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Research article

Mid-upper arm circumference and neck circumference to screen for overweight-obesity in young adults in South India

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ABSTRACT

Introduction: There are many anthropometric techniques to screen for overweight-obesity like the body mass index (BMI), waist circumference (WC), and waist-hip ratio (WHR). These may be difficult or less acceptable in community and outpatient settings. We determine the cut-offs of mid-upper arm circumference (MUAC) and neck-circumference (NC) to screen overweight (BMI ≥25 kg/m^2), abdominal obesity by waist circumference (WC; men: ≥90 cm; women: ≥80 cm) and high percent body fat (PBF) (men: ≥20%; women: ≥30%) and explore participant preference for various anthropometric methods.

Method: ology: We enrolled 282 medical students in South India and performed anthropometry (height, weight, WC, MUAC and NC), bio-impedance analysis (BIA, Inbody 770) to detect PBF. Receiver operator curves were generated and best cut-offs derived using highest Youden Index (sensitivity + specificity-1).

Results: Of the 282 participants, 83 (29.4%) were overweight, 113 (38.7%) had abdominal obesity and 186 (66%) had higher PBF. The MUAC cut-off was 31.3cm for men (sensitivity: 86%; specificity: 74%) to detect overweight and 31.2 cm (sensitivity: 85%; specificity: 73%) to detect abdominal obesity. The corresponding cut-offs in women were 28.5 cm (sensitivity:88%; specificity: 83%) to detect overweight and 28.3 cm (sensitivity: 74%; specificity: 92%) for abdominal obesity. For NC, the proposed cut-off in men was 36.6 cm (sensitivity: 81%; specificity: 82%) for overweight and 37.1 cm (sensitivity:78%; specificity:82%) for abdominal obesity. In women, this was 31.4 cm for both overweight as per BMI (sensitivity: 88%; specificity: 71%) and for abdominal obesity (sensitivity: 75%; specificity: 81%). Neck circumference was preferred by 225 (79.8%) participants.

Conclusion: Both MUAC and NC can be considered for screening overweight and abdominal obesity with good sensitivity and specificity but their sensitivity and specificity for screening high PFB were not very good. Neck circumference was the most preferred anthropometric method.

1. Introduction

Prevalence of overweight in India was 19% in men and 21% in women in the National Family Health Survey—4 (NFHS-4, 2015–16) and this has increased to 22.9% in men and 24% in women in NFHS—5 (2019–21) [1,2]. This was determined using the World Health Organization (WHO) cut-offs for body mass index (BMI), a simple and easy tool for large scale surveys. However, it has certain limitations. First, it does not distinguish between fat mass and lean body mass [3]. Second in Asians, there is predisposition to develop insulin resistance and cardiovascular risk factors at lower levels of BMI compared to other ethnic groups and a higher prevalence of abdominal obesity. Waist circumference (WC) has been used as indicator to detect abdominal obesity and is useful in predicting cardiovascular risk factors in primary care settings [4]. However, cultural acceptability, time consuming nature during busy outpatient work, and the requirement to uncover some parts of the body and especially challenging in winter, busy primary care centres and community settings are some limitation of WC [5].

There are more accurate research grade methods available to identify fatness, and these include body composition using Bio-impedance Analysis (BIA) and dual energy X-ray absorptiometry (DEXA) scan. Unfortunately, these are not practical due to higher cost, time consuming nature in busy outpatient clinics and their non-availability in primary care settings. Neck circumference (NC) and mid-upper arm circumference

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(MUAC) are other anthropometric methods that have been proposed for screening for overweight and obesity and have shown associations with many metabolic risk factors [5,6,7,8]. Their advantages in terms of practicality, simplicity and being less time consuming make them attractive options [8,9]. However, no universal cut-offs are available for use. The objective of the present study was to determine the optimum cut-offs of MUAC and NC to screen for overweight, abdominal obesity and body fat in young adults and their preferences among various anthropometric techniques.

