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Full-Length Research Article

Prevalence of (Pre)Hypertension and Correlations between Blood Pressures and Anthropometric Indices in a Lean Population of Adults from Selected Communities in the Old Eastern Region of Nigeria

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Summary: Hypertension is a prevalent disease globally and its prevalence is rising in sub-Saharan Africa. Urban-rural differences in the prevalence of hypertension are under-reported in Nigeria. Though hypertension is known to be related to obesity, the nature of the relationship is still unclear. This study sought to interrogate these and thus enrolled a total of 1,755 subjects (59% females) from selected communities in five states in the old Eastern Region of Nigeria. Standard protocols and definitions were used to take measurements and diagnose relevant disease states. Appropriate statistical tools were used for data analysis. The results indicate that prehypertension was found in 40.0% of males and 27.5% of females, while hypertension was found in 19.1% of males and 18.6% of females. The prevalence of (pre)hypertension among urban and rural males was similar (19%). However, prehypertension was more prevalent among urban females (29.1% Vs 24.3%); while hypertension was more prevalent among rural females (21.9% Vs 17.1%). SBP was positively and significantly correlated with weight, waist circumference, hip circumference, waist-to-height ratio, and body mass index in the general population. When disaggregated by blood pressure phenotypes, the correlations were mostly consistent among normotensive subjects and females. Among subjects with (pre)hypertension, the correlations varied in strength and direction depending on sex and the adiposity measure used. The urban-rural difference in the prevalence of (pre)hypertension and the relationship between hypertension and obesity are not linear.

Keywords*: adiposity, correlations, hypertension, Nigeria, prevalence*

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INTRODUCTION

Hypertension, or high blood pressure (BP), is a condition in which the blood pressure is persistently elevated, exceeding 139/89 mmHg (WHO, 2013). It is a prevalent condition globally, with prevalence in low- and middle-income countries (LMICs) rising recently (Mills *et al*., 2020). In the WHO African Region a prevalence of 46% has been reported in adults aged ≥ 25 years (WHO 2013); while in Nigeria, a recent review put the prevalence of hypertension among individuals aged ≥ 20 years at 30.6% (Adeloye *et al*., 2021). Ranzani *et al*., (2022) recently, following a meta-analysis of 299 surveys across 66 LMICs, reported an overall prevalence of hypertension of 30.5% (95% CI, 28.9 to 32.0) in urban areas and 27.9% (95% CI, 26.3 to 29.6) in rural areas, indicating a pooled 2.45% urban-rural difference in prevalence of hypertension in LMICs.

Hypertension is a key driver for cardiovascular diseases and often leads to chronic conditions such as kidney diseases, heart failure and strokes (Poznyak *et al*., 2022). Indeed, about 54% of stroke, 47% of ischaemic heart disease and 25% of other cardiovascular diseases (CVDs) worldwide were attributable to hypertension (Banach and Aronow, 2012). The aetiology of hypertension suggests a role for low grade inflammation, mediated by lifestyle factors like obesity, physical inactivity, excessive salt and unsaturated fats consumption, alcohol abuse and cigarette smoking, in the rising prevalence of hypertension globally

(Adeloye and Basquill, 2014; Oseni *et al*., 2024). Indeed, there are reports of positive correlation between blood pressures and obesity. This is the basis for clinical recommendations that emphasise weight loss (especially through physical exercise) as a non-pharmacological management option for hypertension (Ejike and Ukegbu, 2017; Unger *et al*., 2020).

Whereas there appears a consensus around the positive relationship between weight gain and elevated blood pressures, the nature of that relationship is still not sufficiently clarified (Ejike and Ugwu, 2010; Ejike and Ukegbu, 2017). It is known that adiposity and not just weight is the metabolic driver of chronic diseases, including hypertension (Ijeh *et al.,* 2010; Ejike and Ijeh, 2012). The body mass index, which is most often used in epidemiological studies, is known to be a poor measure of adiposity. In this wise, other measures of weight gain which target adipose tissues better, such as waist circumference, waist-to-height ratio and waist-to-hip ratio have been proposed (Ijeh *et al*., 2010; Khanna *et al.,* 2022). Yet there is a dearth of scientific studies that have examined the relationship between various anthropometric measures of obesity and blood pressure, especially when blood pressure is disaggregated into different phenotypes. Indeed, Ejike and Ukegbu (2017) referred to the relationship between blood pressure and measures of obesity as not being a "straitjacket affair".

The old Eastern region of Nigeria (Figure 1) is made up of people of different but related ethnicities, all of sub-Saharan African ancestry. The region currently comprises eight states, but the external boundaries remain the same. Though there are studies on hypertension and related disorders in the different states in the region, there is none to our knowledge that has a regional coverage. This study was therefore designed to not only determine the prevalence of (pre)hypertension in rural and urban parts of the old Eastern region, but also to answer the questions: (1) is the relationship between measures of obesity and blood pressure consistent in the general population and among hypertensive, pre-hypertensive and normotensive subjects? and (2) does the relationship exist irrespective of adiposity index used? The findings will hopefully clarify the relationship between blood pressures and measures of adiposity and contribute to clinical practice recommendations for prevention and management of hypertension.

SUBJECTS AND METHODS

Location: At independence in 1960, Nigeria had three Regions, *viz.:* the Eastern Region, the Northern Region, and the Western Region. The Eastern Region was bordered by the Niger River to the west, Northern Nigeria to the north, Cameroon to the east, and the Gulf of Guinea to the South. The Region is currently divided into eight states, which not only share geographic contiguity but also have considerable cultural similarities (Plate 1). Ten rural towns and five urban cities in five out of the eight states were selected on a convenience basis for this study (Table 1). Convenience here refers to ease of accessibility and familiarity of members of the research team with the terrain (of especially the rural areas) to guarantee security, given the limited budget for the study. Towns with high population densities, modern built-up neighbourhoods, and access to infrastructure/amenities such as paved roads, the national electricity grid, pipe-borne water, etc., were classified as urban, while those lacking such factors and amenities were classified as rural.

