ORIGINAL ARTICLE

Neck Circumference: A Screening Tool for Predicting Metabolic Syndrome in Obese Children

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Abstract

Background: In recent days, neck circumference (NC) has been suggested as a screening technique for overweight individuals because it is easy to measure, does not require instruments such as a stadiometer or weighing scale, and does not require calculations as in body mass index (BMI). Moreover, NC correlates with many fat-related anthropometric measurements and cardiovascular risk factors.

Aims: The objective of this study was to find the association of higher NC with metabolic syndrome (MetS), insulin resistance (IR), and other metabolic complications.

Settings and design: Tertiary care teaching hospital, cross-sectional study.

Methods and materials: A total of 211 overweight and obese children aged between 5 and 13 years were recruited. Anthropometric parameters such as weight, height, NC, and waist circumference (WC) were measured. Fasting blood glucose, total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL) cholesterol, aspartate transaminase (AST), and alanine transaminase (ALT) were estimated. Homeostasis model assessment of insulin resistance (HOMA-IR) and MetS were derived.

Statistical analysis used: Independent *t*-test and Chi-square analysis were applied for continuous and categorical variables, respectively, to find the association.

Results: Out of 79 children in the high-NC group, 11 had MetS, whereas only 4 had MetS in the low-NC group of 132 children, which was statistically significant ($X^2 = 8.87$; $p = 0.003$). Logistic regression analysis showed a significant association between high neck circumference and waist circumference ($p = 0.00$; AOR = 1.164).

Conclusions: High NC reflects high BMI and can predict MetS in overweight and obese children.

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Introduction

Childhood obesity is becoming an increasing concern, especially in developing nations, such as India, where rapid urbanization, changes in dietary patterns, and sedentary lifestyles are contributing factors. More number of children and adolescents are becoming overweight, as highlighted by CNNS survey, which is alarming because it can cause lifestyle health hazards such as cardiovascular diseases in adulthood.[1] The rise in pediatric obesity is indeed concerning because it's closely tied to an increase in metabolic syndrome (MetS) in younger populations.[2]

Abdominal circumference and body mass index (BMI) are frequently utilized as screening tools, particularly in children and adolescents, but their limitations, such as interobserver variation, the need for undressing in females, and the difficulty of identifying accurate landmarks in children due to fat distribution, make them less practical as primary screening tools in certain settings. Neck circumference (NC) is emerging as a promising alternative. It is a simpler, noninvasive measurement that does not require specialized equipment, such as stadiometers or scales, and it avoids some of the cultural or logistical challenges associated with waist circumference (WC) measurements, such as undressing. NC also appears to correlate well with fat distribution patterns, particularly central adiposity, and is associated with various metabolic complications, such as hypertension, insulin resistance, and dyslipidemia. The fact that respiratory movements or postprandial abdominal distention would not change NC measurement values makes it even more appealing as a practical tool.[3,4] Nevertheless, at present, in clinical settings, NC is not utilized as a tool for segregation of obese children due to the paucity of studies in the published literature. We attempted to examine the link between NC (upper body fat deposition) and MetS, insulin resistance (IR), and other metabolic complications.

Materials and Methods

This project was undertaken from January 2022 to December 2022. It was done at a tertiary pediatric setting after obtaining permission from the Ethics board of the institute. Informed consent and assent from older children were obtained before their inclusion in the study. The study population comprised children aged 5–13 years with an adult-equivalent BMI >23 kg/m^2. Children with a BMI of more than 27 kg/m^2 were categorized as obese. Children with a BMI between 23 kg/m^2 and 27 kg/m^2 were categorized as overweight. Weight, height, NC, and WC were recorded. Quetelet index [weight in kg/(height in m)^2] was used for calculating BMI.

Blood pressure (BP) was measured after having the participants rest for 5 minutes in the sitting position. Blood pressure was checked manually by a sphygmomanometer using the Korotkoff method. A flexible ruler tape was used for measuring NC at the thyroid cartilage level.[5] WC was measured at the midpoint between the lower last rib and the iliac crest. WC was measured by a nonstretchable tape to the nearest 0.1 cm while the participant stood in an upright posture.

