Original

Neck circumference as a reliable predictor of obesity and metabolic Syndrome in rural south-west Nigeria: A cross-sectional study

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Abstract

Background: Neck size is a potential indicator for excess weight and metabolic disorders, offering a simple, non-intrusive, and cost-effective evaluation method in remote regions. This study assessed the predictive value of neck size in Nigerian adults, whatever the gender.

Methods: The anthropometries (weights, heights and the waist, hip and neck circumferences) the blood pressure, lipid panel, blood glucose, and HBA1c were determined and analyzed to predict obesity and metabolic syndrome. A multiple logistic regression analysis assessed the relationship between neck circumference and outcomes.

Results: The mean age of the 250 (67 males and 183 females) participants was 58.50 ± 18.73 years, the males were older (60.84 ± 20.09 years vs. 57.64 ± 14.63 years, p= 0.001. The neck circumference was positively associated with body mass index, waist hip ratio and the waist circumference. It was predictive of obesity, central obesity, and metabolic syndrome. The area under the curve (AUC) for non-diabetics and for diabetic males and females were 0.82 to 0.88, and 0.86 and 0.81 respectively. The cutoff values for obesity were 37.75 cm (males) and 32.75 cm (females). Regression analysis showed a positive association between neck circumference and obesity, with odds ratios of 1.774 (males) and 1.559 (females).

Conclusion: The neck circumference was positively associated with, and predictive of central obesity, and metabolic syndrome. It is a reliable, convenient and affordable measure for assessing obesity and metabolic syndrome in Nigeria. Incorporating neck circumference measurements into routine evaluations can provide insights into obesity, central obesity, and metabolic syndrome risk.

Keywords: Anthropometry, rural community, neck circumference, cardiovascular risk, south-west Nigeria

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Introduction

The obesity crisis and its effects on public health, particularly in Africa, are alarming to the global health community. Unhealthy eating habits, sedentary lifestyles, and the absence of comprehensive policies promoting healthy living are driving the surge in obesity rates, leading to increased risks of cardiovascular disease and type 2 diabetes.[1-3.] Limited data exists on the prevalence of obesity in Nigeria, but studies suggest it's a significant issue among adults with increasing health risks. Continuous monitoring is crucial to understanding the scale, prioritizing treatment, and targeting interventions effectively. Healthcare practitioners need ongoing evaluation to make informed decisions and allocate resources appropriately.[4-6]

Body mass index (BMI), weight height ratio (WHtR), weight hip ratio (WHpR), and waist circumference (WC) are reliable indicators of obesity and body fat.[7,8] WC is a straightforward physical measurement, while the other three require calculations. [8] Accurately measuring WHtR, WHpR, and WC can be challenging in cold weather when heavy clothing is worn. Invasive and expensive blood tests are used for diagnosing dyslipidemia and assessing cardiovascular risk.[9]The complexity and high cost of sophisticated methods like computed tomography (CT) and magnetic resonance imaging (MRI) limit their ability to assess body fat.[9]

Neck circumference (NC) is a simple and distinct upper body measurement that effectively distinguishes between obese and non-obese individuals.[10] Numerous studies have shown that NC is a reliable indicator of MetS, as it strongly correlates with traditional measures such as BMI, WC, and WHtR. Researchers from various regions, including the United States, South America, Asia, and the Middle East, have established NC cutoff points for diagnosing obesity and metabolic syndrome.[10-13] Several studies have also compared NC and WC in predicting cardiovascular risk factors and MetS.[13-16] NC is linked to a higher metabolic risk than subcutaneous and visceral abdominal fat.[17] It is strongly associated with factors like free fatty acids, insulin resistance, VLDL-C (very low density lipoproprotein cholesterol) production, oxidative stress, endothelial cell dysfunction, high blood pressure, and vascular injury.[18] Elevated levels of visceral fat in the neck and abdomen increase the chances of developing arteriosclerosis and dyslipidemia.[19] Despite the advantages of using NC as a convenient measure, especially in conservative communities, and for morbidly obese individuals who cannot accurately measure waist and hip circumferences, there is a paucity of research on the appropriate NC cutoff for identifying obesity and MS in Nigeria. Establishing specific NC cutoffs for Nigerians is crucial to effectively addressing obesity and MS, considering the influence of ethnicity on adiposity.

This study aims to assess the effectiveness of NC as a predictor of general and central obesity, as well as MetS, using a representative sample. This research aimed to compare the diagnostic accuracy of NC with other obesity indices and establish the threshold values of NC for identifying obesity and MetS in Nigeria.