Plate 1:
Diagram showing the old Eastern Region of Nigeria
(source: https://en.wikipedia.org/wiki/Eastern_Region,_Nigeria)

Table 1:
Sites where subjects were recruited

S/N	State	Urban area	Rural area
1	Abia	Umuahia	Nsukwe, Ntigha, Umuosu Nsulu, Uratta, Okpuala Ngwa
2	Anambra	Nnewi	NA
3	Cross River	Calabar	Okopedi, Ikot Edem, Esuk Ekpo Eyo
4	Ebonyi	Abakaliki	NA
5	Rivers	Port-Harcourt	Egbu, Igbodo

Subjects: Apparently healthy adults in the selected communities were selected randomly using the modified-cluster sampling technique and the objectives of the study explained to them. Those who gave informed consent and who additionally met the inclusion criteria were recruited. The inclusion criteria included being up to 18 years of age, apparently healthy with no physical deformities that can affect anthropometric measurements, absence of pregnancy in women, and absence (no admittance or obvious signs) of current or historical alcohol or drug abuse. In rural areas, the consents of community leaders were obtained before the participants were approached.

Methods

Blood pressure measurement: Systolic and diastolic blood pressures were measured using an oscillometric digital blood pressure monitor (Omron M2 Basic HEM-7121J-E). The device has a measurement error of ±3 mmHg, according to the manufacturer. Each subject was required to rest in a seated position for an initial 10 minutes before blood pressure readings were taken. Three separate readings were taken at five-minute intervals, with the subject sitting down, and the cuff placed around the upper arm of the non-dominant hand. The mean of the second and third readings was then recorded for the systolic and diastolic blood pressures, respectively.

Anthropometric data: The self-reported age at the last birthday for each subject was recorded. Heights of the subjects were measured with an improvised stadiometre, to the nearest 0.1cm, with the subject standing on bare feet. The weight measurements were taken with the subjects on bare feet and wearing light clothing, with an electronic digital-display scale, to the nearest 0.1kg. The waist circumference (WC) and hip circumference (HC) of each participant were measured using a non-elastic measuring tape, to the nearest 0.1cm. WC was measured midway between the lowest rib and the superior border of the iliac crest with the subject breathing minimally. HC was measured at the widest circumference over the buttocks. From the above measurements, the waist-to-hip ratio (WHpR) was calculated as WC divided by HC; the waist-to-height ratio (WHtR) was calculated as WC divided by Height; and the BMI was calculated as Weight (Kg)/[Height (m)^2].

Vegetable consumption: Vegetable consumption was assessed by self-report. Each subject was asked if they consumed vegetables daily, and only “yes” and “no” options were given. Similarly, physical activity was assessed by self-report, using a single question, “Do you engage in daily physical exercise?” to which they could respond with a “yes” or “no”. Subjects who did not answer the questions or had missing data were excluded from the analysis.

The same trained personnel took all measurements in each location. The field personnel were all trained centrally before deployment. All equipment was appropriately calibrated according to its manufacturer’s specifications before use each morning. Measurements were taken between 7am and 10am each day throughout the study.

Ethical consideration: The protocol, design and methods for this study were approved by the ethics committee of the Federal Medical Centre, Umuahia, Abia state, Nigeria (Approval Number: FMC/QEH/G.596/Vol.10/570).

Definitions: Prehypertension was defined as SBP/DBP (mmHg) > 120/80 but < 140/90. Hypertension was defined as SBP/DBP (mmHg) ≥ 140/90. Subjects with SBP/DBP (mmHg) > 120/80, that is, both those with prehypertension and those with hypertension, were classified as having elevated blood pressure. Subjects with SBP/DBP (mmHg) ≤ 120/80 were classified as normotensive. Subjects were described as having isolated systolic and isolated diastolic hypertension if their systolic and diastolic blood pressures (mmHg) were > 140 and > 90, respectively, when the accompanying systolic and diastolic blood pressures (mmHg) were ≤ 120 and < 90, respectively.

Statistical analyses

Descriptive statistical analysis was carried out on the data generated and reported as mean ± standard deviation in Tables. Frequency counts were used to calculate prevalence and were reported in percentages. Differences between means for continuous data were separated by One Way ANOVA while the Fischer’s exact test was used for categorical data. Pearson’s correlation coefficients were calculated to assess the correlations between blood pressures and anthropometric measures of obesity. For all analyses, a significant threshold of $P < 0.05$ was adopted. Data analyses were carried out using IBM-SPSS Statistics version 26 (IBM Corp., Chicago).

RESULTS

A total of 1,755 subjects (59% female) who met the inclusion criteria were included in the study. Sixty per cent of the subjects were residents of urban areas, and 61% of those studied were female. Fifty-seven per cent of the rural residents were female. The mean ages of male and female rural dwellers were not statistically different; however, urban male and female subjects were significantly younger (P < 0.05) than their rural sex-matched counterparts. Mean systolic blood pressure (SBP) values were not statistically different (P > 0.05) across sex groups; however, urban males had significantly higher SBP values (P < 0.05) than urban females. Mean diastolic blood pressure (DBP) values were statistically similar irrespective of sex and place of residence. Male subjects and urban dwellers were consistently and significantly taller (P < 0.05) and heavier than female subjects and rural dwellers, respectively.

