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CAN NECK CIRCUMFERENCE BE USED AS AN ALTERNATIVE MEASURE OF CENTRAL OBESITY?

Lisa Roy, Debasmita Kar and Subho Roy

Abstract: Body mass index (BMI) as an indicator of obesity has certain limitations. BMI tends to overestimate body weight in individuals with high muscle mass. As a substitute, waist circumference and waist-hip ratio have been adopted by most healthcare professionals for defining obesity, but they do not necessarily illustrate the difference between upper body and lower body fat. Studies show that neck circumference (NC) plays an important role in predicting cardiovascular risk factors beyond the classical anthropometric measures because it provides an indirect assessment of upper body fat distribution and visceral adiposity. In Indian context, studies regarding the association between NC and obesity are scarce. Thus, the present study intends to compare young adult participants of both sexes for NC, BMI and waist-hip-ratio and to investigate the association of NC with central and general obesity. The study further attempted to create the cut-off points for assessing obesity using neck circumference. A total of 115 participants (65 girls and 50 boys) were recruited for this cross-sectional study from Howrah district of West Bengal. Data on socio-demographic and anthropometric measurements were collected following standard protocols. Independent sample 't' test was applied to compare the anthropometric characteristics between the two sexes. Pearson's correlation was performed to understand the association of neck circumference with BMI and WHR. Receiver operating characteristic curve analysis was performed to determine the cut-offs of NC for all the participants. Our study showed a significant positive correlation of NC with both general and central obesity; though a proper cut-off value of NC has not been established in the case of the present population. We conclude from this study that NC could be used as a tool to measure central obesity and thereby predictors of cardiovascular disease, at least among the young adults of this study populations.

Keywords: Neck circumference, Body mass index, Body fat, Cardiovascular disease, Subcutaneous fat, Central obesity, General obesity

Introduction

The body mass index (BMI) is the most widely used anthropometric measure to define overweight and obesity in adults (Romero-Corral et al., 2008; Bogin and Varela-Silva, 2012; Nuttal, 2015). But BMI as an indicator of obesity has certain limitations. Scholars are critical about the use of BMI as a measure of body fat content because body weight takes into account the muscle mass. Thus, BMI tends to overestimate body weight in individuals with high muscle mass (Romero-Corral et al., 2008; Nuttal, 2015). Scholars argue for other measurements and indices like waist circumference (WC), waist-height ratio, and waist-hip ratio (WHR) for precise assessment of centrally distributed body fat (Haufs and Zölner, 2020).WC and WHR

Lisa Roy, Department of Anthropology, University of Calcutta. E-mail: lisa2000roy@gmail.com; Debasmita Kar, Postdoctoral fellow, ICSSR, Department of Anthropology, University of Calcutta. E-mail: kar92debasmita@gmail.com; Subho Roy, Professor, Biological Anthropology Unit, Indian Statistical Institute. E-mail: srayanth@gmail.com

have been adopted by most healthcare professionals for defining and classifying overweight and obesity, but they do not necessarily illustrate the difference between upper body and lower body fat. Measuring waist circumference can be challenging in certain situations since the clothing of the participant, postural status, respiratory phase, and comfortable ambient temperatures may introduce errors in measurement (Saka et al., 2014; Kornej et al., 2022).

Studies show that neck circumference (NC) plays an important role in predicting cardiovascular risk factors beyond the classical anthropometric measures like BMI, WC, and WHR (Saka et al., 2014; Zhang et al., 2020; Kornej et al., 2022). NC indicates the inter-muscular, subcutaneous and perivertibral fat deposition in the cervical region (Arias-Tellez et al., 2021). The neck region has substantial amount of free-fatty acids which help in lipolysis in the upper body. The excessive release of fatty acids into the plasma from subcutaneous fat in the upper body leads to oxidative stress and insulin resistance, which consequently contribute to cardiometabolic risk factors (Verma et al., 2017). It has been postulated that the fat in the neck region is more similar to the visceral fat which is highly correlated to the cardiometabolic risk than the subcutaneous fat (Joshipura et al., 2016). Thus, NC provides an indirect assessment of upper body fat distribution and visceral adiposity, which are known to be significant risk factors for various health problems including cardiovascular diseases (CVD). For example, the Framingham heart study revealed that NC is independently associated with both general and central obesity and better predicts CVD risk factors like atherosclerosis, myocardial infarction, and atrial fibrillation (Kornej et al., 2022). Thus, NC appears to be an alternative to other body fat measures and is highly correlated with both upper and lower body fat (Ben-Noun et al., 2001; Hingorjo et al., 2012; Qureshi et al., 2017). It also offers excellent inter-observer and intra-observer reliability (Saka et al., 2014).

