Original Article

Neck Circumference as a Marker of Overweight and Obesity and Cutoff Values for Bangladeshi Adults

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Abstract

Objective: There are several methods of assessing overweight and obesity. Several studies conducted in different populations indicate that neck circumference (NC) can be used as a simple measure of overweight and obesity. This study was conducted to evaluate NC as a marker of overweight and obesity and to determine respective cutoff values for Bangladeshi male and female participants. **Research Design/Materials and Methods:** This cross-sectional observational study was conducted with during July 2013–June 2014 among randomly selected 871 Bangladeshi participants (male = 496 [56.9%], female = 375 [43.1%], aged >18 years) who visited Outpatient Department of United Hospital, Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and Metabolic disorders, primary health-care centers located in Dhaka, Savar, Gazipur. NC of participants was taken in centimeter to the nearest 1 mm, using plastic tape measure. Main outcome included NC, waist circumferences (WC), body mass index (BMI), and waist: hip ratio (WHR). **Results:** Pearson's correlation coefficients indicated a significant association between NC and height (men, $r = 0.33$; women, $r = 0.28$; $P < 0.0001$), weight (men, $r = 0.61$; women, $r = 0.55$; $P < 0.0001$), BMI (men, $r = 0.51$; women, $r = 0.41$; $P < 0.0001$), WC (men, $r = 0.61$; women, $r = 0.46$; $P < 0.0001$), hip circumference (men, $r = 0.61$; women, $r = 0.44$; $P < 0.0001$), WHR (men, $r = 0.22$; women, $r = 0.18$; $P < 0.0001$). Receiver operating characteristic curve analysis showed that NC ≥34.75 cm in men (area under curve [AUC]: 0.77; $P < 0.001$) and ≥31.75 cm in women (AUC: 0.62; $P < 0.001$) were the best cutoff value for BMI ≥23 (overweight). NC ≥35.25 cm in men (AUC: 0.82; $P < 0.001$) and NC ≥34.25 cm in women (AUC: 0.76; $P < 0.001$) were the best cutoff value for BMI ≥27.5 (obesity). NC ≥35.25 cm in male (AUC: 0.83; $P < 0.001$) and NC ≥31.25 cm in women (AUC: 0.65; $P < 0.001$) were the best cutoff value for WC >90 cm in men and > 80 cm in women, respectively. NC ≥34.45 cm in male (AUC: 0.59; $P = 0.001$) and NC ≥31.25 cm in women (AUC: 0.66; $P = 0.008$) were the best cutoff value for WHR >0.9 in men and >0.8 in women, respectively. **Conclusion:** NC measurement is a simple, convenient, inexpensive screening measure to identify overweight and obese participants. Men with NC ≥34.75 cm and women with NC ≥31.75 cm are to be considered overweight while men with NC ≥35.25 cm and women with NC ≥34.25 cm are to be considered obese. NC ≥35.25 cm in male and NC ≥31.25 cm in women were the best cutoff value for abdominal obesity.

Keywords: Bangladeshi men and women, height, neck circumference, obesity, overweight, waist circumference, waist:hip ratio, weight

Introduction

Overweight and obesity are the terms used to define weight- and height-related anthropometric measures above the cutoff values recommended for the age and sex that poses various metabolic derangements to body and subsequent increase in morbidities and mortality. Once considered as a health-related problem for developed countries, overweight and obesity have become common globally. In 1997, the World Health Organization (WHO) has declared this condition as a global epidemic.[1] According to the International Obesity Task Force report, in 2010, the number of overweight and obese people globally was estimated nearly 1.0 billion and 475 million, respectively. Using Asian

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cutoff value for body mass index (BMI), the number of obese people increased to 600 million.[2] Childhood obesity is increasing in the same trend and it has been estimated that near about 200 million school-going children are overweight or obese.[2]

To define nutritional status and grade overweight and obesity, there are several anthropometric measures. Among them, mostly used measures are BMI, waist circumference (WC), hip circumference (HC), and waist: hip ratio (WHR). Other procedures such as ultrasonography, computed tomography scan, and magnetic resonance imaging scan are expensive, less cost-effective and used for research purposes only.[3] Nowadays, neck circumference (NC) is deserving mentionable magnitude.[4-7]