2. Material and methods

We conducted a cross-sectional study among the medical students of a tertiary teaching hospital in Mangalore, South India during July–September 2019. Each year the college inducts about 150 students and at a time there are more than 500 students studying in the campus. We calculated sample size using single proportion formula and considered the prevalence of overweight as 20% according to NFHS-4 [1]. With an absolute error of 5% and 10% non-enrolment rate, the estimated sample size was 282 participants. The study objectives were disseminated in the campus and the participants were invited to come to a designated anthropometric measurement room available in the institution for further information and possible participation. Participants with unintentional weight loss, neck swelling due to any reason, unable to stand for any reasons, where height and various circumferences cannot be taken, were excluded. We identified neck-swelling such as that due to thyroid and lymphadenopathy using routine clinical examination of the neck. We conducted anthropometry that included height, weight, WC, MUAC and NC; and body composition to determine the percentage body fat (PBF) using BIA (Inbody 770).

2.1. Measurements and operational definitions

All measurements were done in a dedicated room for maintaining privacy of the participants. Weight and height were recorded with accuracy of 100 g and 0.1 cm (Model: SECA 803; Model: SECA 213 respectively) with standard methodology. BMI was calculated using the formula: weight in kilogram/(height in meter)^2. Overweight was defined using the WHO cut-offs (BMI $\geq$25 kg/m^2). Waist circumference was measured in a horizontal plane, midway between the inferior margin of the lowest ribs and superior border of the iliac crest [10]. A WC $\geq$ 90 cm in men and 80 cm in women were used as cut-offs for central/abdominal obesity as per the recommendations of International Diabetes Federation [4]. Mid-upper arm circumference was measured with the calibrated plastic tape (Model: SECA 201) in the right upper arm at the midpoint of the tip of the shoulder (acromion process) and tip of the elbow (olecranon process). Neck circumference was measured in the midway of the neck, between mid-cervical spine and mid-anterior neck, with 1 mm precision. In men with a laryngeal prominence (Adam's apple), it was measured just below the prominence. Body composition and PBF was determined using Bio Impedance Analyzer (BIA) machine (Model: Inbody 770) and a PBF of $\geq$20 in males and $\geq$28 in females was considered as high [11]. For the BIA, protocol provided by the manufacturer was followed. Participants were made to stand on the electrodes on the foot-plate after wiping the soles with a tissue paper. After that, they were to hold the electrode handles with palm, thumb and fingers of both the hands and stand still for a minute to measure the PBF. Preference for anthropometric assessment was determined by asking the participants to grade their preference for height, weight, WC, MUAC and NC into preferred, not preferred or neutral categories.

2.2. Statistical analysis

Data were entered into Microsoft Office Excel 2007 and analyzed using Statistical Package for the Social Sciences (SPSS) for Windows, Version 23.0 (Version 23.0 Armonk, and NY: IBM Corp). Normality was checked for all the continuous variables (all anthropometric indicators, body fat percentage) using Kolmogorov-Smirnov test to confirm normal distribution. Descriptive statistics were computed and reported as mean (SD) and median (IQR) for continuous variables and as frequencies and proportions for categorical variables. Prevalence of overweight, abdominal obesity and PBF was compared between men and women using Chi-squared test and a p-value of 0.05 was considered as significant. Sex stratified receiver operating curves (ROC) were plotted for MUAC and NC to identify the best cut-offs for overweight-obesity with respect to the WHO classification for BMI, WC, and body composition using BIA. The area under the curves (AUC) with 95% confidence intervals (95%CI) were generated and cut-offs points identified using Youden index (J statistic). It is a single statistic that captures the performance of a diagnostic test where "J = sensitivity + specificity—1" [12]. After defining the Youden index for all points of the ROC curve, the maximum values of Youden index were utilized to guide the best cut-off of MUAC and NC.

2.3. Ethics approval

Approval of Institutional Ethics committee of University was obtained before the commencement of the study (YEC-1 2019/132). Participation was voluntary following a due consent process. Privacy and confidentiality was maintained throughout the study.

3. Results

We enrolled 282 medical students (131, 46.5% males; 151, 53.5% females). The mean age of the participants was 21.3 years (SD: 1.3). Table-1 describes mean and medians of all the anthropometric assessment parameters employed in this study.

Table 2 describes the nutritional status of the participants. Using WHO cut-offs for BMI, 83 (29.4%) participants were overweight (BMI: 25–29.9 kg/m^2) and 109 participants (38.7%) with abdominal obesity. All the participants underwent body composition analysis, 71 (54.2) men and 114 (75.5%) women participants had excess of PBF.