Materials and Methods

Study design

The study was a community-based descriptive cross-sectional in design

Study population

The study involved 250 (67 males and 183 females) participants, aged 18 years and older who gave written consent.

Study Area

The study was conducted near the Baptist Medical Center in Ejigbo, a rural community in southwest Nigeria with a population of 132,515 in 2006. An interviewer used a pretested, semi-structured questionnaire (that had variables such as age, gender, marital status, educational attainment, and occupation) to gather data.

Exclusion criteria

Participants less than 18 years, those who declined consent, pregnant women and the unhealthy were excluded.

Study Variables

Diabetics: Reported diabetes, use of antidiabetic drug, previous medical diagnosis of diabetes, or positive diabetes test results according to WHO and ADA guidelines.[28-29]

Dyslipidaemia: Elevated levels of TC, LDL-C, or TG and, low levels of HDL-C, the use of lipid-lowering drugs according to the Third Adult Treatment Panel of the National Cholesterol Education Program and the World Health Organization (WHO) [30]

Metabolic syndrome: presence of at least three out of five factors: central obesity, high triglycerides, low HDL-C levels, high blood pressure, and high fasting glucose using the NCEP-ATPIII criteria.[30]

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Data collection

The height and weight were measured using a stadiometer and a weighing machine with participants bare-footed, without head cover and on light clotting. The BMI was calculated from the formula, kg/m² and values of 30 or higher indicates obesity.[24] The NC was measured using a non-stretch measuring tape below the Adam's apple; the measurement was taken perpendicular to the long axis of the neck.[21] Waist circumference (WC), HC,WHpR, and WHtR were measured as indicators of central obesity. For men, a waist circumference over 94 cm or a WHpR above 0.9 indicated central obesity. For women, the cutoff values were 80 cm for waist circumference and 0.85 for WHpR.(222,23)In both genders, a WHtR value of 0.5 as a significant marker of central obesity.[23]

The participants' seated blood pressure was measured twice using a mercury sphygmomanometer and the average of these measurements was calculated. Blood pressure readings were taken according to standardized protocols. Participants taking anti-hypertensive medications were classified as hypertensive, following the criteria outlined in "The Seventh Report of the Joint National Committee (JNC7).[20]

Laboratory analysis

Participants' venous blood were obtained through sterile techniques for the measurement of plasma glucose and lipid levels following an overnight period of fasting for 8 to 12 hours.

Fasting and two-hour postprandial plasma glucose levels were determined using the glucose oxidase method,[25] while triglycerides and total cholesterol were measured using enzymatic oxidase and peroxidase techniques.[26] The measurement of HDL cholesterol utilized the same methodology as the other cholesterol components after precipitation.[26] The calculation of low-density lipoprotein (LDL) cholesterol employed the Friedwald equation. Randox Laboratories Ltd. Kits were employed for all analytical procedures.[27]

Statistical analysis

Data analysis involved SPSS version 19. Categorical data was summarized using frequencies and percentages, and compared using the Chi-square test. Continuous data was summarized using means and standard deviations (SD) and compared using t-tests or Mann-Whitney U tests.

ROC analyses were performed separately for men and women to assess the predictive value of neck circumference (NC) for general obesity, central obesity, and metabolic syndrome (MetS). BMI, WHpR, and NCEP-ATPIII criteria were used as reference standards. Youden's index was utilized to determine gender-specific NC cutoff values, with the maximum index indicating the optimal cutoff point.[31.] Multiple logistic regression analyses were used to calculate ORs with 95% confidence intervals (CIs) with adjustments for age and WHtR. Statistical significance was defined as $p < 0.05$.

Results

The mean age for the 250 participants (67 males and 183 female) was 58.50 ± 18.73 years, the males were older (60.84 ± 20.09 years vs. 57.64 ± 14.63 years, p= 0.001 (Table 1). Men had higher NC and WHpR, while women had higher BMI, WC, and WHtR. There was a higher prevalence of obesity in women than men (42% versus 14%). Men had higher systolic blood pressure and LDL cholesterol, while the women had higher HDL, TG, TC values. A higher percentage of women were diabetic (24.4% versus 11.2%) but no significant gender differences were found in hypertension, obesity, or metabolic syndrome. (Table 2)

ROC analyses using WHO guidelines, showed that NC can identify general obesity based on BMI and central obesity based on WHpR. Our results indicated that NC demonstrated a strong ability to detect overall obesity with AUC values ranging from 0.82 to 0.88. However, it is noteworthy that WC and WHtR performed even better in this regard, exhibiting AUC values between 0.90 and 0.93.

