hypertension in adolescents

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ABSTRACT

- Background** : Hypertension (HTN) is a major health problem affecting different populations including adolescents worldwide, and it is strongly associated with obesity.
- Objectives** : This study examined the predictive capacity of anthropometric proxies of body fat and determined the threshold values that would identify HTN among Nigerian adolescents.
- Setting and Design** : A cross-sectional study with a total of 2228 in-school adolescents aged 12–16 years.
- Materials and Methods** : Participants were evaluated for physical characteristics including five anthropometric indices of body fat and blood pressure. Receiver operating characteristics curves were used for the analysis of sensitivity, specificity, area under curve (AUC) of the fat indices in detecting HTN.
- Results** : All body fat indicators with the exception of waist-to-height ratio in boys, had significant ($P < 0.0005$) AUC with total fat mass (TFM) in girls and waist circumference (WC) in boys as the best fat indicators for predicting systolic HTN in adolescents. The TFM cut-point for girls was 8.0 kg and the WC cut-point for boys was 66.3 cm. Both TFM and WC demonstrated a stronger association with systolic HTN than other fat indicators in both genders. The likelihood of a girl developing HTN is 1.1 (95% confidence interval [CI] = 1.05–1.20) times with a unit increase in TFM, while boys with unhealthy WC had 3.2 (95% CI = 1.83–5.67) times odd of developing HTN compared to their healthy peers.
- Conclusions** : This study showed that TFM and WC are useful tools for detecting HTN in Nigerian adolescent girls and boys, respectively. The fat indicators used in this study generally showed low predictive capacity.
- Keywords** : Adiposity, adolescents, anthropometry, hypertension, receiver operating characteristic curves

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INTRODUCTION

The prevalence of hypertension (HTN) is increasing in all age groups, making it a major public health problem globally. HTN is considered the third leading cause of mortality worldwide,^[1] and the most prevalent cardiovascular disease risk factor.^[1,2] HTN contributes to the risk of noncommunicable diseases, and its prevalence in childhood is known to track into adulthood with associated sequelae.^[3,4]

Previously, HTN considered a disease of the affluence, adults and predominantly of the Western societies is now prevalent among the poor, all population groups and in developing countries as well, including Africa.^[5] The recent increase in the burden of HTN in youth has been ascribed to the surge in the prevalence of childhood and adolescent overweight (OW) and obesity (OB).^[6] OB is a leading risk factor of HTN in both adults^[7] and adolescents.^[6] Indeed, it has been reported that the prevalence of HTN is about double in OW and obese adults compared to their normal-weight counterparts, and the association of OB with HTN is not just related to excess body fat but more to its distribution.^[8,9] However, the particular measure of fat that is more predictive of HTN in adolescents remains to be clearly determined.

Studies on anthropometric surrogates of body fat in relation to HTN in youth have produced conflicting results. In a study of Canadian adolescents,^[10] blood pressure (BP) was found to be strongly and positively associated with visceral fat (VF) and less strongly and negatively associated with total fat mass (TFM) in boys. In contrast, BP was strongly and positively associated with TFM and not associated with VF in girls. Another study found waist-to-height-ratio (WHtR) to have the best distinguishing power than other body fat indices for detecting HTN. Other studies^[11,12] in adolescents found body mass index (BMI) as the best predictor of elevated BP.

Given these conflicting results, there is a need for further studies to clarify which anthropometric indicator of fat best predicts HTN in adolescents. Information on anthropometric indicator of body fat that best predicts HTN in African adolescents is exiguous. The predictive power of anthropometric indices to predict cardiometabolic risk factors to some extent depends on population and race/ethnicity.^[7,9,13] In a resource-limited setting, the use of anthropometric data to predict HTN will be a cost-effective modality. Many investigators have used this method in different ethnic groups previously.^[11,12,14] However, this may not be applicable to African youth due to different patterns of development, hence the need for this study. The present study aimed to determine the diagnostic accuracy of body fat indicators to identify HTN among Nigerian adolescents.

The ability of each fat indicator to discriminate between healthy (normotensive) and unhealthy (hypertensive) BP levels will be of public health significance. Such information is important for designing intervention strategies for the prevention and screening of HTN among adolescents. The outcome of this study will enable health care and other allied health professionals to identify the value of each anthropometric fat indicator that represents increased risk of HTN in Nigerian adolescents. Anthropometric assessment of body fat indicators are simple and could serve as alternative screening method for the identification of BP disorders especially in school environments where large-scale BP measurements seem cumbersome.

