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Correlations between Anthropometric Indices and Hypertension in Adults: Emerging Trends in a Contemporary Urban Setting

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ABSTRACT

Anthropometric indices are influenced by nutrition, genetics, lifestyle, age, and ethnicity thus assessing these indices is a cheap tool to predict risk factors that affect blood pressure. There is no consensus on the anthropometric index that best predicts adults' blood pressure. This research aimed to determine the relationships between anthropometric indices (weight, height, waist circumference (WC), hip circumference (HP), neck circumference (NC), chest circumference (CC), subscapular fold (SSF), triceps fold (TF), body mass index (BMI), waist-hip ratio (WHR), waist-height ratio (WHtR), subscapular-triceps ratio (STR), and blood pressure; and to determine the best predictor(s) of hypertension among these indices. This cross-sectional study was carried out in Enugu City, South-East Nigeria, and involved 355 adults, aged between 20-75 years. The comparison of the indices was done using the Student's t-test. Pearson correlation coefficient (r) was used to relate the indices with blood pressure, and Receiver Operating Characteristic (ROC) was used to determine the cut-off points of the indices to identify the best predictor(s) of hypertension. The prevalence of hypertension was 38.0%. All the anthropometric indices except height, NC, and STR were significantly higher in hypertensive participants than in the non-hypertensive participants. Pearson correlation coefficient (r) showed that all the indices except height, NC, and STR have weak linear positive relationships with blood pressure ($r=0.1127$-0.375) at $p<0.001$. The ROCs showed that WC was the best predictor with an area under curve (AUC) of 0.692, a cut-off point of 96.50cm, and a PPV of 57%. However, with an AUC <0.7, all the indices were weak predictors of hypertension. Hypertension correlated positively with increased age. Although anthropometric indices are weak predictors of hypertension, WC is the best index in predicting hypertension. Due to the inconsistent effects of WC on sensitivity, specificity, and PPV, WC is still a weak predictor of hypertension. However, the predictive power of WC could be augmented by age if the participants were above 45 years. At age >45 years, the participants had 5 times the chance of developing hypertension regardless of gender.

INTRODUCTION

Anthropometry is a highly effective method for assessing the nutritional and health status of an individual or a population (Hamieda, 2002). Anthropometry is universally applicable, serving as a valuable technique in evaluating body size and proportions, and offers cheap, non-invasive, ease of use and high precision advantages (Bates, 2017). Various indices of anthropometric measurements are influenced by nutrition, genetics, lifestyle, and ethnicity, thus making anthropometric assessment a cheap tool to predict risk factors such as hypertension and obesity.

Standard anthropometric measurements include weight, height/length, mid-upper arm circumference (MUAC), triceps skinfold thickness (TSF), subscapular skinfold, head circumference, chest circumference, waist circumference, and hip circumference. Additionally, various indices such as body mass index (BMI), weight-for-height, weight-for-age, subscapular-triceps ratio, waist-hip ratio, and waist-height ratio are used to assist in assessing health and nutritional status (Hamieda, 2002).

It has been established that anthropometric parameters are related to different metabolic disorders. Metabolic disorders e.g. Hypertension, Adiposity, Diabetes mellitus and Dyslipidemia collectively known as Metabolic Syndrome Diseases (MSDs) are diseases related to one another and have very high morbidity and mortality rates (Ikwuka, 2015; Ikwuka, 2017a; Ikwuka, 2017c; Ikwuka, 2023c; Ikwuka, 2023f; Virstyuk, 2016). Results obtained from different researches have shown that hypertension, diabetes mellitus, adiposity and dyslipidemia, asymptomatic hyperuricemia, activation of systemic immune inflammatory processes, and fibrogenesis can lead to kidney damage (Ikwuka, 2017d; Ikwuka, 2017e; Ikwuka, 2018c; Ikwuka, 2018d; Ikwuka, 2019a; Ikwuka, 2019c; Ikwuka, 2022; Ikwuka, 2023d; Virstyuk, 2017a; Virstyuk, 2018a; Virstyuk, 2019; Virstyuk, 2021a; Virstyuk, 2021b). It has also been reported that chronic metabolic disorders have the ability to compromise immunity (Iorhemba, 2024).

High blood pressure (HBP) or hypertension is a medical condition in which the blood exerts a force on the arterial wall which exceeds normal, 120/80 mmHg (World Health Organization, 2023). The main modifiable causes of HBP are diet (high salt intake), lack of exercise, obesity, and excessive alcohol consumption (Le, 2017). Moreover, HBP, smoking, diabetes, and hyperlipidemia

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are documented risk factors for cardiovascular diseases like coronary artery disease (CAD), atherosclerosis, stroke and heart failure (Le, 2017).

