Original Report: Cardiovascular Disease and Risk Factors

Neck Circumference Cut-Off for Obesity and Metabolic Syndrome in Nigeria

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Objective: Neck circumference (NC) is a novel tool for diagnosing cardiometabolic disorders. We aimed to determine the NC cut-off for obesity and metabolic syndrome (MS) prediction in Nigeria.

Methods: The current study was based on data analysis of 557 staff and students of Ekiti State University/Ekiti State University Teaching Hospital, Ado-Ekiti, Nigeria, who took part in a cross-sectional health screening (August-December 2018). Body mass index (BMI), waist circumference (WC), WHpR (waist-to-hip ratio), WHtR (waist-to-height ratio), systolic and diastolic blood pressure (SBP, DBP) values were determined by standard protocol. Fasting glucose and lipid profile were assayed for, and MS was defined by the harmonized criteria. The predictive ability of NC to identify people with obesity and MS was determined with receiver operating characteristic (ROC) curves.

Results: In both men and women, NC had positive correlation (P<.001) with age, weight, BMI, WC, WHpR, WHtR, SBP and DBP. In men and women, the AUC of NC for all the anthropometric indices were significant (P<.0001). In men, the NC cut-off was 37cm for WHpR, 37.5cm for both BMI and WHtR, 38.3cm for WC, and 40.0cm for MS. In women, the NC cut-off for all the anthropometric indices (except WHpR) and MS was 33cm. In men, NC was as good as other obesity indices in predicting MS (P>.05 for differences in the AUC), but was inferior to BMI, WC and WHtR in women.

Conclusion: NC correlates with indices of adiposity and can serve as an alternate index for obesity and MS detection in Nigerians *Ethn Dis.* 2021; 31(4):501-508; doi:10.18865/ed.31.4.501

Introduction

Neck circumference is an inexpensive and noninvasive novel tool for diagnosing obesity and a marker for cardiometabolic disorders. It is a simple method for assessing upper body adiposity, and it correlates with other surrogates of body fat such as body mass index, waist circumference, waist-to-hip ratio and waist-to-height ratio.[1-4] NC is also associated with other CVD risk factors such as blood glucose and blood pressure, triglyceride, HDL-cholesterol, glycated hemoglobin, and insulin resistance.[1,2,5,6] The usefulness of NC has been demonstrated in systematic reviews and meta-analysis.[6,7]

Additionally, researchers in different parts of the world such as the United States,[2] South America,[8,9] Asia,[3,10] and Middle East,[1,11] have determined NC cut-off for diagnosing obesity or metabolic syndrome. Other researchers have compared the predictive ability of NC and WC for cardiovascular risk factors/metabolic syndrome.[9,10]

In Nigeria, researchers have shown that NC predicted, or is associated with, cardiometabolic risk factors.[12-15] Iwuala and colleagues[13] reported NC cut-off for central obesity, but the sample size was small. However, the NC cut-off for identification of MS is yet to be reported in Nigeria. Since ethnicity contributes to, and/or determines adiposity, there is need to know the NC cut-off for obesity and MS in Nigeria. This report aims to determine the NC cut-off for obesity and MS prediction in Nigeria, and compares the diagnostic performance of NC and other obesity indices to detect MS.

Keywords: Neck Circumference; Obesity; Metabolic Syndrome; Nigeria

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Methodology

For the current study, we analyzed data obtained from a cross-sectional health screening involving students and staff of Ekiti State University and Ekiti State University Teaching Hospital, Ado-Ekiti, Nigeria. The screenings were conducted between August and December 2018; we used results from 557 people in the analysis.

Participants, aged ≥18 years were recruited using convenient sampling method. Written informed consent was obtained from the participants. Using a self-administered questionnaire, participants reported demographic data of age, sex, marital status, educational attainment, and occupation. Pregnant women were excluded from the study, due to influence on anthropometric measurements. The Research and Ethics Committee of Ekiti State University Teaching Hospital, Ado-Ekiti approved the study protocol (EKSUTH/A67/2018/08/004).