Vague, who was the first to describe that different body morphology and types of fat distribution are related to health-related risks, used neck skin-fold thickness as an index for assessing upper body fat distribution.[7] Through subsequent studies, it has been found that upper body obesity and fat distribution are more strongly associated with glucose intolerance, hyperinsulinemia, diabetes mellitus, hyperuricemia, gout, hypertriglyceridemia, uric calculus, etc., than lower body obesity and fat distribution.[3,7]

Though BMI and WC have been adopted by most health-care professionals for defining and classifying overweight and obesity, they do not necessarily illustrate the body composition regarding upper body and lower body morphology and fat distribution. Hence, it has been suggested that NC can be a good index for defining upper body fat distribution, overweight, and obesity.[4] Moreover, in busy everyday primary care practice, NC can be used as a convenient tool to define and grade overweight and obesity.

Several studies have been conducted in different populations which indicate that NC can be used as a simple measure for overweight and obesity.[4,6] Yet, no such study of this kind has been done in Bangladesh. This study has been designed to evaluate NC as a marker of overweight and obesity and to define respective cutoff values for Bangladeshi male and female.

Materials and Methods

Study design and research ethics

This cross-sectional study was conducted between July 2013 and June 2014. Bangladeshi adult participants, aged more than 18 years, both male and female, who visited Outpatient Department of United Hospital, Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and Metabolic Disorders, primary health-care centers located in Dhaka, Savar, Gazipur, were randomly selected. Those having goiter, cervical lymphadenopathy, cystic or mass lesion in the neck or any anatomical abnormality of the neck region, ascites, intra-abdominal organomegaly or intra-or extra-abdominal mass lesion, kyphosis, scoliosis or any anatomical abnormality of the waist and hip region, pregnancy, and participants suffering from severe comorbid conditions were excluded from the study. After exclusion, a total of 871 participants were included in the study. The data were collected in a preformed standard printed data collection form after explaining the study purpose, procedure, and taking informed consent from the study participants. All coresearchers involved in data collection were briefed and trained before commencement of the study.

Study tools

a. Participants were examined regarding height, weight, BMI, WC, HC, WHR, and NC
   1. Height (cm): Standing height was measured in centimeter (cm) using stadiometer and height rod (Detecto Scale Company, USA) with minimal clothes. The participant was positioned fully erect, with the head in the Frankfurt plane (with the line connecting the outer canthus of the eyes and the external auditory meatus perpendicular to the long axis of the trunk), the back of the head, thoracic spine, buttocks, and heels touched the vertical axis of the anthropometer, and the heels were together. Height was recorded to the nearest 1 mm. If the reading fell between two values, the lower reading was recorded
   2. Weight (kilogram [kg]): Standard weight measuring device was used that was placed on a hard flat surface and checked for zero balance before measurement. Each participant was placed in the center of the platform wearing light clothes without shoes, after emptying bladder. Weight was recorded to the nearest 0.5 kg
   3. BMI: BMI of participants were calculated by dividing weight in kg with the square of height in meter using formula kg/m^2
   4. WC: WC was measured in centimeter to within 1 mm that was taken horizontally in using plastic tape measure at midpoint between the costal margin and iliac crest in the midaxillary line, with the participant standing and at the end of a gentle expiration. Average of two readings was used for analysis
   5. HC: HC was measured in centimeter using a plastic tape measuring, at the horizontal level of greater trochanters, with the legs close together. Average of two readings was used for analysis
   6. WHR: WC was divided by HC to get the WHR
   7. NC: NC of participants was taken in centimeter to the nearest 1 mm, using plastic tape measure. It was taken in a plane as horizontal as possible, at a point just below the larynx (thyroid cartilage) and perpendicular to the long axis of the neck (the tape line in front of the neck at the same height as the tape line in the back of the neck). While taking this reading, the participant was asked to look straight ahead, with shoulders down, but not hunched. Care was taken not to involve the shoulder/neck muscles (trapezius) in

the measurement. Average of two readings was used for analysis.