Female subjects and urban dwellers consistently had significantly ($P < 0.05$) higher mean hip circumference values relative to males and rural dwellers; while females had significantly ($P > 0.05$) higher waist circumference values compared to males, irrespective of place of residence. Mean WHpR were statistically similar ($P > 0.05$) irrespective of sex or place of residence comparisons. Urban females (but not males) had significantly ($P < 0.05$) higher WHtR compared to their male counterparts. Just like WHpR and WHtR, the mean body mass index (BMI) values of the subjects were within the normal range. Female subjects and urban dwellers consistently had significantly ($P < 0.05$) higher BMI values relative to males and rural dwellers, respectively (Table 2).

When the data are disaggregated by blood pressure phenotypes, irrespective of place of residence (Table 3), it is observed that only normotensive male subjects were significantly older (P < 0.05) than their female counterparts. The females consistently had significantly higher waist circumference, hip circumference, WHtR, and BMI values (P < 0.05) than the males across all three blood pressure phenotypes.

Among hypertensive and prehypertensive subjects, 58% and 63%, respectively, reported regular physical activity. More rural dwellers reported being physically active, reaching 70% in both hypertensive and prehypertensive subjects (Figure 1). Only 30% of the subjects reported consuming vegetables daily across all blood pressure phenotypes. More rural dwellers reported consuming vegetables than urban dwellers (36% vs 17% for prehypertensive subjects and 40% vs 28% for normotensive subjects) (Figure 2).

Elevated blood pressure was more prevalent in males (59%) than females (46%), though as a result of prehypertension (40.0% vs 27.5%) and not hypertension (19.1% vs 18.6%). The prevalence of prehypertension and hypertension among urban and rural males were similar (19%). However, whereas more urban females were prehypertensive (29.1%) compared to their rural counterparts (24.3%), more rural females were hypertensive (21.9%) compared to urban females (17.1%) (Figure 3).

Table 2:
Relevant general characteristics of the population

		Age (Years)	SBP (mmHg)	DBP (mmHg)	Height (cm)	Weight (Kg)	Waist circ. (cm)	Hip circ. (cm)	Waist-to-Hip Ratio	Waist-to-Height Ratio	Body Mass Index (kg/m^2)
Rural	Female (N=334)	33 ± 9	122 ± 22	78 ± 14	158.2 ± 8.4	59.0 ± 13.9	81.5 ± 12.2	93.7 ± 11.7	0.87 ± 0.09	0.52 ± 0.08	23.6 ± 5.3
	Male (N = 256)	31 ± 9	123 ± 18	76 ± 13	169.1 ± 9.0	62.9 ± 10.1	77.3 ± 8.0	88.8 ± 9.0	0.93 ± 0.07	0.46 ± 0.05	22.0 ± 3.4
	P	0.076	0.390	0.058	< 0.001	< 0.001	< 0.001	< 0.001	0.197	0.001	< 0.001
Urban	Female (N = 708)	28 ±10*	121 ± 16	78 ± 11	163 ± 7.5*	66.3 ± 14.4*	83.7 ± 12.5*	97.6 ± 12.3*	0.86 ± 0.12	0.60 ± 0.03*	25.0 ± 5.4*
	Male (N = 457)	29 ±10*	125 ± 15	77 ± 12	171.3 ± 9.2*	68.3 ± 11.4*	78.8 ± 11.1	91.9 ± 12.5*	0.90 ± 0.08	0.48 ± 0.04	23.3 ± 3.8*
	P	0.005	< 0.001	0.260	< 0.001	0.010	< 0.001	< 0.001	0.328	< 0.001	< 0.001

** indicates a statistically significant difference (p < 0.05) for comparisons between rural and urban areas within the sexes.*

Table 3:
Relevant general characteristics of the population stratified by blood pressure phenotype

Blood pressure phenotype	Sex	Age (Years)	Height (cm)	Weight (Kg)	Waist circ. (cm)	Hip circ. (cm)	Waist-to-Hip Ratio	Waist-to-Height Ratio	Body Mass Index (kg/m^2)
Hypertensive	Female (N=194)	36 ± 10	160.6 ± 8.8	68.0 ± 17.0	88.0 ± 13.0	99.9 ± 13.0	0.88 ± 0.09	0.58 ± 0.19	26.3 ± 6.3
	Male (N = 136)	35 ± 10	170 ± 9.3	70.1 ± 12.5	81.9 ± 10.5	93.3 ± 10.1	0.88 ± 0.07	0.48 ± 0.06	24.4 ± 4.1
	p	0.199	<0.001	0.155	<0.001	<0.001	0.935	<0.001	<0.001
Prehypertensive	Female (N=287)	30 ± 10	162.5 ± 8.3	67.5 ± 15.1	85.4 ± 13.3	98.1 ± 13.0	0.88 ± 0.12	0.61 ± 0.19	25.6 ± 5.6
	Male (N = 285)	**29 ± 9**	**171.7 ± 8.8**	**68.2 ± 11.3**	**79.1 ± 8.8**	**92.0 ± 9.0**	**0.86 ± 0.08**	**0.48 ± 0.13**	**23.2 ± 3.5**
	p	0.170	<0.001	0.482	<0.001	<0.001	0.798	<0.001	<0.001
Normotensive	Female (N=561)	27 ± 8	161.1 ± 7.7	60.7 ± 12.7	80.1 ± 10.9	94.3 ± 11.2	0.85 ± 0.11	0.55 ± 0.21	23.4 ± 4.7
	Male (N = 292)	29 ± 9	169.8 ± 9.3	62.8 ± 9.5	75.7 ± 10.6	88.5 ± 13.6	0.97 ± 0.42	0.45 ± 0.10	21.9 ± 3.3
	p	<0.001	<0.001	0.027	<0.001	<0.001	0.005	<0.001	<0.001

