Original Article

Neck height ratio is an important predictor of metabolic syndrome among Asian Indians

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ABSTRACT

Background and Aims: The predictive potential of neck circumference (NC) based indices (a measure of upper body fat distribution) for predicting metabolic syndrome (MetS) and its components among Indians is not known. This study aimed to evaluate the role of NC and neck height ratio (NHtR) as independent predictors of MetS and its components as compared to traditional anthropometric indices. **Materials and Methods:** A total of 451 individuals from 867 screened individuals, 30–80 years age, without any co-morbid state who gave informed written consent underwent clinical, anthropometric, and biochemical assessment. **Results:** Patients with MetS in both the sexes had significantly higher NC, NHtR, glycated hemoglobin, fasting glucose, and dyslipidemia (higher triglycerides, total cholesterol/high-density lipoprotein cholesterol (HDL-C) ratio, low-density lipoprotein cholesterol/HDL-C ratio, and lower HDL-C). In both sexes, individuals in the highest tertile of NC had significantly greater central and generalized obesity, lower HDL-C, and significantly higher MetS. Receiver operating characteristic analysis revealed waist circumference (WC) to have the largest area under the curve for predicting MetS in both sexes, followed by NHtR, NC, and body mass index. NC and NHtR of >34.9 cm (sensitivity 78.6%; specificity 59.3%) and >21.17 cm/m (sensitivity 80.7% and specificity 64.6%) respectively for men and >31.25 cm (sensitivity 72.3%; specificity 64.4%) and >20.48 cm/m (sensitivity 80.4% and specificity 60%) respectively for women were the best values for identifying MetS. Increased NC and NHtR had odds ratio of 1.52 (95% confidence interval [CI]: 1.37–1.68; $P < 0.001$) and 1.96 (95% CI: 1.67–2.29; $P < 0.001$) respectively in identifying MetS. **Conclusion:** NC and NHtR are good predictors of MetS and cardiovascular risk factors in Asian Indians. NHtR is reliable and perhaps an even better index than NC with regards to cardiovascular risk prediction.

Key words: Insulin resistance, metabolic syndrome, neck height ratio, waist circumference

Introduction

Cardiovascular disease is the predominant cause for mortality in patients with type-2 diabetes mellitus, accounting for 50–60% of deaths.[1] Metabolic syndrome (MetS) refers to a conglomeration of cardiovascular risk factors that identifies a cohort of individuals with increased risk of cardiovascular morbidity.[2] Asian Indians are ethnically predisposed to increase cardiovascular morbidity.[3] Increased adiposity (overall and especially visceral) in spite of lower body mass index (BMI), as compared to other ethnic groups (like Caucasians) may contribute to this increased risk.[4] Visceral adipose tissue (VAT) has traditionally been linked with increased cardiovascular risk.[5] BMI, waist

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circumference (WC), waist-hip ratio, and waist-height ratio (WHtR) are simple anthropometric indices to measure this generalized and central adiposity. Specific challenges associated with diabetes in India, the single most important contributor to cardiovascular morbidity and mortality, is the high prevalence of diabetes (9%)[6,7] and also prediabetes (12–14%),[6,7] young age of disease onset, with significantly higher rates of disease progression (prediabetes to diabetes conversion rate in India, China, Finland, and the USA being (14–18%, 11%, 6%, and 2.5%, respectively).[8-10] Hence, there is an urgent need of easy to measure anthropometric marker, specific to the Indian population, which is a good marker for early diagnosis of this high-risk cohort of individuals, who are predisposed to MetS, diabetes, and cardiovascular morbidity.

Few studies have suggested that subcutaneous adipose tissue in the upper body distribution (upper body obesity), to have an independent role in predicting cardiovascular morbidity.[11,12] Neck circumference (NC) has been validated to be a simple measure of upper body subcutaneous fat deposition and being a predictor of cardiovascular risk factors.[13,14] Data on the evaluation of NC as a predictor of cardiovascular risk factors in scant from India. Furthermore, the predictive potential of NC based indices for predicting MetS and its components, as compared to the traditional anthropometric indices (BMI, WC, and WHtR) among Indians are not known. Neck height ratio (NHtR) has also been suggested to be a measure of upper body adiposity like NC. NHtR has the advantage over NC, as it adjusts for the difference in NC attributable to differences in heights. NHtR has not been previously evaluated as an index for predicting MetS and other cardiovascular risk factors. Hence, the aim of this study was to evaluate the role of NC and NHtR as independent predictors of MetS and its components among Asian Indians as compared to traditional anthropometric indices (BMI, WC, and WHtR).

