

# Neck Circumference: Independent Predictor for Overweight and Obesity in Adult Population

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## Abstract

**Background:** Neck circumference (NC) measurement, an index of upper body fat (BF) distribution, seems promising as a community-based screening measure for overweight and obesity in want of evidence on its validity as a screener. **Objective:** The objective of this study was to determine the validity of NC as a screener for overweight and obesity in adults in community settings against BF percentage (BF%). **Materials and Methods:** This cross-sectional community-based study involved data collection on a predesigned, pretested, and semi-structured schedule that included the sociodemographic characteristics and anthropometric measurements of respondents. **Results:** NC correlated positively with body weight, waist circumference, and hip circumference. NC was found to have good discriminatory power with cutoff values of 36.55 cm for males and 34.05 cm for females, with maximum sensitivity and specificity to predict overweight and obesity in comparison to direct BF% estimation on receiver operating characteristic analysis. **Conclusion:** NC has a fair validity as a community-based screener for overweight and obese individuals in the study context. Further studies may be carried out to explore the generalizability of this observation.

**Keywords:** Anthropometry, correlation, neck circumference, obesity, overweight

## INTRODUCTION

There is a need to identify some anthropometric parameter that is more feasible and accurate than the existing parameters and relate more closely to the new epidemic called obesity. The general view that obesity is a problem of prosperous Western countries has been repealed with substantial evidence showing that low- and middle-income countries like India are now at the heart of a “fat explosion.”<sup>[1]</sup>

Some of the most common methods for the assessment of obesity in adults include body mass index (BMI), waist circumference (WC), waist/hip ratio (WHR), skin-fold thickness, and waist height ratio (WHtR).<sup>[2]</sup> Out of these, BMI is still the most widely used marker for defining adult obesity.<sup>[3]</sup> Overweight is globally defined as BMI between 25.0 and 29.9 kg/m<sup>2</sup> and obesity as BMI of 30.0 kg/m<sup>2</sup> or higher,<sup>[4]</sup> but these values are debated for the Asian Indian population.<sup>[5-7]</sup> Estimation of these indices has faced certain problems in community as seen during noncommunicable disease surveys. Either they require standardized instruments to avoid intra- and inter-observer bias (height or weight measurement) or they need to be calculated (BMI, WHR, and WHtR) which might

be a problem for health workers who are working at subcenter level as it is time-consuming for them. If not these, the indices may not be culture sensitive (WC, hip circumference [HC]); women might not be comfortable in measurements of these indices by a male health worker. Other procedures, such as ultrasound, computed tomography, and magnetic resonance imaging, are expensive and not suitable for community-based screening.

Neck circumference (NC) is an index of upper body fat (BF) distribution. It holds promise as a screener for overweight and obesity.<sup>[8-10]</sup>

The NC is believed to be a fine predictor of fatness because of the strong correlation between higher NC and central adiposity (fat around the abdomen). NC has the extra advantage of

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**How to cite this article:** Verma M, Rajput M, Sahoo SS, Kaur N. Neck circumference: Independent predictor for overweight and obesity in adult population. Indian J Community Med 2017;42:209-13.

**Received:** 01-07-16, **Accepted:** 21-07-17

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#### Quick Response Code:



**Website:**  
www.ijcm.org.in

**DOI:**  
10.4103/ijcm.IJCM\_196\_16

measuring it more conveniently than other indices as discussed above.<sup>[3]</sup>

The Framingham Heart Study indicated that upper body subcutaneous fat measured as NC may be a unique, pathogenic fat deposit.<sup>[11]</sup> In a study of 3182 type 2 diabetic patients in China, NC was positively related with BMI, WC, and metabolic syndrome (MetS).<sup>[12]</sup> Nevertheless, NC has an independent contribution to predict the metabolic abnormalities which is beyond the capabilities of the classical anthropometric indices such as BMI, WC, and waist/hip ratio (WHR), and hence it may be used as an optimal screening method for other obesity-related chronic diseases.<sup>[13,11]</sup>

There is a close correlation between an increased quantity of visceral adipose tissue (VAT) and cardiovascular diseases.<sup>[14]</sup> Even as NC could suffice as a surrogate index of VAT in primary care settings, evidence on the validity of NC for the same at population level in India is scarce. The aim of the present study was to determine the validity of NC as a screener for overweight and obesity in adults in community settings against BF% as measured by bioimpedance analysis.