The utility of neck circumference compared to other standard measurements such as BMI, WC, and waist-height ratio is very less explored. In Indian context, studies regarding the association between NC and obesity are scarce. Majority of the studies used BMI and central obesity as indicators of non-communicable diseases (Prasad et al., 2011; Kar and Roy, 2023). Thus, it is important to estimate the relationship between neck circumference and BMI, and central obesity, and to check if NC can be used as a substitute to other measures of CVD risk factors. It will also be interesting to study the sex-specific differences in neck circumference among young adult populations to understand the trend of overweight and obesity.

Thus, the present study intends to compare young adult participants of both sexes for NC, BMI and WHR and to investigate the association of neck circumference with central and general obesity. The study further attempted to create the cut-off points for assessing obesity using neck circumference.

Materials and methods

Study area

The present cross-sectional study was conducted in the city of Howrah, which is the urban agglomeration of the Howrah district of West Bengal. The city is located in the eastern part of India, on the west bank of the river Hooghly. We selected Howrah Sadar Subdivision as the study area, which includes 50 municipal wards of Howrah Municipal Corporation and 29 municipal wards of Bally Municipality. Only two municipal wards (ward no 23 and 24) under the Howrah Municipal Corporation were selected for the present study.

Study participants

A total of 150 participants were initially recruited on the basis of the following inclusion criteria: participants were from Bengali-speaking Hindu ethnic group, aged between 18 and 30 years, with no recorded history of any metabolic disorders. A total of 35 participants were excluded from the study, either for not meeting the inclusion criteria (n=22) or for not volunteering (n=13) to participate in the study. Finally, a total of 115 participants (65 girls and 50 boys) were recruited for this study. The nature and purpose of the study were explained, and written informed consent was obtained from the participants.

Data collection and data types

The participants were interviewed in person by the first author (LR) to obtain data on socio-demographic characteristics using a pretested structured schedule (Kar and Roy, 2023). Data on socio-demographic characteristics include age of the participants at the time of interview (in years), number of family members, educational levels (in years) and occupational types, and monthly household expenditure (in Indian rupees) of the participants. Per capita expenditure was divided into two categories- <5000 and 5000-10000 (Dasgupta and Ray, 2017). Anthropometric measurements like stature, weight, waist circumference, neck circumference and hip circumference (HC) were measured following standard protocol (Lohman et al., 1988). Stature (to the nearest 0.1 cm) was measured using a portable GPM anthropometric rod for each participant standing without shoes on Frankfurt-horizontal surface. WC and HC were measured to the nearest of 0.1 cm with a non-stretchable measuring tape over light clothing. WC was measured at the minimum circumference of the torso between the iliac crest and the rib cage. HC was measured horizontally at the level of maximum extension of the buttocks. NC was measured by wrapping a non-stretchable measuring tape around the neck at the level of the thyroid cartilage and perpendicular to the long axis of the neck. The tape was placed between the mid-cervical spine and

mid-anterior neck, horizontally (just below the laryngeal prominence), with the participants looking straight ahead, shoulders down and relaxed, but not hunched. Anthropometric indices like body mass index and waist-hip ratio were calculated following standard formulae:

BMI = Weight (kg) / height (m^2)

WHR= WC (cm)/HC (cm)

Statistical analysis

Descriptive statistics was applied to find out the distribution of socio-demographic and anthropometric characteristics (height, weight, BMI, WC, HC, WHR, and NC) of the participants. Kolmogorov-Smirnov test was performed to check the normality of the variables. Independent sample 't' test was applied to compare BMI, WC, HC, WHR, and NC between male and female participants. Pearson's correlation was performed to understand the association of neck circumference with BMI, WC, and WHR. Receiver operating characteristic (ROC) curve analysis was performed to determine the cut-offs of NC in relation to BMI, WC, and WHR for all the participants. A minimum 'p' value of 0.05 was considered as the statistically significant level for all inferential statistics. The entire data was analyzed with the help of statistical package for social science version 20.0(IBM corporation, 2011).The study was conducted during the time period of April to May 2023.