Table 3 describes proposed cut-offs for men and women in the study population for MUAC and NC, their respective sensitivity and specificity and the AUCs (95%CI) to screen for overweight, abdominal obesity, and high PBF. Using the highest Youden index to identify the cut-offs, we found MUAC of 31.3cm for men (sensitivity: 86%; specificity: 74%) to detect overweight and 31.2 cm (sensitivity: 85%; specificity: 73%) to

Table-1. Anthropometric assessment and body fat percentage of study participants (N = 282).

Anthropometric indicator	Men (n = 131)		Women (151)	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
Weight (kg)	72.0 (13.1)	70.9 (167.7, 177.8)	58.2 (9.9)	57.4 (155.0, 163.0)
Height (cm)	172.2 (6.8)	173 (62.6, 80.9)	159.1 (5.7)	159 (51.3, 63.9)
BMI (kg/m^2)	24.2 (3.9)	23.8 (21.2, 26.8)	23.0 (3.7)	22.7 (20.5, 25.6)
WC (cm)	84.8 (10.4)	83.5 (77.0, 92.0)	79.2 (10.2)	78.5 (72.0, 84.9)
Body fat (%)	22.1 (7.3)	20.3 (16.7, 28.8)	33.8 (7.8)	34.0 (28.1, 39.2)
MUAC (cm)	30.9 (3.4)	30.6 (28.2, 33.1)	27.5 (3.4)	27.3 (25.3, 29.9)
NC (cm)	36.6 (2.4)	36.4 (34.8, 37.7)	31.1 (1.9)	31.2 (29.9, 32.3)

SD = Standard Deviation; IQR = Interquartile range; BMI = Body mass index; WC = weight circumference; MUAC = Mid upper arm circumference; NC = Neck circumference.

Table 2. Anthropometry of study participants using body mass index, waist circumference and percent body fat (N = 282).

Nutritional status	N	Men (n = 131) (%)	Women (n = 151) (%)	p-value*
BMI (WHO criteria)				
Underweight (<18.5 kg/m^2)	24 (8.5)	5 (3.8)	19 (12.6)	p = 0.025
Normal (18.5–24.9 kg/m^2)	160 (56.7)	74 (56.5)	86 (57.0)	
Overweight (25–29.9 kg/m^2)	83 (29.4)	42 (32.1)	41 (27.2)	
Obese (≥30 kg/m^2)	15 (5.3)	10 (7.6)	5 (3.3)	
Waist Circumference				
Normal	173 (61.3)	90 (68.7)	83 (55.0)	p = 0.020
Overweight (≥90 cm in men; ≥ 80 in women)	109 (38.7)	41 (31.3)	68 (45.0)	
Body Fat Percentage#				
Normal	97 (34.4)	60 (45.8)	37 (24.5)	P < 0.001
Overweight (≥20% in men; ≥ 28% in women)	185 (65.6)	71 (54.2)	114 (75.5)	

* Chi-square test.
# Percent body fat was estimated using InBody 770 Bioimpedence analyzer.

detect abdominal obesity. The corresponding cut-offs in women were 28.5 cm (sensitivity of 88%; specificity of 83%) to detect overweight and 28.3 cm (sensitivity of 74%; specificity of 92%) for abdominal obesity. For NC, the proposed cut-off in men was 36.6 cm (sensitivity: 81%; specificity: 82%) for overweight and 37.1 cm (sensitivity: 78%; specificity: 82%) for abdominal obesity. In women, this was 31.4 cm for both overweight as per BMI (sensitivity: 88%; specificity: 71%) and for abdominal obesity (sensitivity: 75%; specificity: 81%). Mid-upper arm circumference cut-off to detect high PBF was 30.5 cm in men (sensitivity: 77%; specificity: 72%) and 25.7 cm in women (sensitivity: 87%; specificity: 76%) and that for NC was 36.6 cm in men (sensitivity: 68%; specificity: 80%) and 31.1 cm in women (sensitivity: 63%; specificity: 78%).

Figure 1 shows the ROC curves for MUAC and Figure 2 for that of NC against the BMI, WC and PBF.

As far as the preferences were concerned, NC was the most preferred anthropometric technique for 225 (79.8%) participants (82.4% men and 77.5% women) followed by waist circumference (214, 75.9%) as described in Table 4. There was no difference in preferences amongst men and women ($p > 0.05$).

