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Original Article

Is Neck Circumference Independently Associated with Metabolic Syndrome?

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Abstract

Background Abdominal obesity, atherogenic dyslipidemia, increased blood pressure (BP), and increased plasma glucose are all elements of metabolic syndrome (MS). Patients with above diseases have higher risks of developing insulin resistance, visceral obesity, atherogenic dyslipidemia, and thus coronary artery disease and stroke. So, the purpose of this study was to explore potential neck circumference (NC) cutoff lines for the diagnosis of MS.

Methods Between November 2020 and November 2022, a total of 150 patients with MS along with age and sex-matched controls (150) were enrolled in this cross-sectional study. Anthropometric indices like waist–hip ratio (WHR), body mass index (BMI), NC, as well as biochemicals like lipid profiles, fasting blood sugar (FBS), and BP were assessed.

Results MS was found to be substantially correlated with NC. The NC threshold for diagnosing MS was 34 cm, with 77% sensitivity and 73% specificity. NC was found to be significantly correlated with BMI, systolic and diastolic BP, total cholesterol, triglycerides, high-density lipoprotein, FBS, and WHR, with *p*-values of all variables less than 0.001.

Conclusion MS can be evaluated using NC. To identify people at risk of developing MS, a cutoff value might be employed.

Keywords
- metabolic syndrome
- neck circumference
- anthropometric measurements

Introduction

A complex network of related illnesses known as metabolic syndrome (MS) increases the risk of cardiovascular disease (CVD) and type 2 diabetes.[1] Hyperglycemia, abdominal obesity, hypertension, and dyslipidemia are the key contributing factors. MS was initially defined by the World Health Organization (WHO) in 1998. Insulin Resistance Syndrome and Syndrome X were other names for MS.[2] Sleep apnea, nonalcoholic fatty liver disease, chronic proinflammatory and prothrombotic states, and other abnormalities or contributory variables have all been added to the complicated pathophysiology of MS.[1]

The American College of Cardiology and American Health Association's National Cholesterol Education Program-modified Adult Treatment Plan III (NCEP-ATP III) criteria, however, are the most typical and frequently applied diagnostic standards.[3] To diagnose MS, three out of the five categories must be present. The criteria are waist circumference (WC) of more than 90 cm for Asian men and 80 cm for Asian women; triglyceride (fasting) level of 150 mg/dL or higher; high-density lipoprotein cholesterol (HDL-C) level less than 40

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mg/dL in males and less than 50 mg/dL in females; systolic blood pressure (SBP) of 130 mmHg or higher or diastolic blood pressure (DBP) of 85 mmHg or higher or both; and a fasting plasma glucose level of 100 mg/dL or higher.

Many assessments have been investigated to improve the effectiveness and sensitivity of anthropometric markers in routine measurements to detect visceral fat. Due to its usefulness and simplicity of measurement, neck circumference (NC) has attracted attention recently. The NC appears to correlate well with an elevated risk of CVD and has been shown to be able to detect extra upper-body adipose tissue.[4] Contrary to WC, it is a simple and affordable procedure that does not cause diurnal change.[5,6] Also, it can get around cultural restrictions on removing clothing from the upper torso for more precise measurement.

In this study, the NC of patients with MS will be measured to look for any relationships with study participants' risk factors or other components.

Materials and Methods

This cross-sectional study was performed in a rural, tertiary care teaching hospital after receiving approval from the institution's ethics committee in a letter with the designation–Datta Meghe Institute of Medical Sciences(DMIMS)/IEC/2022/344 for a period of 2 years. Patients who met the NCEP-ATP III criteria for the MS (WC > 102 cm in males and > 88 cm in females, serum triglycerides > 150 mg/dL, serum high-density lipoprotein (HDL) less than 40 mg/dL in males and less than 50 mg/dL in females, blood pressure (BP) > 130/85 mmHg, and fasting blood sugar [FBS] >100) were included in the trial.