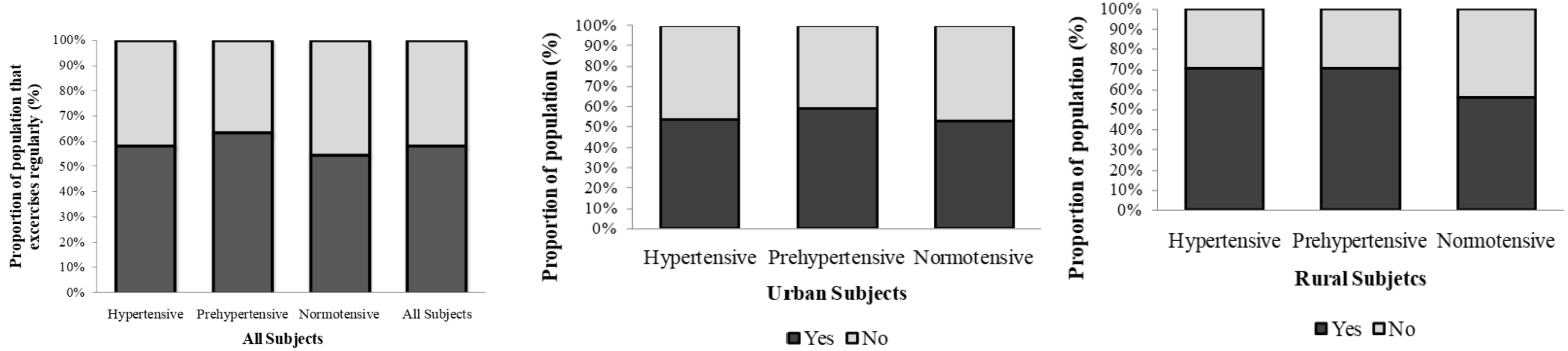

Figure 1:
Physical activity patterns of the studied population

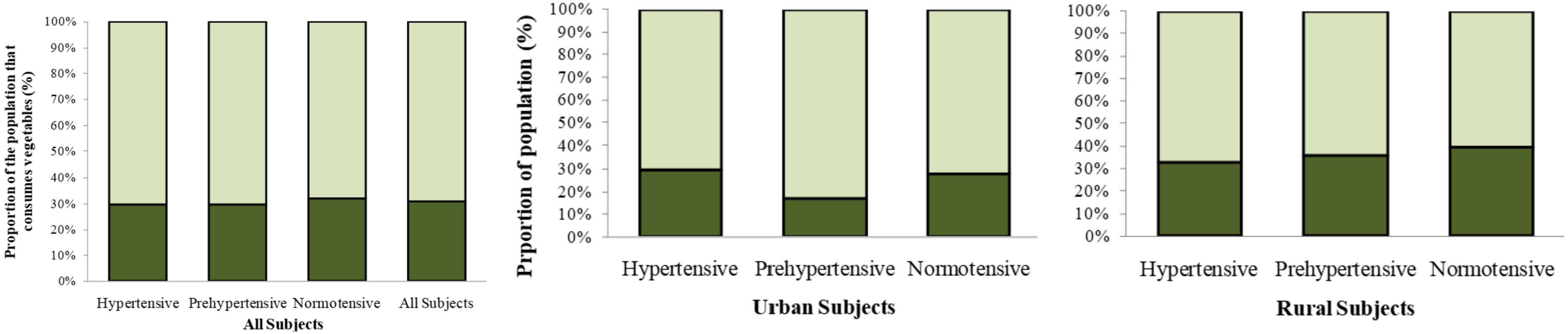

Figure 2:
Vegetable consumption patterns of the studied population

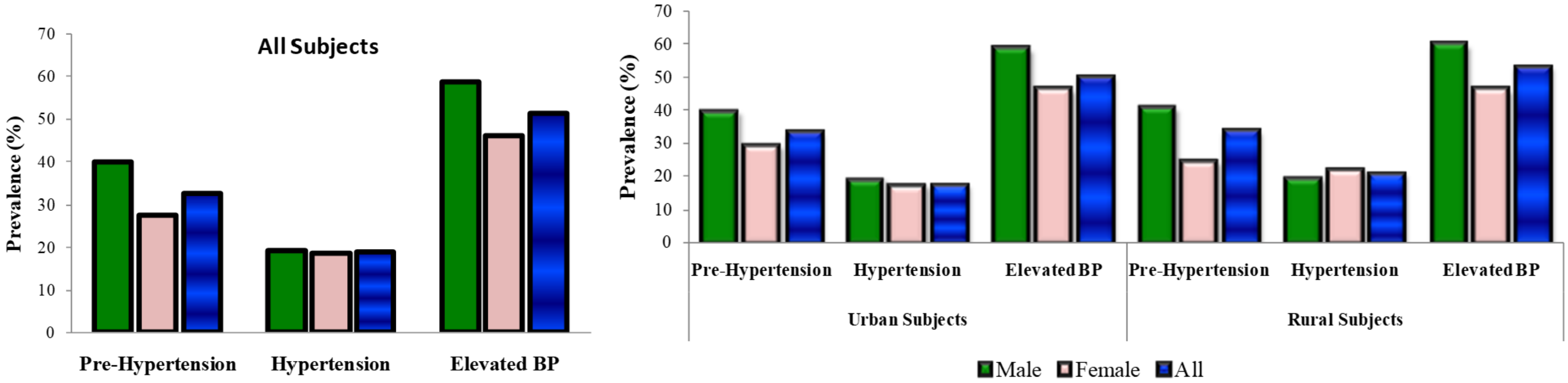

Figure 3:
Prevalence of (pre)hypertension in the population

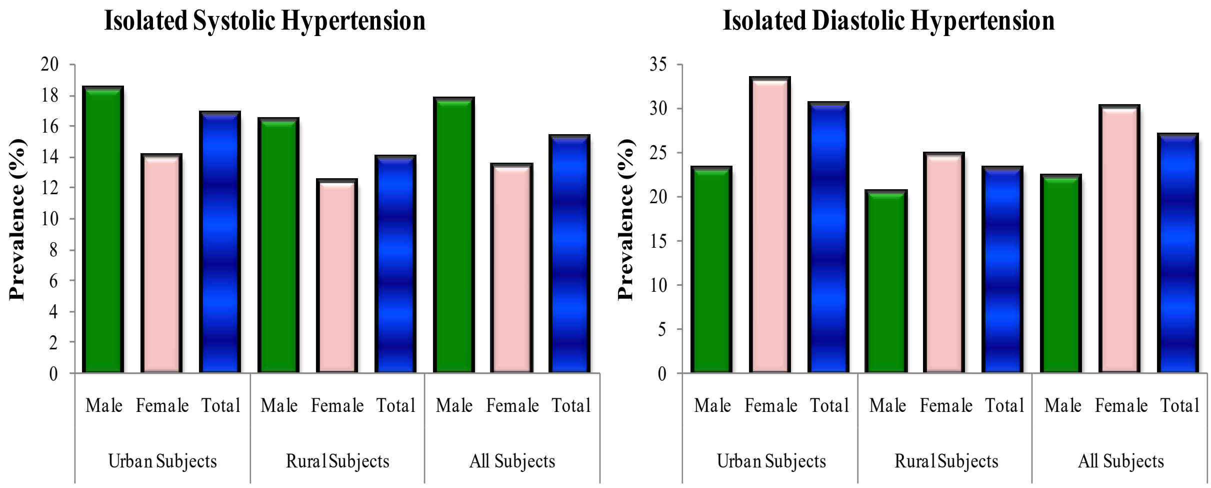

Figure 4:
Prevalence of isolated systolic and diastolic hypertension among hypertensive subjects

Table 4:
Correlations between SBP and measures of weight gain

		Systolic Blood Pressure Versus					
		Weight	WC	HC	WHpR	WHtR	BMI
All subjects	r	+0.213**	+0.223**	+0.113**	+0.014	+0.159*	+0.199**
	p	<0.001	<0.001	<0.001	0.548	0.014	<0.001
All female subjects	r	+0.177**	+0.250**	+0.125**	+0.161**	+0.179*	+0.202**
	p	<0.001	<0.001	<0.001	<0.001	0.010	<0.001
All male subjects	r	+0.272**	+0.240**	+0.157**	-0.013	+0.112**	+0.262**
	p	<0.001	<0.001	<0.001	0.727	0.003	<0.001
All subjects with elevated BP	r	+0.002	+0.129**	+0.023	+0.139**	+0.001	+0.071*
	p	0.957	<0.001	0.497	<0.001	0.975	0.033
Females elevated BP	r	-0.054	+0.094*	-0.027	+0.141**	-0.026	+0.013
	p	0.238	0.039	0.551	0.002	0.576	0.775
Males elevated BP	r	+0.119*	+0.178**	+0.090	+0.130**	+0.032	+0.178**
	p	0.015	<0.001	0.065	0.007	0.512	<0.001
All hypertensive subjects	r	-0.126*	+0.044	-0.089	+0.194**	+0.004	-0.052
	p	0.022	0.423	0.106	<0.001	0.947	0.347
Female hypertensives	r	-0.180*	-0.007	-0.171*	+0.217**	-0.035	-0.097