Among individuals with diabetes, the effectiveness of the mentioned metrics was slightly reduced. Overall, the indices performed better in the male demographic. The WHpR exhibited the least desirable AUC values (Table 3}. In terms of discriminative ability, both WC and WHtR outperformed NC (Table 3). For MetS, the AUCs for NC were 0.74 in males and 0.72 in females. In contrast, WC and WHtR had higher AUC values than NC (Table 4). Notably, BMI demonstrated the lowest AUC among the other indices (Table 4).

Youden's index was utilized to determine the optimal threshold values for NC for accurately predicting obesity and metabolic syndrome. For males, the NC cutoff was set at 37.75 cm, while for females it was 32.75 cm. Sensitivities of over 80% were observed in both males and females, with specificities of 85.7% for males and 54.1% for females. In terms of positive predictive values (PPVs), NC effectively predicted obesity in men (91.7%) and moderately predicted it in women (76.7%). The negative predictive values (NPVs) were moderately effective in ruling out obesity in both males and females. (Table 5). A larger NC is associated with higher odds of

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obesity in both men (1.774) and women (1.559). It also increases the likelihood of metabolic syndrome in men (1.40) and women (1.50). However, the impact of NC on central obesity is modest and lacks statistical significance (Table 6).

Table 1: Sociodemographic characteristics of participants

Variables	Number N=250	Percentage (%)
Sex		
Male	67	26.8
Female	183	73.2
Ethnic Group		
Others	8	3.2
Yoruba	242	96.8
Marital status		
Single	18	7.2
Married	177	70.8
Separated/Divorced	10	10.0
Widowed	45	12.0
Smokers		
No	241	96.2
Yes	9	3.8

Table 2: Characteristics of the Study Sample according to Gender

Variable	Female	Male	P-value
Age	57.64 ± 14.63	60.84 ± 20.09	0.000
Neck Circumference	34.24 ± 2.82	38.23 ± 3.28	0.000
Hip Circumference	88.35 ± 12.29	89.16 ± 12.16	0.000
Waist Circumference	101.65 ± 12.04	95.58 ± 9.74	0.000
Waist/Height Ratio	0.57 ± 0.08	0.54 ± 0.08	1.000
Waist/Hip Ratio	0.87 ± 0.07	0.93 ± 0.06	1.000
BMI	27.57 ± 6.92	26.4 ± 4.84	1.000
SBP	133.24 ± 23.35	134.3 ± 21.2	0.000
DBP	80.26 ± 14.18	78.82 ± 13.46	0.000
LDL	3.08 ± 1.57	3.09 ± 1.54	0.484
TC	5.35 ± 1.84	4.97 ± 1.66	0.000
TG	1.11 ± 0.88	0.96 ± 0.58	0.000
HDL	1.66 ± 0.7	1.41 ± 0.53	0.000
Obesity	105 (42.0)	35 (14.0)	0.000
Diabetes	61 (24.4)	28 (11.2)	0.048
Hypertension	90 (36.0)	30 (12.0)	0.949
Metabolic Syndrome	46 (18.4)	12 (4.8)	0.000

Legend: SD Standard Deviation, BMI body mass index, TC total cholesterol, HDL high density lipoprotein cholesterol, LDL low density lipoprotein Cholesterol, TAG triglycerides

Table 3: Area under the Curve (AUC) by Anthropometric Indices for obesity according to gender, and diabetic status

