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Assessment of Obesity Anthropometric Indices and Hypertension Risk Thresholds in Adolescents: A Cross-Sectional Study in Jos, Plateau State, Nigeria

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ABSTRACT

Hypertension is a growing global health challenge, affecting people of all ages, including adolescents, with obesity being a significant risk factor. Early identification of adolescents at risk for hypertension is critical for preventing future cardiovascular complications. This study sought to determine hypertension risk cut-off values and identify the most effective anthropometric index for assessing hypertensive risk in adolescents. A total of 402 adolescents, aged 12-19, were evaluated through measurements of blood pressure and various anthropometric indices, including Body Mass Index (BMI), Waist Circumference (WC), Waist-to-Height Ratio (WHtR), Waist-to-Hip Ratio (WHR), and Body Surface Area (BSA). Correlation analysis was performed to assess the relationship between these indices and systolic blood pressure, while Receiver Operating Characteristic (ROC) curve analysis was used to establish hypertension cut-off values. Among the indices studied, Body Surface Area (BSA) demonstrated the strongest correlation with systolic blood pressure ($R = 0.232$, $p < 0.01$), indicating its potential as the most suitable indicator of hypertension risk. ROC curve analysis identified a BSA cut-off value of 1.50 m^2 as a reliable threshold for hypertension risk in this age group. The findings highlight BSA as the most promising anthropometric index for predicting hypertensive risk in adolescents. This study suggests that BSA may serve as a more reliable tool for early detection and underscores the need for further research to confirm its effectiveness in broader adolescent populations, especially in Jos, Plateau State, Nigeria.
Keywords: Hypertension Risk, Adolescents, Obesity Anthropometry, Body Surface Area.

INTRODUCTION

Hypertension, once considered an adult-only condition, is becoming an increasingly urgent issue among adolescents. This rise in adolescent hypertension is closely linked to the global obesity epidemic. In adults, hypertension is diagnosed when blood pressure reaches 140/90 mmHg, but in adolescents aged 12 to 19, elevated blood pressure is defined as 120-129 mmHg systolic, with hypertension starting at 130/80 mmHg or higher (Riley et al., 2018). Unfortunately, because most adolescents appear healthy and rarely seek medical care unless visibly ill, hypertension often goes undetected in this age group.

Early identification of hypertension in adolescents is critical, as blood pressure in childhood strongly predicts future risk in adulthood (Chen et al., 2008). The prevalence of hypertension and pre-hypertension among Nigerian adolescents is concerning, as studies in Uyo show 3.5% of adolescents with hypertension and 2.5% with pre-hypertension (Okpokowuruk et al., 2017). Globally, similar trends are observed, with obesity, a primary risk factor for hypertension, continuing to rise at alarming rates.

Despite the growing burden of adolescent hypertension, many remain unaware due to limited access to healthcare and screening, especially in low-income areas. This highlights the importance of simple, non-invasive screening methods, such as anthropometric measurements like Body Mass Index (BMI), Waist Circumference (WC), and Body Surface Area (BSA). These indices provide valuable tools for early detection of hypertension and its risk factors.

Hypertension in adolescents often goes unnoticed because they generally appear healthy and rarely visit a doctor unless they're visibly ill. This makes routine blood pressure monitoring in young people crucial for early detection (National High Blood Pressure Education Program, 2004). Elevated blood pressure in childhood is a strong predictor of adult hypertension, highlighting the need for timely intervention (Chen et al., 2008).

Early diagnosis of pre-hypertension and hypertension can prevent long-term complications, as hypertension can silently progress for years without any visible symptoms. The importance of early screening cannot be overstated.

Obesity is a major risk factor for hypertension, and according to the World Health Organization, the alarming rise in obesity among adolescents poses a significant threat to their health. Despite this growing crisis, many adolescents remain unaware of their risks due to a lack of education and access to proper screening. Since 1990, global obesity rates in adults have more than doubled, while adolescent obesity has increased fourfold (WHO, 2024). Without immediate action, these trends will only continue to fuel the rise of hypertension in younger populations, making early detection and intervention more essential than ever.

If hypertension screening and treatment aren't made more accessible for adolescents, the prevalence will continue to rise. In 2015, a staggering 30% of people in sub-Saharan Africa were hypertensive, yet 73% were unaware of their condition before screening (Atakite et al., 2015). In Nigeria, this problem is even more pronounced among adolescents, especially in low-income areas where access to hospitals for routine blood pressure checks is limited. This underscores the need for alternative, easy-to-use methods to identify at-risk individuals early.