Limitation

The present study has certain limitations. The study would have provided a more precise estimate of the association of neck circumference with central obesity if other variables like blood pressure and blood glucose levels had been incorporated. Despite these limitations, our study highlights the importance of neck circumference as a cost-effective measure and an alternative to BMI and waist circumference, especially in low-resource settings where advanced diagnostic tools are limited.

Results

Socio-demographic variables	*Males (n=50)*	*Females (n=65)*	*t-test / Chi-square test*	*p-value*
Age of the participants (years) at the time of interview (mean±sd)	21.64±3.17	21.70±2.42	0.13	0.89
Occupational categories of the participants Student Working	28 (56.0) 22 (44.0)	56 (86.2) 9 (13.8)	13.05	0.0001

Socio-demographic variables	*Males (n=50)*	*Females (n=65)*	*t-test / Chi-square test*	*p-value*
Educational categories of the participants Higher Secondary Graduation and above	24 (48.0) 26 (52.0)	24 (36.9) 41 (63.1)	1.42	0.23
Per capita expenditure (INR) Less than 5000 5000-10000	29 (67.4) 14 (32.6)	54 (85.7) 9 (14.3)	5.02	0.02

Table 1: Socio-demographic characteristics of the participants (n=115). Figures in the parenthesis indicates percentage value

The table shows that the age of the participants reported at the time of interview and educational categories of the participants did not differ significantly between the male and female participants. The majority of the female participants were students, while 44.0% of the male participants were working. Occupational categories and per capita expenditure of the participants differed significantly between the two sexes (Table 1).

Variables	*Males (n=50)*	*Females (n=65)*	*t value*	*p value*
	mean±sd	*mean±sd*		
Neck Circumference (cm)	36.67±2.91	33.90±2.00	5.74	0.0001
Waist Circumference (cm)	85.56±10.24	82.07±9.76	1.85	0.06
Hip Circumference (cm)	96.26±8.33	97.95±10.60	0.93	0.35
BMI	23.60±4.03	24.63±4.74	0.65	0.51
Waist-hip Ratio	0.88±0.05	0.83±0.05	4.93	0.0001

Table: 2 Comparison of body fat patterning between the male and female participants (n=115)

The table shows that neck circumference and waist-hip ratio differed significantly between the two sexes. Neck circumference and waist-hip ratio were found to be significantly higher among the male participants, while the hip circumference and BMI were found to be higher among the females, though the difference was not significant. Variables like waist circumference, hip circumference, and BMI did not differ significantly between the two sexes (Table 2).

Variables	*Pearson correlation (r)*	*p-value*
Neck circumference and BMI	0.33	0.0001
Neck Circumference and WHR	0.32	0.0001

Table 3: Correlation of neck circumference with BMI and WHR (n=115)

The table exhibited that neck circumference to be positively correlated with both BMI (r= 0.33) and WHR (r=0.32) (table 3).

Variables	*Males (n=50)*	*Females (n=65)*	*Chi-square test/ Fisher's exact test*	*p value*
BMI			0.39	0.94
Underweight (<18.5)	6 (12.0)	7 (10.8)		
Normal (18.5-24.9)	16 (32.0)	18 (27.7)		
Overweight (25-29.9)	9 (18.0)	12 (18.5)		
Obese (≥ 30)	19 (38.0)	28 (43.1)		
WHR			13.65	0.0001
Normal (<0.85)	12 (24.0)	38 (58.5)		
Risk (≥0.85)	38 (76.0)	27 (41.5)		
NC (cm)*			27.03	0.0001
Normal (≤ 36.25)	21 (42.0)	57 (87.7)		
Overweight (>36.25)	29 (58.0)	8 (12.3)		