Since ethnicity contributes to, and/or determines adiposity, there is need to know the NC cut-off for obesity and MS in Nigeria.

Anthropometric and Blood Pressure Measurements

Weight (in kilogram) and standing height (in meters) of participants were determined with bathroom scales and stadiometer, respectively. Waist (at the level of umbilicus) and hip (widest diameter) circumferences (in centimeters) were determined with non-stretchable tape. Body mass index (BMI) was calculated as weight divided by the square of the height; waist-to-hip ratio (WHpR) was calculated as waist circumference/hip circumference; and waist-to-height ratio (WHtR) was calculated as waist circumference/height in centimeters.

Neck circumference was measured between the mid-cervical point posteriorly and mid-anterior neck (below the laryngeal prominence). Measurements were taken while the participant was standing upright and looking straight ahead.

With a participant seated, blood pressure was assessed twice with an electronic/mercury sphygmomanometer; the average of both readings was used. The first and fifth Korotkoff sounds were taken as the systolic and diastolic blood pressures, respectively.

Laboratory Analysis

After an overnight fast, a participant's venous sample was obtained through aseptic techniques for plasma glucose and lipids measurements. Plasma glucose was determined by glucose oxidase method. Total cholesterol and triglyceride were determined by enzymatic oxidase/peroxidase methods. High density lipoprotein (HDL) cholesterol was estimated by the same method after precipitation of other cholesterol fractions. Low density lipoprotein (LDL) cholesterol was calculated by Friedwald equation. All analyses were done with kits by Randox (Randox Laboratories Ltd., UK)

General obesity was regarded as BMI ≥ 30kg/m^2 in both men and women.[16] Central obesity was defined as: 1) WC ≥ 94cm and ≥ 80cm in men and women, respectively[17]; 2) WHpR ≥.9 and ≥ .85 in men and women, respectively[16]; and 3) WHtR >.5 in both men and women.[18] Metabolic syndrome was defined according to the harmonized criteria.[19]

Data Analysis

Continuous variables were presented as means (SD) while categorical variables were presented as (n) percentages. In trend analysis, ANOVA was used to compare means of relevant variables in the quartiles of NC.

Kolmogorov-Smirnov test of normality was used to determine the distribution of continuous variables. Because the continuous variables were not normally distributed, Spearman's correlation between NC and cardiovascular risk factors was determined. The predictive ability of NC to identify people with general obesity, central obesity and metabolic syndrome was determined with the receiver operating characteristic (ROC) curves. The area under the receiver operating characteristics curve (AUC) and the corresponding 95% CI were used to summarize the discriminatory power of NC. Youden J statistic (Youden index analysis) was used to determine the optimal NC cut-off (threshold) for obesity and metabolic syndrome. We also compared the diagnostic ability of NC with measures of central obesity for MS. Analyses were done separate-

Table 1. Characteristics of the participants according to quartiles of neck circumference (NC)