According to the WHO, hypertension is a growing world health problem as the prevalence is on a steady rise. The global prevalence of HBP is approximately 1.28 billion adults between ages 30–79 years, of which a majority (2/3) of them reside in low- and middle-income countries (WHO, 2023). The WHO African Region has a 27% prevalence of hypertension (WHO, 2023), and in Nigeria, approximately 38.1% of adults are hypertensive according to a national survey (Odili, 2020). In addition, hypertension is termed "a silent killer" because it may express no symptoms, a reason 46% of hypertensive individuals are unaware they have it (WHO, 2023). To make this situation worse, HBP previously known as a disease for adults is now becoming common in teenagers and children (Katamba, 2020).

Anthropometry has been enormously studied in children (Sebati, 2020; WHO, 2017), in adolescents (Katamba, 2020; WHO, 2017), in youth and adults (Ejheisheh, 2022). Fat deposit in the body is logically the link associating anthropometry to blood pressure. Anatomically, fat is stored in the hypodermis and yellow bone marrow, and pathologically in the stroma of organs and within blood vessels. Accumulation of fat in the hypodermis causes robustness in the physique and if uncontrolled can lead to obesity. Similarly, the accumulation of cholesterol (fat) plaques in the elastic arteries causes atherosclerosis which occludes the lumen of elastic arteries (Le, 2017). Just as hypertension is a risk factor for atherosclerosis, atherosclerosis on its own can be asymptomatic and could be fatal when complications set in (Le, 2017). With possible complications and a set relationship between atherosclerosis, hypertension, and excess fat accumulation, it is therefore crucial to assess anthropometric indices among adults in order to boost the awareness of their health status and to determine the best predictor(s) for high blood pressure in such adults.

MATERIALS AND METHODS

Study Area

Enugu State University Teaching Hospital (ESUTH), Parklane is in Enugu City, South-East Nigeria. With a total land area of 556 km^2, the city is made up of three local government areas (Enugu North, Enugu South, and Enugu East), and is historically known for coal mining.

Study Design

This research employed a descriptive, cross-sectional approach because the data was meant to be collected quickly. Data collection in this study spanned over 3 months (September to November 2023), at the Enugu State University Teaching Hospital (ESUTH), Parklane, Enugu City.

Study Population

Enugu City has a population of approximately 875,552 (World Population Review, 2024), but the adult population was not delineated. However, with this figure, the adult population is estimated to be over 100,000.

Sample Size

With an estimated adult population of over 100,000 in Enugu City, the Cochran equation for descriptive, cross-sectional studies with a study population >10,000 was used to determine the sample size (Udeh, 2023a).

n_0, sample size for large population >10,000 = $(Z^2\ PQ)/d^2$

Where:

Z is the abscissa of the normal curve that cuts off an area α at the tail set at a 95% confidence interval (1.96);

P is the proportion of participants with hypertension which is 35.3% (0.353) as derived from the studies of (Ekwunife, 2011) and (Akinlua, 2015);

Q is (1 - P) = (1 – 0.353) = 0.647; and

d is the precision set at 5% ($p<0.05$).

The prevalence of hypertension among adults in Enugu City is unknown but (Ekwunife, 2011) and (Akinlua, 2015) estimated the prevalence of hypertension in Nigeria to be 12.4-34.5% and 47.2% respectively. The prevalence of 35.3% was derived from the mean of the two studies and used to calculate the minimum sample size (n_0).

$n_0 = (1.96^2 \times 0.353 \times 0.647)/\ 0.05^2 = 350.95 \sim 351$

The minimum sample size (n) of 351 participants was generated. Meanwhile, after adding 10% attrition rate, 386 was generated as the sample size.

Inclusion and Exclusion Criteria

To be included in this study, participants must reside in Enugu City, consent to participate with no motive of financial compensation, must be between ages 20-75 years, and must possess basic education. Excluded in this study were pregnant women, individuals residing outside Enugu City, the physically impaired whose physique has a great chance to alter the results of this study, patients using psychotropic drugs, and those with renal disease confirmed by either self-reporting or medical confirmation.

Study Instruments

The following instruments were used to obtain data for this study:

A well-structured questionnaire to collect socio-demographic characteristics, past medical history, past family history, and record the anthropometric indices and blood pressure.

For anthropometric indices: an electronic weighing scale was used to measure the weight of the study participants to the nearest 0.1 kg; a stadiometer was used for height measurement to the nearest 0.1 cm; fibre-glass in elastic tape was used for the measurement of waist circumference (WC), head circumference (HC), neck circumference (NC), and chest circumference (CC) to the nearest 0.1 cm; Holtian skinfold calliper was used to measure subscapular skinfold (SSF) and triceps fold (TF) to the nearest 0.1mm.

Accoson® Desktop mercury sphygmomanometer was used to measure blood pressure (BP).

Data Collection

Anthropometric measurements: Eight anthropometric indices were measured directly from the participants, others were calculated from measured indices:

Body Mass Index (BMI = (weight (kg))/(height^2 (m^2)));

Waist-Hip Ratio (WHR = (waist circumference (cm))/(hip circumference (cm)));

Waist-Height Ratio (WHtR =(waist circumference (cm))/(height (cm)));

Subscapular-Triceps ratio (STR = (subscapular fold (cm))/(triceps fold (cm))).