4. Discussion

This study was done to determine the optimum cut-offs for MUAC and NC to screen for overweight, abdominal obesity and high body fat. We found that an MUAC cut-off of 30.5–31.3 cm can predict BMI ≥25 kg/m^2, WC ≥ 90 cm and high percent body fat of ≥20% in men. In case of women, 28.3–28.5 cm can be used to screen for overweight as per BMI and WC, but the cut-off to screen for high PBF is much lower (25.7 cm). In case of NC, cut-offs of 36.6–37.1 cm in men and 31.1–31.4 cm in women had good sensitivity and specificity for overweight as well as abdominal obesity. NC had good specificity but did not have good sensitivity to screen for high PBF. A high proportion of participants had high PBF (65.6%) and more so in women.

Different anthropometric measures are available to identify overweight and obesity, of which BMI is the most commonly used. The gold standard to assess 'fatness' or PBF is by dual energy X-Ray absorptiometry scan (DEXA Scan) and body composition analysis using BIA machines. These may not be available in low resource settings and are not appropriate for population based screening. As a result, BMI is considered practical at population level to identify overweight and obesity as it is easy to measure, reliable and has good correlation with PBF [13]. However, BMI has its own limitations; it does not change with age where the PBF increases with age and muscle mass decreases [14]. Also it is not ideal measure to detect abdominal obesity and for that WC helps in identifying those at greater risk for cardiac problems, diabetes mellitus, hypertension, dyslipidaemia, non-alcoholic fatty liver disease [15]. This is especially useful in persons with BMI ≥25 kg/m^2. However, WC can be culturally difficult in community setting and if done with suboptimal rigor can influence accuracy [16].

Mid-upper arm circumference is a feasible option as it does not require any calculation with exponentials and the tape is simple, portable and inexpensive [17]. While it has been incorporated into maternal nutrition assessment screening algorithms, there is a scope for its expansion to adult malnutrition screening with due consideration of ethnic variation [8,18]. It has been more often used to screen for undernutrition and MUAC cut-offs in the range of ≤23.5 to ≤25.0 cm have been proposed to screen underweight adults [17]. Similarly, NC has been proposed as a screening tool for overweight and obesity in adults [9]. 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, there is a soft tissue that includes muscles and fat and they reach full development by the end of puberty [19]. As a result, any change in NC in adulthood is attributed to increase in fat mass in the soft-tissue space in healthy individuals and correlates well with triglycerides and central obesity [20].

Table 3. Sensitivity and specificity of MUAC and NC cut-offs to screen for overweight, abdominal obesity and high percentage body fat and the receiver operator curves (ROC).

Mid upper arm circumference cut-offs in cm		Sensitivity (%)	Specificity (%)	Youden's index	ROC*–AUC† (95% CI)
WHO cut-offs for men for overweight (BMI ≥ 25 kg/m^2)	31.3	86	74	0.60	0.820 (0.749, 0.890)
WHO cut-offs for women for overweight (BMI ≥ 25 kg/m^2)	28.5	88	83	0.71	0.895 (0.843, 0.947)
Waist circumference for central obesity in men (≥90 cm)	31.2	85	73	0.59	0.854 (0.788,0.919)
Waist circumference for central obesity in women (≥80 cm)	28.3	74	92	0.65	0.888 (0.836, 0.939)
High percent Body fat Men (≥20%)	30.5	77	72	0.49	0.779 (0.698, 0.859)
High percent Body fat Women (≥28%)	25.7	87	76	0.63	0.874 (0.804, 0.943)
Neck Circumference cut-offs in cm		**Sensitivity (%)**	**Specificity (%)**	**Youden's index**	**ROC*–AUC† (95% CI)**
WHO cut-offs for men for overweight (BMI ≥ 25 kg/m^2)	36.6	81	71	0.52	0.769 (0.686, 0.852)
WHO cut-offs for women for overweight (BMI ≥ 25 kg/m^2)	31.4	88	72	0.60	0.830 (0.758, 0.903)
Waist circumference for central obesity in men (≥90 cm)	37.1	78	82	0.60	0.876 (0.809, 0.942)
Waist circumference for central obesity in women (≥80 cm)	31.4	75	81	0.56	0.836 (0.773, 899)
High percent Body fat men (≥20%)	36.6	68	80	0.48	0.771 (0.691, 0.851)
High percent Body fat women (≥28%)	31.1	63	78	0.42	0.781 (0.705, 0.856)

* Receiver operating curves.
† Area under the curve.