MATERIALS AND METHODS

Participants

We sampled 2228 school children aged 12–16 years from Benue State, Nigeria. Multistage and systematic sampling techniques were applied to select participants from 24 schools in the state. The study was conducted over a 4 months period (April–July 2013). Details of the sampling procedures have been previously described.^[15]

The research protocol was approved by the ethics review board of Benue State University, and written informed consent of parents and assent of minors were obtained before participation. All study procedures were consistent with the ethical guidelines of the Helsinki declaration.

Physical characteristics measurements

Participants' physical characteristics were measured according to standard procedure.^[16] Details of the measurement protocols have been previously described.^[15] Body mass and stature were assessed with the aid of an electronic weighing scale (Seca digital floor scale, sec-880, Seca, Birmingham, UK) and a wall-mounted stadiometer (model sec-206; Seca, Birmingham, UK). Both body mass and stature were measured to the nearest 0.1 kg and 0.1 cm, respectively. Participants' BMI ($\text{kg}\cdot\text{m}^{-2}$) was determined and used to estimate body fatness. Percent body fat (PBF) was estimated from measures of triceps and medial calf skinfold thickness using the revised regression equations of Heyward and Wagner, as cited.^[17]

The waist circumference (WC) was assessed with a retractable metal tape (Creative Health Products, Ann Arbor, MI, USA) and used to estimate abdominal fat.^[18] WHtR was calculated as the waist in centimeters divided by height in centimeters. TFM was calculated as: $\text{PBF} \times \text{body mass}$. The cut-off points used for BMI and PBF were those proposed by The Cooper Institute.^[19] The cut-off points used for WC and WHtR were those recommended by The International Diabetes Federation^[20] and McCarthy *et al.*,^[21] respectively.

Blood pressure measurement

Participants' BP was measured with an oscillometric device (HEM-705 CP; Omron, Tokyo, Japan) after sitting quietly for 10 min. The resting systolic BP (SBP) and diastolic BP (DBP) were monitored on each participant's right arm using appropriate cuff sizes. Measurements were taken three times at 2-min intervals, and the average of the three readings recorded. Specific details of the BP protocol have been described elsewhere.^[15] Participants, BP cut-point for HTN (95th percentile for age and sex) was based on the standards of the fourth report on the diagnosis, Evaluation and Treatment of High BP in Children and Adolescents 2004.^[22]

Data analysis

Data analyses were performed with the Statistical Package for the Social Sciences (SPSS Version 20.0, SPSS Inc., Chicago, IL, USA) at an alpha level of 0.05 or less. Descriptive statistics (Mean \pm standard deviation) were used to summarize participants' general characteristics. Differences in physical and hemodynamic characteristics between girls and boys were computed using the independent samples *t*-test. The receiver operating characteristics (ROCs) curve analyses were constructed, including the area under curve (AUC) and 95% confidence interval (CI). The SBP and DBP thresholds for the five indices of body fat were defined as the coordinates that had the closest values to 1 for the differences between the true positive (sensitivity) and false-positive (1-specificity) values. The AUC was used to determine the predictive capacities of the body fat proxies for HTN. Hosmer and Lemeshow^[23] guidelines were used to interpret the values of AUC: An AUC of 1 represented perfectly accurate test; 0.5 = no discriminatory power; >0.9 = excellent; 0.8-0.9 = good; 0.7-0.8 = acceptable; <0.7 = poor. Pearson's product-moment correlations were used to assess the relationship between the independent and dependent variables. The independent associations of body fat indices with the dependent variables were calculated using the binary logistic regression models. Separate analyses were performed for girls and boys.

RESULTS

Physical and hemodynamic characteristics

The physical and hemodynamic characteristics of participants are presented in Table 1. Averagely, girls were significantly taller ($P = 0.01$), heavier ($P < 0.0005$), fatter ($P < 0.0005$), and had higher BMI ($P = 0.014$) and WC ($P < 0.0005$) than boys. The boys were leaner ($P = 0.002$), had higher WHtR ($P < 0.0005$), lower SBP ($P < 0.0005$) and mean arterial pressure ($P = 0.001$) than girls. There were no significant ($P > 0.005$) gender differences in age and DBP. The overall prevalence of systolic HTN was 10.1% and diastolic HTN, 10.2%.