Height

Participants were asked to remove their wig (if any), jewelry, and shoes. They stood on the stadiometer platform with the back straight against the backboard and the head aligned in Frankfort's horizontal plane. The headpiece was lowered to compress the hair as they took and held a deep breath.

Weight

With wig (if any), jewelry, shoes, and extra clothing removed except underwear, the participants stood on an electronic scale placed on a solid-flat ground. The arms were by the sides and face forward, then the weight was recorded.

WC was measured as the study participants stood erect and raised their clothes to reveal their waists. The tape was wound around from the left/right anterior superior iliac spine to the other.

HC was measured at the level of the widest buttocks with the tape not loosened or too tight.

CC was measured by encircling the upper part of the chest with the tape.

NC was measured at the level of cervical vertebra 4 (C4) or below the laryngeal prominence (in men) with the tape while the participants stood and looked straight ahead with the shoulders relaxed.

Skinfolds

The study participants stood at ease while measuring the subscapular and triceps folds. A thickness of skinfold was pinched at the inferior angle of the right scapular and the midpoint of the posterior arm respectively, with the left thumb and index finger. The caliper's jaws were applied 2cm above the two fingers and 2cm laterally (for the subscapular fold). Readings were taken after three seconds.

BP

The study participants sat comfortably for 5-10 minutes. Three consecutive measurements of 4-5 minutes apart were made on the dominant arm by tying an adult cuff 2-3 cm above the cubital fossa. The radial artery was palpated as the cuff was inflated until the pulse disappeared. The bell of the stethoscope was placed over the brachial artery in the cubital fossa as the cuff was gradually deflated. The first sound (1st Korotkoff) denotes the systolic blood pressure and the disappearance of the sound (5th Korotkoff) is the diastolic blood pressure. The average of the last two blood pressure measurements was recorded to the nearest 2 mmHg.

Data Analysis

Data collected was analyzed using Statistical Package for Social Sciences (SPSS) version 22.0. The socio-demographic characteristics, blood pressure, and anthropometric indices were presented as mean and standard deviation. Mean was compared using a Student's t-test. Pearson correlation coefficient (r) was used to measure the relationship between anthropometric indices and blood pressure. The association between anthropometric indices and hypertension was done using logistic regression. Receiver Operating Characteristic (ROC) was used to determine the cut-off values of anthropometric indices used to identify the predictors of hypertension. Sensitivity and specificity were calculated and the point having the highest sum was taken as the cut-off of the indicator. All tests of significance were two-tailed and the level of significance was set at $p<0.05$.

Ethical Consideration

Ethical clearance and permission to conduct the research were obtained from the Ethics Committee of Enugu State University Teaching Hospital (ESUTH), Parklane, Enugu City.

RESULTS AND DISCUSSION

Table 1: Socio-demographic characteristics of the study participants

Parameters	Frequency	Percentage
Sex		
Male	154	43.4
Female	201	56.6
Age group		
20 – 24	32	9.0
25 – 29	38	10.7
30 – 34	54	15.2
35 – 39	53	14.9

40 – 44	40	11.3
45 – 49	40	11.3
≥50	98	27.6
Marital status		
Single	93	26.2
Married	231	65.1
Divorced	3	0.8
Widow/widower	28	7.9
Occupation		
Administrative	126	35.5
Skilled labor	98	27.6
Unskilled labor	4	1.1
Unemployed	20	5.6
Pensioner	15	4.2
Others	92	25.9
Level of education		
Primary	40	11.3
Secondary	72	20.3
Tertiary	243	68.5
Level of physical activity		
Trekking	239	67.3
Riding of bicycle	10	2.8
Always using vehicle	101	28.5
Involvement in exercise	5	1.4

A total of 355 study participants were involved in this study, males and females accounted for 43.4% and 56.6% respectively. 9.0% of the participants were between ages 20-24 years, 10.7% were between 24-29 years, 15.2% were between 30-34 years, 14.9% were between 35-39 years, 11.3% were 40-44 years old, 11.3% were 45-49 years old, and 27.6% were ≥50 years old.

Only 26.2% of the participants were single, while a greater percentage (65.1%) were married. 35.5% of the participants were administrative employees, 27.6% were skilled workers, 1.1% were unskilled workers, 5.6% were unemployed, 4.2% were retired, and 25.9% were in various jobs classified as others.

Most (68.5%) of the participants had tertiary education, 11.3% had only primary school education, and 20.3% had only secondary school education. The level of physical activity shows that 67.3% of the participants trek, 2.8% ride bicycles, 1.4% were generally involved in an exercise, and 28.5% drive always irrespective of the distance.

Table 2: Family history of study participants

Disease condition	Frequency (%)
Diabetes mellitus	72 (20.3)
Hypertension	119 (33.5)
Stroke	49 (13.8)
Fatness	152 (42.8)

Table 2 shows that approximately one-fifth (20.3%) of the participants had a family history of diabetes mellitus, 33.5% had a family history of hypertension, 13.8% had a family history of stroke, and 42.8% had a family history of obesity, respectively.