Fasting blood glucose (FBG), total cholesterol (TC), triglyceride (TG), high-density lipoprotein (HDL-C), aspartate transaminase (AST), and alanine transaminase (ALT) were assessed using standard reagent kits. Low-density lipoprotein (LDL-C) and very low-density lipoprotein (VLDL) levels were calculated from the triglyceride value using Friedewald's formula. The chemiluminescence method was used for estimating fasting insulin levels. The homeostasis model assessment of insulin resistance (HOMA-IR) is calculated as:

$$\text{HOMA-IR} = [\text{Fasting glucose (mg/dL)} \times \text{fasting insulin } (\mu\text{IU/mL})]/405.$$ [6,7]

The criteria set by the International Diabetes Federation (IDF) were used for defining metabolic syndrome (MetS). Diagnosis of MetS was made for the children with abdominal obesity (defined by WC >90th percentile for the child's age and sex) along with at least three metabolic parameters:[8,9]

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1. TG >150 mg/dL.
2. HDL-C <40 mg/dL.
3. SBP or DBP >130 or 85 mm Hg, respectively.
4. FBG >100 mg/dL.

Considering the sensitivity and specificity of neck measurement as 62% and 86% observed by Kurtoglu et al.,[10] with alpha error as 5%, error of margin as 20% and the proportion of MetS as 11%, the minimum required sample size would be 206 using the formula given below.[11]

- Formula for sensitivity:
  - Step 1: $TP + FN = Z^2\alpha/2 \times SN\ (1-SN)/w^2$
  - Step 2: $N1 = (TP + FN)/P$
- Formula for specificity:
  - Step 1: $FP + TN = Z^2\alpha/2 \times SP(1-SP)/w^2$
  - Step 2: $N2 = (FP + TN)/(1-P)$

Z-alpha is the table value from the standard normal distribution corresponding to the area (1–alpha)/2, here 1.96 for 5% alpha. SN is sensitivity. SP is specificity. w is the margin of error. P is the proportion of MetS.

The receiver operating characteristic (ROC) curve was plotted, and the area under the curve (AUC) was calculated to evaluate the diagnostic accuracy in predicting MetS. For examining the associations between variables, an independent *t*-test was used for continuous variables, and a Chi-square test was used for categorical variables.

Results

A total of 158 obese and 53 overweight children were recruited, which included 106 boys and 105 girls, aged from 5 to 13 years. The mean age was 10 years (SD = 2.18) and 9 years (SD = 1.82) for boys and girls, respectively. All clinical and metabolic parameters are summarized in Tables 1 and 2. Out of 211 children, 15 children satisfied the criteria for MetS.

Receiver operating characteristic analysis was plotted, taking MetS as the yardstick. The AUC for NC was 0.766, 95% CI = 0.689–0.882 for boys, whereas it was noted as 0.749, 95% CI = 0.683–0.808 for girls (Table 3 and Fig. 1). The cutoff value for NC 31.5 cm has the maximum sensitivity and specificity. The study parameters were compared between two

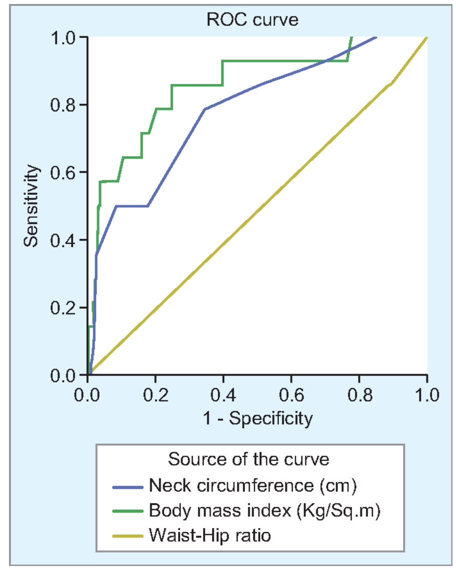

Fig. 1: ROC curve [receiver operating characteristic analysis was carried out regarding the presence of MetS as the gold standard. The area under the curves (AUC) for NC was 0.766 (95% CI = 0.689–0.882) for boys and 0.749 (95% CI = 0.683–0.808) for girls. Cutoff value for NC 31.5 cm has the maximum sensitivity and specificity]