Figures in the parenthesis indicate percentage value

*The cut-off value of NC has been established by using both BMI (figure 2) and WHR (figure 1)

Table 4: Prevalence of general and central obesity among the participants (n=115)

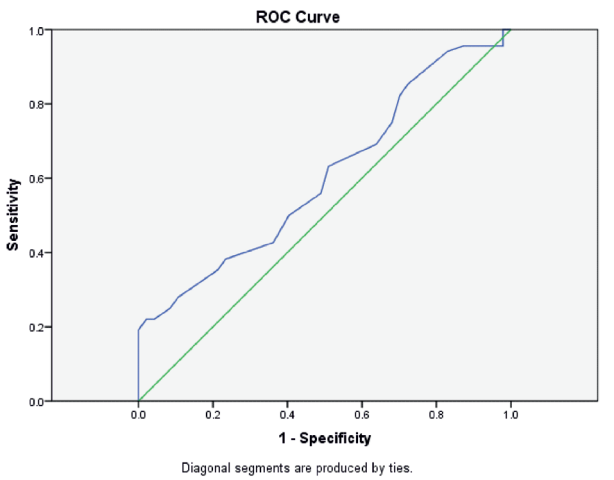

Figure 1: The receiver operating curve (ROC) of NC using WHR for all the participants (n=115)

ROC analysis revealed that NC ≥36.25 as the best cut-off level for identifying the participants with overweight and obesity, with 61% accuracy (AUC= 0.61). The analysis has been performed for all the participants (figure 1).

It appears from the table that the incidence of general obesity was significantly higher among the females (43.1%), while that of central obesity significantly higher among the males (76.0%). The incidence of overweight, following the cut-offs of NC, was found to be significantly higher among the male participants. None of the participants appeared to be obese following the cut-offs of NC (table 4).

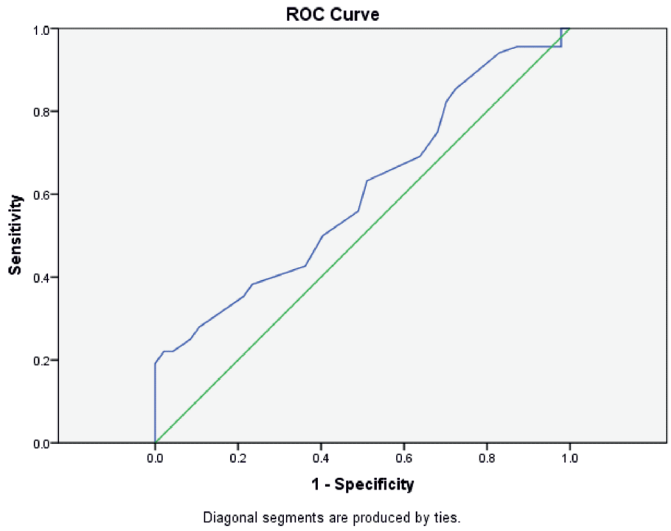

Figure 2: The receiver operating curve (ROC) of NC by using BMI for all the participants (n=115)

ROC analysis revealed that NC ≥ 36.25 to be the best cut-off level for identifying the participants with overweight and obesity, with 60% accuracy (AUC= 0.60) (Figure 2).

Discussion and Conclusion

Our study showed that neck circumference and waist-hip ratio differed significantly between male and female participants. The male participants showed higher values for waist circumference, waist-hip ratio and NC, while the female participants showed higher values for BMI and hip circumference, showing consistency with some studies (Hossain et al., 2019; Prasad et al., 2020), but not with others (Deepa et al., 2009; Muscogiuri et al., 2023). For instance, a study on the adult Chinese populations did not show significant difference in BMI between male and female participants. The same study further showed that females exhibited significantly lower WC, WHR, and NC compared to males, which aligns with the findings of the present study (Yang et al., 2014). In contrast, a couple of studies carried out in India (Prasad et al., 2020) and Bangladesh (Hoque et al., 2017) reported that females have a relatively higher prevalence of central obesity than their male counterparts.