Anthropometry, which assesses body composition through measurements of mass, size, shape, and fat levels, offers a simple, cost-effective solution. It is a powerful tool for the early screening of obesity, hypertension, and other metabolic disorders (Lee et al., 2014). Measurements like Waist Circumference (WC), Waist-to-Height Ratio (WHtR), and Waist-to-Hip Ratio (WHR) effectively capture abdominal obesity, while Body Mass Index (BMI) and Body Surface Area (BSA) provide insights into overall obesity (Sirisena et al., 2020).

Once considered a condition exclusive to adults, hypertension is increasingly affecting adolescents. Early detection is critical, as elevated blood pressure in youth often persists into adulthood (Chen et al., 2008). Studies across Africa have highlighted the poor detection and control of hypertension, particularly among young people (Ekwunife et al., 2010), emphasizing the urgent need for targeted interventions. In Nigeria, research shows that between 4% and 7.6% of adolescents are hypertensive, with the rise closely linked to increasing rates of obesity (Odili et al., 2017; Chijioke et al., 2018; Peters et al., 2008).

Anthropometric measures are non-invasive and cost-effective, making them ideal for hypertension screening in adolescents. Studies have shown that indices like BMI, WHtR, and WC are reliable predictors of hypertension risk, with some combinations proving even more effective for identifying cardiovascular risk factors (Ononamadu et al., 2017; Lam et al., 2015). The growing body of research highlights the need to incorporate these tools in routine health checks, especially in resource-limited settings.

Research on the link between body fat and blood pressure has uncovered key differences between boys and girls. Pausova et al. (2015) found that in Canadian adolescents, blood pressure (BP) in boys is more strongly linked to visceral fat (VF), while in girls, it is more closely associated with total fat mass (TFM).

This gender-specific difference in fat distribution and its relationship to BP highlights the complexity of hypertension risk in youth. Further studies by Rimarrova et al. (2018) and Kuciene et al. (2019) identified Body Mass Index (BMI) as the strongest predictor of elevated BP in adolescents.

Whye et al. (2018) suggest BMI cut-offs of 20 kg/m² for boys and 20.7 kg/m² for girls, alongside Waist Circumference (WC) cut-offs of 67.1 cm and 68.2 cm respectively, as reliable markers for detecting elevated BP. Kuciene et al. (2019) also found BMI and WC to be more effective predictors than Waist-to-Height Ratio (WHtR) in adolescents. Research from adult populations in Nigeria (Sirisena et al., 2020; Adegoke et al., 2021) underscores the importance of exploring additional indices like Body Shape Index (BSI) and Abdominal Height (AH) in predicting hypertension risk.

As studies like Cecilia et al. (2022) emphasize, there is an urgent need to explore obesity-related anthropometric indices for early hypertension screening in African adolescents. While Dereje et al. (2021) recommend WHtR for adult hypertension screening in Ethiopia, their findings do not extend to adolescents. Musa et al. (2022) identified WC and total fat mass as useful tools for detecting hypertension in Nigerian adolescents, but left out key measures like BMI, Waist-to-Hip Ratio (WHR), and Body Surface Area (BSA), which will be included in this current research.

With obesity and hypertension rates rising among adolescents in Africa, it is crucial to conduct more studies on the best anthropometric indicators for predicting hypertension. Given the high prevalence of elevated blood pressure among adolescents in Jos, Nigeria (Atoh et al., 2023), this research aims to compare a range of anthropometric indices (BMI, WC, WHtR, WHR, BSA) and establish optimal cut-off points for identifying hypertensive heart disease risk. This study will contribute to improved early detection and intervention strategies for this growing public health issue.

MATERIALS AND METHODS

Materials

Various measuring instruments were used in this study to get the blood pressure, demographic and anthropometric data, these include: The OMRON (Model; M2 Basic) automatic digital blood pressure measuring machine produced by OMRON Healthcare with serial number 20100612239LF (Made in China) used to measure the blood pressure, The Pese-Personne Bathroom weighing Scale with maximum measurement of 130kg (Made in China) used to measure the body mass, The Fiber Optics Measuring Tape (Made in China) used to measure the waist and hip circumference and the Meter Rule (100cm long) used to measure the student heights. In this study, 404 randomly selected adolescent students from different secondary schools in Jos were used.

Measurement of Blood Pressure

The Blood pressure was measured with the blood pressure machine in millimetres mercury (mmHg). The systolic and Diastolic readings were both taken twice and the average calculated.

The subject is allowed to sit quietly for 3 to 5 minutes before the measurement. With both feet on the floor and the arm resting on the table. The arm stretched out upward on the table then, the cuff placed on the upper arm one inch above the bend of the elbow. The end of the cuff is pulled so that it’s evenly tight around the arm. It was placed tight enough so that we can only slip two finger tips under the top edge of the cuff. The start button is then pressed after waiting for a moment. The student remains still and quiet as the machine begins measuring. The cuff inflates and deflates slowly so that the machine takes the measurement. The blood pressure and pulse was displayed on the digital panel by the monitor at the end of the reading.

