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Comparison between Body Mass Index and Measures of Central Obesity in Predicting Prehypertension Risk among Selected Workers in Kano State, Nigeria

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ABSTRACT

The study aimed at testing the null hypothesis that body mass index (BMI) is not associated with higher risk of prehypertension. This was a cross-sectional study of a group of workers enrolled in a part-time degree program at Bayero University Kano, Kano State Nigeria. Body weight was measured using a digital weighing scale, body height was measured using a portable stadiometer, and waist and hip circumferences were measured using an inelastic measuring tape. All anthropometric measurements were done based on standardized protocols. Blood pressure was measured using a mercury sphygmomanometer. Data analysis was done using R software. Null hypothesis was rejected only if its probability was less than 0.05. Four hundred subjects had their data analyzed. There were 200 prehypertensive cases consisting of 125 males (mean age = 38 years, ±7.8) and 75 females (mean age = 35 years, ±8.6). The 200 normotensive subjects consisted of 118 males (mean age = 39 years, ± 7.0) and 82 females (mean age = 32 years, ±8.6). Among the female subjects, the probabilities of null hypotheses comparing BMI with the three measures of central obesity i.e. waist circumference, waist-to-height ratio and weight-to-hip ratio were 0.83, 0.57 and 0.4 respectively. The corresponding probabilities among the male subjects were 0.53, 0.62 and 0.2 respectively. In conclusion, the null hypothesis was accepted and thus generalized obesity was not associated with greater risk of prehypertension than central obesity among the study subjects.

Keywords: body mass index, central obesity, prehypertension, Nigeria

INTRODUCTION

Prehypertension (PHTN) is a borderline high-risk blood pressure status defined as systolic Blood Pressure (BP) of 120-139 mmHg and/or diastolic BP of 80-89 mmHg[1]. The risk of cardiovascular diseases increases in a log-linear fashion from systolic blood pressure of 115 mmHg and diastolic blood pressure of 75 mmHg with a doubling of the risk for cardiovascular-related death for each 20 mmHg and 10mmHg increase in systolic and diastolic blood pressures[2]. The risk of continuous rise in blood pressure therefore warrants defining a cut-off value so as to set a threshold of action for both clinical and public health interventions. National High Blood Pressure Education Program defined this threshold as systolic blood pressure of 140 mmHg and/or diastolic blood pressure of 90 mmHg[1].

There is a worldwide increase in the burden of high blood pressure. To demonstrate this, a pooled analysis of 1479 studies from 174 countries including 19.1 million participants, had shown that the number of people with high blood pressure increased from 594 million in 1975 to 1.13 billion people in 2015 with the increase largely in developing countries[3]. Eighty-eight percent (88%) of mortality attributable to high blood pressure is now in developing countries[3].

In a meta-analysis of 242,322 individuals from 11 countries including Nigeria, prevalence of prehypertension was 38%[4]. In a recent meta-analysis comprising of 21 studies (conducted in the years 2011 to 2021), with a total of 25839 participants, the pooled prevalence of prehypertension in Nigeria was found to be 34%, corresponding to 41.4 million adults; males have a higher prehypertension prevalence of 39.1% when compared to females' prevalence of 28.5%[5].

Prehypertension has been known to be associated with both generalized measures of obesity (body mass index) [6-9] and central measures of obesity such as waist circumference[7-9]. While many studies reported higher risk of hypertension was associated with central measures of obesity, others have reported the opposite. These conflicting findings were found to be related to age among a cohort of Chinese subjects with BMI being higher risk factor among younger subjects[9]. A Systematic review and meta-analysis of Thirty-eight original articles involving 309,585 subject reported WHtR as having the strongest association with hypertension risk (OR, 1.68; 95% confidence interval, [CI]:1.29–2.19) and prediction ability[10]. However, this same meta-analysis found BMI to have the highest prediction ability in a subset of Chinese subjects (10). One of the probably strongest evidence of higher risk of prehypertension in generalized obesity compared to central obesity was a 10-year follow up study of a Brazilian population which found BMI to be superior in its predictive capacity when compared to Body Adiposity Index (BAI), Body Roundness Index (BRI), and Visceral Adiposity Index (VAI)[11]. This was found across age groups and genders[11]. The findings from the literatue suggest the relative roles of generalized and central obesity in predicting hypertension and prehypertension to be dependent on age, sex and racial group. The aim of this study is to compare the risk of prehypertension associated with body mass index and central obesity measures (waist circumference, waist-to-hip ratio and waist-to-height ratio) among selected categories of workers in Kano State, Nigeria. Towards this aim, the study controlled for age and gender through case-control matching to eliminate the confounding effects of these variables.