Details of the gender-specific prevalence rates are shown in Figure 1. OW prevalence rates determined by the body fat proxies were highest for WC and WHtR in both genders [Figure 2].

Threshold of adiposity indices for detecting hypertension

The ROC curve analyses for SBP in girls and boys are displayed in Table 2. In girls, TFM demonstrated the best discriminatory power in distinguishing adolescents with systolic HTN from those without (AUC = 66% [95% CI = 61.4%-70.1%]). This was followed by WC, with AUC of 65% (95% CI = 60.2%-69.1%). For boys, WC indicated the best discriminatory power for diagnosing HTN (AUC = 67% [95% CI = 59.5%-73.4%]). Next was TFM with an AUC of 66% (95% CI = 59.3%-74.3%). With respect to DBP in girls, only BMI had significant ($P < 0.0005$) AUC (59.8%; 95% CI = 54.4%-65.1%). In the case of boys, only WC displayed the highest AUC ($P = 0.033$) of 56% (95% CI = 50.0%-62.6%). WHtR had the lowest AUC. In general, the performance of the independent variables in identifying diastolic HTN in both sexes was poor.

Correlation of body fat indicators and blood pressure in participants

The correlations between the indicators of body fat and the dependent variables are presented in Table 3. The relationships were generally weak though significant. In girls, the highest correlations were found between TFM and SBP ($r = 0.279$, $P = 0.01$), followed by WC and SBP ($r = 0.191$, $P = 0.01$). In boys, the highest correlation was between WC and SBP ($r = 0.213$, $P = 0.01$). This was followed by the correlation between TFM and SBP ($r = 0.05$, $P = 0.01$). Other correlations, including those between the independent variables and DBP were generally weak.

Multivariate models for predicting of blood pressure

Different predictive models of SBP were computed using the logistic regression statistic in order to determine the predictive ability of each independent variable to

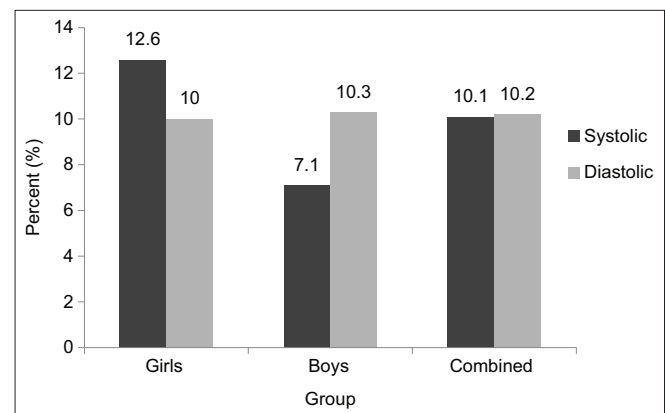


Figure 1: Prevalence of hypertension among participants

Table 1: Physical and hemodynamic characteristics of participants

Variable	Combined (n=2226)	Girls (n=1188)	Boys (n=1038)	t	P
Age (years)	13.6±1.3	13.6±1.3	13.5±1.3	0.43	0.67
Stature (cm)	150.4±11.4	151.0±10.8	149.8±12.0	2.54	0.01
Body mass (kg)	43.5±9.0	44.3±8.8	42.7±9.2	4.32	0.0005
LBM (kg)	36.5±7.4	36.0±6.5	37.0±8.2	3.16	0.002
BMI (kg/m ²)	19.2±3.8	19.4±3.7	19.0±3.9	2.45	0.014
Body fat (%)	15.9±6.4	18.3±5.5	13.1±6.3	20.65	0.0005
TFM (kg)	7.1±3.6	8.3±3.6	5.7±3.2	18.4	0.0005
WC (cm)	66.3±8.2	67.3±8.1	65.1±8.2	64.9	0.0005
SBP (mmHg)	113.8±17.4	116.0±18.0	111.2±16.3	7.04	0.0005
DBP (mmHg)	69.7±14.2	69.6±13.8	69.6±1.8	0.31	0.80
MAP (mmHg)	84.3±12.8	85.1±13.1	83.4±12.4	3.47	0.001