Measurement Of Body Mass

The body mass was measured with the Bathroom Scale in kilograms (kg) by placing the scale on a flat and hard surface and the students were allowed one at a time to Step and stand still on the scale with both feet without touching or holding on to anything. The student weight is indicated on the digital scale in kilograms, and this value is read and recorded down after which the student gently Step off the scale ensuring.

Measurement Of Height

The meter rule was used as improvised Stadiometer to measure the heights in centimeters (cm).

One end of the Meter rule is placed flat on the floor and positioned so it's pressed vertically against the wall. The top end of the ruler is marked with a pencil. Then, the meter rule is moved up so the bottom aligns with that pencil mark and a new top edge is marked. This mark is high enough for the height of the entire student so the meter rule was attached to the wall and the students take turns in the height measurement by standing with their back directly on the wall and the reading on the meter rule at the head level is taken.

Measurement Of Waist Circumference

The waist and hip circumferences were measured with the Measuring tape in centimeters (cm) by the subject made to stand straight then the waist region is made free by Shifting any thick material or clothing around the waist. Then, the measuring tape is wrapped around the waist by holding the end of the tape at the naval and circled around the back to the front of the waist.

The waist measurement is at the place on the tape where the zero end meets the slack end of the tape measure. This was read and recorded.

RESULTS

The Demographic Data, WC, HC and Systolic and Diastolic Blood Pressures (SBP and DBP), for each subject were measured and tabulated on Excel spread sheet for the 404 subjects after which the Anthropometric Data (WHtR, WHR, BSA and BMI) were computed.

The descriptive statistics for the demographic and anthropometric data (Table 1), the correlation coefficient between SBP and DBP with Demographic and the anthropometric data (Table 2) and the ROC curve (Figure 1) of the best correlating anthropometric index (BSA) with SBP were determined using the SPSS software.

Table 1: Descriptive Statistics of Demographic Indices

	N	Minimum	Maximum	Mean	Std. Deviation
AGE (Years)	404	12	19	15.03	1.377
HEIGHT (cm)	404	115	190	160.35	11.395
BODY MASS (kg)	404	3	87	52.83	8.538
Valid N (listwise)	404				

Table 2: Correlation Between Blood Pressure and Anthropometric Indices

		SBP	DBP	WC	WHtR	WHR	BSA	BMI
SBP	Pearson Correlation	1	.182**	.118*	.071	-.047	.232**	.121*
	Sig. (2-tailed)		.000	.017	.153	.342	.000	.015
	N	404	404	404	404	404	404	404
DBP	Pearson Correlation	.182**	1	.097	.096	-.023	.035	.038
	Sig. (2-tailed)	.000		.051	.053	.648	.488	.451
	N	404	404	404	404	404	404	404
WC	Pearson Correlation	.118*	.097	1	.874**	.052	.415**	.232**
	Sig. (2-tailed)	.017	.051		.000	.293	.000	.000
	N	404	404	404	404	404	404	404
WHtR	Pearson Correlation	.071	.096	.874**	1	.030	.097	.521**
	Sig. (2-tailed)	.153	.053	.000		.550	.051	.000
	N	404	404	404	404	404	404	404
WHR	Pearson Correlation	-.047	-.023	.052	.030	1	.023	-.014
	Sig. (2-tailed)	.342	.648	.293	.550		.650	.779
	N	404	404	404	404	404	404	404
BSA	Pearson Correlation	.232**	.035	.415**	.097	.023	1	.241**
	Sig. (2-tailed)	.000	.488	.000	.051	.650		.000
	N	404	404	404	404	404	404	404
BMI	Pearson Correlation	.121*	.038	.232**	.521**	-.014	.241**	1
	Sig. (2-tailed)	.015	.451	.000	.000	.779	.000	
	N	404	404	404	404	404	404	404