The sample size was calculated on the basis of the following formula used: "Sample size $(n) = [DEFF * Np(1-p)]/[(d2/Z21-\alpha/2^{*}(N-1)+p * (1-p)]$." Taking prevalence as 24.9% as per the study by Gupta et al, total sample was 148, which were rounded off to 150 with a 99% confidence interval (CI).[7] Thus 150 subjects were taken in each group (case and control), and a total of 300 individuals were studied.

Total 150 patients with MS who were either newly diagnosed or previously diagnosed; receiving antidiabetic oral hypoglycemic drugs, insulin, or antihypertensive medication; attending the medical outpatient department; or who were admitted to the medical department, were considered cases. Another 150 age- and sex-matched individuals with normal metabolism served as the control group. Both of these groups were studied, examined, and interviewed for the study. Patients with thyroid, Cushing's, and pregnant women were excluded from this study.

Under aseptic conditions, blood samples from the patients were taken in a simple bulb, centrifuged to extract the serum, and then returned to the patients. Hemoglobin, total platelet count, and total leucocyte count were measured using an automated cell counter (Horiba-Pentra XLR/Horiba ABX Pentra XL80). Using a Coulter counter, platelet indices were obtained from the $1/5{,}000$ dilution (Beckman Coulter's Z series: Z counter produced by Beckman Coulter, Germany). Serum was measured by using turbidimetry, and the VITROS 5600 evaluated and estimated the fasting lipid profile and fasting blood glucose. Flow chart of the study has been highlighted in ►**Fig. 1**.

Study Definitions

Body mass index (BMI) was calculated as weight (in kilograms) divided by the square of height in (kg/m^2). According to the WHO, underweight was considered less than 18.5 kg/m^2, overweight was considered as 25.0–29.9 kg/m^2, whereas normal weight is between 18.5 and 24.9 kg/m^2. Cases with BMI of 30.0–34.9 kg/m^2 were considered moderately obese, while those with 35.0–39.9 kg/m^2 were considered severely obese.[6]

Circumference of the Waist

The measurement of WC was taken approximately midway between the top of the iliac crest and the border of the last felt rib. According to the third report of the NCEP, waist sizes greater than 102 cm for men and greater than 88 cm for women were considered abnormal.[7]

Circumference of the Hip

Hip circumferences were measured at the largest circumference around the buttocks using a flexible narrow nonstretch tape on participants wearing the bare minimum of clothing while standing straight but not drawing in their stomachs.[6]

Circumference of the Neck

NC (cm) was measured using nonstretchable plastic tape to the nearest 1 mm and was measured from the level just below the laryngeal prominence perpendicular to the long axis of the neck with head positioned in Frankfurt horizontal plane. It was measured below the prominence in both sexes who had an Adam's apple-shaped laryngeal prominence. The patients were all standing straight, facing forward, and with relaxed shoulders when the circumference measurements were taken.[8] NC measurement was taken by two postgraduate residents who were blind to the study, trained in taking all the anthropometric measurements.

Measuring Blood Pressure

BP was measured following the standard protocol as patient should be empty stomach 30 minutes prior to BP measurement; patient should sit in a comfortable chair with back supported for at least 5 minutes before reading, having both feet flat on the ground and legs uncrossed. Patient should rest their arm with the cuff on a table at chest height and the BP cuff is snug but not too tight. Average of three BP readings was recorded. Readings above 130 mmHg for SBP or 80 mmHg for DBP were considered according to the American Heart Association.[9]

Statistical Analysis

The MS factors were not evenly distributed throughout the groups and subgroups. To compare groups of individuals, nonparametric tests like the Wilcoxon-Mann-Whitney *U*-test were used, with subgroups of age, gender, SBP, DBP, HDL, triglyceride, FBS, WC, waist–hip ratio (WHR), and NC