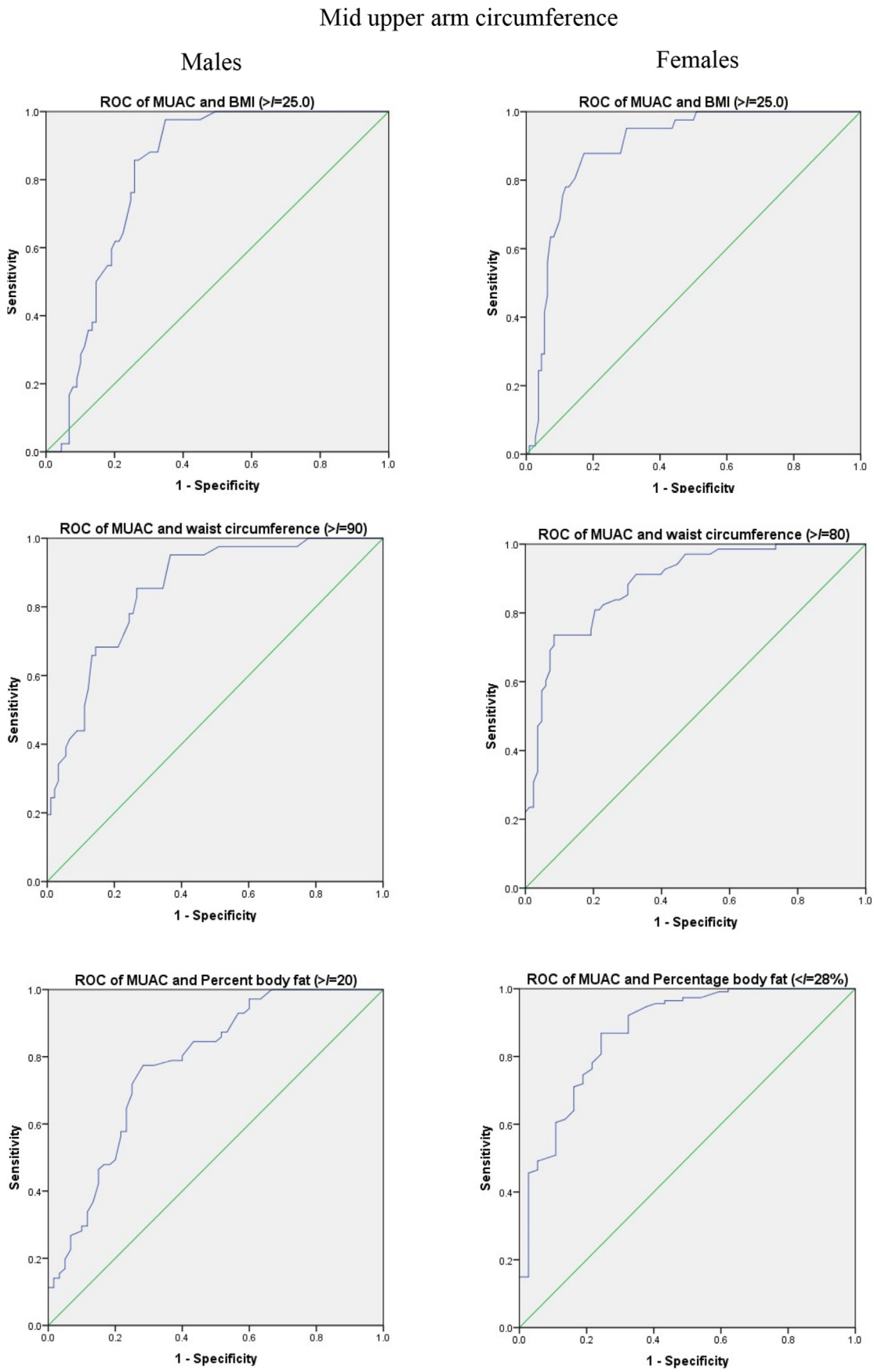

Figure 1. Receiver operator curves (ROC) to determine optimum cut-offs for mid-upper arm circumference to screen for overweight (BMI $\geq$25 kg/m^2), abdominal obesity (WC) and high percent body fat.