MATERIALS AND METHODS

Study design

The study design was cross-sectional analytical study. The prehypertensive cases were age-matched with equal number of controls.

Study area

The study was conducted in Bayero University Kano (BUK), a university located in the North-

West Region of Kano State in Nigeria, a lower middle income[12]. Western African nation. Kano State shares boundary with Katsina in the northwest, Jigawa State in the northeast, Bauchi State in the southeast and Kaduna in the southwest. It has total land area of 21,276.9 Km^2 and a projected population of 12,150,811 by 2017 (Figure 1)[13].

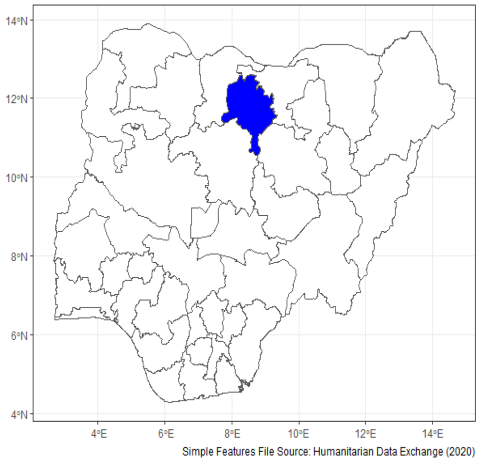

Figure 1: Map of Kano State in Nigeria (Source of Simple Features File: Humanitarian Data Exchange)[14]

Study population

The study population consists of the students of the School of Continuing Education (SCE) of Bayero University Kano. The university is leading tertiary institution in Nigeria founded in 1976 and about fifty thousand (50,000) students currently enrolled[15]. SCE is a part-time program school meant mostly for workers with classes taking place mostly on weekends. There are 25 programs across five (5) departments and currently enrolls more than four thousand (4, 000) students[16].

Sample size calculation

The minimum sample size of one hundred and fifty-two (152) per group (prehypertensive or normal blood pressure) was calculated using Epitools[17] online calculator of sample size for case-control studies based on 95% confidence level, precision of 0.05, power of 80%, expected overweight prehypertension odds ratio of 1.9[6] and expose to overweight and obesity among normal subjects of 39%[18].

Sampling methods

Figure 2 shows the process of the multi-stage sampling methodology employed in the study. The 25 programs in the school were assigned numbers 1 to 25 and then two programs were randomly selected using random number generator function in R Software[19]. Next, each of the four levels of the selected programs were assigned numbers and two levels were randomly selected from each of the selected programs using the same random number generator function[19]. The four selected levels had the sample size equally divided and systemic sampling (every other student in a serialized list) was employed to recruit the desired sample size.

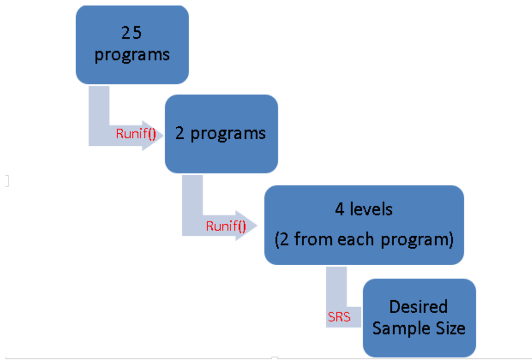

Figure 2: Multi-stage Sampling. Runif() = Random number generator function. SRS = Systematic Random Sampling

Inclusion criteria

Inclusion Criteria were any student of the SCE BUK who is a worker, gave informed consent, is not diabetic or hypertensive and does not have a cardiovascular endpoint event such as coronary heart disease or stroke.