LBM: Lean body mass, BMI: Body mass index, TFM: Total fat mass, WC: Waist circumference, SBP: Systolic blood pressure, DBP: Diastolic blood pressure. MAP: Mean arterial pressure

Table 2: Age-adjusted binary logistic regression model and receiver operating characteristics analysis for systolic hypertension by gender

Variable	Girls					Boys				
	BMI	PBF	TFM	WC	WHtR	BMI	PBF	TFM	WC	WHtR
LRM										
OR	1.7	0.3	1.1	1.6	0.7	1.2	0.1	1.2	3.2	0.3
P	0.147	0.013	0.0005	0.018	0.177	0.798	0.039	0.001	0.0005	0.033
DC										
AUC	0.60	0.58	0.66	0.65	0.54	0.59	0.58	0.66	0.67	0.49
95% CI	0.559-0.649	0.531-0.628	0.614-0.701	0.602-0.691	0.487-0.585	0.526-0.659	0.499-0.652	0.593-0.743	0.595-0.734	0.418-0.553
P	0.0005	0.002	0.0005	0.0005	0.152	0.008	0.030	0.0005	0.0005	0.675
Cut-point	19.2	17.3	8.0	68.1	0.45	18.8	13.5	5.7	66.3	0.44
Sensitivity	0.600	0.600	0.653	0.647	0.533	0.595	0.554	0.662	0.649	0.486
Specificity	0.462	0.511	0.416	0.431	0.499	0.437	0.323	0.342	0.438	0.490

LRM: Logistic regression model, OR: Odd ratio, DC: Diagnostic accuracy, AUC: Area under curve, CI: Confidence interval, BMI: Body mass index, PBF: Percent body fat, TFM: Total fat mass, WC: Waist circumference, WHtR: Waist-to-height-ratio

Table 3: Correlations between adiposity indices and the blood pressure variables (n=2226)

Variable	Girls (n=1188)		Boys (n=1038)	
	SBP	DBP	SBP	DBP
BMI	0.157**	0.123**	0.187**	0.074*
PBF	0.188**	0.076*	0.062*	0.067*
TFM	0.279**	0.130**	0.205**	0.111**
WC	0.191**	-0.012	0.213**	0.044
WHtR	0.031	-0.042	0.034	-0.004

*P=0.05, **P=0.01. BMI: Body mass index, PBF: Percent body fat, TFM: Total fat mass, WC: Waist circumference, WHtR: Waist-to-height-ratio, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

predict HTN. Models were adjusted for age [Table 2]. The variable that obtained the best goodness-of-fit ($\chi^2_{(6,N=1038)} = 58.8, P < 0.0005$) for girls was TFM (OR = 1.1, 95% CI = 1.05-1.20, P = 0.0005). This was followed by age (OR = 1.2, 95% CI = 1.04-1.37, P = 0.015). The model for boys was significant ($\chi^2_{(6,N=1038)} = 58.8, P = 0.0005$). Both WC (OR = 3.2, 95% CI = 1.83-5.67, P < 0.0005) and age (OR = 1.5, 95% CI = 1.20-1.83, P < 0.0005) were uniquely associated with systolic HTN, respectively.

The girls model for DBP was significant ($\chi^2_{(6,N=1188)} = 14.87, P = 0.021$). Age was the best predictor of diastolic HTN (OR = 1.3, 95% CI = 1.11-1.50, P = 0.001). The boys' model was also significant ($\chi^2_{(6,N=1038)} = 18.66, P = 0.005$). As with SBP, WC (OR = 2.2, 95% CI = 1.34-3.54, P = 0.002) was the best predictor

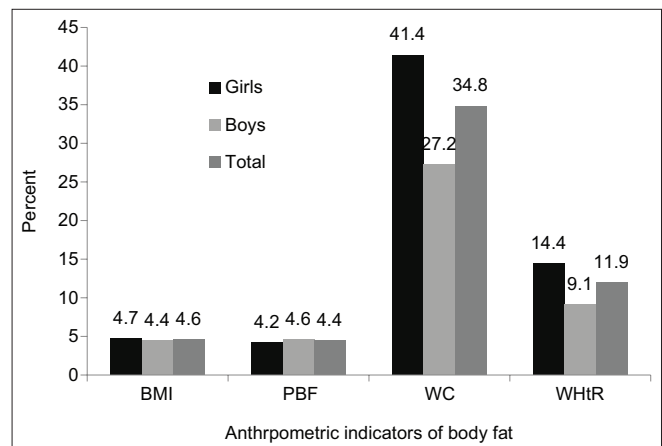


Figure 2: Prevalence of overweight by different body fat indicators
Cut-off points: Body mass index = 95th percentile; Percent body fat = 95th percentile; Waist circumference = 90th percentile; Waist-to-height-ratio = 0.50

of diastolic HTN. The remaining variables were not significantly associated with diastolic HTN.