## MATERIALS AND METHODS

This cross-sectional community-based study was conducted between September 2013 and August 2014 in Anganwadis present under Community Health Centre, Beri block of Dubaldhan, district Jhajjar, Haryana, which is the rural field practice area of the Department of Community Medicine, Post Graduate Institute of Medical Sciences (PGIMS), Rohtak, Haryana.

Assuming both the sensitivity and specificity of NC to measure overweight and obesity as 50%, with an allowable error of 7% at 95% confidence level, sample size obtained was 196. Considering the prevalence of overweight and obesity in general population as 20%,<sup>[15]</sup> the sample size calculated was 980, but a higher sample size of 1080 was finally included in the study. Multistage random sampling was used. Two subcenters from each PHC ( $n = 3$ ) and 12 Anganwadi Centres (AWCs) from six subcenters were chosen. Gender-wise enumeration of the study population was done from the Anganwadi registers. From each Anganwadi, 45 males and 45 females, equally divided into five age groups, i.e., 20–29, 30–39, 40–49, 50–59, and 60 years, were interviewed after systematic random sampling.

Apparently healthy controls, residing in the study area for 6 months, registered at the subcenter, and had given informed written consent, were included in the study, while migrants and bedridden patients were excluded from the study. In case the desired number of participants was not available in any Anganwadi area, subsequent AWC was included.

After ensuring the confidentiality of the information, data were collected on a predesigned, pretested, and semi-structured schedule by the investigator himself to minimize the interobserver bias. After filling the questionnaire that included

sociodemographic characteristics, the respondents were called to a separate room for anthropometric measurements, and variables such as weight (kg), height (cm), WC (cm), HC (cm), NC (cm), BF%, BMI ( $\text{kg}/\text{m}^2$ ), and WHR were recorded and calculated using standard procedures. Weight of the study participants was measured using a digital weighing machine (SECA 874 U digital scale), and height for the study participants was measured using a stadiometer (SECA 213 Stadiometer).<sup>[12]</sup> NC was measured with a calibrated plastic tape in the midway of the neck, between midcervical spine and midanterior neck, within 1 mm. In men with a laryngeal prominence (Adam's apple), it was measured just below the prominence. BF% was measured using a commercially available bioelectric impedance analyzer (HBF-306, Omron Health care Co., Kyoto, Japan).

The modified classification of BMI for Asian Indian populations was used in this study to define overweight ( $23\text{--}24.99 \text{ kg}/\text{m}^2$ ) and obesity ( $>25 \text{ kg}/\text{m}^2$ ).<sup>[16]</sup> Standard cutoff points were used to define central obesity (men:  $\text{WC} \geq 90 \text{ cm}$ ; women  $\geq 80 \text{ cm}$ ), WHR (men:  $\text{WC} \geq 0.90 \text{ cm}$ ; women  $\geq 0.80 \text{ cm}$ ), and WHtR ( $0.5$ ).<sup>[17]</sup>  $\text{NC} > 37 \text{ cm}$  in men and  $> 34 \text{ cm}$  in women was set as the upper limit.<sup>[8]</sup>  $\text{BF}\% > 25\%$  in males and  $> 30\%$  in females was set as the upper limit.<sup>[18]</sup>

Prior permission and ethical clearance for the study were obtained from the Institutional Review Board. The participants who were found to have any comorbidities were referred to PGIMS, Rohtak, after counseling for further intervention. Analysis of the data was carried out using the Statistical Package for the Social Sciences (SPSS) for Windows version 17.0, released 2008 (SPSS Inc., Chicago, IL, USA).

## RESULTS

Mean age of the study participants was  $44.55 \pm 15.65$  years (males:  $45.06 \pm 16.17$  years; females:  $44.04 \pm 15.13$  years). Mean height of males was more than that of females, whereas the mean weight, BMI, BF%, WC, HC, and WHR were more in females than those of males as summarized in Table 1. The mean value of our main anthropometric parameter under evaluation, i.e., the NC of the male study population ( $34.90 \pm 3.94 \text{ cm}$ ), was higher than that of the females ( $33.65 \pm 3.81 \text{ cm}$ ). Furthermore, the variations in BMI, NC, and BF% with age were statistically nonsignificant in the study population as depicted in Table 2.

In this study, the overall prevalence of overweight and obesity as per the modified criteria for Asian Indians ( $\text{BMI} \geq 23 \text{ kg}/\text{m}^2$ ) was 49.62% (females: 51.48% and males: 47.77%). The prevalence of overweight ( $\text{BMI} = 23.0\text{--}24.9 \text{ kg}/\text{m}^2$ ) was 15.0% (males: 15.4% and females: 14.6%). The prevalence of obesity ( $\text{BMI} \geq 25 \text{ kg}/\text{m}^2$ ) was 34.6% and it was higher among females (36.9%) as compared to males (32.4%).