Exclusion criteria

Exclusion Criteria were any student who is not a worker, is pregnant, refused participation in the study or is diabetic, hypertensive or both.

Ethical considerations

Ethical clearance was sought from Bayero University Health Research Ethical Committee (BUK-HREC) and the Kano State Ministry of

Health ethical committee (NHREC/17/03/2018). Informed written consents was sought from the study participants

Anthropometric measurements

Body weight

Body weight was measured using an electronic weighing scale (Seca, Germany) with maximum reading of 150 kg and accuracy of 0.1 kg. With the scale reading zero, the subject stood on the centre of the scale without support and with the weight distributed evenly on both feet[20].

Height

Height was measured using a portable stadiometer (Seca, Germany) with maximum of 200 cm and accuracy of 0.1 cm. With the subject standing with the feet together and the heels, buttocks and upper part of the back touching a wall and the head placed in the Frankfort plane (a position of the head whereby the lower edge of the eye socket is in the same horizontal plane as the notch superior to the tragus of the ear). When aligned, the Vertex was the highest point on the skull[20].

Body mass index

The body mass index (BMI) was calculated as weight (in kilograms) divided by the square of height (in meters). Normal BMI was defined as the range 18.50-24.99 kg/m^2. Values at 25.0 kg/m^2 and above were defined as abnormal2[1]. There are 4 (four) categories of abnormal BMI; the preobesity and classes I-III of obesity. The ranges of the categories are, respectively, 25-29.kg /m^2, 30-34.99 kg/m^2, 35-39.99 kg/m^2 and values of 40kg/m^2 or greater[21].

Waist circumference

Waist circumference was measured using an inelastic measuring tape (MEDLINE, 1-800-Medline, USA). With the subject assuming a relaxed standing position with the arms folded across the thorax, measurement was taken at the mid-point between the lower costal (10th rib) border and the iliac crest at the end of expiration. Central obesity was defined as values ≥ 94 cm in males and ≥ 80 cm females[21].

Hip circumference and waist-hip ratio

Hip circumference was measured using an inelastic measuring tape (MEDLINE, 1-800-Medline, USA). With the subject assuming a relaxed standing position with the arms folded across the thorax, the circumference was taken at the level of the greatest posterior protuberance of the buttocks which usually corresponds anteriorly to about the level of the symphysis pubis[20]. Central Obesity was defined as waist-to-hip ratio > 0.9 in males and > 0.85 in females[22].

Blood pressure measurement

Blood pressure (BP) was measured using a portable mercury sphygmomanometer (Accoson, England) calibrated in millimeters of mercury (mmHg) with minimum recording of 0mm Hg and maximum of 320 mmHg. The accuracy of the instrument is 2 mmHg. Littman's stethoscope (Master Classic IITM, United States) was used to auscultate the Korotkoff sounds.

The subjects were allowed to relax, sitting in a chair (feet on floor, back supported) for >5 minutes. The subjects were advised to avoid caffeine, exercise and smoking for at least 30 min before measurement. Neither the subject nor the observer were allowed to talk during the measurement. All clothing covering the location of cuff placement were removed. Subject's arm was placed resting on a desk. The middle of the cuff was positioned on the patient's upper arm at the level of the right atrium (the midpoint of the sternum). Correct cuff size, such that the bladder encircles 80% of the arm, was used. Either the stethoscope diaphragm or bell were used for auscultatory readings. A palpated estimate of radial pulse obliteration pressure was used to estimate SBP. The cuff was inflated 20–30 mmHg above this level for an auscultatory determination of the BP level. For auscultatory readings, the cuff pressure was deflated at the rate of 2 mmHg per second and Korotkoff sounds listened for. Systolic BP and diastolic BP was recorded as onset of the first Korotkoff sound and disappearance of all Korotkoff sounds, respectively, using the nearest even number[2]. An average of two readings was taken as the subject's blood pressure. Prehypertension was defined as systolic BP of 120-139 mmHg and/or diastolic BP of 80-89 mmHg[1].