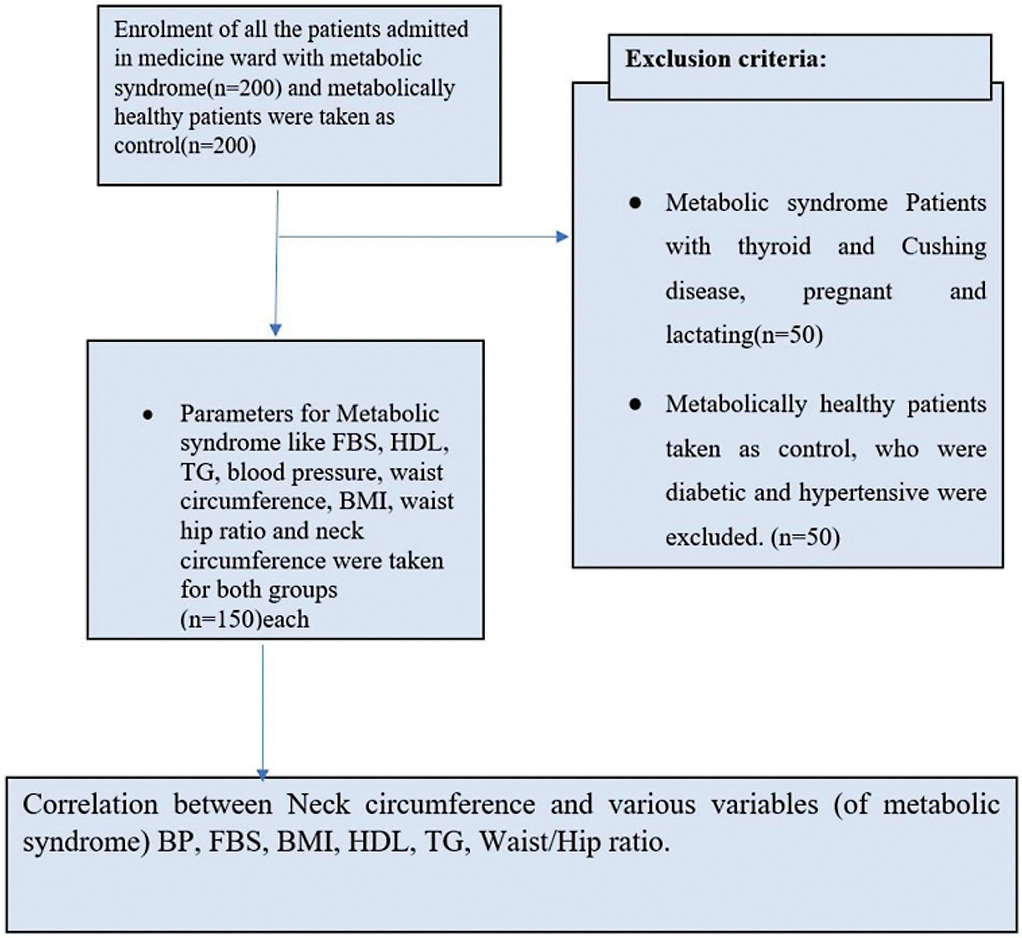

Fig. 1 Flowchart of the study. BMI, body mass index; BP, blood pressure; FBS, fasting blood sugar; HDL, high-density lipoprotein; TG, triglyceride.

included. A value of *p*-value less than 0.05 was considered to be significant.

Result

Seventy-six cases out of 150 were between 41 and 60 years of age and 91 (60.7%) were male. Average NC in male was found to be 34.62 ± 2.37 cm (case) and 29.98 ± 2.17 cm (control), where as in female it was 34.88 ± 2.11 cm and 30.17 ± 2.48 cm, respectively. Other base line characteristics are listed in ►**Table 1**. There was statistically significant correlation between BMI and NC ($p < 0.001$; $R^2 = 0.7139$) as shown in ►**Fig. 2** scatter plot. The scatter plot in ►**Fig. 3** shows the relationship between NC and waist/hip

Table 1 Distribution and association of study parameters among cases and controls ($n = 300$)

Parameters	Group		*p*-Value
	Case ($n = 150$)	Control ($n = 150$)	
Age (in years)***			
18–40	10 (6.7%)	11 (6.9%)	
41–60	76 (50.7%)	74 (49.4%)	
> 60	64 (42.7%)	65 (43.7%)	
Gender			0.116[b]
Male	91 (60.7%)	94 (61.3%)	
Female	59 (39.3%)	56 (38.7%)	
Hemoglobin (g/dL)***	12.48 ± 2.12	11.37 ± 2.22	< 0.001[b]
WBC	8,690.00 ± 4,327.25	8,062.00 ± 3,031.24	0.564[a]