It was also observed that 827/1080 study participants (336 males and 491 females) had a high WHR, i.e.,  $> 0.80$  in females and  $> 0.90$  in males. Moreover, nearly half of the participants (513/1080) had high BF (280 males and

233 females), i.e., >25% in males and >30% in females and 537/1080 participants had central obesity, i.e., >90 cm in males and >80 cm in females (361 males and 176 females).

As per the standard cutoff values used to define the upper limit for NC,<sup>[8]</sup> nearly 47.41% of males ( $n = 256$ ) and 42.03% of females ( $n = 227$ ) were underweight or normal and had their NC values below the cutoff values of 37 and 34 cm, respectively. Nearly 23.88% of males ( $n = 23.88$ ) and 34.44% of females ( $n = 186$ ) were overweight and obese and had NC above the cutoff values [Table 3]. This observation was also statistically significant (men,  $\chi^2 = 109.48$ ; women,  $\chi^2 = 0.159$ ; each  $P = 0.000$ ). True-positive participants were those with high BMI and high NC ( $n = 315$ ). True-negative participants were those with low or normal BMI and low NC ( $n = 483$ ). False-positive participants were those with high NC and low BMI ( $n = 61$ ). False-negative participants were those with low NC and high BMI ( $n = 221$ ) [Table 3].

If we use the modified guidelines of BMI for defining overweight and obesity for the Asian Indian population,<sup>[16]</sup> then the upper limit for NC can also be reconsidered. NC was found to have a good discriminatory power to predict overweight and obesity as per the modified criteria of BMI classification on receiver operating characteristic (ROC) analysis. It was compared against BF%, with reference line laid according to the modified criteria of overweight and obesity that separated the overweight and obese from the normal or underweight study participants. Area under the curve (AUC) was higher for BF% estimation (AUC for males: 0.873 and females: 0.887;  $P < 0.001$ ) as compared to NC (AUC for males: 0.822 and females: 0.873;  $P < 0.001$ ). In addition, the maximum sensitivity (males: 63.2% and females: 66.9%) and specificity (males: 84.8% and females: 86.6%) of NC obtained at a cutoff value of 36.55 cm for males and 34.05 cm for females was similar to the sensitivity (males: 64.7% and females: 71.9%) and specificity (males: 86.5% and females: 87.4%) of BF% estimation for predicting overweight and obesity in the study population [Table 4 and Figures 1, 2].

In both the genders, as per the Pearson's correlational analysis, NC was positively correlated with age (men,  $r = 0.09$  [ $P < 0.05$ ] and women,  $r = 0.35$  [ $P > 0.05$ ]), BMI (men,  $r = 0.670$  [ $P < 0.05$ ]; women,  $r = 0.564$  [ $P < 0.05$ ]), BF% (men,  $r = 0.407$  [ $P < 0.05$ ]; women,  $r = 0.283$  [ $P < 0.05$ ]), WC (men,  $r = 0.598$  [ $P < 0.05$ ]; women,  $r = 0.615$  [ $P < 0.05$ ]), HC (men,  $r = 0.512$  [ $P < 0.05$ ]; women,  $r = 0.523$  [ $P < 0.05$ ]), and WHR (men,  $r = 0.380$  [ $P > 0.05$ ]; women,  $r = 0.022$  [ $P > 0.05$ ]).

Kappa statistics depicted a fair agreement with BMI ( $\kappa = 0.299$ ) ( $P < 0.000$ ), slight agreement with WCs ( $\kappa = 0.14$ ) ( $P < 0.000$ ) and BF% ( $\kappa = 0.013$ ) ( $P = 0.637$ ), and poor agreement with WHR ( $\kappa = 0.004$ ) ( $P = 0.825$ ) and NC in the study population.