Materials and Methods

Individual attending the biannual health camps conducted by the department of Endocrinology and Metabolism across the city of Calcutta were considered. Screening of apparently healthy individuals that included family members of patients with diabetes was done during these camps by either fasting blood glucose (FBG) if they came after an overnight fast, or a non-FBG using a glucometer (Accu-Chek Active; Roche, Mumbai, India). Individuals, 30–80 years age, without any co-morbid states, were considered for the study. Patients not metabolically stable with uncontrolled blood glucose values on glucometer screening, viz. fasting/random blood glucose >300 mg/dl were excluded. For those patients having blood glucose values in the diabetes range, only those who were recently diagnosed with diabetes (within last 6 months) were considered for the study. Patients with significant goiter were excluded. Patients on medications that can interfere with body composition and lipids such as anti-depressants, glucocorticoids, and anti-lipid medications were excluded. Pregnant women were not considered for the study. The study protocol was explained, and only those who gave informed written consent were included in the study. The Institutional Ethics Committee approved the study protocol. The study duration was from November 2011 to February 2015.

Included individuals attended the camp again the next day after 12 h fast, underwent anthropometric assessment, blood samples collected, serum separated which was transported to the department in cold chain and stored at −80°C. Height (to ±0.1 cm) was measured in all individuals using a Charder HM200PW wall-mounted stadiometer (calibrated using a 36" calibration rod [Perspective Enterprise, Portage, Michigan, USA]), and body weight (to ±100 g) measured using an electronic calibrated scale (Tantia, Japan, Model-HA521, Lot number-860525). BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). NC was measured using a calibrated plastic tape, with the head positioned along the Frankfurt plane, at mid-neck height, between the mid-cervical spine and mid-anterior neck, to within 1 mm.[14] In men with a laryngeal prominence, it was measured just below the prominence.[14] A single observer in triplicate made all measurements. The coefficient of variation of the NC measurement ranged from 3 to 6%. WC was measured at the end of a gentle expiration midway between the lower rib margin and iliac crest with the patient standing with feet 23–30 cm apart. All participants underwent detailed clinical examination.

The collected blood samples were used for estimation of FBG, glycosylated hemoglobin (HbA1c%) and fasting lipid profile using clinical chemistry analyzer (Daytona, serial number-58260536, Furuno Electric, Nishnomeya, Japan). The presence of MetS was ascertained using the modified national cholesterol education program adult treatment panel (NCEP ATP) III criteria (ethnic-specific cutoffs for WC viz. >90 cm in males and >80 cm in females) with the presence of three or more considered diagnostic.[15] The prevalence of MetS in India has been reported to be 31.6%.[16] Keeping a power of 80% and type-I error at 5%, it was calculated that we needed to evaluate at least 235 individuals with MetS in our study.

Statistical analysis

Normality of the distribution of variables was checked using the Kolmogrov–Smirnov test. Continuous variables

were expressed as mean ± standard deviation. $P < 0.05$ was considered as statistically significant. ANOVA with *post hoc* analysis and Kruskal–Wallis nonparametric ANOVA with Dunn's postcorrection were performed for normally and nonnormally distributed variables, respectively. Chi-squared tests were used for categorical variables. Pearson's or Spearman's correlation coefficient was calculated for normally and nonnormally distributed variables, respectively. For categorical data, frequencies, and percentages were estimated. The associations between metabolic risk factors and anthropometric parameters were assessed using partial correlation analysis. Receiver operating characteristic (ROC) analyses were performed to assess the accuracy of the anthropometric parameters as diagnostic tests for detecting MetS and determine optimal sex-specific NC cut-offs in relation to MetS. The Youden index, defined as (sensitivity + specificity)-1 was used to determine the optimal cut-off points. SPSS version 16 (Chicago, IL, USA) was used for statistical analysis.