(*Continued*)

Table 1 (*Continued*)

Parameters	Group		*p*-Value
	Case ($n = 150$)	Control ($n = 150$)	
MCV (g/dL)	81.03 ± 10.05	82.95 ± 11.54	0.084[a]
Platelet count (/mm^3)***	2.71 ± 0.89	2.04 ± 0.86	< 0.001[a]
Plateletcrit (%)***	0.37 ± 0.11	0.16 ± 0.03	< 0.001[a]
MPV (fL)***	12.21 ± 0.80	7.35 ± 1.05	< 0.001[a]
PDW (%)***	18.82 ± 5.09	13.17 ± 1.67	< 0.001[a]
Weight (kg)***	99.06 ± 5.41	78.06 ± 8.72	< 0.001[a]
Height (cm)	167.73 ± 4.43	167.80 ± 7.58	0.738[a]
BMI (kg/m^2)***	35.27 ± 2.44	27.64 ± 1.38	< 0.001[b]
BMI***			
23.0–24.9 kg/m^2	0 (0.0%)	5 (3.3%)	< 0.001[c]
25.0–29.9 kg/m^2	1 (0.7%)	141 (94.0%)	
30.0–34.9 kg/m^2	68 (45.3%)	4 (2.7%)	
35.0–39.9 kg/m^2	77 (51.3%)	0 (0.0%)	
40.0–44.9 kg/m^2	4 (2.7%)	0 (0.0%)	
Systolic BP (mmHg)***	143.56 ± 11.47	120.61 ± 5.85	< 0.001[a]
Diastolic BP (mmHg)***	85.00 ± 7.21	79.81 ± 5.62	< 0.001[a]
Total cholesterol (mg/dL)***	185.83 ± 34.47	171.46 ± 5.65	< 0.001[a]
Triglycerides (mg/dL)***	288.50 ± 51.00	137.17 ± 8.37	< 0.001[a]
LDL (mg/dL)***	224.53 ± 46.15	48.78 ± 5.38	< 0.001[a]
HDL (mg/dL)***	29.41 ± 5.98	125.27 ± 8.40	< 0.001[a]
Fasting blood glucose***	224.82 ± 50.03	102.28 ± 11.74	< 0.001[a]
HbA1c (%)***	8.16 ± 0.99	4.80 ± 0.40	< 0.001[a]
Waist circumference (cm)***	119.97 ± 12.25	69.47 ± 6.34	< 0.001[a]
Hip circumference (cm)***	117.75 ± 20.33	107.67 ± 13.49	< 0.001[a]
Waist/hip ratio***	1.04 ± 0.17	0.65 ± 0.06	< 0.001[a]
Neck circumference male (cm)***	34.62 ± 2.37	29.98 ± 2.17	< 0.001[a]
Neck circumference female (cm)***	34.88 ± 2.11	30.17 ± 2.48	< 0.001[a]

Abbreviations: BMI, body mass index; BP, blood pressure; HbA1c, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MCV, mean corpuscular volume; MPV, mean platelet volume; PDW, platelet distribution width; WBC, white blood cell.
***Significant at $p < 0.05$.
[a]Wilcoxon-Mann-Whitney *U*-test.
[b]*t*-Test.
[c]Fisher's exact test.

circumference having statistically significant correlation ($R^2 = 0.6359$). The scatter plots in ►**Figs. 4** and **5** show the relationship between NC and SBP and DBP, which had statistically significant positive correlation ($R^2 = 0.528$ and $R^2 = 0.1166$, respectively).