## DISCUSSION

Before the 20<sup>th</sup> century, obesity was rare; in 1997, the WHO formally recognized obesity as a global epidemic.<sup>[19]</sup> According

**Table 1: Anthropometric parameters of the study population**

Quantitative parameters	Mean $\pm$ SD		
	Male (n=540)	Female (n=540)	Total (n=1080)
Age (years)	45.06 $\pm$ 16.17	44.04 $\pm$ 15.13	44.55 $\pm$ 15.65
Weight (kg)	60.70 $\pm$ 12.91	60.98 $\pm$ 13.79	60.84 $\pm$ 13.35
Height (cm)	161.76 $\pm$ 9.72	160.24 $\pm$ 9.58	161.00 $\pm$ 9.67
BMI (kg/m <sup>2</sup> )	23.19 $\pm$ 4.53	23.71 $\pm$ 4.82	23.45 $\pm$ 4.68
BF (%)	26.02 $\pm$ 8.51	28.69 $\pm$ 8.25	27.36 $\pm$ 8.48
Waist circumference (cm)	84.97 $\pm$ 12.31	87.40 $\pm$ 13.53	86.19 $\pm$ 12.99
Hip circumference (cm)	92.73 $\pm$ 9.21	93.65 $\pm$ 10.54	93.19 $\pm$ 9.91
Waist hip ratio	0.91 $\pm$ 0.08	0.95 $\pm$ 0.46	0.93 $\pm$ 0.33
NC (cm)	34.90 $\pm$ 3.94	33.65 $\pm$ 3.81	34.28 $\pm$ 3.93

BMI: Body mass index, SD: Standard deviation, BF: Body fat, NC: Neck circumference

**Table 2: Age-wise distribution of body mass index, neck circumference, and body fat percentage in the study population**

Age group (years)	BMI (kg/m <sup>2</sup> )	NC (cm)	BF (%)
20-29	22.82 $\pm$ 4.17	34.14 $\pm$ 3.68	26.46 $\pm$ 8.04
30-39	23.43 $\pm$ 5.07	33.93 $\pm$ 3.74	27.20 $\pm$ 08.99
40-49	23.40 $\pm$ 4.42	34.02 $\pm$ 4.08	27.31 $\pm$ 8.49
50-59	23.79 $\pm$ 4.94	34.94 $\pm$ 3.83	27.43 $\pm$ 8.23
60	23.81 $\pm$ 4.71	34.34 $\pm$ 4.21	28.37 $\pm$ 8.60
Total	23.45 $\pm$ 4.68	34.28 $\pm$ 3.92	27.36 $\pm$ 8.42
P	0.171	0.059	0.237

BMI: Body mass index, BF: Body fat, NC: Neck circumference

**Table 3: Comparison of neck circumference with overweight and obesity according to the modified criteria for the Asian Indians**

	Males (%)		Females (%)	
	NC >37 cm	NC <37 cm	NC >34 cm	NC <34 cm
Overweight and obese (BMI $\geq$ 23 kg/m <sup>2</sup> )	129 (83.2)	129 (33.5)	186 (84.2)	92 (28.8)
Normal and underweight (BMI <23 kg/m <sup>2</sup> )	26 (16.8)	256 (66.5)	35 (15.8)	227 (71.2)
Total	155 (100)	385 (100)	221 (100)	319 (100)
$\chi^2$ and P	109.48 and 0.000		159.0 and 0.000	

BMI: Body mass index, NC: Neck circumference

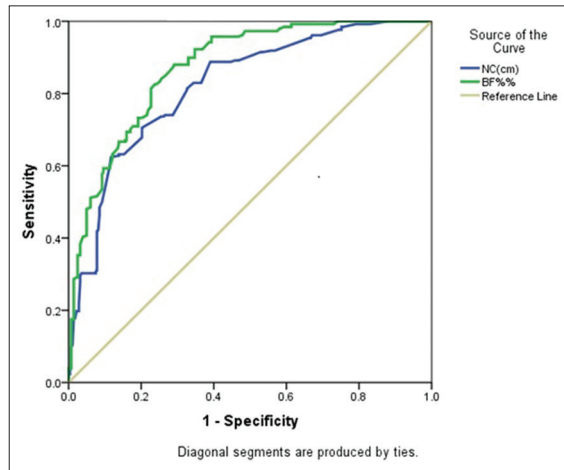
to the WHO report, 65% of the world's population live in countries where overweight and obesity kill more people than underweight.<sup>[20]</sup> NC, as an index of upper body subcutaneous adipose tissue distribution, is a reliable, simple, and quick method for assessment of overweight and obesity.