NC Quartiles	ALL	Q1	Q2	Q3	Q4	F	P
Men							
N	205	11	32	56	106		
Age, years	38.6 (11.1)	36.7(10.9)	37.9 (12.2)	33.5 (9.7)	41.6 (10.5)	7.3	<.001
Weight, kg	72.3(13.0)	57.9(8.6)	61.9(8.8)	67.6(7.2)	79.4(12.5)	37.2	<.001
Height, m	1.70(.08)	1.63(.09)	1.66(.10)	1.70(.06)	1.72(.07)	8.0	<.001
BMI, kg/m^2	25.0(3.9)	21.8 (1.6)	22.5 (3.5)	23.3 (2.8)	26.9(3.7)	25.3	<.001
WC, cm	85.5(12.8)	75.0(6.3)	78.8(9.9)	77.8(10.0)	92.6(11.2)	34.2	<.001
HC, cm	97.1(11.7)	90.5(4.6)	92.9(7.9)	92.8(9.5)	101.2(12.6)	10.9	<.001
WHpR	.88(.08)	.83 (.05)	.85 (.07)	.84 (.07)	.92 (.07)	19.5	<.001
WHtR	.50(.08)	.46(.04)	.48(.07)	.46 (.06)	.54 (.07)	22.9	<.001
SBP, mm Hg	119.8(16.0)	109.5(17.5)	111.9(14.6)	115.1(14.3)	125.6(14.9)	12.4	<.001
DBP, mm Hg	76.2(11.8)	68.5 (11.7)	72.9 (11.2)	72.8 (10.4)	79.9 (11.6)	8.1	<.001
Women							
N	352	112	116	89	35		
Age, years	39.0 (11.3)	34.7 (12.5)	39.4 (10.4)	42.5(9.3)	42.8(10.8)	10.3	<.001
Weight, kg	70.2(15.2)	70.2(15.2)	68.0(10.6)	80.2(11.4)	89.5(15.3)	102.9	<.001
Height, cm	1.6(.07)	1.6(.07)	1.6(.06)	1.6(.07)	1.7(.06)	13.2	<.001
BMI, kg/m^2	27.2(5.8)	23.3(4.5)	26.6(4.3)	30.9(4.7)	32.4(6.2)	59.6	<.001
WC, cm	88.1(13.3)	78.6(10.8)	86.7(10.9)	96.0 (9.7)	103.3(11.6)	73.9	<.001
HC, cm	102.8(13.9)	93.6(12.7)	102.9(9.7)	110.4(9.6)	112.0(12.9)	48.1	<.001
WHpR	.86(.14)	.86 (.24)	.84 (.07)	.87 (.06)	.92(.05)	2.8	.039
WHtR	.55(.08)	.50 (.06)	.54 (.07)	.60 (.07)	.62(.08)	45.8	<.001
SBP, mm Hg	118.9(18.8)	114.2(18.3)	116.6(17.5)	124.7(17.5)	127.3(16.7)	8.6	<.001
DBP, mm Hg	75.8(12.8)	71.8(11.7)	75.7(13.3)	78.66(12.5)	81.8 (11.5)	8.1	<.001

Data are expressed as mean (SD).
BMI, body mass index; WC, waist circumference; HC, hip circumference; WHpR, waist-to-hip ratio; WHtR, waist-to-height ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure.

ly for men and women. A two-sided probability P value of <.05 was taken as significant. Data were analyzed with SPSS, version 25 for Windows (IBM Corp., Armonk, NY, USA), and MedCalc Statistical Software version 19.1.5 (Ostend, Belgium; https://www.medcalc.org; 2020).

Results

We analyzed data from 205 men and 352 women with mean age of 38.6 (±11.1) years and 39.0 (±11.3) years, respectively. In men and women, all the anthropometric and blood pressure indices were significantly associated with quartiles of NC (P=.039 for WHpR in women, and <.001 for all the other parameters in men and women). Thus, compared with those in the first quartile, participants in the last quartile of NC had higher mean of BMI, WC, WHpR, WHtR, SBP and DBP (Table 1).

In both men and women, NC had significant correlation (P<.001) with age, weight, BMI, WC, HC, WHpR, WHtR, SBP and DBP. In women, NC had positive correlation with fasting plasma glucose (r=.217, P<.001), whereas there was no significant correlation in men. Among the anthropometric indices, WC and WHpR showed the highest and lowest correlation coefficient respectively, in both men (.665 vs .524) and women (.643 vs .351). There was no significant correlation between NC and lipid indices or parameters. (Data table available from corresponding author).