The scatter plots in ►**Figs. 6** and **7** show the relationship between NC and triglycerides and HDL with statistically significant correlation ($R^2 = 0.7105$ and $R^2 = 0.8909$, respectively). The scatter plot in ►**Fig. 8** shows the relationship between NC and fasting blood glucose having statistically significant relationship ($R^2 = 0.6674$). The area under the receiver operating characteristic curve (AUROC) for NC predicting case versus control was 0.822 (95% CI: 0.7–0.8), showing better diagnostic performance ($p < 0.001$), as shown in ►**Fig. 9**. It predicts MS with a sensitivity of 77% and a specificity of 73% at a cutoff of NC 34 cm. A regression analysis was done comparing NC with other components of MS as provided in ►**Table 2**.

Discussion

NC was related to cardiometabolic risks and contributed to the prediction in addition to the traditional anthropometric indices. We found that NC somehow predicted the likelihood of cardiometabolic hazards in both males and females and was significantly linked with cardiometabolic risk variables.

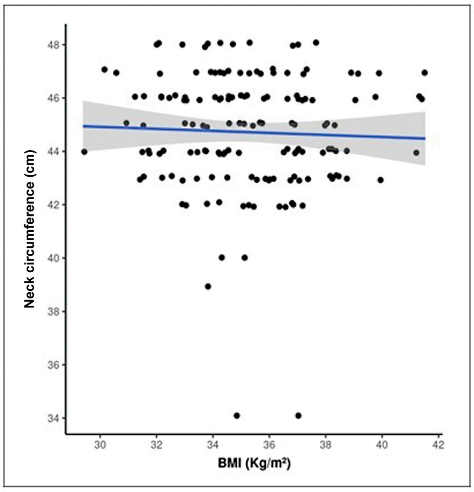

Fig. 2 Correlation between body mass index (BMI; kg/m^2) and neck circumference.

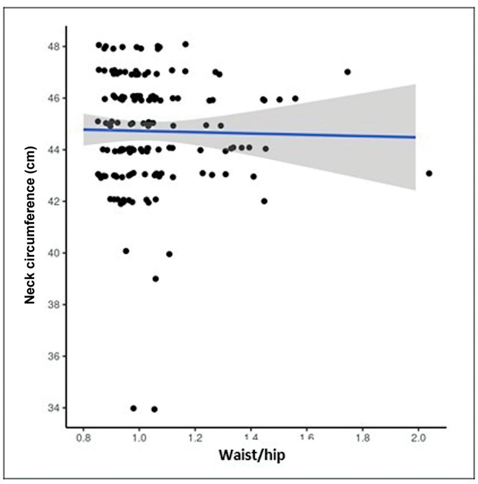

Fig. 3 Correlation between waist/hip and neck circumference.

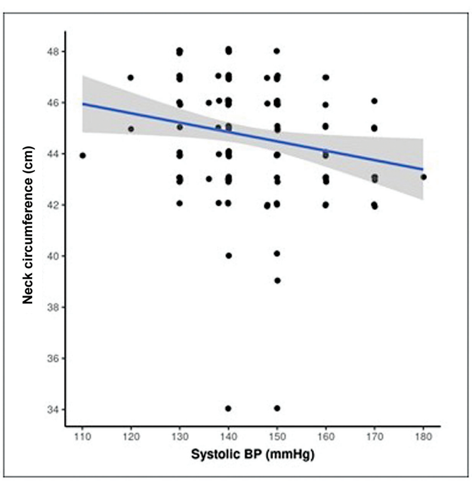

Fig. 4 Correlation between systolic blood pressure (BP; mmHg) and neck circumference.

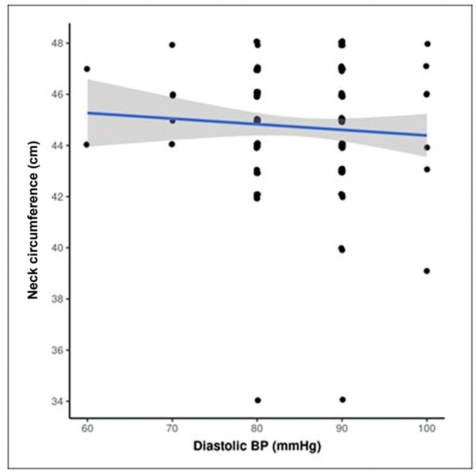

Fig. 5 Correlation between diastolic blood pressure (BP; mmHg) and neck circumference.