a. Primary outcomes of this study were NC, BMI, WC, and WHR.
   1. BMI: As specified for the Asia-Pacific population by the Western Pacific Regional Office of the WHO, BMI was classified as following: BMI <18.50 kg/m^2: underweight; BMI 18.50–22.99 kg/m^2: Normal; BMI ≥23.00–27.49 kg/m^2: Overweight, and BMI ≥27.5.00 kg/m^2: Obesity[8-10]
   2. WC*:* WC >90 cm in male and >80 cm for female were used for data analysis as cutoff values to define abdominal obesity[10-12]
   3. WHR*:* The data were analyzed using cutoff values >0.9 for male and >0.8 for female to define obesity.[10,13]

Statistical analysis

Data were collected in preformed record form and were analyzed with IBM SPSS for Windows version 20 (IBM SPSS Statistics for Windows, Version 20.0. IBM Corp. Armonk, NY, USA). All data were analyzed and reported by sex. The means and standard deviations (SD) were used to describe continuous data. For categorical data, frequencies and percentages were estimated. The significance of differences in proportions was tested using Chi-square test. The associations between NC and anthropometric parameters of studied participants were assessed using Pearson's correlation analysis. Receiver operating characteristic (ROC) curve analysis was employed to determine optimal sex-specific cutoffs of NC in relation to BMI, WC, and WHR. Statistical significance was set at $P < 0.05$.

Results

Among 871 studied participants, 496 (56.9%) were male and rest were female (43.1%) and their anthropometric and metabolic characteristics are presented in Table 1. Mean BMI (kg/m^2) was 22.71 ± 3.49 and female had higher BMI than male (female: 23.42 ± 3.70, male: 22.17 ± 3.23). According to BMI, totally 35.1% of participants were overweight and 9.2% were obese. Compared to male, female were more overweight (male = 31.9%, female = 39.5%) and obese (male = 6.3%, female = 13.1%) [Table 2]. As mean ± SD, WC (cm) of studied participants was as follows: total participants: 82.02 ± 8.47, in male: 82.32 ± 7.87 and in female: 81.62 ± 9.20. As per WC, 16.9% of men and 49.1% of women had abdominal obesity. As mean ± SD, HC (cm) of studied participants was as follows: Total participants: 90.30 ± 7.38, in male: 90.20 ± 6.90 and in female: 90.43 ± 7.98 and WHR was as follows: total participants: 0.91 ± 0.06, in male: 0.91 ± 0.05 and in female: 0.90 ± 0.06 [Table 1].

Mean of NC (cm) of studied participants was 33.45 ± 2.22 and was higher in male than female participants (in male: 34.16 ± 1.95 and in female: 32.50 ± 2.20) [Table 1]. The Pearson's correlations between NC and studied parameters showed positive and significant correlation with weight (total participants: $r = 0.59$, $P < 0.001$; in male: $r = 0.61$, $P < 0.001$ and in female: $r = 0.55$, $P < 0.001$), BMI (total participants: $r = 0.36$, $P < 0.001$; in male: $r = 0.51$, $P < 0.001$ and in female: $r = 0.41$, $P < 0.001$), WC (total participants: $r = 0.51$, $P < 0.001$; in male: $r = 0.61$, $P < 0.001$ and in female: $r = 0.46$, $P < 0.001$), and HC (total participants: $r = 0.48$, $P < 0.001$; in

Table 1: Anthropometric and metabolic characteristics of studied participants

Studied parameters	Mean±SD		
	Total participants (*n*=871)	Male (*n*=496; 56.9%)	Female (*n*=375; 43.1%)
Age (years)	30.97±10.74	30.81±10.24	31.18±11.37
Height (meter)	1.61±0.08	1.64±0.06	1.56±0.06
Weight (kg)	58.65±9.66	59.89±9.82	57.02±9.21
BMI (kg/m^2)	22.71±3.49	22.17±3.23	23.42±3.70
SBP (mmHg)	115.91±13.29	116.17±12.44	115.57±14.36
DBP (mmHg)	75.47±8.08	75.84±7.72	74.99±8.51
WC (cm)	82.02±8.47	82.32±7.87	81.62±9.20
HC (cm)	90.30±7.38	90.20±6.90	90.43±7.98
WHR	0.91±0.06	0.91±0.05	0.90±0.065
NC (cm)	33.45±2.22	34.16±1.95	32.50±2.20