Table 3: Social history of study participants

Lifestyle	Frequency	(%)
Cigarette smoking		
Yes	27	7.6
No	328	92.4
Use of snuff		
Yes	17	4.8
No	338	95.2
Use of alcohol		
Yes	173	48.7
No	182	51.3
Patronise fast-food vendors		
Yes	213	60.0
No	142	40.0

Table 3 shows that most participants were non-tobacco users (92.4% do not smoke cigarettes and 95.2% do not use snuff). However, 7.6% of the participants were

cigarette smokers whereas 4.8% used snuff. 48.7% of the participants drink alcohol while 60.0% patronize fast-food vendors.

Table 4: Medical history of study participants

Disease	Medical history	On medication
	Frequency (%)	Frequency (%)
Diabetes mellitus	29 (8.2)	25 (7.0)
High blood pressure	97 (27.3)	83 (23.4)
Stroke	6 (1.7)	6 (1.7)
Heart attack	9 (2.5)	6 (1.7)

Table 4 shows that a total of 8.2% of the participants had diabetes mellitus. However, almost all of them were on medication. 27.3% were hypertensive of which 23.4% were on medication for hypertension. All of the participants with transient stroke were also on medication (1.7%). 2.5% of the participants had heart attack of which 1.7% were on medication for heart attack.

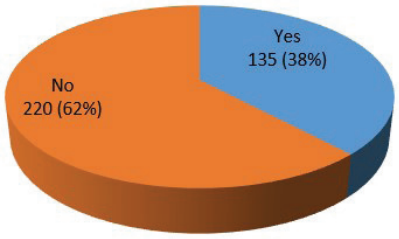

Figure 1: Pie chart showing the prevalence of hypertension in study participants

Yes = hypertensive participants; No = non-hypertensive participants

38% of the participants were hypertensive while 62% were non-hypertensive.

Table 5: Comparison of mean anthropometric indices between hypertensive and non-hypertensive study participants

Anthropometric indices (scale)	Hypertension			
	Yes Mean ± SD	No Mean ± SD	t	p-value
Weight (kg)	83.69 ± 18.08	76.56 ± 14.19	4.127	< 0.001
Height (m)	1.69 ± 0.11	1.69 ± 0.09	0.131	0.896
WC (cm)	99.72 ± 12.74	91.45 ± 11.20	6.404	< 0.001
HC (cm)	108.60 ± 12.66	101.67 ± 11.02	5.432	< 0.001
NC (cm)	37.48 ± 4.25	37.15 ± 9.85	0.365	0.715
CC (cm)	100.27 ± 13.11	93.52 ± 12.54	4.841	< 0.001
SSF (mm)	25.31 ± 11.24	20.19 ± 10.36	4.374	< 0.001
TF (mm)	19.81 ± 10.60	15.98 ± 8.68	3.705	< 0.001
BMI (kg/m^2)	29.56 ± 6.26	27.03 ± 5.36	4.045	< 0.001
WHR	0.92 ± 0.07	0.90 ± 0.08	2.262	0.024
WHtR	59.39 ± 8.45	54.38 ± 7.54	5.795	< 0.001
STR	1.41 ± 0.47	1.51 ± 1.44	0.770	0.442

$p<0.05$ = statistically significant relationship; $p\geq0.05$ = no statistically significant relationship

Table 5 shows that all the anthropometric indices used in this study were significantly higher in hypertensive participants ($p<0.001$) than in non-hypertensive participants except for Height, NC, WHR, and STR. The most significant of all indices were WC ($t=6.404$ at $p<0.001$), and HC ($t=5.432$ at $p<0.001$). The least significant was WHR ($t=2.262$ at $p=0.024$).

Table 6: Relationships between anthropometric indices and blood pressure

Indices	Statistics	Systolic BP	Diastolic BP
Weight (kg)	r	0.288	0.321
	p-value	< 0.001	< 0.001
Height (m)	r	0.010	0.076
	p-value	0.851	0.154
WC (cm)	r	0.375	0.374
	p-value	< 0.001	< 0.001
HC (cm)	r	0.312	0.323
	p-value	< 0.001	< 0.001
NC (cm)	r	0.046	0.025
	p-value	0.385	0.634

CC (cm)	r	0.278	0.382
	p-value	< 0.001	< 0.001
SSF (mm)	r	0.285	0.277
	p-value	< 0.001	< 0.001
TF (mm)	r	0.228	0.185
	p-value	< 0.001	< 0.001
BMI (kg/m^2)	r	0.268	0.266
	p-value	< 0.001	< 0.001
WHR	r	0.147	0.127
	p-value	0.005	0.017
WHtR	r	0.332	0.307
	p-value	< 0.001	< 0.001
STR	r	-0.006	0.007
	p-value	0.917	0.898