Results

A total of 867 individuals were screened of which 451 individual who fulfilled all inclusion and exclusion criteria, gave informed consent, and came for detailed anthropometric and biochemical evaluation were included in the study and analyzed [Figure 1]. In our study, 228, 55 and 168 individuals were classified as having normoglycemia, prediabetes, and diabetes respectively as per FBG and HbA1c values. Males constituted 57.21% of the study cohort (258/451 individuals). Males had significantly lower BMI, but higher NC as compared to females [Table 1]. The occurrence of hypertension, dysglycemia (prediabetes or newly diagnosed diabetes) was significantly higher in males [Table 1]. Total cholesterol and low-density lipoprotein cholesterol (LDL-C) were significantly higher in females [Table 1]. The occurrence of MetS was significantly higher in females [Table 1]. Patients with MetS in both the sexes had significantly higher NC, NHtR, HbA1c, FBG, and dyslipidemia (higher triglycerides, total cholesterol/high-density lipoprotein cholesterol (HDL-C) ratio, LDL-C/HDL-C ratio, and lower HDL-C), as compared to those without MetS [Table 1].

Males and females were divided into subgroups based on NC tertile [Table 2]. In both the sexes, individuals in the highest tertile of NC had significantly greater central obesity, significantly more likely to have BMI in the overweight and obese range, lower HDL-C and significantly higher occurrence of MetS [Table 2]. Males, but not females in the highest tertile of NC had significantly higher occurrence of hypertriglyceridemia [Table 2]. NC had a strong significantly positive correlation with other evaluated anthropometric parameters (WC, BMI, and NHtR) in both the sexes after adjusting for age [Table 3]. NC had significant positive correlation with serum total cholesterol and triglycerides in males [Table 4]. A significant inverse correlation was observed between NC and HDL-C in both the sexes [Table 4]. WC, BMI, and NHtR had significant positive correlation with total cholesterol, triglycerides, and LDL-C in males [Table 4].

The areas under the ROC curves (area under the curves [AUCs]) were constructed to evaluate the predictive values of anthropometric indices for MetS and its components [Table 5]. The AUC for NC for predicting MetS in males and females was 0.753 and 0.768 respectively,

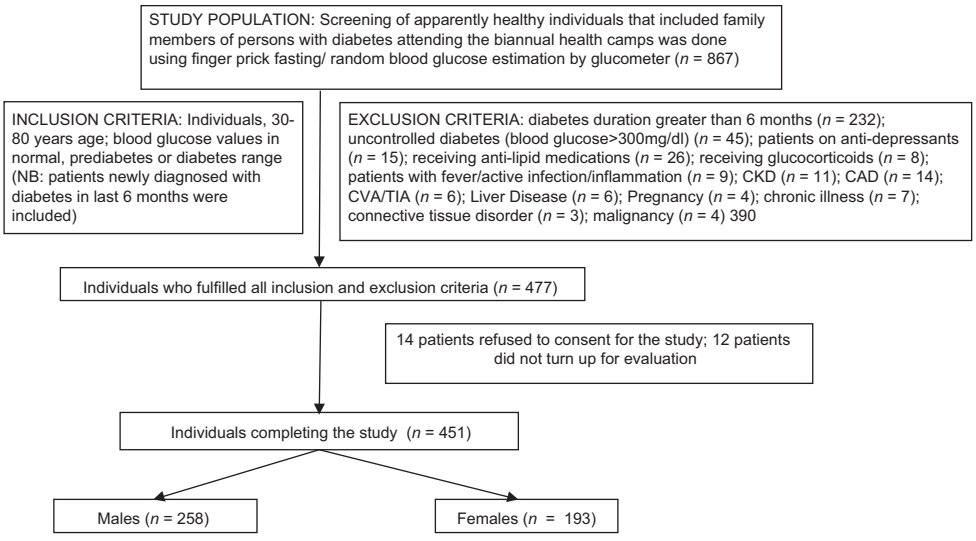

Figure 1: Flowchart elaborating the study protocol. CKD: chronic kidney disease; CLD: chronic liver disease; CVA: cerebrovascular accident; TIA: transient ischemic attack; CAD: coronary artery disease

Table 1: Baseline characteristics of the study population with regards to sex distribution and occurrence of metabolic syndrome (*n*=451)