	p	0.012	0.926	0.017	0.002	0.630	0.178
Male hypertensives	r	+0.023	+0.151	+0.081	+0.131	+0.173*	+0.061
	p	0.790	0.080	0.348	0.129	0.044	0.484
All prehyper-tensive subjects	r	+0.157**	+0.099*	+0.013	+0.111**	+0.032	+0.103*
	p	<0.001	0.018	0.759	0.008	0.446	0.014
Female prehypertensives	r	+0.118*	+0.161**	+0.036	+0.148*	+0.105	+0.102
	p	0.046	0.006	0.540	0.012	0.076	0.084
Male prehypertensives	r	+0.210**	+0.081	+0.044	+0.072	-0.033	+0.186**
	p	<0.001	0.173	0.455	0.228	0.582	0.002
All normotensives	r	+0.145**	+0.085*	-0.007	+0.056	+0.071*	+0.115**
	p	<0.001	0.013	0.848	0.103	0.038	0.001
Female normotensives	r	+0.147**	+0.118**	+0.015	+0.109**	+0.102*	+0.152**
	p	<0.001	0.005	0.722	0.010	0.016	<0.001
Male normotensives	r	+0.129*	+0.065	+0.000	+0.071	+0.057	+0.072
	p	0.027	0.267	0.994	0.225	0.328	0.217

From Figure 4, it is seen that among hypertensive subjects, isolated systolic hypertension was found in 15.2% of the sub-population (17.6% in males and 13.4% in females). Isolated systolic hypertension was more prevalent in the urban area (irrespective of sex) and among males (irrespective of place of residence). Isolated diastolic hypertension was more prevalent among hypertensive subjects (26.7%), reaching 30.0% in all females and 22.1% in all males. Isolated diastolic hypertension was more prevalent in the urban area (irrespective of sex), and among females (irrespective of place of residence).