BP = Blood pressure; r = Pearson correlation coefficient (-1 = negative linear correlation, 0 = no linear correlation, +1 = positive linear correlation); p<0.05 = statistically significant relationship; p≥0.05 = no statistically significant relationship

Table 6 shows statistically significant relationships between anthropometric indices and BP (systolic and diastolic), except for Height, NC, WHR, and STR with p≥0.05. Using Pearson correlation coefficient (r), the anthropometric indices had a weak positive linear correlation with BP, except for STR. STR had a weak negative linear correlation. The index that showed the most significant relationship with BP was WC (r=0.375 systolic and 0.374 diastolic, at p<0.001) and HC (r=0.312 systolic and 0.323 diastolic, at p<0.001). The index with the least significant correlation was WHR (r=0.147 systolic and 0.127 diastolic, at p=0.005 and 0.017 respectively).

Table 7: Association between BMI, WC, and hypertension

Indices	**Hypertension**				
	Yes n (%)	**No n (%)**	**p-value**	**OR**	**95% C.I. for OR**
BMI (kg/m^2)					
Normal	37 (32.5)	77 (67.5)			
Underweight	2 (18.2)	9 (81.8)	0.339	0.462	0.095 – 2.249
Overweight	34 (31.2)	75 (68.8)	0.840	0.943	0.537 – 1.658
Class 1 Obesity	36 (45.0)	44 (55.0)	0.077	1.703	0.944 – 3.071
Class 2 Obesity	20 (62.5)	12 (37.5)	0.003	3.468	1.534 – 7.844
Class 3 Obesity	6 (66.7)	3 (33.3)	0.022	4.162	0.986 – 17.572
Waist circumference (cm)					
Obese	107 (44.8)	132 (55.2)	<0.001	2.548	1.552 – 4.183
Normal	28 (24.1)	88 (75.9)			

Table 7 shows that participants with Class 2 obesity were 3.5 times more likely to have hypertension when compared to normal participants (p=0.003, OR=3.468, 95% C.I.=1.534–7.844). Class 3 obesity participants were 4 times more likely to have hypertension when compared to normal participants (p=0.022, OR=4.162, 95% C.I.=0.986–17.572). Obese participants based on WC were 2.5 times more likely to have hypertension when compared to normal participants (p<0.001, OR=2.548, 95% C.I.=1.552–4.183).

Table 8: Association between age, sex, and hypertension

Indices	**Hypertension**				
	Yes n (%)	**No n (%)**	**p-value**	**OR**	**95% C.I. for OR**
Age group (years)					
>45	79 (61.7)	49 (38.3)	< 0.001	4.923	3.086 – 7.853
≤ 45	56 (24.7)	171 (75.3)			

Sex					
Male	62 (40.3)	92 (59.7)	0.449	1.182	0.767 – 1.820
Female	73 (36.3)	128 (63.7)			

Table 8 shows that the likelihood of developing hypertension is increased in participants above 45 years of age at 95% C.I. irrespective of gender.

The test result indices: weight, height, WC, HC, NC, CC, SSF, TF, BMI, WHR, WHtR, and STR have at least one tie between the positive actual state group and the negative actual state group.

Table 9: Receiver Operating Characteristics (ROCs) for anthropometric indices predicting hypertension with their areas under curves

Area Under Curve (AUC)					
Test Result Indices	**AUC**	**Std. Error[a]**	**Asymptotic Sig.[b]**	**Asymptotic 95% Confidence Interval**	
				Lower Bound	**Upper Bound**
Weight (kg)	.615	.031	.000	.554	.677
Height (m)	.492	.033	.792	.427	.556
WC (cm)	.692	.029	.000	.635	.749
HC (cm)	.656	.031	.000	.595	.716
NC (cm)	.620	.031	.000	.559	.680
CC (cm)	.664	.030	.000	.605	.722
SSF (mm)	.639	.031	.000	.579	.699
TF (mm)	.603	.031	.001	.541	.664
BMI (kg/m^2)	.621	.031	.000	.559	.682
WHR	.609	.031	.001	.547	.671
WHtR	.679	.030	.000	.621	.738
STR	.527	.032	.396	.465	.589

a. Under the non-parametric assumption

b. Null hypothesis: true area = 0.5

In Table 9, WC had the best AUC (0.692; p=0.000). Next is WHtR with a good AUC (0.679; p=0.000), followed by HC (0.656; p=0.000). All the anthropometric indices had significant positive AUC except for Height (0.492; p=0.792), and STR (0.527; p=0.396). All AUCs were <70% (0.70) signifying poor predictive power for hypertension.