Parameter	Males			Females			*P* value (males vs. females)
	All (*n*=258)	With MetS (*n*=145)	Without MetS (*n*=113)	All (*n*=193)	With MetS (*n*=148)	Without MetS (*n*=45)	
Age (years)	49.30±10.16	50.69±9.88[c]	47.49±10.27[c]	47.84±9.84	48.27±10.11	46.4±8.86	0.130
Height (meters)	1.63±0.07	1.63±0.07	1.63±0.08	1.50±0.07	1.51±0.06	1.49±0.08	<0.001
Weight (kg)	66.22±12.95	69.97±11.35[d]	61.4±13.33[d]	60.37±12.49	62.86±11.32[d]	52.2±12.77[d]	<0.001
BMI (kg/m^2)	24.73±4.28	26.31±3.80[d]	22.71±3.99[d]	26.62±4.81	27.61±4.41[d]	23.3±4.69[d]	<0.001
WC (cm)	91.41±11.12	96.2±8.95[d]	85.27±10.62[d]	91.36±11.05	94.14±9.87[d]	82.2±9.77[d]	0.958
NC (cm)[a]	35.5 (17)	36.5 (14)[f]	34 (14)[f]	32 (19)	33 (16.5)[f]	30 (9)[f]	<0.001
Neck height ratio[a]	21.72 (11.11)	22.53 (9.96)[f]	20.73 (8.13)[f]	21.33 (10.33)	21.65 (9.01)[f]	20 (7.54)[f]	0.196
Hypertension	131 (50.78%)	87 (60%)	44 (38.94%)	69 (35.75%)	60 (40.54%)	9 (20%)	0.002[b]
PreDM or T2DM	143 (55.43%)	92 (63.45%)	51 (45.13%)	80 (41.45%)	73 (49.32%)	7 (15.56%)	0.003[b]
SBP (mm Hg)[a]	129 (130)	130 (130)[f]	120 (110)[f]	120 (110)	120 (100)	120 (90)	0.025
DBP (mm Hg)[a]	80 (66)	80 (56)	80 (60)	80 (60)	80 (53)	78 (60)	0.095
HbA1c%[a]	6.5 (12.5)	6.8 (10.4)[f]	6.1 (12.5)[f]	6.1 (10.2)	6.35 (8.7)[f]	5.6 (10.2)[f]	0.003
FBG (mg/dl)[a]	115.5 (328)	121 (291)[e]	105 (328)[e]	114 (340)	120 (332)[f]	98 (87)[f]	0.111
Total cholesterol (mg/dl)	184.32±45.77	188.73±48.63[c]	178.66±41.34[c]	195.60±41.28	197.4±42.1	189.64±38.0	0.007
Triglycerides (mg/dl)[a]	133 (564)	155 (564)[f]	108 (209)[f]	133 (536)	147 (536)	104 (172)[f]	0.989
LDL-C (mg/dl)	104.52±36.09	110.11±37.89[c]	98.01±32.95[c]	120.88±35.06	123.86±35.8	109.52±30.2	<0.001
HDL-C (mg/dl)	46.33±11.99	41.6±9.81[d]	52.41±11.84[d]	46.93±11.99	44.37±9.88	55.33±14.39[d]	0.602
VLDL-C (mg/dl)[a]	26.5 (112.8)	31 (112.8)[f]	21.6 (41.8)[f]	26.6 (107.2)	29.4 (107.2)[f]	20.8 (34.4)[f]	0.925
TC/HDL-C ratio[a]	4.06 (7.82)	4.55 (7.49)[f]	3.58 (3.95)[f]	4.2 (9.48)	4.4 (9.48)[f]	3.36 (5.69)[f]	0.423
LDL-C/HDL-C ratio[a]	2.29 (5.36)	2.74 (5.13)[f]	2.04 (3.3)[f]	2.5 (6.40)	2.77 (6.4)[f]	1.94 (1.97)[f]	0.362
Metabolic syndrome	145 (56.2%)	-	-	148 (76.68%)	-	-	<0.001[b]
Hypertriglyceridemia	87 (33.72%)	78 (53.79%)	9 (7.96%)	71 (36.79%)	68 (45.95%)	3 (6.67%)	0.499[b]
Low HDL-C[b]	79 (30.62%)	71 (48.97%)	8 (7.08%)	128 (66.32%)	112 (75.68%)	16 (35.56%)	<0.001

All continuous variables expressed as mean (standard deviation), [a]All non-normally distributed variable expressed as median (range), all discreet variables have been expressed as absolute numbers (percentage). NC: Neck circumference, WC: Waist circumference, BMI: Body mass index, LDL-C: Low density lipoprotein cholesterol, HDL-C: High density lipoprotein cholesterol, VLDL-C: Very low density lipoprotein cholesterol, TC: Total cholesterol, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, FBG: Fasting blood glucose, PPBG: Post prandial blood glucose, [b]*P* value calculated using Chi-Square test, for normally distributed variables *P* value calculated using unpaired *t*-test, *P*<0.05 considered statistically significant, [c]*P*<0.05, unpaired *t*-test, [d]*P*<0.001, unpaired *t*-test, [e]*P*<0.05, Mann-Whitney U-test, [f] *P*<0.001, Mann-Whitney U-test