DISCUSSION

The main findings of this study include first, the prevalence of HTN is relatively higher than the prevalent rates previously reported for adolescents in high- and some low-income countries, and it is higher in girls.

Second, all measures of adiposity were higher in girls compared to boys. Third, TFM demonstrated the highest discriminatory capacity in detecting systolic HTN in girls, while WC displayed the highest diagnostic capacity in boys. The discriminatory capacities of the independent variables in detecting diastolic HTN were generally low.

The prevalence of systolic HTN of 10.1% and diastolic HTN of 10.2% is higher than the values of 9.6% and 3.5% for systolic HTN and diastolic HTN respectively reported for Eastern Nigerian adolescents.^[24] However, the prevalence rate of systolic HTN of 3.6% and diastolic HTN of 19.0% reported by Dewi *et al.*^[25] is at variance with the values in the present study. The higher adiposity in girls relative to boys in the present study is in conformity with previous studies in adolescents.^[26,27] A plausible reason for this gender difference in adiposity may be due to the adolescent growth spurt leading to increase in muscle mass in boys and greater fat deposition in girls during this period. In this study, the prevalence of OW determined by these body fat indicators was highest for WC and WHtR compared to the other fat indicators [Figure 2]. This is consistent with recent findings.^[25,28]

Our results showed that TFM with a cut-point of 8.0 kg was the body fat proxy with the highest distinguishing capacity for systolic HTN in adolescent girls while WC with a cut-point of 66.3 cm proved to be the best fat indicator to detect systolic HTN in boys. Our findings are in conformity with those of Canadian,^[10] Spanish,^[29] Lithuanian,^[12] and Malaysian^[30] adolescents. With the exception of TFM in girls and WC in boys, the diagnostic accuracies of the independent variables were generally poor. This finding is consistent with previous results.^[11] This study clearly indicated that TFM and abdominal adiposity were the best fat indicators to identify HTN while WHtR was the worst. This finding is at variance with studies in Malaysian,^[31] Iranian,^[14] and Puerto-Rican^[27] children which found WHtR as the best predictor of HTN. A possible reason for this inconsistency may be due to higher OW/OB rates reported among youth in these countries compared to the Nigerian youth. Race and ethnicity may be other reasons.^[9]

Compared to the reference standards,^[19-21] the thresholds for detecting HTN documented in the present study are generally lower. This implies that these international standards are not applicable to Nigerian adolescents. A possible reason for this may be the exclusive use of foreign samples for developing these standards which most of the time did not include African samples.

We observed that the relationships between BP and the independent variables were generally weak, but the relationships with TFM in girls and WC in boys were stronger. Furthermore, correlations of the independent variables with SBP were generally stronger than those

with DBP among participants. These findings are in agreement with previous research.^[11]

The cross-sectional design used in this study is a limitation as it precludes confirmation of causality relationship among the variables. Another limitation was the lack of control for other factors that may influence BP such as unhealthy living habits. Nevertheless, a major strength of this study is the gender-specific analysis of ROC which makes extrapolation to both sexes possible. The large sample size is additional strength as this improves the validity and applicability of the findings.

CONCLUSIONS

Based on the findings of this study, Both TFM and WC were the best predictors of HTN independent of age in girls and boys, respectively. TFM with a cut-point of 8.0 kg and WC with a cut-point of 66.3 cm are useful tools for identifying HTN in Nigerian adolescent girls and boys, respectively. However, these body fat indicators demonstrated low capacity to detect HTN in this cohort of adolescents.

Measurement of anthropometric proxies of body fat, particularly TFM and WC should be incorporated in the physical examination program to diagnose and monitor HTN in adolescents especially in a school setting where BP evaluation could pose a big challenge because of the large student population.

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Conflicts of interest

There are no conflicts of interest.

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