N.B.: As mean±SD, parameters of studied participants. SBP: Systolic blood pressure, DBP: Diastolic blood pressure, SD: Standard deviation, BMI: Body mass index, WC: Waist circumference, HC: Hip circumference, WHR: Waist:hip ratio, NC: Neck circumference

Table 2: Body mass index status of studied participants

	Studied participants according to BMI (kg/m^2)			
	Underweight (%)	Normal (%)	Overweight (%)	Obesity (%)
Total	10.3	45.4	35.1	9.2
Male	11.8	50	31.9	6.3
Female	8.2	39.2	39.5	13.1

N.B.: As per Asian cutoff value. Overweight: BMI ≥23.00-27.49 kg/m^2, Obesity: BMI ≥27.5.00 kg/m^2. BMI: Body mass index

male: $r = 0.61$, $P < 0.001$ and in female: $r = 0.44$, $P < 0.001$) of studied participants while WHR ratio was less positively correlated with NC (total participants: $r = 0.23$, $P < 0.001$; in male: $r = 0.22$, $P < 0.001$ and in female: $r = 0.18$, $P < 0.001$). NC was more correlated with weight, BMI, WC, and HC of male participants than that of female participants [Table 3].

ROC curve analysis was used to determine sex-specific the best cutoff values of NC in relation to BMI, WC, and WHR. In male, ROC curve analysis indicated that NC ≥34.75 cm (area under curve [AUC] = 0.77, 95% confidence interval [CI] = 0.73–0.82, $P < 0.001$) and ≥35.25 cm (AUC = 0.82, 95% CI = 0.73–0.89, $P < 0.001$) were the best cutoff levels to determine overweight (BMI ≥23) and obese (BMI ≥27.5) participants, respectively [Figures 1 and 2]. For defining abdominal obesity, ROC curve analysis suggested that NC ≥35.25 cm (AUC = 0.83, 95% CI = 0.78–0.88, $P < 0.001$) was the best cutoff value corresponding to WC >90 cm [Figure 3]. However, NC ≥34.45 cm (AUC: = 0.59, 95% CI = 0.54–0.64, $P = 0.001$) was the best cutoff value for WHR >0.9, which was less positively correlated [Figure 4].

In female, ROC curve analysis suggested that NC ≥31.75 cm (AUC = 0.62, 95% CI = 0.56–0.68, $P < 0.001$) and ≥34.25 cm (AUC = 0.76, 95% CI = 0.69–0.84, $P < 0.001$) were the best cutoff values to determine overweight (BMI ≥23) and obese (BMI ≥27.5) participants, respectively [Figures 5 and 6]. For defining abdominal obesity, ROC curve analysis suggested that NC ≥31.25 cm (AUC = 0.65, 95% CI = 0.59–0.70, $P < 0.001$) was the best cutoff value for corresponding to WC >80 cm [Figure 7]. NC ≥31.25 cm (AUC: = 0.65, 95% CI = 0.53–0.77, $P = 0.008$) was the best cutoff value for WHR >0.8 [Figure 8].

Discussion

Upper body fat distribution has been considered as risk factor of cardiovascular disease.[7] It has been reported that

Table 3: The Pearson's correlations between neck circumference and studied obesity parameters

Studied parameters	Correlation between NC and studied parameters					
	Total (n=871)		Male (n=496)		Female (n=375)	
	r	*P*	*r*	*P*	*r*	*P*
Height (m)	0.44	<0.001	0.33	<0.001	0.28	<0.001
Weight (kg)	0.59	<0.001	0.61	<0.001	0.55	<0.001
BMI (kg/m^2)	0.36	<0.001	0.51	<0.001	0.41	<0.001
SBP (mmHg)	0.13	0.001	0.09	0.03	0.16	<0.01
DBP (mmHg)	0.18	0.001	0.16	<0.001	0.19	<0.001
WC (cm)	0.51	<0.001	0.61	<0.001	0.46	<0.001
HC (cm)	0.48	<0.001	0.61	<0.001	0.44	<0.001
WHR	0.23	<0.001	0.22	<0.001	0.18	<0.001

N.B.: Analysis done with Pearson's correlation coefficient. (r=0-1, more value more correlation). SBP: Systolic blood pressure, DBP: Diastolic blood pressure, BMI: Body mass index, WC: Waist circumference, HC: Hip circumference, WHR: Waist:hip ratio, NC: Neck circumference