Table 2: Anthropometric and biochemical characteristics of the study subjects as per the distribution of neck circumference

Parameter	Males (*n*=258)			*P* value	Females (*n*=193)			*P* value
	Neck circumference				Neck circumference			
	<25th (<34cm) (*n*=63)	25-75th (34-37.5cm) (*n*=134)	>75th (>37.5cm) (*n*=61)		<25th (<31cm) (*n*=45)	25-75th (31-34cm) (*n*=102)	>75th (>34cm) (*n*=46)	
Age	48.54±11.36	50.41±8.81	48.21±10.71	0.621	47.24±9.31	49.46±10.77	46.38±8.86	0.194
Central obesity[a]	11 (17.46%)	73 (54.48%)	58 (95.08%)	<0.001	23 (51.11%)	93 (91.18%)	45 (97.82%)	<0.001
BMI								
Normal (<23kg/m^2)	51 (80.95%)	35 (26.12%)	1 (1.63%)	<0.001	28 (62.22%)	12 (11.76%)	1 (2.17%)	<0.001
Overweight (23-27.5kg/m^2)	10 (15.87%)	78 (58.21%)	27 (44.26%)	<0.001	14 (31.11%)	57 (55.88%)	9 (19.56%)	<0.001
Obesity (>27kg/m^2)	2 (3.17%)	21 (15.67%)	33 (54.10%)	<0.001	3 (6.67%)	33 (32.35%)	36 (36.96%)	<0.001
Hypertension	31 (49.21%)	64 (47.76%)	36 (59.02%)	0.331	17 (37.78%)	36 (32.35%)	16 (34.78%)	0.947
Hypertriglyceridemia	12 (19.05%)	43 (32.10%)	32 (52.45%)	<0.001	11 (24.44%)	43 (42.16%)	17 (36.96%)	0.121
Low HDL-C	14 (22.22%)	39 (29.10%)	26 (42.62%)	0.041	23 (51.11%)	70 (68.63%)	35 (76.10%)	0.047
PreDM or T2DM	35 (55.56%)	77 (57.46%)	31 (50.82%)	0.926	19 (42.22%)	46 (45.10%)	15 (32.61%)	0.358
MetS	16 (25.40%)	81 (60.45%)	48 (78.69%)	<0.001	22 (48.89%)	82 (80.39%)	44 (95.65%)	<0.001

[a]Central obesity defined as waist circumference >90cm in males and >80cm in females. BMI: Body mass index, PreDM: Prediabetes, T2DM: Type-2 diabetes, MetS: Metabolic syndrome, HDL-C: High density lipoprotein cholesterol

which was statistically significant [Table 5]. This AUC for NC was lower than that for WC but higher than that for BMI with regards to predicting MetS in both the sexes [Table 5]. NHtR had a higher AUC than NC for predicting MetS in males (0.77 and 0.753, respectively) [Table 5]. Among all the 4 anthropometric parameters evaluated, NHtR had the highest AUC with regards to predicting MetS, hypertension, hypertriglyceridemia, and low HDL-C in males [Table 5]. In females, WC had the highest AUC with regards to predicting MetS and hypertension, whereas NC had the highest AUC with regards to predicting low HDL-C.

A NC of >34.9 cm (sensitivity 78.6%; specificity 59.3%) for men and >31.25 cm (sensitivity 72.3%; specificity 64.4%)

Table 3: Relation between anthropometric indices after adjusting for age in males and females

Parameter	NC[a]	WC	NHtR[a]	BMI
Males (*n*=258)				
NC[a]	1	0.742[d]	0.858[d]	0.744[d]
WC	0.742[d]	1	0.636[d]	0.839[d]
NHtR[a]	0.858[d]	0.636[d]	1	0.713[d]
BMI	0.744[d]	0.839[d]	0.713[d]	1
Females (*n*=193)				
NC[a]	1	0.713[d]	0.852[c]	0.682[c]
WC	0.713[d]	1	0.632[c]	0.826[c]
NHtR[a]	0.852[d]	0.632[d]	1	0.660[c]
BMI	0.682[d]	0.826[d]	0.660[d]	1