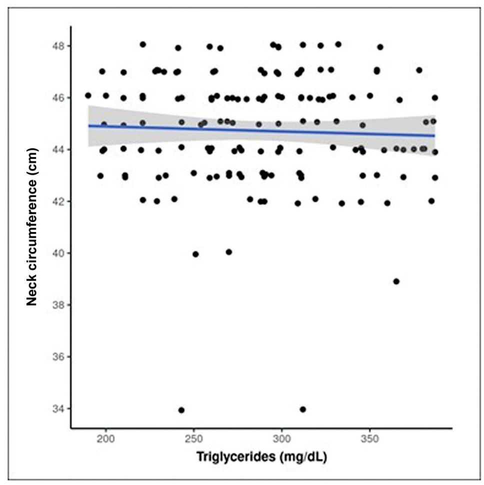

Fig. 6 Correlation between triglycerides (mg/dL) and neck circumference.

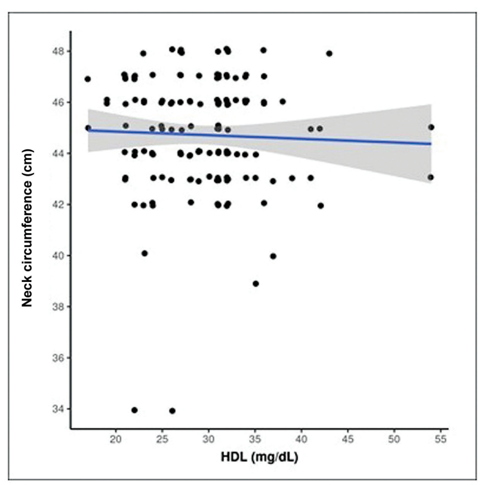

Fig. 7 Correlation between high-density lipoprotein (HDL; mg/dL) and neck circumference.

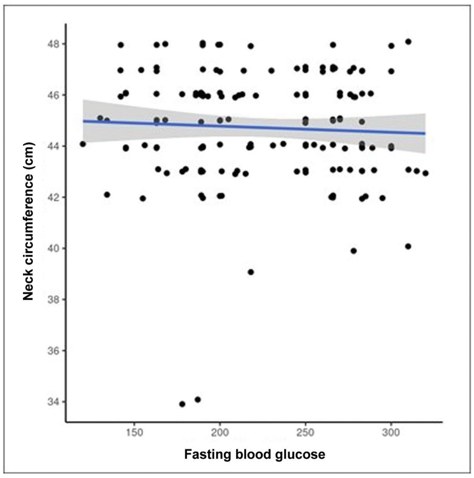

Fig. 8 Correlation between fasting blood glucose and neck circumference.

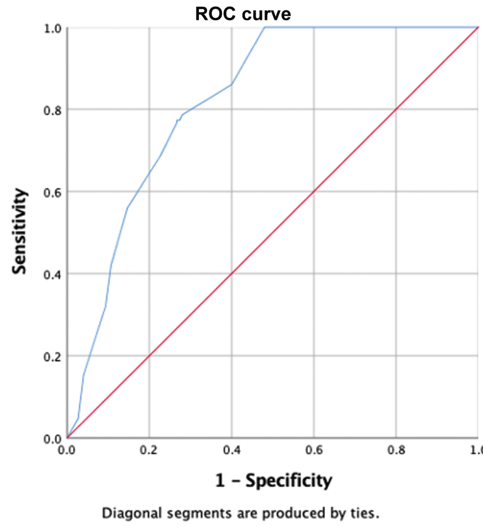

Fig. 9 Receiver operating characteristic curve for neck circumference predicting case versus control.