Table 1: The anthropometric and biochemical characteristics of the study population stratified by gender

Variables	*All (n = 211)*		*Male (n = 106)*		*Female (n = 105)*		*t-test p-value*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	
BMI (kg/m^2)	23.65	3.44	24.08	3.92	23.23	2.83	0.07
SBP (mm Hg)	112.80	8.40	106.83	11.75	106.33	9.59	0.31
DBP (mm Hg)	72.38	7.93	72.58	8.51	72.18	7.35	0.71
Cholesterol (mg/dL)	155.97	36.23	156.49	38.74	155.46	33.71	0.83
TG (mg/dL)	111.34	52.90	110.61	50.32	112.07	55.56	0.83
HDL (mg/dL)	36.30	7.81	36.22	7.71	36.39	7.94	0.84
LDL (mg/dL)	102.19	28.374	103.26	26.296	101.14	30.382	0.87
VLDL (mg/dL)	21.99	10.51	21.76	10.05	22.22	10.99	0.58
AST (IU/L)	39.96	14.37	39.85	15.32	40.08	13.44	0.91
ALT (IU/L)	43.18	21.25	42.99	20.34	43.37	22.22	0.897
Insulin (IU/L)	8.73	5.17	9.37	5.48	8.09	4.78	0.073
HOMA-IR	1.81	1.08	1.96	1.13	1.66	1.01	0.042

Table 2: The anthropometric and biochemical characteristics for the two groups with neck circumference >31.5 cm and NC <31.5 cm

Variables	*NC > 31.5 cm*		*NC < 31.5 cm*		*t-test p-value*
	Mean	*SD*	*Mean*	*SD*	
Age (years)	11.07	1.64	9.31	1.95	0.00
BMI (kg/m^2)	25.48	3.16	22.56	3.12	0.00
SBP (mm Hg)	110.7	8.96	116.98	6.77	0.35
DBP (mm Hg)	74.42	8.05	71.16	7.63	0.00
WC (cm)	82.51	7.34	72.59	6.33	0.00
Cholesterol	162.57	47.93	152.02	26.32	0.07
TG (mg/dL)	110.86	47.24	111.63	56.19	0.91
HDL (mg/dL)	36.13	6.45	36.41	8.54	0.78
LDL (mg/dL)	108.03	35.04	98.70	22.95	0.04
VLDL (mg/dL)	21.75	9.35	22.14	11.17	0.79
AST (IU/L)	42.24	15.96	38.59	13.20	0.09
Insulin (µIU/L)	11.40	5.18	7.12	4.47	0.00
HOMA-IR	2.36	1.02	1.48	0.97	0.03

Table 3: Area under the curve

Test result variable (s)	*Area*	*Std error*	*p-value*	*95% confidence interval for AUC*	
				Lower bound	*Upper bound*
Neck circumference (cm)	0.782	0.065	0.000	0.654	0.910
Body mass index (Kg/m^2)	0.855	0.057	0.000	0.744	0.966
Waist–hip ratio	0.485	0.082	0.850	0.325	0.645

In this table, the AUC is 0.78 for NC. This suggests a 78% chance that the physician measuring the NC will correctly distinguish a non-MetS patient from a MetS patient based on the measurement of the NC readings. However, with a p-value < 0.001, it indicates that this NC has acceptable discriminating ability

groups of NC above and below the 31.5 cm cutoff value.

BMI was found to be significantly higher in higher NC (>31.5 cm) group (p-value = 0.00). WC was high in high NC group ($p = 0.00$). DBP was elevated in the high NC group ($p = 0.00$). LDL-C levels were high in the high NC group ($p = 0.037$). The high NC group had more insulin values ($p = 0.00$) and HOMA-IR values ($p = 0.04$).