Statistical analysis and visualizations

The statistical analysis was carried out in R statistical environment[19]. Data manipulations were done using tidyverse R package[23] and visualizations using ggplot2[24] and tidybayes R packages[25]. Bayesian hierarchical logistic models were fitted using brms R package[26]. The odds ratio of prehypertension was used as the response variable of the models whereas obese and normal categories were used as predictor/confounding variables. The null hypothesis tested was:

H_0: *Compared to central obesity measures body mass index was not associated with higher risk of prehypertension.*

The corresponding alternative hypothesis tested was:

H_A: *Compared to central obesity measures body mass index was associated with higher risk of prehypertension.*

Two group of models fitted to test the hypothesis were as follows:

Group I Models: risk of prehypertension was modelled separately for obesity defined by each of the anthropometric measures (BMI, WC, WHR and WHtR) controlling for gender and age.

Group II Models: risk of prehypertension associated with BMI-defined obesity was additionally controlled for central obesity as defined by WC, WHR and WHtR.

Age as confounding variable was controlled at the level of the study design as all pre-hypertensive cases were age-matched with equal number of controls during the selection of subjects. These hierarchical models have 2 levels with the first (population) level estimating the overall odds of prehypertension and the second (group) level formed by the gender variable. Three (3) statistics reported by the hypothesis tests conducted were: Probability of null hypothesis with the level of significance set at 0.05; probabilities greater than 0.05 indicate a high probability of the null hypothesis precluding its rejection.

Evidence ratio in favor of alternative hypothesis. This measures the ratio of probability of the alternative hypothesis to that of null hypothesis. An evidence ratio of 1 means the alternative and null hypothesis have equal probabilities, a value greater than 1 means the alternative hypothesis has a bigger probability and a value of less than 1 means the null hypothesis is more probable than alternative hypothesis. 95% credibility interval (95% CrI). The set of values falling within this interval have 95% probability.

RESULTS

Characteristics of the study subjects

Four hundred (400) subjects were recruited into the study with 200 prehypertension cases and 200 age-matched controls. The prehypertension cases consisted of 125 males (mean age = 38$\pm$7.8 years) and 75 females (mean age = 35 $\pm$8.6 years). The prehypertension control consisted of 118 males (mean age = 39 $\pm$ 7.0 years) and 82 females (mean age = 32 $\pm$8.6 years).

Table 1: Characteristic of the study subjects

Parameter	Gender	Mean($\pm SD$)	
		Cases (200)	Controls (200)
Age	Females	34.9($\pm$8.6)	32.9($\pm$8.6)
	Males	38.1($\pm$7.8)	39.4($\pm$7.0)
BMI	Females	29.4($\pm$7.1)	27.6($\pm$7.9)
	Males	26.3($\pm$4.9)	24.6($\pm$4.8)
WC	Females	88..9($\pm$14.2)	84.4($\pm$13.1)
	Males	89.5($\pm$11.0)	84.9($\pm$12.5)
WHtR	Females	0.56($\pm$0.08)	0.53($\pm$0.10)
	Males	0.53($\pm$0.07)	0.50($\pm$0.08)
WHR	Females	0.86($\pm$0.07)	0.82($\pm$0.08)
	Males	0.91($\pm$0.06)	0.88($\pm$0.06)
SBP	Females	126.8($\pm$10.8)	107.2($\pm$10.4)
	Males	130.3($\pm$7.9)	107.7($\pm$9.3)
DBP	Females	88.2($\pm$4.6)	71.7($\pm$6.6)
	Males	85.8($\pm$6.4)	72.5($\pm$6.4)

SD = standard deviation, BMI = body mass index, WC = waist circumference,
WHR = waist-to-hip ratio, WHtR = waist-to-height ratio, SBP = systolic blood pressure, DBP = diastolic blood pressure

The risk of prehypertension associated with generalized and central obesity

The odds ratios of prehypertension associated with generalized obesity, WC-defined, WHR-defined obesity and WHtR-defined obesity were shown in Table 2 and Figure 3. The results were statistically significant in both sexes for the WHtR measure of central obesity with alternative hypothesis being 110 and 199 times more likely than null hypothesis in males and females respectively. For WC and WHR measure of central obesity, the odds ratios reached the level of statistical significance among females only. However, even among males the alternative hypothesis was respectively 19 and 7 times more likely than null hypothesis for WC and WHR measures of central obesity.