Based on prior research, it was widely believed that obesity may be linked to metabolic diseases and cardiovascular risk factors, which can increase NC.[10] Although BMI, WC, and WHR are often-used anthropometric indices to represent obesity and forecast cardiometabolic risks, a growing body of research indicates that NC is a more straightforward, creative, and useful anthropometric measure. In a Framingham Heart Study by Preis et al,[10] which included 2,732 participants, it was found that NC was positively linked with risks of type 2 diabetes, hypertension, decreased HDL-C, and elevated triglyceride. Even after further BMI and WC corrections, NC continued to be linked to type 2 diabetes. Similar results were seen in a Turkish Adult Cohort Study in 1912 of middle-aged and elderly persons.[11]

In this study, we found that cardiometabolic risks were substantially correlated with NC in both genders. Mean NC (cm) values in male were 34.62 ± 2.37 (cases) and 29.98 ± 2.17 (controls); whereas in female the values were 34.88 ± 2.11 (cases) and 30.17 ± 2.48 (controls). In a study conducted in the central region of rural India, NC was employed as a predictive factor for obesity, according to Kumar et al.[8]

On optimum cutoff points and the independent contribution of NC we found that in this study, the best NC cutoff for the prediction of MS was 34 cm, which was consistent with earlier research. For the prediction of MS and insulin resistance, however, substantially higher NC cutoffs were found in the Brazil study (> 40 cm in men and > 36 cm in women).[12] In a study by Aswathappa et al, there was significant increase in NC in diabetics as compared with nondiabetics. Mean NC was 34.9 ± 6.01 cm. It was reported to be positively associated with glycemic status, WHR, and BMI. Their study also showed positive correlation of NC with BMI, WC, WHR, as in our study.[13] In a study by Gubbala et al, overall, the mean NC with MS was 37.11 cm with a standard deviation (SD) of 1.66 cm. Mean NC without MS was 34.62 with an of SD 2.29 cm. There was a statistically significant difference between mean NC and MS.[14]

It was found that the relationships between NC and cardiometabolic risk variables were comparable. Initially, the model included age adjustments for each component of the cardiometabolic syndrome and found that NC was substantially related with the chance of MS. In light of this observation, we could draw the conclusion that NC, independently of other anthropometric indices, could aid in the prediction of early MS, which was consistent with a prior study based on a diabetic population.[13] The identification of the cardiometabolic syndrome may benefit from extra information that a measurement of NC could provide.[15–19] Most

Table 2 Linear regression showing neck circumference with components of metabolic syndrome

Variable	Slope	Intercept	R^2	Confidence interval
Body mass index	1.51	−10.14	0.71	1.17
Waist/hip ratio	26.35	15.14	0.63	42.24
Systolic blood pressure	0.38	−13.00	0.52	0.27
Diastolic blood pressure	0.377	6.256	0.11	0.44
Triglyceride	0.07	20.70	0.74	0.15
High-density lipoprotein	−0.14	48.94	0.89	0.27
Fasting blood glucose	0.08	22.96	0.66	0.19

of the components of MS like BP, triglycerides, and FBS were statistically correlated with NC in this study as confirmed with linear regression. The AUROC for NC predicting case versus control was 0.822 (95% CI: 0.7–0.8), showing better diagnostic performance ($p < 0.001$). There was low sensitivity of 77% and a specificity of 73% at a cutoff of NC 34 cm. Main reason may be small size of the study, hence more research is required to consolidate this observation of NC as a possible screening anthropometric index for MS.

Limitations

One of the limitations of this study is that being a single-center study with relatively small sample size, results may not be applicable in general population. Moreover, NC is a proxy for upper-body subcutaneous fat; we had no measure to directly quantify this fat depot adding to major limitation of the study.

Conclusion

According to our research, NC may be a possible anthropometric index for detecting MS. Beyond the traditional anthropometric indices of BMI, WC, and WHR, NC plays an independent role in predicting metabolic abnormalities and may be utilized as a screening tool for cardiometabolic risks and other chronic diseases linked to obesity.

Statement of Institutional Review Board Approval
The study was started after clearance from the institutional ethics committee of DMIMS (Deemed to be university), Sawangi (Meghe), Wardha. Approval number: DMIMS(DU)/IEC/2022/344 dated 10/10/2022.

Funding
None.

Conflict of Interest
None declared.

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