In low NC group, NC values correlated with BMI ($r = 0.44$, $p = 0.01$); WC ($r = 0.42$, $p =$ <.001); HOMA-IR ($r = 0.18$, $p < 0.05$). Similarly, in the high NC group, positive correlation was found with BMI ($r = 0.39$, $p = 0.01$); WC ($r = 0.40$, $p = 0.01$); HOMA-IR ($r = 0.23$, $p = 0.03$).

A statistically significant association between obese children and high NC compared to the overweight group was found (p-value = 0.04). Out of 79 children in the high NC group, 11 had MetS, whereas only four had MetS in the low NC group of 132 children, which was statistically significant ($X^2 = 8.87$; $p = 0.003$). Logistic regression confirmed a significant association between high neck circumference and waist circumference (*p-value* = 0.00; AOR: 1.164).

Discussion

Many studies conducted in adults have proven that NC would serve as an effective tool to identify individuals with metabolic risks.[12] However, fewer studies have examined NC as a detector of IR and derangements of MetS parameters in children.[10,13] It is evident from recent reports that NC is a reliable and pragmatic tool that provides consistent results in identifying upper-body fat accumulation. Thus, we attempted to explore the relationship of NC with both MetS and IR.

We found that NC was associated with BMI, which is concordant with previous similar studies.[13–15] Although we use BMI routinely to assess body fat content, it is not a high-standard tool to find body fat distribution. NC can give the details of upper body fat distribution, and as proven in other studies, it can be used as an alternative to predict obesity. We also found that NC is significantly associated and positively correlated with WC, as demonstrated by many previous observational studies.[10,13,15] NC offers several advantages over WC as a measurement tool. Additionally, adolescents prefer NC in comparison to WC as it is more acceptable in Indian settings. Given these benefits, NC can be used as a reliable alternative to waist circumference.

In obese subjects, high NC increases vulnerability for hypertension, as demonstrated by Nafiu et al.[16,17] In our study, NC was associated with DBP, which is similar to Nafiu et al.[17] NC was also linked with LDL-C levels, which is concordant with two previous observational studies.[10]

Neck circumference was associated with insulin levels and HOMA-IR according to Kurtoglu et al. Similarly, in our study, we observed a correlation of NC with insulin and HOMA-IR, aligning with the findings of Kurtoglu et al.[10] Additionally, our observations revealed a positive association of NC and MetS, which is consistent with meta-analysis of adult subjects conducted by Ataie-Jafari et al.[18] Although the precise mechanism linking upper body fat to metabolic risk factors remains unclear, early evidence suggests that subcutaneous fat of upper body release free fatty acids which play a significant role in the development of metabolic complications.[19]

Neck circumference can be a simple and effective tool for predicting upper body fat and metabolic syndrome MetS identification in children is a significant progress in pediatric research. We highlight the need for larger studies to confirm these results and solidify the role of NC as a standard screening method. The limitation related to the study sample being from a single ethnic group is significant. Ethnic variations in fat distribution patterns, metabolic risk factors, and even anthropometric measurements could affect how NC correlates with MetS. The other reason for the lower cut-off in our study is the inclusion of children only up to 13 years, whereas most studies included the study population up to 15–18 years of age. Age-wise cutoff values for NC were not possible as the sample size was smaller.

What this study adds: Neck circumference can predict metabolic syndrome in children with obesity.

Sources of Support

Nil.

Conflict of Interest

None.

Author contributions

The manuscript had been read and approved by all the authors. SP Tharanidharan and Srinivasan Thiagarajan conceived the idea and designed the research work, while SP Tharanidharan and Srinivasan Thiagarajan were involved in collecting the data and literature review. Data analysis was done by SP Tharanidharan and Srinivasan Thiagarajan, and the manuscript was prepared by SP Tharanidharan and Srinivasan Thiagarajan. All authors contributed to the initial drafting and critical revision of the manuscript.

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