Pearson's correlation coefficient calculated; [a]Not normally distributed; Spearman's correlation coefficient calculated; *P*<0.05 considered statistically significant; [b]*P*<0.05; [c]*P*<0.01; [d]*P*<0.001. NC: Neck circumference, WC: Waist circumference, NHtR: Neck height ratio, BMI: Body mass index

Table 4: Correlation between anthropometric indices and cardio-metabolic risk factors after adjusting for age

Parameter	NC[a]	WC	NHtR[a]	BMI
Males (*n*=258)				
SBP (mm Hg)[a]	0.106	0.101	0.180	0.118
DBP (mm Hg)[a]	0.113	0.165	0.242[b]	0.181
HbA1c%[a]	0.024	0.090	0.062	0.057
FBG (mg/dl)[a]	0.025	0.114	0.009	0.082
Total cholesterol	0.211[b]	0.333[d]	0.274[c]	0.275[c]
Triglycerides[a]	0.365[d]	0.449[d]	0.379[d]	0.409[d]
LDL-C	0.185	0.302[c]	0.270[c]	0.280[c]
HDL-C	−0.319[c]	−0.343[d]	0.249[b]	−0.328[c]
Females (*n*=193)				
SBP (mm Hg)[a]	0.172	0.303[c]	0.165	0.134
DBP (mm Hg)[a]	0.028	0.185	0.010	0.037
HbA1c%[a]	0.144	0.131	0.102	0.142
FBG (mg/dl)[a]	0.221	0.159	0.176	0.164
Total cholesterol	0.003	0.121	0.146	0.090
Triglycerides[a]	0.112	0.067	0.072	0.037
LDL-C	0.092	0.192	0.061	0.198
HDL-C	−0.327[c]	−0.148	−0.328[c]	−0.197

Pearson's correlation coefficient calculated, [a]Not normally distributed, Spearman's correlation coefficient calculated, *P*<0.05 considered statistically significant, [b]*P*<0.05, [c]*P*<0.01, [d]*P*<0.001. NC: Neck circumference, WC: Waist circumference, NHtR: Neck height ratio, BMI: Body mass index, Hyper-TG: Hypertriglyceridemia, HDL-C, High density lipoprotein cholesterol, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, FBG: Fasting blood glucose, HbA1c: Glycated haemoglobin

for women were the best values of combined sensitivity and specificity in identifying MetS. A logistic regression analysis, using MetS as the dependent variable, showed that the relationship between NC and MetS after adjusting for sex and age was statistically significant (odds ratio 1.52 [95% confidence interval [CI]: 1.37–1.68]; $P < 0.001$). Similarly a NHtR of >21.17 cm/m (sensitivity 80.7% and specificity 64.6%) for men and >20.48 cm/m (sensitivity 80.4% and specificity 60%) for women were the best values of combined sensitivity and specificity in identifying MetS. A logistic regression analysis, using MetS as the dependent variable, showed that the relationship between NHtR and MetS after adjusting for sex and age was statistically significant (odds ratio 1.96 [95% CI: 1.67–2.29]; $P < 0.001$). Twenty-four out of 258 males (9.3%) and 8 out of 148 females (5.4%) with MetS had normal WC. Ten (41.66%) and 18 (75%) of these 24 males had NC >24.9 cm and NHtR >21.17 cm/m, respectively. Three (37.5%) and 4 (50%) of these 8 females had NC >31.25 cm and NHtR >20.48 cm/m, respectively.

Discussion

WC a measure of abdominal subcutaneous and visceral fat traditionally has served as the standard index to identify patients with MetS.[15] However, it has been observed that a significant proportion of patients with cardiovascular disease with normal WC, thereby highlighting its shortcomings.[16] Studies have suggested that upper body subcutaneous fat is responsible for a much larger proportion of systemic free fatty acid release than visceral fat, as it is lipolytically more active than lower body adipose tissue.[17] Hence, this fat may have a significant contribution to genesis of insulin resistance and dyslipidemia.[17] NC has been demonstrated to be an index of upper body subcutaneous fat,[8] with correlation with indices of obesity and individual cardiovascular risk factors.[10,18-20] In a longitudinal follow-up study, it was shown that the change is NC correlated with changes in cardiovascular risk factors and that using WC alone was a simplification and did not account for all the changes in risk factors.[21] Preis *et al*. followed up participants from the Framingham heart study over a period of 10 years prospectively and noted that NC correlated with development of multiple cardiovascular risk factors.[22] The same group also estimated visceral adiposity by computed tomography along with anthropometry and metabolic parameters and demonstrated that NC was associated with CVD risk factors even after adjustment for VAT and BMI, thus, suggesting that upper body subcutaneous fat may be a unique pathogenic fat depot.[22]