The correlations between SBP and measures of weight gain were positive and significant in the general population (Table 4). SBP was found to be positively and significantly correlated with weight, waist circumference, hip circumference, WHtR and BMI. These correlations were found even when the subjects were separated by sex. The correlations were nonetheless weak (r < +0.450).

Table 5:
Correlations between DBP and measures of weight gain

		Diastolic Blood Pressure Versus					
		Weight	WC	HC	WHpR	WHtR	BMI
All subjects	r	+0.195**	+0.224**	+0.198**	+0.009	+0.012	+0.198**
	p	<0.001	<0.001	<0.001	0.693	0.628	<0.001
All female subjects	r	+0.211**	+0.222**	+0.209**	+0.033	-0.025	+0.208**
	p	<0.001	<0.001	<0.001	0.287	0.428	<0.001
All male subjects	r	+0.185**	+0.215**	+0.167**	+0.012	+0.082*	+0.167**
	p	<0.001	<0.001	<0.001	0.747	0.029	<0.001
All subjects with elevated BP	r	+0.050	+0.185**	+0.160**	+0.053	-0.007	+0.131**
	p	0.132	<0.001	<0.001	0.113	0.840	<0.001
Females elevated BP	r	+0.041	+0.104*	+0.096*	+0.011	-0.108*	+0.063
	p	0.369	0.022	0.035	0.808	0.018	0.169
Males elevated BP	r	+0.090	+0.214**	+0.155**	+0.100*	+0.053	+0.156**
	p	0.065	<0.001	0.001	0.041	0.279	0.001
All hypertensive subjects	r	+0.057	+0.129*	+0.122*	+0.027	-0.033	+0.072
	p	0.299	0.019	0.026	0.622	0.551	0.193
Female hypertensives	r	+0.075	+0.058	+0.069	-0.014	-0.140	+0.033
	p	0.302	0.424	0.344	0.847	0.052	0.647
Male hypertensives	r	+0.054	+0.188*	+0.135	+0.109	+0.205*	+0.090
	p	0.533	0.029	0.117	0.205	0.017	0.297
All prehyper-tensive subjects	r	+0.021	+0.143**	+0.158**	+0.008	+0.023	+0.099*
	p	0.613	0.001	0.000	0.843	0.590	0.018
Female prehypertensives	r	+0.002	+0.060	+0.083	-0.025	-0.072	+0.037
	p	0.969	0.310	0.159	0.679	0.226	0.530
Male prehypertensives	r	+0.058	+0.149*	+0.153**	+0.022	+0.022	+0.076
	p	0.328	0.012	0.010	0.716	0.716	0.201
All normotensives	r	+0.098**	+0.060	+0.125**	+0.033	-0.052	+0.070*
	p	0.004	0.080	0.000	0.334	0.130	0.040
Female normotensives	r	+0.164**	+0.060	+0.169**	-0.116**	-0.101*	+0.138**
	p	<0.001	0.153	<0.001	0.006	0.016	0.001
Male normotensives	r	+0.011	+0.020	+0.037	+0.070	-0.023	-0.099
	p	0.855	0.731	0.530	0.236	0.697	0.090

When disaggregated by blood pressure phenotypes, the correlations were mostly consistent among normotensive subjects and females. For normotensive subjects, there were significant positive correlations between SBP and weight, waist circumference, WHpR, WHtR and BMI, but among females. For subjects with elevated blood pressure, significant correlations with SBP were found only for waist circumference and WHpR in both sexes, and BMI only in males. Among subjects with hypertension, the correlations were significant with weight and WHtR among females only. The correlation coefficients were negative for weight but positive for WHtR. Male hypertensive subjects only had BMI significantly correlated with SBP. Among prehypertensive subjects, the significant correlations were with weight, waist circumference and WHpR among females. Males with prehypertension only had BMI significantly correlated with SBP.

The pattern of correlations for DBP and measures of weight gain was fairly similar with that of SBP with correlations being found in the general population, but largely driven by normotensive subjects and females (Table 5).

DISCUSSION

The studied population had an average age of 30 years (range: 18 to 60 years) and represents a typical adult Nigerian population. Nigeria's population distribution indicates a youth bulge; and life expectancy at birth in Nigeria is 63 years (2021 data) (WHO, 2024). Urban subjects, irrespective of sex, were significantly ($P < 0.05$) younger than their rural sex-matched counterparts. This is reflective of the rural to urban migration that is typical in LMICs where young persons migrate to the urban cities in search of better economic opportunities and access to basic social amenities such as electricity and cleaner household energy, potable water, sanitation, healthcare, etc. (Tonne *et al.*, 2021). This net migration not only alters the population dynamics of rural dwellers but also contributes to poverty and poor health outcomes in rural areas as the very young and elderly that dominate such places have high nutritional and health needs but very low economic productivity (Ranzani *et al*., 2022).

Male subjects were significantly ($P < 0.05$) taller and heavier than female subjects, yet the females had significantly ($P < 0.05$) higher BMI relative to males in this study. This is a common observation among *Homo sapiens.* Due to the nature of the BMI equation (where the denominator is the square of height), taller individuals have a more favourable BMI relative to shorter individuals of comparable (or even lesser) weight. Urban dwellers were significantly ($P < 0.05$) taller and heavier than rural dwellers. This may be linked to the food environment in urban centres which favour weight gain (Ejike *et. al,* 2009). Indeed, urban dwellers had significantly ($P < 0.05$) higher BMI values relative to rural dwellers. This also agrees with our finding that rural dwellers were more physically active and consumed more vegetables than the urban dwellers. Interestingly, the measures of adiposity studied such as WHpR, WHtR, and BMI of the subjects were within the normal range, indicating that the population studied was considerably lean.