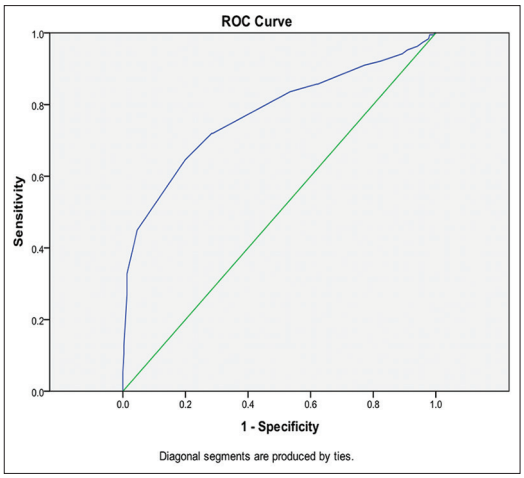

Figure 1: Receiver operating characteristic curve for neck circumference in male overweight participants (body mass index ≥23). NB: Neck circumference cutoff value: ≥34.75 cm

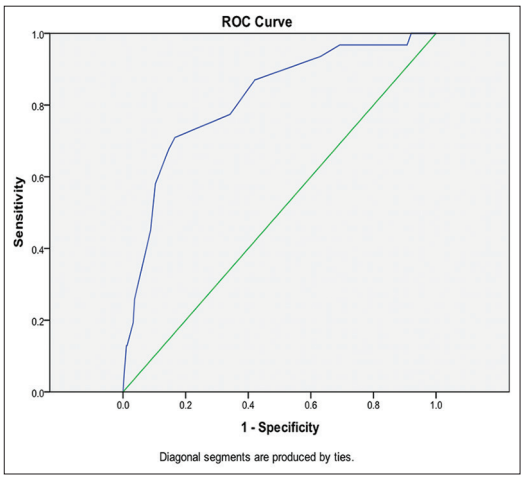

Figure 2: Receiver operating characteristic curve for neck circumference in male obese participants (body mass index ≥27.5). NB: Neck circumference cutoff value: ≥35.25 cm

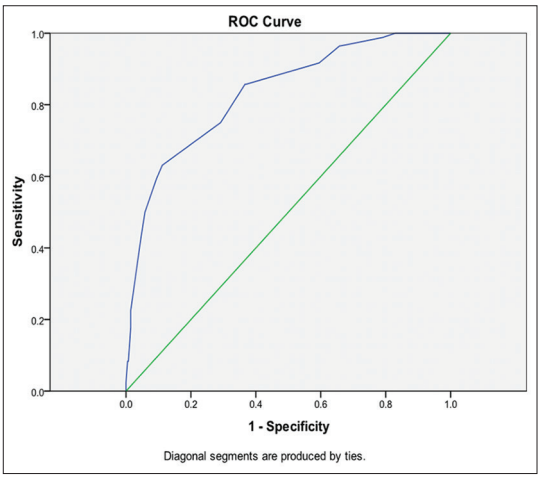

Figure 3: Receiver operating characteristic curve for neck circumference in male participants with abdominal obesity (waist circumference >90 cm). NB: Neck circumference cutoff value: ≥35.25 cm

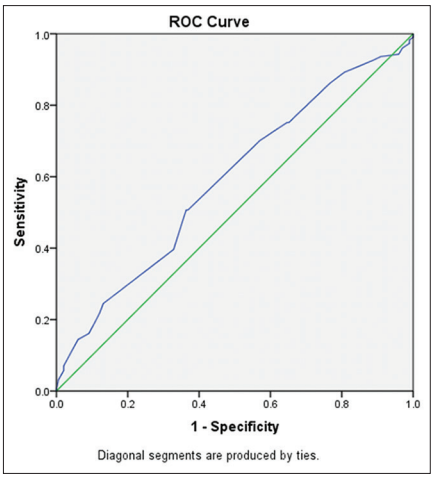

Figure 4: Receiver operating characteristic curve for neck circumference in male subjects with abdominal obesity (Waist: Hip ratio >0.9). N.B.: NC cut-off value: ≥34.45 cm