The shape of the neck in humans is formed from the upper part of the vertebral column at the back and a series of cartilages that surround the upper part of the respiratory tract. Around these sit soft tissues, including muscles and fat. The development of these organs is completed by the

**Table 4: Comparison of sensitivity and specificity of neck circumference and body fat percentage estimation to predict overweight and obesity by receiver operating characteristic analysis**

Anthropometric variable	Male				Females			
	AUC (P)	95% CI	Sensitivity (%)	Specificity (%)	AUC (P)	95% CI	Sensitivity (%)	Specificity (%)
NC (cm)	0.822 (<0.001)	0.787-0.857	63.2	84.8	0.827 (<0.001)	0.793-0.861	66.9	86.6
BF (%)	0.873 (<0.001)	0.844-0.901	64.7	86.5	0.887 (<0.001)	0.860-0.914	71.9	87.4

BF: Body fat, NC: Neck circumference, AUC: Area under the curve, CI: Confidence interval



**Figure 1:** Receiver operating characteristic analysis for the male study participants

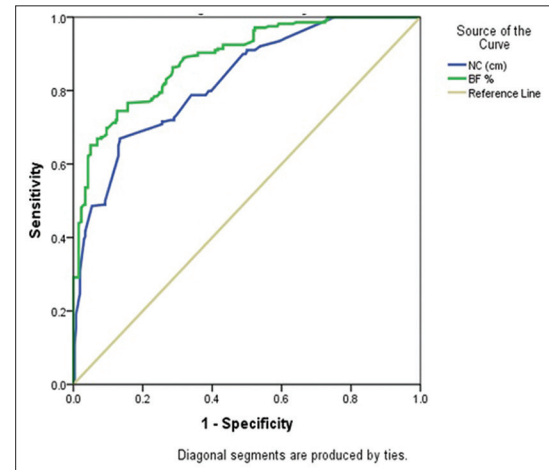
end of puberty, and any change in NC after this is attributed to increase in fat mass in the soft-tissue space in healthy individuals.<sup>[21]</sup>

Our study has shown a strong association ( $P=0.000$ ) between NC and BMI for males and female study participants which is considered a reliable overweight and obesity index.

More males (47.41%;  $n=256$ ) than females (42.03%;  $n=227$ ) were underweight or normal and had their NC values below the cutoff values of 37 and 34 cm, respectively, in our study. Simpson explained similar results in his study with the fact that lean tissue is a substantial contributor to NC in men; whereas, in women, an increased NC appears to be more likely associated with a disproportionate increase in fat, despite the tendency of women to accumulate fat more peripherally, as compared with men.<sup>[22]</sup>

Furthermore, there is insufficient literature evidence regarding the cutoff levels of NC in Asian Indian population for determining overweight and obesity. ROC analysis in our study depicted cutoff values of 36.55 cm for males and 34.05 cm for females with maximum sensitivity and specificity. Jean Vague was the first researcher to use a neck skinfold to assess upper BF distribution.<sup>[23]</sup>

The cutoff level used is the NC determined by Ben-Noun *et al.*<sup>[8]</sup> according to which  $NC \geq 37$  cm for men and  $\geq 34$  cm for women were the best cutoff levels for determining the individual with  $BMI \geq 25$  kg/m<sup>2</sup>, which are similar to our study. Our results are also similar to those proposed by Ben-Noun



**Figure 2:** Receiver operating characteristic analysis for the female study participants

*et al.* in Israeli population<sup>[8]</sup> and Yang *et al.* in Chinese population,<sup>[12]</sup> but higher than those proposed by Hingorje *et al.* in Pakistani population.<sup>[24]</sup>

NC is a valid marker for identifying obese individuals and depicts positive correlation with most of the anthropometric variables except that a significant negative correlation was found between NC and height among women, but not in men, in our study results. Similar results were also observed by Ben-Noun *et al.*<sup>[8]</sup> This finding was explained by differences in bodily structures between men and women.

In a population-based evaluation among middle-aged and elderly Turkish adults, NC contributed to obesity and related metabolic disorders such as MetS likelihood beyond other anthropometric and MetS components. Similar relation was depicted in another community-based study done among Chinese type 2 diabetic patients which related NC with BMI, WC, and MS.<sup>[12,25]</sup>

The use of NC in epidemiological research is further favored by many studies done in India and abroad that highlight its role in predicting metabolic abnormalities in adult population.<sup>[26,11]</sup>

## CONCLUSION

The facts and figures depicted in our study illustrate that there was a significant correlation between NCs and different anthropometric measurements in either gender. Keeping these results in mind, the convenience it offers as a simple screening measure to identify overweight and obese people, especially



for clinical practices and epidemiological surveys, cannot be ignored. Particularly in the resource-poor settings of Indian healthcare, NC as an epidemiological tool for predictor of obesity and overweight calls for a wider application in its true context.

### Limitations of the study

The predefined NC cutoff values used in the study do not consider the ethnical differences seen between South Asian population and rest of the world, because of the scarcity of the literature. Although new cutoff values are laid down through this study, more studies involving larger sample size are called for to validate these values for the Indian population that can define overweight and obesity.

### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.

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