Males had higher prevalence of elevated blood pressures [driven largely by the prevalence of prehypertension (40.0% vs 27.5%)] than females. This is consistent with the cardiovascular risk advantage which premenopausal women are known to have (Xue *et al.,* 2013). Recall that the mean age of the urban subjects was 28 ± 10 years for females and 29 ± 10 years for males. The reproductive age of the females may therefore be responsible for the lower prevalence of (pre)hypertension among females, but due to the fact that premenopausal women enjoy an oestrogen-driven cardiovascular advantage over their age-matched male counterparts, as mentioned earlier. Conversely, the higher prevalence of both disorders in the urban areas is not likely driven by this age advantage (especially among females) as the urban dwellers were significantly younger than their rural counterparts. The stress and pressures of urban lifestyles may contribute to elevations in blood pressures. Furthermore, it is plausible that other lifestyle factors such as physical exertion and consumption of vegetables for which the rural dwellers reported better indices are responsible for the observed difference in urban-rural prevalence of (pre)hypertension, even if they were minimal. The rural-urban difference in prevalence was highest in females as females in the urban area had approximately 5% higher prevalence for (pre)hypertension compared to rural females. This 5% difference is nonetheless twice the 2.45% difference reported by Ranzani *et al*., (2022) after a meta-analysis of 299 surveys across 66 LMICs. An earlier study in South-East Nigeria (a part of the studied region) had however reported a nearly 10% difference in urban-rural prevalence of hypertension (Ulasi *et al.* 2010). The preponderance of hypertension in urban areas reported in this study is consistent with the literature from Nigeria and other LMICs (Ejike *et al.*, 2009; Ulasi *et al.* 2010; Mills *et al.*, 2016; Adeloye *et al*., 2021; Ranzani *et al.*, 2022). It appears that the gap between urban and rural hypertension prevalence rates is closing in parts of Nigeria. Indeed, Ranzani *et al.* (2022) had noted that in the last 10 years, there has been a convergence of rural-urban hypertension rates in LMICs that is related to particular rates of transition. This may be driven by changes in nutrition and lifestyles and socio-economic dynamics in rural areas (Ijeh *et al*., 2010), and an ageing in the population of rural areas, relative to urban areas, as seen in this study. It is known that urbanization and the changes associated with it, such as shifts from occupations that are physically demanding to those that are sedentary, and increased access to processed foods, increase the risks of chronic diseases such as hypertension (Popkin, 2019), and often occur more rapidly in rural areas compared to urban areas (Mills *et al*., 2016; Olsen *et al*., 2016).

The prevalence of hypertension in this population was 19% for males irrespective of place of residence and 18.6% for females (17.1% in the urban areas, and 21.9% in the rural areas). Hypertension was more prevalent in urban males than their female counterparts, but more prevalent in rural females than their male counterparts. This may be explained by the premenopausal age of the urban females which could have conferred a cardiovascular risk advantage on them, one the older rural females may have lost. Oestrogens in pre-menopausal females are capable of modulating the renin-angiotensin-aldosterone system (RAAS) in a manner that is protective against hypertension (Xue *et al.,* 2013). The higher prevalence in rural women relative to rural men may be related to other risk factors not accounted for in this study.

The 18.6 to 21.9% prevalence of hypertension reported in this study is a lot lower than the 46% reported in adults aged ≥ 25 years in the WHO Africa region (WHO 2013). Furthermore, it is considerably lower than the findings of a recent review of the prevalence of hypertension among Nigerians aged ≥ 20 years which reported a prevalence of 30.6% (Adeloye *et al*., 2021); and the 30.5% (urban) and 27.9% (rural) prevalence of hypertension reported by Ranzani *et al.* (2022) following a meta-analysis of 299 surveys across 66 LMICs. The reports by the cited authors compare more with our findings for prehypertension [males, 40% (39.6% urban, 40.6% rural) and females, 27.5% (29.1% urban, 24.3% rural)] in this population.

The lower prevalence of hypertension reported here may be due to the fact that the population was essentially lean and obesity is a major driver of hypertension (Cartier *et al*., 2010). Additionally the population both in the urban and rural areas were considerably physically active and exercise is known to positively modulate blood pressures (Adeloye and Basquill, 2014). Even among subjects with elevated blood pressures (hypertensive and prehypertensive subjects) in this study, approximately 60% reported regular physical activity. Again, the studied population was young (mean age approximately 33 years), though in line with Nigeria's demography, and age is known to be positively associated with elevations in blood pressure. Indeed the prevalence values reported here are close to values reported in a young adult (undergraduate) population of Nigerians (Ejike and Ukegbu, 2017). There may be other plausible reasons for the observed lower prevalence values, such as education, socio-economic factors, and genetics which this study did to account for. The results should thus be discussed cautiously. More importantly, the rather high prevalence of prehypertension reported in this study is worrisome as the individuals can easily transit to hypertension if appropriate lifestyle modifications are not made. Prehypertension is known to be a transitional state and a pointer to future hypertension, and thus requires urgent intervention to forestall progression (Ejike and Ukegbu, 2017).