Table 10: Data showing the sensitivity and specificity at various cut-off points of the anthropometric indices to predict hypertension

Indices	**Hypertensive (n=135)**		**Normal (n=220)**		**Sensitivity**	**Specificity**	**1-specificity**	**Positive predictive value (PPV %)**	**Negative predictive value (NPV %)**
	True positive (TP)	**False negative (FN)**	**False positive (FP)**	**True negative (TN)**					
Weight (kg)									
77.500	82	53	98	102	0.607	0.509	0.491	45	66
78.500	79	56	91	109	0.585	0.545	0.455	46	66
79.500	77	58	83	117	0.570	0.586	0.414	48	67
80.500	72	63	73	127	0.533	0.636	0.364	50	67
81.500	66	69	68	132	0.489	0.659	0.341	49	66
Height (m)									
1.6850	67	68	111	89	0.496	0.445	0.555	38	57
1.6950	64	71	107	93	0.474	0.464	0.536	37	57
1.7050	58	77	100	100	0.430	0.500	0.500	37	57
1.7110	55	80	87	113	0.407	0.564	0.436	39	58
1.7160	55	80	86	114	0.407	0.568	0.432	39	59

Waist circumference (cm)									
94.5000	92	43	82	118	0.681	0.591	0.409	53	73
95.5000	89	46	75	125	0.659	0.627	0.373	54	73
96.5000	85	50	64	136	0.630	0.682	0.318	57	73
97.5000	78	57	60	140	0.578	0.700	0.300	57	71
98.5000	74	61	56	144	0.548	0.718	0.282	57	70
Hip circumference (cm)									
102.500	87	48	93	107	0.644	0.536	0.464	48	69
103.500	84	51	86	114	0.622	0.568	0.432	49	69
104.500	80	55	75	125	0.593	0.627	0.373	52	70
105.500	75	60	67	133	0.556	0.664	0.336	53	69
106.500	73	62	59	141	0.541	0.705	0.295	55	69
Neck circumference (cm)									
35.5000	101	34	104	96	0.748	0.482	0.518	49	74
36.5000	80	55	83	117	0.593	0.586	0.414	49	68
37.5000	62	73	61	139	0.459	0.695	0.305	50	66
38.5000	47	88	47	153	0.348	0.764	0.236	50	63
39.5000	38	97	32	168	0.281	0.841	0.159	54	63
Chest circumference (cm)									
95.5000	91	44	83	117	0.674	0.586	0.414	52	73
96.5000	87	48	75	125	0.644	0.623	0.377	54	72
97.5000	84	51	70	130	0.622	0.650	0.350	55	72
98.5000	78	57	62	138	0.578	0.691	0.309	56	71
99.5000	68	67	53	147	0.504	0.736	0.264	56	69
Subscapular fold (mm)									
20.5000	87	48	89	111	0.644	0.555	0.445	49	70
21.5000	85	50	85	115	0.630	0.577	0.423	50	70
22.5000	82	53	75	125	0.607	0.627	0.373	52	70
23.5000	77	58	69	131	0.570	0.655	0.345	53	69
24.5000	74	61	65	135	0.548	0.677	0.323	53	69
Triceps fold (mm)									
15.5000	80	55	87	113	0.593	0.564	0.436	48	67
16.5000	79	56	85	115	0.585	0.577	0.423	48	67
17.5000	75	60	79	121	0.556	0.605	0.395	49	67
18.5000	68	67	75	125	0.504	0.627	0.373	48	65
19.5000	68	67	71	129	0.504	0.645	0.355	49	66
BMI (kg/m^2)									
27.5984	77	58	87	113	0.570	0.564	0.436	47	66
27.6456	77	58	86	114	0.570	0.568	0.432	47	66
27.6912	77	58	85	115	0.570	0.573	0.427	47	66
27.7093	77	58	85	115	0.570	0.577	0.423	48	67
27.7250	77	58	84	116	0.570	0.582	0.418	48	67
WHR									
0.9071	83	52	81	119	0.615	0.595	0.405	51	70
0.9083	83	52	80	120	0.615	0.600	0.400	51	70
0.9095	80	55	77	123	0.593	0.614	0.386	51	69
0.9100	78	57	76	124	0.578	0.618	0.382	51	68
0.9104	78	57	75	125	0.578	0.623	0.377	51	69

WHtR									
56.7627	89	46	71	129	0.659	0.645	0.355	56	74
56.8466	89	46	69	131	0.659	0.655	0.345	56	74
56.8806	89	46	68	132	0.659	0.659	0.341	57	74
56.8914	89	46	67	133	0.659	0.664	0.336	57	74
56.9366	88	47	66	134	0.652	0.668	0.332	57	74
STR									
1.2829	71	64	98	102	0.526	0.509	0.491	42	61
1.2887	71	64	96	104	0.526	0.518	0.482	42	62
1.2958	71	64	95	105	0.526	0.527	0.473	43	62
1.3022	70	65	95	105	0.519	0.527	0.473	43	62
1.3060	70	65	94	106	0.519	0.532	0.468	43	62

In Table 10, the best cut-off points and AUC of the anthropometric indices for predicting hypertension are shown. The summary is shown in Table 11. None of the anthropometric indices had significant predicting power for hypertension. However, WC (AUC=0.692, cut-off points=96.5cm, sensitivity=63.0%, specificity=68.2%, PPV=57%, and NPV=73%), and WHtR (AUC=0.679, cut-off points=56.88, sensitivity=65.9%, specificity=65.9%, PPV=57%, and NPV=74%) were the best predictors for hypertension. The indices with the worst predictive power for hypertension were Height (AUC=0.492, best cut-off points=1.71m, sensitivity=43.0%, specificity=50.0%, PPV=37%, and NPV=57%), and STR (AUC=0.527, best cut-off points=1.30, sensitivity=52.6%, specificity=52.7%, PPV=43%, and NPV=62%).