Table 2: Separate risk of prehypertension associated with generalized and central obesity measures of obesity

Parameter	Gender	Prehypertension Odds Ratio	P_{null}	E.R
Generalized Obesity vs Normal	Females	2.62 (0.91-7.16)	0.04*	27
	Males	2.53 (0.89-6.22)	0.04*	24
Central Obesity (WC) vs Normal	Females	2.71 (1.35-7.02)	<0.001*	210
	Males	2.31 (0.83-4.70)	0.05	19
Central Obesity (WHR) vs Normal	Females	2.23 (0.94-4.61)	0.03*	30
	Males	1.68 (0.71-2.98)	0.12	7
Central Obesity (WHtR) vs Normal	Females	2.51 (1.24-5.49)	0.01*	110
	Males	2.44 (1.29-4.11)	<0.001*	199

Values in brackets are 95% credible intervals. WC = waist circumference, WHR = waist-to-hip ratio, WHtR = waist-to-height ratio, E.R = evidence ratio in favor of alternative hypothesis, P_{null}= probability of null hypothesis. * indicates statistically significant odds ratios.

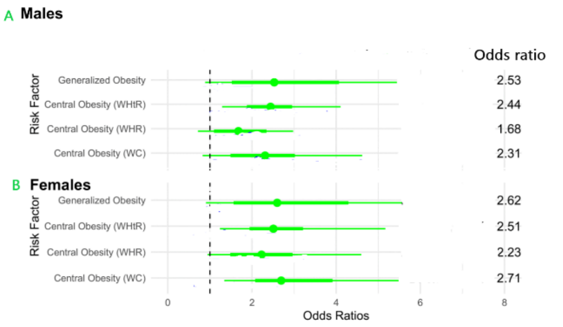

Figure 3: Risk of Prehypertension associated with Generalized and Central Obesity measures and Physical Inactivity in Males (A) and Females (B). OR associated with generalized obesity = 2.53 (95% CrI: 0.89-6.22) in females and 2.62 (95% CrI: 0.91-7.16) for males. The values for WC-defined central obesity are 2.71 (95% CrI: 1.35-7.02) for females and 2.31 (95% CrI: 0.83-4.70) for males.

Figure 4 shows the result running the models to test the difference between BMI and measures of central obesity in predicting prehypertension risk in both sexes. Both WC and WHtR outperformed BMI in predicting prehypertension in both sexes. However, in both males and females, BMI outperformed WHR (Figure 4). Figure 5 shows that the probabilities of the null hypothesis for all the comparisons were too high and thus the null hypothesis could not be rejected. However, the evidence was in favor of BMI having higher prehypertension risk compared to WHR (evidence ratio of 4). For the other two measures of central obesity (WC and WHtR) the evidence was against the hypothesis of higher BMI risk (evidence ratios < 1).

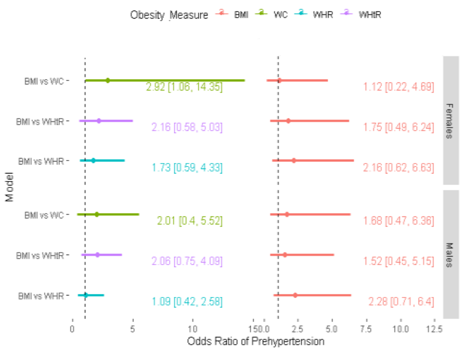

Figure 4: Models of BMI risk of prehypertension controlling for central obesity.

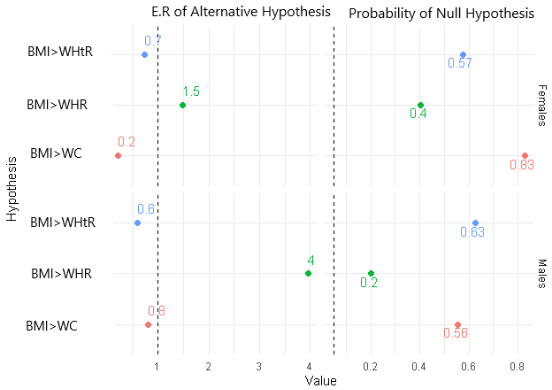

Figure 5: Probabilities of the null hypothesis and evidence ratios of alternative hypotheses for the models. E.R = evidence ratio