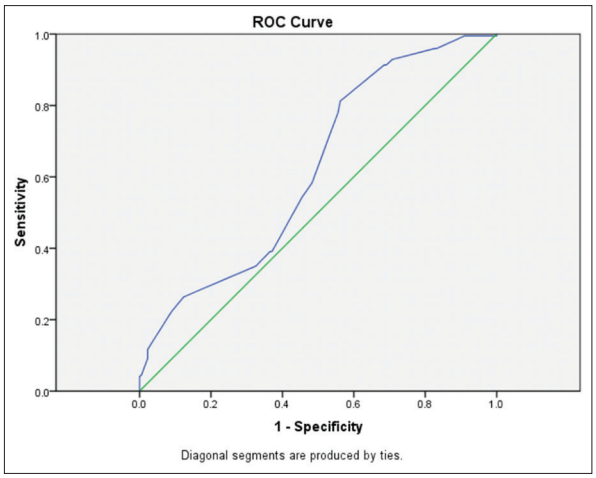

Figure 5: Receiver operating characteristic curve for neck circumference in female overweight participants (body mass index ≥23). NB: Neck circumference cutoff value: ≥31.75 cm

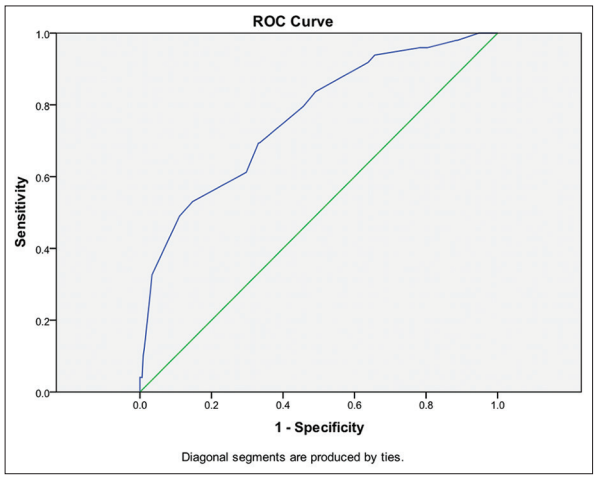

Figure 6: Receiver operating characteristic curve for neck circumference in female obese participants (body mass index ≥27.5). NB: Neck circumference cutoff value: ≥34.25 cm

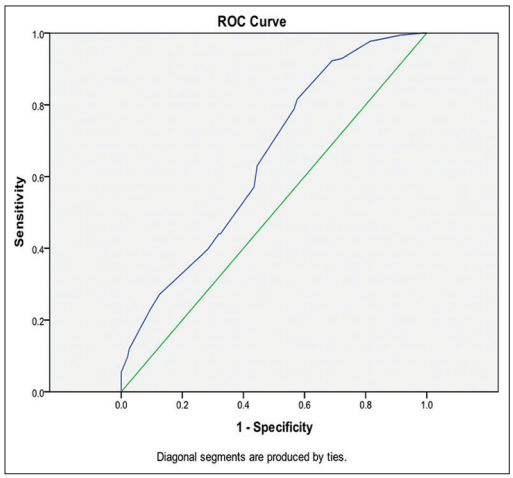

Figure 7: Receiver operating characteristic curve for neck circumference in female participants with abdominal obesity (waist circumference >80 cm). NB: Neck circumference cutoff value: ≥31.25 cm

free fatty acids are released in larger proportion from upper body subcutaneous fat than lower body subcutaneous fat.[14] Moreover, NC has been used as an index for such an adverse risk profile.[15,16]