Variable and categories	AUC (CI 95%) NC	AUC (CI 95%) WC	AUC (CI 95%) WHtR	AUC (CI 95%) WHpR
Obese				
Male	0.87 (0.76 – 0.99)	0.92 (0.85 – 0.99)	0.93 (0.87 – 1.00)	0.82 (0.72 – 0.93)
Female	0.79 (0.70 – 0.88)	0.90 (0.86 – 0.95)	0.92 (0.88 – 0.96)	0.67 (0.58 – 0.76)
Obese nondiabetics				
Male	0.88 (0.70 – 1.00)	0.95 (0.86 – 1.00)	0.96 (0.89 – 1.00)	0.80 (0.63 - 0.98)
Female	0.82 (0.71 - 0.92)	0.90 (0.77 - 0.96)	0.91 (0.83 - 0.99)	0.69 (0.55 - 0.84)
Obese diabetics				
Male	0.78 (0.90 – 1.00)	0.82 (0.70 -0.90)	0.90 (0.80 – 1.0)	0.73 (0.90 – 1.0)
Female	0.66 (0.41 - 0.90)	0.75 (0.70 -0.91)	0.85 (0.67 – 1.0)	0.65(0.56 - 0.99)
Central Obesity	NC	WC	WHtR	BMI
Males	0.82 (0.77 - 0.86)	0.79 (0.82 – 1.0)	0.84 (0.81 – 1.0)	0.71(0.70 – 0.89)
Females	0.75 (0.70 - 0.82)	0.77 (0.67 - 0.87)	0.78 (0.69 - 0.88)	0.62 (0.50 -0.90)
Non-diabetic with central obesity				
Males	0.78 (0.65 - 0.84)	0.85 (0.79 – 1.0)	0.80 (0.81 – 1.0)	0.68 (0.48– 0.80)
Females	0.72 (0.67 - 0.78)	0.80 (0.67 - 0.87)	0.74 (0.66- 0.91)	0.60 (0.45 -0.80)
Diabetics with central Obesity				
Males	0.70(0.56-0.75)	0.80 (0.72-0.85)	0.80 (0.75- 0. 90)	0.65(0.60—0.85)
Females	0.62 (0.33 - 0.86)	0.78 (0.75 – 1.0)	0.85 (0.71 – 1.0)	0.60 (0.6 – 0.7)

Legend: NC neck circumference, WC waist circumference, WHtR waist height ratio, WHpRwaist hip ratio, BMI body mass index CI Confidence Interval

Table 4: Area under the curve (AUC) by Anthropometric Indices for Metabolic Syndrome according to Gender

Gender	AUC (Cl 95%) NC	AUC (Cl 95%) WC	AUC (Cl 95%) WHtR	AUC (Cl 95%) WHpR	AUC (Cl 95%) BMI
Male	0.80 (0.56 – 0.92)	0.89 (0.79 – 0.98)	0.90 (0.80 – 0.99)	0.77 (0.63 – 0.91)	0.70 (0.65 – 0.85)
Female	0.76 (0.66 – 0.86)	0.81 (0.75 – 0.88)	0.81 (0.75 – 0.88)	0.67 (0.59 – 0.76)	0.65 (0.50 – 0.75)

Legend: NC neck circumference, WC waist circumference, WHtR waist-height ratio, WHpR waist hip ratio.

Table 5: Neck circumference Cut-off values to diagnose general obesity

Gender	Sensitivity	Specificity	PPV	NPV
Male	81.5	85.7	91.7	70.6
Female	86.2	54.1	76.7	69.0

Legend: NC cutoff to diagnose obesity for males = 37.75 & for females is 32.75, PPV positive predictive value, NPV negative predictive value

Table 6: Gender-specific Odds Ratio of Obesity and Metabolic Syndrome for Neck Circumference

Variables	Adjusted OR	95% CI
General Obesity		
Males	1.774	1.25 - 2.52
Females	1.559	1.25 - 1.94
Central Obesity		
Males	1.153	0.83 - 1.59
Females	1.144	0.99 - 1.33
Metabolic Syndrome		
Males	1.40	1.04 - 1.88
Females	1.50	1.23 - 1.83

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Discussion

This study assessed the predictive ability of NC for general and central obesity, as well as metabolic syndrome, in a diverse sample of men and women. Significant variations were found in age, NC, other obesity measures, blood pressure readings, obesity rates, and metabolic syndrome prevalence between genders. The study revealed that specific NC threshold values were associated with overall obesity, central obesity, and metabolic syndrome in both men and women. NC showed a strong ability to distinguish between individuals with and without overall obesity, with AUC values ranging from 0.82 to 0.88, particularly among those without diabetes. Furthermore, the estimated threshold values for NC exhibited excellent sensitivity and negative predictive value (NPV) across all participant groups. The sensitivity ranged from 81.5% to 86.2%, indicating a high proportion of true positive results in accurately identifying obesity. The positive predictive value (PPV) ranged from 76.7% to 91.7%, indicating moderate to high precision in identifying individuals with obesity.