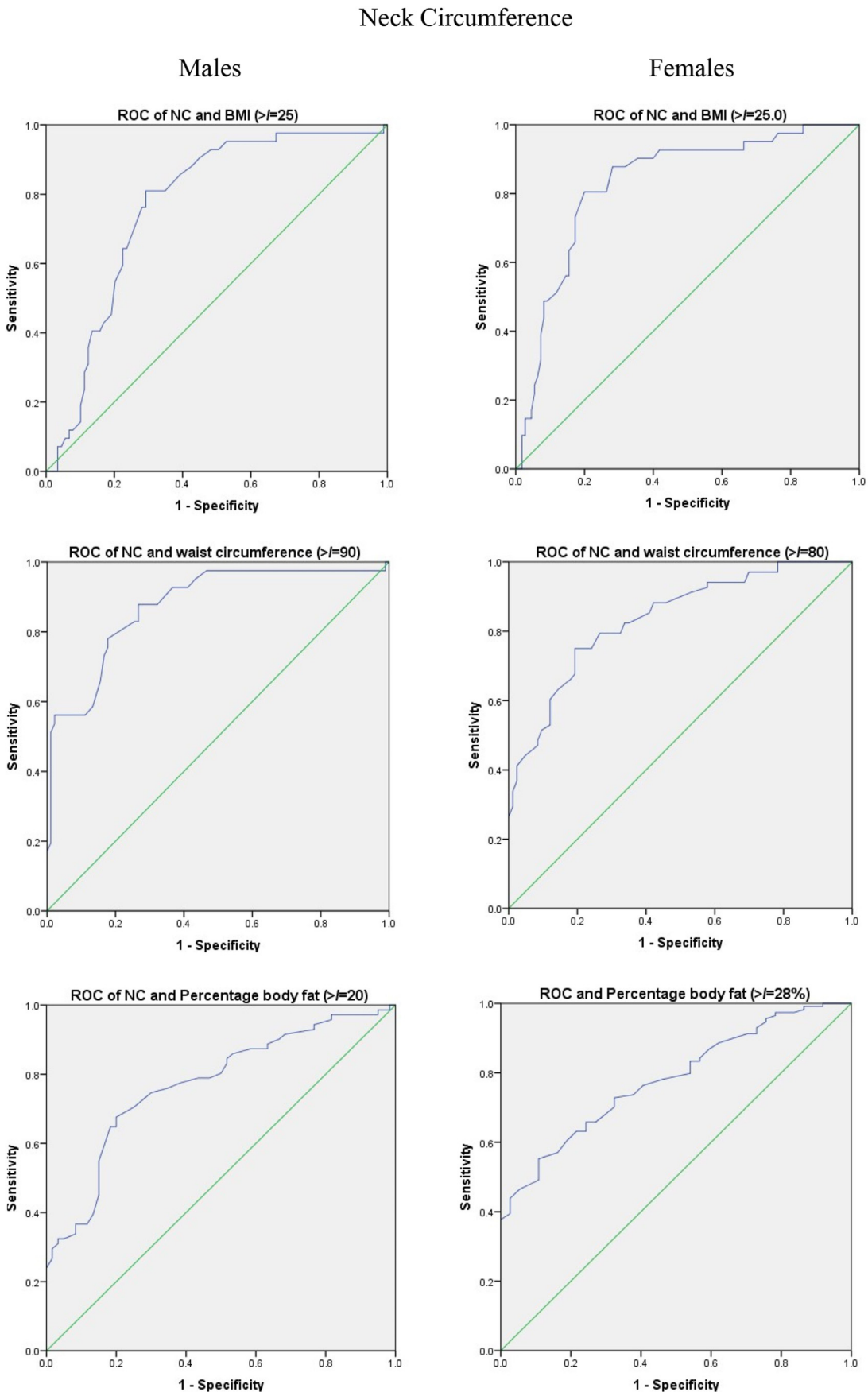

Figure 2. Receiver operator curves (ROC) to determine optimum cut-offs for neck circumference to screen for overweight (BMI ≥25 kg/m^2), abdominal obesity (WC) and high percent body fat.

Table 4. Preference for various anthropometric measurements in study participants (N = 282).