A study conducted among the Malaysian adults reported a higher incidence of general obesity among the female participants compared to the males, which is in line with our findings (Chan et al., 2017). Biological evidence revealed that excess weight gain and the differential metabolism of adipose tissue are related to age and sex, resulting in the occurrence of sex-specific central obesity (Popkin et al., 2012). For example, studies indicate that men are more likely to accumulate visceral or central body fat before reaching the fifth decade of their life, while women tend to develop central adiposity after reaching menopause (Carr, 2003; Prasad et al., 2020). Simpson et al. (2010) explained that lean tissue significantly contributes to the increase in neck circumference for men. In contrast, women might experience an increased neck circumference due to a disproportionate increase in fat, even though women tend to accumulate fat more peripherally than men. Whittle et al. (1999) revealed that the gender differences in fat deposition in the neck region are due to the greater loading of soft tissue on the airway region in men. These may explain the higher prevalence of central obesity and greater neck circumference among the male participants of this present study.

Our study reported a significant positive correlation of NC with both BMI and WHR. Several researchers have identified significant associations of neck circumference with BMI and central obesity (Hingorjo et al., 2012; Yan et al., 2014; Kroll et al., 2017; Raju et al., 2023). These findings align with the present study; but the strength of these associations appears to differ by sex, with males exhibiting a stronger correlation than females (Hingorjo et al., 2012). The present study did not find any significant sex-specific correlation of NC with BMI and WHR, but after considering all the participants, irrespective of sex, significant positive correlation of NC exists with both BMI and central obesity, corroborating with previous studies conducted in India and elsewhere (Hingorjo et al., 2012; Mondal et al., 2017; Zaciragic et al., 2018). For example, a study conducted among Asian Indian adults showed a positive correlation of NC with both general and central obesity (Mondal et al., 2017). A recent study involving young Indian adults showed that neck circumference is significantly associated with general and central obesity in both the sexes. The same study established the cut-off for male and female participants to be ≥34 cm and ≥30.5 cm with a sensitivity of 88.3% and 84.4% for assessing obesity (Raju et al., 2023). Countering this study, a recent study reported a significant positive correlation of NC with central obesity, but not with general obesity (Aswathappa et al., 2014). Another study by Liria-Domínguez et al. (2021) conducted among 9218 individuals from eight Latin American countries indicated moderate positive correlations between NC and central obesity, as well as between NC and general obesity.

With respect to NC, the male participants (58%) showed a higher incidence of overweight compared to the females. We generated the cut-off of NC by using both BMI and WHR. The cut-offs (>36.25) appeared to be the same in both cases, with

41% sensitivity for WHR (AUC=0.61) and 38% sensitivity for BMI (AUC=0.60). Previous studies conducted among the young adults established cut-off values of NC by using BMI with 91% to 98% accuracy for both males and females (Ben-Noun et al., 2001; Patnaik et al., 2017; Turkay and Kabaran, 2022). For example, Coelho et al. (2016) established cut-off values of NC of 40.5 cm for men and 35.7 cm for women in Southeastern Brazil; Saad et al. (2017) developed cut-off values of ≥33.7 cm for women and ≥39.4 cm for men; Baena et al. (2016) established cut-off values of ≥40 cm for men and ≥ 34.1cm for women in Brazil; and Tanaka et al. (2019) created cut-off values of 40.6 cm for men and 34.2 cm for women in Japan. In our study, the AUC values showed that the cut-off value of neck circumference could not accurately differentiate between normal and overweight individuals. Additionally, we could not establish sex-specific cut-offs because of the small sample size.

Finally, our study observes a significant positive correlation of NC with both BMI and waist-hip ratio. This perhaps suggests the use of neck circumference as an indicator of both general and central obesity for this population; though a proper cut-off value of NC has not been established in the case of the present population. Our study adds to the evidence that NC is well correlated with both general and central obesity and may be used as a good marker of CVD and metabolic syndrome and can be used as a surrogate for visceral body fat. These findings suggest the need for further research with a larger and more diverse population to determine ethnic-specific reliable NC cut-off values. Future studies should also consider additional factors such as age and ethnicity to enhance the accuracy of these measurements.

We conclude from this study that NC could be used as a tool to measure central obesity and thereby predictors of CVD, at least among the young adults of this study populations. However, the findings need to be tested across different ethnic groups and age categories.

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