The NPV ranged from 69.0% to 70.6%, indicating moderate accuracy of the NC in excluding obesity when the test result is negative. These findings agree or mirror findings that recommended the NC as a screening tool for obesity.[10-12] Precision may vary due to individual characteristics and genetic factors. However, NC's usefulness as a diagnostic tool for overall obesity is well established, with studies confirming its reliability as an indicator of body fatness. Additionally, a positive correlation has been observed between NC and WC, WHtR, and BMI.[32-34] NC was slightly less effective in predicting central obesity compared to overall obesity in our study and could be because it mainly reflects subcutaneous fat in the upper body and neck regions.(35) The diagnostic usefulness of NC, WC, and WHtR was reduced in our subjects with diabetes probably due to their impact on lipid metabolism dynamics.[13] However, further research with a large sample size and precise quantitative methods to measure body fat accurately is needed to validate the use of NC in diabetics. Multiple studies have shown consistent results, indicating the effectiveness of NC in predicting central obesity based on ROC analyses with comparable AUC values.[10,11, 13,14]

Despite being less commonly used than WC and WHtR, NC possesses certain characteristics that contribute to its effectiveness as a measurement tool. One significant advantage is its cultural acceptance in the specific region. Additionally, unlike WC and WHtR, NC consistently proves to be a reliable predictor of both central and overall obesity, regardless of gender.[13,19] Another benefit is that NC remains unaffected by physical or physiological factors such as satiety level, respiratory movements, or ease and cultural acceptability, which can impact the accuracy of WC measurements. Moreover, NC exhibits excellent inter-rater and intra-rater reliability, eliminating the need for multiple measurements [36,37]

The link between visceral obesity and MetS suggests that WC, WHtR, and WHpR are more effective predictors of MetS compared to other measurements. However, this study suggests that NC has a similar predictive ability for MetS as WC and WHtR and closely resembles WHpR. Additionally, a larger population-sized study conducted in Brazil revealed a positive correlation between NC and established risk factors for MetS. Furthermore, a recent investigation focusing on individuals with obesity found NC as effective or even a superior indicator of metabolic health compared to WC.[38]

Cutoff values for NC that distinguish between obese and non-obese individuals vary among studies, emphasizing the need for ethnicity-specific thresholds. [14,31, 39-40]. To ensure the generalizability of our findings, it is important to calculate these cutoffs using a large multi-ethnic population size. However, a study reported higher cutoff values for both males and females, potentially influenced by differences in sample size, participant characteristics, and methodology. [19]

Multiple regression analysis showed no that gender impact, as the ORs were similar for both genders. The strongest correlation observed was between overall obesity and Metabolic Syndrome.NC, like the WC was an independent predictor of MetS. Multiple studies have linked NC to various health markers, including free fatty acids, insulin resistance, cholesterol levels, oxidative stress, hypertension, and vascular endothelial damage.[14,18,19] Conversely, previous studies have revealed an inverse association between NC and levels of HDL cholesterol.[41-43]

Limitations

The study has both limitations and strengths. Imaging techniques that would have strengthen the precision of obesity diagnosis. The participants were not categorized into age groups as previous studies have done. The study cross-sectional design precluded the determination of causation. The sample size was relatively small. Participants were not screened for infection with the human immunodeficiency virus, which can cause

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lipodystrophy and fat deposits in the upper torso and neck. We couldn't determine the thyroid function status of the participant to rule out its subtle effects on the neck circumference. However, comparing the different obesity indicators and establishing a local neck circumference threshold strengthened the study.

Conclusion

Neck circumference (NC) is a reliable predictor of obesity and Metabolic Syndrome. The specific thresholds of 37.75 cm for men and 32.75 cm for women are considered reliable thresholds for evaluating these conditions. Incorporating NC measurements into routine examination is a simple and non-invasive way to identify individuals at likelihood of developing obesity and MetS. This allows for timely intervention and targeted prevention strategies to improve overall health and could guide healthcare professionals to identify at-risk individuals and implement timely interventions to reduce complications and improve healthcare outcomes.
Declarations: The Bowen University Teaching Hospital, Ogbomoso Research and Ethics Committee (NHREC/12/04/2012) approved the research protocol.

Authors' Contribution: Oluwabukola Ayodele Ala (Conceived and designed the study, approved the design and implementation, coordinated and supervised data collection, drafted the initial Article and critically reviewed and revised the draft. She is the corresponding author), Patience Olayinka Akinwusi (Approved the design and implementation of the study and critically reviewed and revised the draft), Opeyemi Oni (Approved the design and implementation of the study, coordinated, supervised data collection and critically reviewed and revised the draft), Abiola Oluwadamilola Odeyemi (Approved the design and implementation of the study, coordinated, supervised data collection and critically reviewed and revised the draft), Gbenga Michael Israel (Approved the design and implementation of the study, coordinated, supervised data collection and critically reviewed and revised the draft), Oluwaseyi Kikelomo Israel (Coordinated, supervised data collection and critically reviewed and revised the draft).
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