All the obesity indices studied and NC were able to identify people with MS, as revealed by the significant AUC. In men, the AUC was largest for WC (.830, 95%CI, .766 - .883, P<.0001), and least for WHpR (.697, 95%CI, .623 - .765, P=.0042). In women, the AUC was largest for WHtR (.768, P<.0001), and least

Table 2: AUC of neck circumference (NC) and other obesity indices for MS[a]

	Men, n=205				Women, n=352			
	AUC	95%CI	Z	P	AUC	95%CI	Z	P
NC	.733	.661 - .797	3.362	.0008	.688	.632 - .740	5.4	<.0001
BMI	.810	.743 - .865	6.346	<.0001	.755	.702 - .802	7.846	<.0001
WC	.830	.766 - .883	6.201	<.0001	.765	.713 - .812	9.155	<.0001
WHpR	.697	.623 - .765	2.859	.0042	.625	.567 - .680	3.514	.0004
WHtR	.810	.743 - .866	6.558	<.0001	.768	.716 - .815	9.516	<.0001

a. Metabolic syndrome was determined for participants with full laboratory results.
BMI, body mass index; WC, waist circumference; WHpR, waist-to-hip ratio; WHtR, waist-to-height ratio; AUC, area under curve; 95%CI, 95% confidence interval.

for WHpR (.625, 95%CI, .567 - .680, P=.0004) as shown in Table 2.

Table 3 shows pairwise comparison of AUC of NC and other obesity indices. In men, NC was as good as other obesity indices in predicting MS (P>.05 for differences in the AUC). For MS prediction in women, NC was inferior to: BMI (difference in AUC, .0665, P=.0468); WC (difference in AUC, .0771, P=.0136); and WHtR (difference in AUC, .0800, P= .0230). In both sexes, NC and WHpR were equal in predictive ability for MS (P>.05 for differences in the AUC).

In both sexes, NC significantly correlated with blood pressure, as well as general and central obesity indices.

Table 4 provides the AUC and NC cut-off for the obesity indices and MS. In men and women, the AUC of NC for all the anthropometric indices were significant (P<.0001). In men, it was greatest for BMI (.824), followed by WC (.818), WHtR (.781), and WHpR (.762). In men, the NC cut-off was 37cm for WHpR, 37.5cm for BMI, and 37.5cm WHtR, and 38.3cm for WC. The lowest cut-off gives the (highest) sensitivity of 82.3% and specificity of (67.5%). NC cut-off of 38.3cm gives the highest Youden index, with modest sensitivity (76.5%) and specificity (77.9%). NC cut-off for MS in men was 40cm. This cut-off has sensitivity and specificity of 50.0% and 91.5%, respectively. In women, the NC cut-off for all the anthropometric indices (except WHpR) and MS was 33cm. Compared with men, NC is less sensitive for obesity identification in women. WC gave the highest Youden index of .509, with sensitivity and specificity of 65.3% and 85.6%, respectively.

Discussion

We evaluated the relationship between NC and cardiovascular risk factors and determined the NC cut-off for obesity and MS identification. We found that compared with those in the first quartile, men and women in the last quartile of NC had higher mean of BMI, WC, WHpR, WHtR, SBP and DBP. Additionally, in both sexes, NC significantly correlated with blood pressure, as well as general and central obesity indices. But no correlation was found between NC and lipid parameters. Furthermore, we found that NC was as good as other obesity indices in predicting MS. However, in women, BMI, WC and WHtR were superior to NC for MS prediction.

Our findings are consistent with previous reports. Researchers from different ethnic groups have reported significant correlation between NC with anthropometric and blood pressure indices.[1,2,20-24] NC is a measure of upper body subcutaneous fat. WC measures both subcutaneous and visceral fat in the abdomen, while BMI measures total body fat (lower and upper body). Therefore, it is expected that NC correlates with measures of central and total adiposity. Similarly, since blood pressure correlates with general and central obesity,[25] it should correlate with NC.

NC Cut-off for Central Obesity

Most guidelines recommended WC measurement for detection of central obesity (IDF, ATP111, Harmonized). Therefore, we chose NC cut-off for WC to detect central obesity. Moreover, among the three indices of central obesity, the AUC and Youden index for WC were largest.