The sensitivity, specificity, and PPV values of the best predictors were below 70% which means they have low predictive powers.

Table 11: Summary of results of anthropometric indices in predicting hypertension

Area Under Curve (AUC)						
Anthropometric Indices	**AUC**	**Best cut-off points**	**Sensitivity**	**Specificity**	**PPV**	**NPV**
Weight (kg)	0.615	79.50	57%	59%	48%	67%
Height (m)	0.492	1.71	43%	50%	37%	57%
WC (cm)	0.692	96.50	63%	68%	57%	73%
HC (cm)	0.656	104.50	59%	63%	52%	70%
NC (cm)	0.620	37.50	46%	70%	50%	66%
CC (cm)	0.664	97.50	62%	65%	55%	72%
SSF (mm)	0.639	22.50	61%	63%	52%	70%
TF (mm)	0.603	17.50	56%	61%	49%	67%
BMI (kg/m^2)	0.621	27.69	57%	57%	47%	66%
WHR	0.609	0.91	59%	61%	51%	69%
WHtR	0.679	56.89	66%	66%	57%	74%
STR	0.527	1.29	53%	53%	43%	62%

In Table 11, an area under the curve (AUC) of less than 0.70 showed that the test is weak for predicting hypertension. Tables 10 and 11 showed that the anthropometric indices were not excellent for predicting hypertension. However, the best predictors in the list were WC and WHtR. Their best cut-off points still yielded weak results. At these cut-off points, the sensitivity, specificity, and PPV of these anthropometric indices were below 70%.

Anthropometry is related to high blood pressure (hypertension) and obesity. Obesity is a risk factor for hypertension. Obesity is also a risk factor for Non-Hodgkin lymphoma (Ikwuka, 2023e). Due to globalization and commercialization, diet transition is sweeping across the globe and Enugu City is not an exception. This diet transition has led to the sprouting of fast food restaurants in all the nooks and crannies of Enugu City. Linked with the induction of oxidative stress are major free radicals. Among these major free radicals, superoxide anion, hydroxyl radical, and hydroperoxyl radical are of physiological significance. Non-radical of physiological significance is hydrogen peroxide (Ikwuka, 2023b; Ama, 2023). Increased oxidative stress can lead to mutation which is an alteration in the DNA sequence which produces new alleles (Ikwuka, 2023a). The combination of these factors and other factors such as reduced physical activities and sedentary life will affect anthropometry and blood pressure. This was in line with the research findings that 60.0% of the study participants

patronized fast-food vendors, 48.7% drank alcohol, and 28.5% always drove their vehicles irrespective of the distance thereby reducing their physical activities.

The prevalence of hypertension in this present study was 38%. This result is almost the same as the 38.1% prevalence reported by (Odili, 2020), and 47.2% reported by (Akinlua, 2015). Interestingly, 33.5% of the participants in this present study reported having a positive family history of hypertension.

The mean anthropometric indices measured in the study were significantly higher in the hypertensive participants than in the non-hypertensive participants except for Height and NC which showed no difference, and STR which was not significantly higher in non-hypertensive participants. These findings agree with the findings in a Korean study (Lee, 2014), in a Nigerian study (Ononamadu, 2017), in a study in the Netherlands (Grievink, 2014), in Greece (Panagiostakos, 2009), and in Japan (Sakurai, 2006). The marked significance of WHtR in hypertensive participants in this present study corresponds with the findings in Barbados (Rodrigues, 2011), in Taiwan (Tseng, 2010), and in Korean men (Park, 2009).

Obesity is due to massive body fat deposits, and it has been noted as a risk factor for hypertension. With the report that 60.0% of the participants ate fast food with high calories, consumption of these meals coupled with other risk factors could be implicated as the cause of overweight or obesity noted in the hypertensive participants. This explains why the hypertensive participants had significantly higher anthropometric indices. Obesity is also a major nexus between anthropometry and hypertension. In this present study, the mean values of BMI, SSF, WC, HC, and WHR were significantly higher ($p<0.005$) in the hypertensive participants compared to the non-hypertensive participants. WC, HC, SSF, and WHR are measures of central obesity while BMI is a measure of general obesity (Lee, 2015). Using Pearson correlation coefficient (r); WC, HC, SSF, WHtR, and BMI showed a statistically significant but weak relationship with high blood pressure ($r=(0.113-0.375)$; $p<0.05$). The greater the level of obesity, the higher the chances of developing hypertension (class 2 obesity with OR=3.47 at $p=0.003$; class 3 obesity with OR=4.16 at $p=0.022$, the obese band of WC has an OR= 2.55 at $p<0.001$), all set at 95% confidence interval (CI). These findings in this present study agree with the findings in a Korean anthropometric study (Lee, 2014).