This study found that isolated diastolic hypertension was more prevalent than isolated systolic hypertension (26.7% Vs 15.2% of the hypertensive population). Aortic stiffening due to ageing is believed to cause isolated systolic hypertension (Palatini *et al.*, 2018). In the elderly, large artery stiffness rather than small vessel resistance is the dominant hemodynamic feature of hypertension. Sadly untreated isolated systolic hypertension may accelerate the rate of development of large artery stiffness, which creates a vicious spiral of hypertension and its sequelae (Himmelmann *et al*., 1998). In young people aged 18–30, however, isolated systolic hypertension is thought to be due to brachial blood pressure augmentation, and elastic arteries. It could also be due to increased pulse wave velocity that is sequel to vascular stiffening (Unger *et al*., 2020; Palatini *et al.*, 2018). Diastolic blood pressure is the main contributor to mean arterial pressure. Our finding of a preponderance of isolated diastolic hypertension over isolated systolic hypertension in this population is consistent with reports in young populations. Romero *et al*. (2021) reported that isolated diastolic hypertension is the most frequent hypertensive phenotype in individuals younger than 50 years. Its prevalence in hypertensive patients decreases with age, and it is almost nonexistent in elderly patients, even among untreated ones (Franklin *et al*., 2001). Recent opinions suggest that isolated diastolic hypertension is not a phenotype of significant concern (Romero *et al.,* 2021); and that young subjects, especially males with isolated systolic hypertension, have little cardiovascular risks and therefore may not need medical interventions (Scott *et al*., 2021). This may be the case in the studied young and lean population.

From this study, it is seen that the relationship between measures of obesity and blood pressure is not linear across blood pressure phenotypes. The correlations were stronger in the general population and among normotensive subjects; but weak or non-existent among hypertensive and prehypertensive subjects. This dichotomous or hyperbolic relationship where blood pressures are positively correlated with obesity in normotensive subjects but taper among prehypertensives and hypertensive is a phenomenon that has been reported earlier in Nigeria (Ejike *et al*. 2009; Ejike and Ukegbu, 2017). It suggests that the recommendations of weight loss for the prevention of hypertension may be appropriate, but among those who are already hypertensive, additional measures are required.

Furthermore, the relationship between blood pressures and anthropometric measures of adiposity is dependent on the measure of adiposity used. In this study, differences were observed for the strength and direction of the correlations with SBP and DBP and the studied anthropometric indexes; and even between the sexes. Whereas BMI correlated with blood pressures in males, waist circumference and waist-to-height ratio was correlated with blood pressures in females. SBP was found to be positively and significantly correlated with weight, waist circumference, hip circumference, WHtR and BMI. These correlations, though largely weak, were found even when the subjects were separated by sex. When disaggregated based on blood pressure phenotypes, the correlations were found to be consistent mostly among normotensive subjects and among females. The measures of adiposity that had the most significant correlations with blood pressures were weight, WC, WHpR, WHtR and BMI. Even with the above indices, the directions and strengths of the correlations varied. For example, among subjects with hypertension, the correlations with SBP were significant and negative for weight but positive for WHtR; and only males had BMI significantly correlated with SBP. These patterns of correlations were fairly similar for DBP.

Other than weight, BMI and WHtR were the most correlated with SBP and DBP. This is instructive as it shows that the relationship between blood pressure and measures of obesity is not just non-linear along the BP spectrum, but also varies by sex and by the measure of adiposity used, even to the extent of varying in the direction of correlation. The finding of a weak negative correlation between SBP and weight among hypertensive females suggests a *prima fascia* advantage of weight gain among female hypertensives. Though the correlation is weak, the observed relationship is counterintuitive and warrants further study to illumine the veracity and possible drivers of this observation. These findings call for a more detailed study of the relationship between blood pressures and obesity with a view to developing specific sensitive guidelines for prevention and management of hypertension from a weight prism.

This study is limited by a number of factors. First it would be ideal to recruit a larger number of older subjects and a larger sample size so as to increase the number of (pre)hypertensive subjects and therefore the robustness of the analysis. Second, the study would have benefitted from a more specific and direct measure of adiposity rather than the indirect anthropometric indices used. Given that it is the adipose tissues that are known to be responsible for the metabolic consequences of obesity, it would have been ideal to quantify the adipose tissue fats of the subjects and examine its relationship with hypertension. A detailed collection of other variables that can contribute to elevations in blood pressure would have also been useful in presenting a clearer picture of the underlying dynamics of the relationship between blood pressure and adiposity. Finally a more representative sampling of more urban and rural areas of the old Eastern Region of Nigeria would have been better for more balanced generalization. These require a cautious interpretation of the data presented here. However, given the challenges of conducting epidemiological studies in our environment, especially the limited financial resources and cultural practices that are inimical to research inquisition, it was impossible for this study to achieve the above. This study nonetheless made significant findings based on the fairly large and representative sample size and a robust analytical approach. It is hoped that the findings will spur further interest in this subject and elicit deeper research attention.

In conclusion, this study examined the rural-urban differences in the prevalence of (pre)hypertension in the old Eastern Region of Nigeria. Prehypertension was found in 40.0% of males and 27.5% of females while hypertension was found in 19.1% of males and 18.6% of females. The prevalence of both hypertension and prehypertension among males were similar (19%) irrespective of place of residence. However, among females, prehypertension was more prevalent in the urban area (29.1% Vs 24.3%); while hypertension was more prevalent in the rural area (21.9% Vs 17.1%). SBP was found to be positively and significantly correlated with weight, WC, HC, WHtR and BMI in the general population. When disaggregated based on blood pressure phenotypes, the correlations were found to be consistent mostly among normotensive subjects and among females. Among subjects with (pre)hypertension, the correlations varied in strength and direction depending on sex and measure of adiposity used. The urban-rural difference in the prevalence of hypertension appears to have closed among the males and inverted among rural females. The relationship between hypertension and obesity in this study is not linear or unidirectional, and is dependent on blood pressure phenotype, sex and measure of adiposity used. Public health messaging related to blood pressure, and clinical practice guidelines need not be omnibus, but should be adaptive and reflective of current research realities.

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The authors have no real of potential conflicts of interest to declare

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