We found that the optimal NC cut-offs or decision threshold for central obesity in men and women were 38.3cm and 33cm, respectively. The NC cut-off for central obesity in men from our study was consistent with previous reports from the United States (38cm),[2] Bosnia and Herzegovina (37.45cm),[26] China (38.5cm),[24] Saudi Arabia (39.25cm),[1] and Thailand (38cm).[3]

Similar to our findings, many researchers reported NC cut-off of between 32.6-34.5cm for prediction of central obesity in women.[2,3,24,27,28] Thus, comparable threshold was reported among Chinese,[24,27] Bosnians,[26] Thais,[3] and Americans.[2] On the other hand, higher cut-off of 34.75cm was reported among Saudis,[1] while lower cut-off of 31.25cm was reported among Bangladeshi.[29] The study by Qureshi et al[29] also reported NC cut-off value of 31.25cm for prediction of central obesity determined by WHR, whereas we found a higher threshold of 33.0cm. Furthermore, Qureshi et al reported a lower NC cut-off of 35.25cm for prediction of central obesity in men.[29] When compared with our participant characteristics, lower cut-off values determined by Quereshi et al may be due to characteristics of their participants: younger age (30.7 vs 38.8 years); lower BMI (22.7 vs 26.1 kgm^2); and WC (86.8 vs 88.1 cm). Of note, the same NC cut-off was determined for both WC and WHR in their study, similar to what we found.

Table 3: Pairwise comparison of AUC of neck circumference (NC) and other obesity indices

	Area difference	95% CI	Z	P
NC vs BMI				
Men	.0766	-.0306 to .184	1.400	.1615
Women	.0665	.0009 to .132	1.988	.0468
NC vs WC				
Men	.0971	-.00481 to .199	1.867	.0618
Women	.0771	.0158 to .138	2.467	.0136
NC vs WHpR				
Men	.0356	-.137 to .208	.405	.6852
Women	.0633	-.0242 to .151	1.418	.1563
NC vs WHtR				
Men	.0770	-.0388 to .193	1.304	.1924
Women	.0800	.0110 to .149	2.274	.0230

BMI, body mass index; WC, waist circumference; WHpR, waist-to-hip ratio; WHtR, waist-to-height ratio

NC Cut-off for General Obesity

The NC cut-off for general obesity in men and women was 37.5cm and 33.0cm, respectively. Compa-

Table 4. Optimal neck circumference (NC) cut-points for detecting obesity and metabolic syndrome

	AUC	95%CI	Z	P	NC cut-off	Sensitivity	Specificity	Youden index
Men								
BMI	.824	.766-.882	11.0	<.0001	>37.5	79.55	73.50	.5305
WC	.818	.746-.890	8.7	<.0001	>38.3	76.47	77.92	.5439
WHpR	.762	.692-.832	7.4	<.0001	>37	82.28	67.46	.4974
WHtR	.781	.716-.845	8.5	<.0001	>37.5	73.20	72.22	.4542
MS	.733	.597-.869	3.34	.0008	>40	50.00	91.50	.4150
Women								
BMI	.793	.744-.841	11.8	<.0001	>33	69.81	79.29	.4910
WC	.814	.767-.860	13.2	<.0001	>33	65.32	85.58	.5090
WHpR	.673	.61 -.728	6.2	<.0001	>34	48.13	79.14	.2727
WHtR	.787	.736-.839	10.9	<.0001	>33	65.31	84.11	.4942
MS	.688	.619-.757	5.4	<.0001	>33	70.77	55.98	.2675

BMI, body mass index; WC, waist circumference; HC, hip circumference; WHpR, waist-to-hip ratio; WHtR, waist-to-height ratio; MS, metabolic syndrome.

rable values were reported by researchers from India,[29,30] Indonesia,[22] and Saudi Arabia.[31] However, the study by Qureshi et al[29] found a lower NC cut-off value for men.

NC Cut-off for Metabolic Syndrome

The NC of 40cm in men, and 33cm in women were the best thresholds for MS. A Pakistani study found a similar cut-off in women but a lower cut-off in men. A South African study by Hoebel et al[32] found NC threshold of 35cm and 39cm in older and younger African men, respectively. These researchers also reported NC cut-off of 35cm and 32cm in older and younger African women, respectively. The cut-off for men in our study had a sensitivity of 50% and specificity of 91.5%. The implication is that nearly half of men with MS may be missed with this threshold.