Anthropometric technique		Not preferred	Neutral	Preferred method
Height	Men	41 (31.3)	19 (14.5)	71 (54.2)
	Women	48 (31.8)	15 (9.9)	88 (58.3)
Weight	Men	22 (16.8)	19 (14.5)	90 (68.7)
	Women	26 (17.2)	15 (9.9)	110 (72.8)
Waist Circumference	Men	11 (8.4)	17 (13.0)	103 (78.6)
	Women	17 (11.3)	23 (15.2)	111 (73.5)
Mid-upper arm circumference	Men	10 (7.6)	24 (18.3)	97 (74.0)
	Women	20 (13.2)	33 (21.9)	98 (64.9)
Neck circumference	Men	3 (2.3)	20 (15.3)	108 (82.4)
	Women	12 (7.9)	22 (14.6)	117 (77.5)

Our proposed cut-offs for MUAC of 30.5–31.3 cm in men is close to that proposed for identifying central obesity in a large Chinese cohort where it was ≥30.9 cm in males. However, 28.3–28.5 cm cut-off for women in our study is lower than that proposed in females in the same study (≥30.0 cm) [21]. Another large cohort in community based study in Ethiopian women of reproductive age; the proposed cut-off was 28.0 cm in age category of 25–34 years [22]. There have been very few studies that have used MUAC to screen for adult overweight and obesity in India. One study from South India in pregnant women between 14–36 weeks proposed MUAC cut-offs for obesity screening as 29.2 cm [23]. In a Srilankan study (consisting of cardiac patients) this was 28.8 cm in males and 26.7 cm in females [24]. An increase of one Standard Deviation (3.13 cm) of MUAC in a study in China indicated doubling of association with central obesity and positive association with HT, low HDL and subclinical atherosclerosis [25].

Our proposed cut-offs for NC of 36.6 cm in men and 31.4 cm in women are similar to other studies from India [26,27]. In a hospital-based study in India, the participants were evaluated for metabolic syndrome and cardiovascular risk factors and the investigators considered the NC cut-off of ≥37 cm in men and ≥34 cm in women for overweight. Here higher NC was found to be significantly associated with metabolic syndrome and hypertension and correlated with higher BMI and WC [28]. A study from Bangladesh, found 34.7 cm in men and 31.7 cm in women as best cut-offs to identify overweight and 35.2 in men and 31.2 in women for abdominal obesity [29]. In a study from Israel, the cut-offs derived were ≥37 cm in men and ≥34 cm in women with 98% sensitivity and 89% specificity in men and 100% sensitivity and 98% specificity in women [6]. The diversity of cut-offs from regional studies clearly indicates the importance of large scale country-wide studies to come to a consensus cut-off. Moreover, it will also be good to have standardized neck tapes like the MUAC tapes with a colour-coded range for easy screening. While our study shows a sensitivity of 75–88% and specificity of 71–82% in identifying overweight (high BMI) and obesity (high WC) in both men and women, the sensitivity was poor (63–68%) for high PBF.

Both MUAC and NC are inexpensive tools that can be easily incorporated in primary care screening methods for overweight and obesity. Their adoption in clinical examination in busy primary care practice can be valuable to screen for an important risk factor for non-communicable diseases.

Neck circumference was found to be the most preferred anthropometric method when compared to height, weight, WC and MUAC. This is probably due to its ease of accessibility of neck measurement and novelty. While WC is also known to be useful, the intimate nature is perceived as a barrier by many health care providers especially in out-patient department where patients may have to loosen or remove the clothes [30].

4.1. Strengths and limitations

The study use single centre measurements consisting of only young adults and this is the most important limitation. Underlying medical conditions in other age-groups can confound the MUAC and NC. However, the study participants are students that come for medical training from all over India although more so from Southern states. Moreover, the cut-offs we propose are based on the anthropometric surrogates and the gold standard based on body-composition. The strength of the study was single observer measurements with minimum inter-observer variation.

5. Conclusion

This study was done to find the cut-offs of MUAC and NC to screen for overweight, obesity and high PBF in young adults studying in a medical college. The proposed cut-offs of MUAC are 31.3 cm and 28.5 cm and that of NC are 36.6 cm and 31.4 cm in men and women respectively. More research in larger representative sample size is needed for a vast country like India where there can be regional variations. The ease of use of these anthropometric measures makes them ideal for large scale surveys and out-patient screening tools. Neck circumference was the most preferred anthropometric technique followed by WC in this study population. Stakeholder perspective needs to be considered and preferences need to be understood for better uptake of anthropometric measures.

Declarations

Author contribution statement

Kiran R: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Harshitha: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Madhavi Bhargava, M.D: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare the following conflict of interests: Corresponding author is Associate Editor in Heliyon.

Additional information

No additional information is available for this paper.

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