DISCUSSION

The positive relationship between central obesity measures and risk of prehypertension found in this study reflects the role of body fat in blood pressure control. Blood pressure is dependent on the metabolic needs of the body tissues and is affected by exercise, heavy lifting, feeding, sleep, etc[27]. Increased local metabolic needs leads to local vasodilation, which can cause a decrease in total peripheral resistance and fall in cardiac output if the tissue receives significant portion of the cardiac output. To prevent such fall in cardiac output, increased metabolic demand also stimulates a widespread sympathetic nervous system activation. Local tissue escapes this sympathetic activation to ensure adequate blood supply through a mechanism known as 'sympatholysis'. Consequently, this has the effect of diverting blood towards tissues that need it most i.e. those that are metabolically most active at the moment[28,29]. Fat tissue receives 3 ml of blood per 100 g of tissue in the fasting state which is twice the blood flow to inactive skeletal muscle[30, 31]. This means obesity significantly increases the absolute amount of cardiac output that goes to the fat tissue making this tissue an important player in systemic blood pressure control.

The adipose tissue works closely with muscle and gastrointestinal tract in controlling blood pressure; increased adipose tissue blood is associated with either increased splanchnic blood flow during feeding to deposit absorbed lipids[32] or increased skeletal muscle flow during exercise to release fatty acids for skeletal muscle oxidation[30]. Increased blood flow to fat, skeletal muscle and gastrointestinal tract triggers systemic sympathetic system activation. Blood pressure at any given point is a balance between the local vasodilatation and the triggered systemic vasoconstriction. Obesity is by definition, increased fat mass without the corresponding increase in lean body/skeletal muscle mass. Although the relatively low skeletal muscle mass means less metabolic demand on the adipose tissue, the increased fat mass and thus increased adipose tissue innervation in obesity means an increase, in absolute terms, of adipose tissue afferent reflex (AAR) stimulation of the sympathetic nervous system; the increased sympathetic stimulation would in turn leads to higher adipose tissue metabolic activity (lipolysis) and thus an even more AAR stimulation of sympathetic nervous system; without a corresponding increase in skeletal muscle mass and blood flow, this sympathetic overstimulation leads to abnormally high blood pressure[33,34].

The higher odds of prehypertension associated with generalized obesity found in this study is smaller than what was found in a Brazilian study of health workers[6]. The potential reason for the disparity is that the Brazilian subjects might possess higher body adiposity and thus higher metabolic risk for the same cut off value of body mass index. However, the odds ratio of prehypertension found among female subjects in this study was higher than what was found in a much larger cross-sectional population-based study of Chinese adults[9]. The opposite is true for males' odds ratio with Nigerians having lower values than their Chinese counterparts [9]. The reason might be due to the fact that Asians were found to have higher level of adiposity at any level of given weight compared to non-Asians and the latter might include Nigerian males[22].

The more than 150% higher odds of prehypertension associated central obesity found in this study for both sexes was similar to what was found in a cross-sectional study of adults in Northeast China[35]. The dose-response effect of generalized overweight on odds of prediabetes uncovered by this study was in agreement with what was found in a cross-sectional study of overweight and obese Hispanic adults[36].

The pattern of body mass index having higher odds of prehypertension than central obesity measures found in this study is inconsistent with previously reported greater cardiometabolic risk of central versus generalized obesity[37]. However, the present study is not alone in reporting body mass index as having greater risk. In a 10-year follow up of participants in Brazil, body mass index was associated with higher odds ratio of incident hypertension compared with waist-to-height ratio and waist circumference[11]. In another study from five South Asian countries (Afghanistan, Bangladesh, Bhutan, Nepal, and Sri Lanka) generalized obesity was consistently found to be associated with bigger odds ratio of hypertension than central obesity measures[38].

CONCLUSION

While body mass index was found to outperform waist to hip ratio in predicting prehypertension risk in an unadjusted model, this effect disappeared after controlling for the effects of both variables. Waist to height ratio and waist circumference outperformed body mass index in predicting prehypertension risk in both unadjusted and adjusted models.

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