This study evaluated NC as a marker of overweight and obesity and suggestive respective cutoff values have been determined. Of 871 studied participants, mean of NC was 33.45 ± 2.22 cm. Male had higher NC than that of female participants (as mean ± SD, in male: 34.16 ± 1.95 cm and in female: 32.50 ± 2.20 cm). NC showed positive and significant correlation with BMI, WC, and HC of studied participants. With ROC curve analysis, sex-specific the best cutoff values of NC in relation to BMI, WC, and WHR were determined. NC ≥34.75 cm in men (AUC: 0.77; $P < 0.001$) and ≥31.75 cm in women (AUC: 0.62; $P < 0.001$) were the best cutoff values corresponding to BMI ≥23 (overweight). For obesity (BMI ≥27.5), NC ≥35.25 cm in men (AUC: 0.82; $P < 0.001$) and ≥ 34.25 cm in women (AUC: 0.76; $P < 0.001$) were the best cutoff values. For abdominal obesity, NC ≥35.25 cm in male (AUC: 0.83; $P < 0.001$) and ≥31.25 cm in women (AUC: 0.65; $P < 0.001$) were the best cutoff values corresponding to WC >90 cm in men and >80 cm in women, respectively. For WHR >0.9 in men and >0.8 in women, NC ≥34.45 cm in male (AUC: 0.59; $P = 0.001$) and ≥31.25 cm in women (AUC: 0.66; $P = 0.008$) were the best cutoff values.

In a similar study but smaller sample size conducted in this region (41 male and 109 female, aged 18–20 years) also reported, NC was found higher in males than in females (35.56 ± 2.77 cm vs. 31.52 ± 1.96 cm, $P < 0.001$). NC had a strong and positive correlation ($P < 0.001$) with BMI ($r = 0.861$, $P < 0.0001$ in males; $r = 0.704$, $P < 0.0001$ in females) and WC ($r = 0.858$, $P < 0.0001$ in males; $r = 0.623$, $P < 0.0001$ in females). At BMI of 23.0 and 25.0, males had

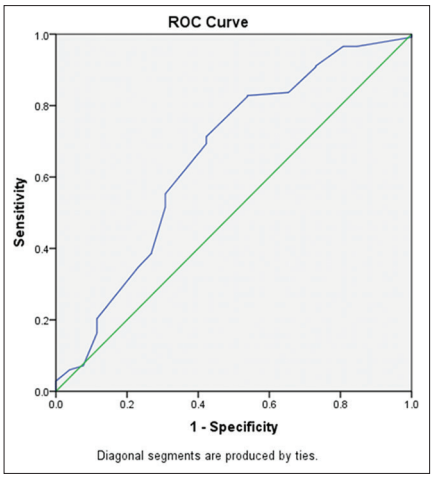

Figure 8: Receiver operating characteristic curve for neck circumference in female participants with abdominal obesity (waist: hip ratio >0.8). NB: Neck circumference cutoff value: ≥31.25 cm

NC 35.7 cm and 37.5 cm while females had it at of 32.2 cm and 33.5 cm respectively.[6]

In another study (979 Israeli participants, 460 men and 519 women), significant association was found between NC and BMI (men, r = 0.83; women, r = 0.71; each, P = 0.0001), WC (men, r = 0.86; women, r = 0.85; each, P = 0.0001), HC (men, r = 0.62; women, r = 5 0.56; each, P = 0.0001), and WHR (men, r = 5 0.66; women, r = 0.87; each, P = 0.0001). NC ≥37 cm for men and ≥34 cm for women were the best cutoff levels for determining the participants with BMI ≥25.0 kg/m^2 using ROC analysis, and NC ≥39.5 cm for men and ≥36.5 cm for women were the best cutoff levels for determining the participants with BMI ≥30 kg/m^2.[4]

The study has several limitations. Sample size was small, selected from few health-care facilities that cannot be generalized over the whole population. Age group-specific cutoff points were not determined. Urban and rural stratification was not done. NC was not studied in relation to metabolic components as well. Despite the limitations, the study has important implications that points that in detection of overweight/obesity in adults NC can be a practical and an easier alternative tool.

Conclusion

NC measurement as a simple and time-saving screening measure could be used to identify overweight and obese population. It is a straightforward, easy, and inexpensive tool that can be performed in any situation with a tape measure. This study, conducted among Bangladeshi participants, has suggested that men with NC ≥34.75 cm and women with NC ≥31.75 cm are to be considered overweight while men with NC ≥35.25 cm and women with NC ≥34.25 cm are to be considered obese. NC ≥ 35.25 cm in male and NC ≥ 31.25 cm in women were the best cutoff value for abdominal obesity. Further studies with age-grouped, urban-rural stratified in larger sample are required for validation of this tool.

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Conflicts of interest

There are no conflicts of interest.

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