In this present study, the Receiver Operator Characteristics (ROCs) for anthropometric indices predicting hypertension, all the areas under curves were less than 0.7 denoting that the anthropometric indices were not very strong in predicting hypertension because of probable confounding factors. However, the best predictors of hypertension for both genders were WC and WHtR, and their cut-off points still yielded a weak result because sensitivity, specificity, and PPV were below 70%. Conversely, height was the least predictor with a PPV of 37%.

For the male study participants, the best predictors for hypertension were WC (best cut-off points=92.5 cm; PPV=61%), WHtR (best cut-off points=53.92; PPV=57%), and CC (best cut-off points=93.5 cm; PPV=54%). For the female study participants, the best predictors for hypertension were WC (best cut-off points=97.5 cm; PPV=53%), HC (best cut-off points=108.5 cm; PPV=55%), and WHtR (best cut-off points=58.98 cm; PPV=54%). These findings agree with the WHO recommendation cut-off point for cardiometabolic risk: WC ≥94 cm for WC in males and WHR ≥0.90 cm for both men and women (WHO, 2008). Meanwhile, the findings were at variance with the WHO cut-off recommendation for WC which is (>80 cm) for cardiometabolic risk for women (WHO, 2008). Moreover, the WC cut-off point (WC >120 cm) for males in an American study was higher compared to this present study, just as the WC cut-off point (88 cm) for females differs with the findings of this present study (Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001). The regionalization, sometimes intra-regionalization, nutrition in childhood, and the current nutritional status accounted for the difference in anthropometric indices cut-off points (WHO, 2008; IDF, 2006).

The prevalence of hypertension in this study was 38%. Hypertension reported in this present study might not be attributed to obesity even as 60% of the participants patronize fast-food vendors because 71.5% of the participants were involved in at least a form of physical activity. However, there is a link connecting hypertension to genetics in this present study because 33.5% of the participants had a positive family history of hypertension. In addition, 20.3% had a positive family history of diabetes mellitus, and 8.2% of the participants were diabetics. Other factors that could be associated with hypertension in this present study were cigarette smoking (7.6%), use of snuff (4.8%), alcohol use (48.7%), patronizing fast-food vendors (60.0%) and age. Tobacco has a teratogenic effect on fetuses and causes hepatorenal injury during pregnancy (Udeh, 2023b; Udeh, 2023c). At above 45 years of age, the likelihood of becoming hypertensive significantly increases. The consequences of hypertension were also present among the study participants – heart attack (2.5%), and stroke (1.7%).

Nevertheless, there is also need for new and effective treatment options in patients with Metabolic Syndrome Diseases. Sodium-Glucose Linked Transporter 2 (SGLT-2) inhibitors e.g. Dapagliflozin and Glucagon-like Peptide 1 Receptor Agonists (GLP-1 RAs) e.g. Liraglutide have been found to improve the efficacy of treatment and clinical course of type 2 diabetes mellitus and hypertension in patients with such comorbidities (Ikwuka, 2017b; Ikwuka, 2018a; Ikwuka, 2018b; Ikwuka, 2019b; Ikwuka, 2021; Ikwuka, 2024; Virstyuk, 2017b; Virstyuk, 2018b; Virstyuk, 2018c). It has also been documented that coconut water has hepatorenal protective functions in alloxan-induced type 1 diabetes mellitus (Ekechi, 2023).

However, it is pertinent to point out some of the limitations of this present study because other causes of hypertension e.g. renal disease, aortic and renal artery stenosis, and pheochromocytoma were not investigated. Bias in this present study could be from selection, information, and measurements even though extreme case sampling, well structured self-administered questionnaire, participants with basic education, and standardized equipments were used. The AUCs of ROCs were not adjusted in this study. Therefore, the relationship between each anthropometric index and hypertension might be confounded by the influence of age, thereby underestimating the actual predictive value of the anthropometric index during ROC determination.

CONCLUSION

Anthropometry is related to hypertension and obesity is a risk factor for hypertension. Hypertension is a global health challenge which also affects Enugu City in South-East Nigeria. The prevalence of hypertension in this present study was 38.0%. Apart from obesity, other factors such as nutrition or diet transition, genetics, medical conditions, and age are also associated with hypertension. All the mean values of anthropometric indices were higher in the hypertensive participants than in the non-hypertensive participants except height, NC and STR. WC best correlated with systolic blood pressure (SBP) and diastolic blood pressure (DBP) and thus WC was the best predictor of hypertension, followed by WHtR. The sensitivity, specificity, and PPV for all anthropometric indices were below 70%.

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