****. Correlation is significant at the 0.01 level (2-tailed).**

***. Correlation is significant at the 0.05 level (2-tailed).**

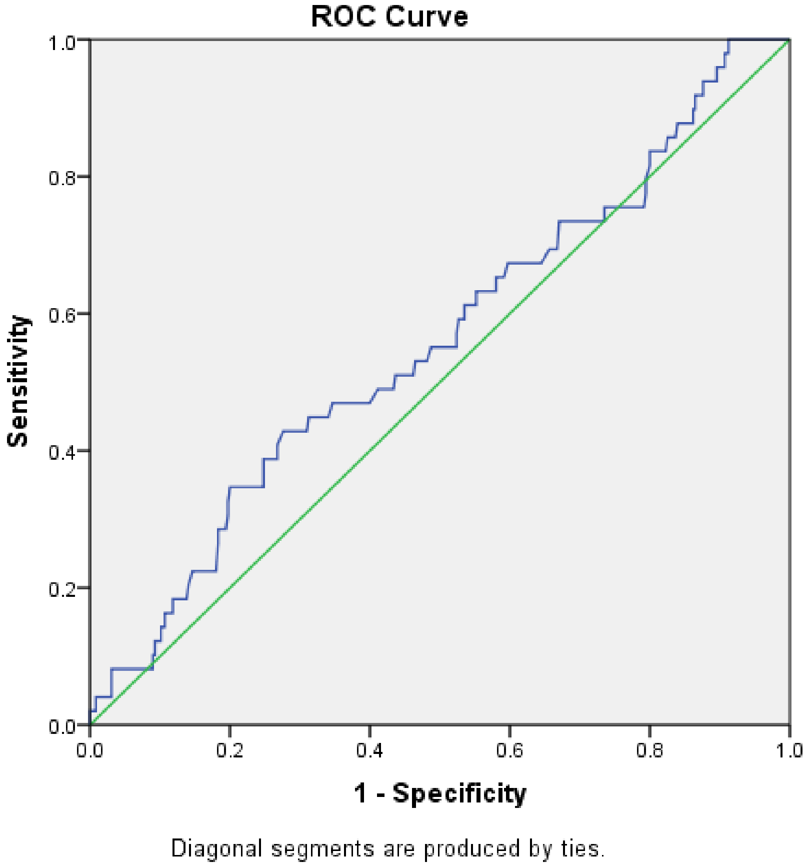

Figure 1: ROC curve for BSA

DISCUSSION

Descriptive Statistics of Demographic indices

The descriptive statistics for the demographic indices (age, body mass and height) as shown in Table 1 indicates the mean age with the standard deviation (SD) as 15.03 ± 1.38 years with age range from 12-19 years. The mean value ± S.D of height was found to be 160.4 ± 11.40 and the mean value of body mass was found to be 52.8 ± 8.5kg.

Correlation between Blood Pressure and Anthropometric Indices

It is shown in Table 2 that BSA (R=0.232) positively correlates with SBP at 0.01 level. A positive correlation also exist between BMI (R=0.121) and SBP at 0.05 level. However, weak positive correlations were observed between DBP and BSA as well as BMI. Here, BSA was the best correlating predictor of adolescents hypertensive risk among the anthropometric indices used.

It was observed by Khalid et al (2020) in the correlation between body mass index and blood pressure levels among hypertensive patients that a significant weak negative correlation of BMI with both systolic and diastolic blood pressure levels for male patients.

According to Kammar-Garcia et al (2019), BMI and BSA correlated well with cardiovascular disease risk factors. They were superior to WC, WHtR, WHR, BF% C-Index, AVI and AT. Odeigah L.O et al (2023) studied the association between blood pressure, body mass index and age and observed that there were no appreciable positive connections between BMI and either SBP or DBP or age. According to Evans et al (2017), even though BMI has been clearly shown to influence blood pressure, those results were based on a very large number of subjects. Their study showed that, in a small group of subjects, BMI was not strongly related to SBP as were weight, height or BSA.

Receiver Operating Characteristics (ROC) Curves

The ROC curves for the best correlating anthropometric index, BSA with SBP is shown in Figure 1. The area under curves of the ROC curve analysis for BSA was found to be 0.558 with Sensitivity of 61.2% and Specificity of 55.2%. The cut-off (threshold) value of BSA for hypertension was found to be 1.50 m^2. The ROC analysis showed the cut-off values for WC, WHR, WHtR and BMI as 68.5cm, 0.84, 0.44 and 20 kg/m^2 respectively. Meaning Waist Circumference (WC) above 68.5cm, Waist to Hip Ratio (WHtR) above 0.44, can be considered to be at risk of hypertension, the subjects with Body Surface Area (BSA) and Body Mass Index (BMI) above 1.50 kg/m^2 and 20 kg/m^2 respectively are also at risk.

CONCLUSION

This study sheds light on important factors for assessing hypertension risk in adolescents. Both Body Surface Area (BSA) and Body Mass Index (BMI) demonstrate moderate potential as indicators, but the analysis reveals a stronger link between BSA and systolic blood pressure. This suggests that BSA stands out as a more reliable measure for evaluating hypertension risk in adolescents compared to other anthropometric indices considered in the study.

Furthermore, adolescents with a BSA exceeding 1.50 m^2 were identified as being at heightened risk for hypertension. It is therefore essential that every adolescent receive proper guidance on maintaining a balanced diet, engaging in regular physical activity, and consistently monitoring their blood pressure to ensure early detection and prevention of potential health complications.

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