There were variations in the NC thresholds for identifying obesity and metabolic syndrome in different parts of the world. Different body composition, ethnic background and environment may explain the variations in the NC cut-off in recent studies. For example, in the study by Hoebel et al,[32] NC thresholds were reported for Caucasians, even though they shared a common environment with the Africans.

NC vs Other Obesity Indices for MS Detection

In men, we found that NC was as good as other obesity indices in predicting MS. However, in women BMI, WC and WHtR were superior to NC for MS prediction. In both sexes, NC and WHpR were equal in predictive ability for MS. Our findings bear some similarities to previous reports.

Many researchers have compared the usefulness of NC and other obesity indices for CVD risk factors/ MS identification or detection.[9,21,27] Joshipura et al[21] found that among Americans, NC was similarly effective or superior to WC for prediction of cardiometabolic factors such as triglycerides, HDL-cholesterol and hypertension and prediabetes. Notably, they also demonstrated that the odds of NC for HOMA-IR (8.42), a measure of insulin resistance, the pathophysiologic disorder in metabolic syndrome, was greater than the odds of WC for HOMA-IR (7.99). Luo et al[27] also found that among the Chinese, NC was not inferior to WC in detecting MS and its components. Importantly, these researchers employed imaging techniques in the study. Caro and colleagues[9] determined and compared the predictive ability of NC vs WC for cardiometabolic disorders among the Chileans with ROC. Similar to our findings, they found sex disparities in the ability of NC to detect CVD risk factors. We found that WC performed better than NC in women, but not in men. However, they reported similar performance of WC and NC in women, but found that WC was superior to NC in men. When Caro et al used adjusted logistic regression models, they found that AUC for NC and WC (.814 and .822, respectively) were not different statistically. Methodological differences may explain these disparities. These researchers defined cardiovascular risk with Framingham tables, whereas we used criteria for metabolic syndrome. Framingham tables include age, smoking and total cholesterol, in addition to metabolic syndrome criteria.

Sex differences in predictive ability of NC were also obseved in our study. Compared with men, NC is less sensitive but more stable for obesity identification in women. Sex hormones influence fat distribution. In men, low testosterone and sex hormone binding globulins levels favor insulin resistance through fat mobilization to subcutaneous adipose tissue compartments of both truncal and peripheral areas.[33] On the other hand, estrogen favors fat deposition in the gluteofemoral region and subcutaneous adipose tissue.

Study Limitations

Our study has some limitations and strengths. Firstly, imaging studies were not performed for better diagnosis of obesity. Secondly, we did not stratify into different age groups as was done in some previous studies that reported different NC cut-offs for different age groups. Finally, the cross-sectional design precluded inference on causality. Nevertheless, for the first time, we were able to determine local cut-offs for NC in our environment and, we were also able to compare common obesity indices including WHtR.

Conclusion

We found that NC can be used as surrogate for both total and central obesity in both sexes, especially in men. Using NC cut-off of 38.3cm for men, and 33.0cm for women, the prevalence of obesity was 36.1% and

68.2%, respectively. Neck circumference is easy to determine, culturally attractive, and unlike waist circumference, is not influenced by fullness or hunger, and respiration. Since the neck is exposed most of the time in most people, its measurement does not cause embarrassment that may attend determinations of waist and hip circumferences. Moreover, pregnancy does not influence NC measurement. Thus, NC correlates with indices of adiposity and can serve as an alternate index for obesity and metabolic syndrome detection in our population.

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Conflict of Interest

No conflicts of interest to report.

Author Contributions

Research concept and design: Raimi, Dele-Ojo, Dada, Ajayi; Acquisition of data: Dele-Ojo, Ajayi; Data analysis and interpretation: Raimi; Manuscript draft: Raimi, Dada; Statistical expertise: Raimi; Acquisition of funding: Raimi, Dele-Ojo, Dada, Ajayi; Administrative: Dele-Ojo, Dada, Ajayi; Supervision: Dele-Ojo

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