In our study, patients in the highest tertile of NC had significantly higher occurrence of MetS, central obesity, and dyslipidemia parameters that are established predictors of cardiovascular morbidity. NC had a strong positive correlation with traditional anthropometric indices of central obesity (BMI and WC), which are also established predictors of cardiovascular risk. This observation is in accordance with previous studies.[13,19,20] Similar observations were noted with NHtR. NC had significant positive correlation with total cholesterol, triglycerides, and significant negative correlation with HDL-C in males. These correlations grew stronger with NHtR. In our study, WC had the largest AUC for predicting MetS in both males and females, followed by NHtR, NC, and BMI. NHtR had the largest AUC for predicting hypertriglyceridemia and low

Table 5: Area under the ROC by different anthropometric indices as predictor of metabolic syndrome and cardio-metabolic risk factors (*n*=451)

	NC		WC		NHtR		BMI	
	AUC (95%CI)	*P* value	AUC (95%CI)	*P* value	AUC (95%CI)	*P* value	AUC (95%CI)	*P* value
Males (*n*=258)								
MetS	0.753 (0.694-0.813)	<0.001	0.797 (0.740-0.854)	<0.001	0.777 (0.720-0.835)	<0.001	0.749 (0.688-0.810)	<0.001
Type-2 DM	0.453 (0.382-0.524)	0.196	0.484 (0.412-0.555)	0.655	0.488 (0.418-0.559)	0.750	0.421 (0.350-0.491)	0.029
Hypertension	0.535 (0.465-0.606)	0.327	0.516 (0.446-0.587)	0.650	0.584 (0.515-0.654)	0.019	0.520 (0.449-0.590)	0.585
Hyper-TG	0.670 (0.600-0.739)	<0.001	0.666 (0.598-0.734)	<0.001	0.693 (0.626-0.760)	<0.001	0.668 (0.601-0.736)	<0.001
Low HDL-C	0.611 (0.537-0.685)	0.005	0.619 (0.549-0.690)	0.002	0.629 (0.556-0.701)	0.001	0.595 (0.522-0.668)	0.015
Females (*n*=193)								
MetS	0.768 (0.687-0.849)	<0.001	0.805 (0.730-0.879)	<0.001	0.754 (0.668-0.839)	<0.001	0.750 (0.663-0.837)	<0.001
Type-2 DM	0.439 (0.357-0.520)	0.147	0.516 (0.434-0.599)	0.697	0.491 (0.409-0.574)	0.840	0.465 (0.383-0.547)	0.410
Hypertension	0.501 (0.416-0.586)	0.987	0.623 (0.542-0.703)	0.005	0.528 (0.444-0.611)	0.527	0.537 (0.453-0.621)	0.399
Hyper-TG	0.546 (0.463-0.629)	0.287	0.546 (0.463-0.630)	0.285	0.543 (0.461-0.625)	0.322	0.560 (0.478-0.643)	0.163
Low HDL-C	0.622 (0.537-0.707)	0.006	0.560 (0.474-0.646)	0.172	0.621 (0.536-0.706)	0.006	0.599 (0.513-0.684)	0.025

MetS: Metabolic syndrome, NC: Neck circumference, WC: Waist circumference, NHtR: Neck height ratio, BMI: Body mass index, Hyper-TG: Hypertriglyceridemia, HDL-C: High density lipoprotein cholesterol. Hypertriglycerdemia was defined as serum triglycerides >150mg/dl; Low HDL-C was defined as serum HDL-C <40mg/dl in males and <50mg/dl in females

HDL-C in males. NC, in contrast, had the largest AUC for predicting low HDL-C in females.

Our study demonstrated that among south Asians, an NC of >34.9 cm for men and >31.25 cm for women were the best predictors for identifying MetS. These cut-offs are lower than that previously reported in literature from other parts of the globe. Onat *et al.* suggested cut-offs of 39 cm and 35 cm for diagnosing MetS among Turkish population.[23] The same cut-off was proposed by Yang *et al.* for diagnosing MetS in the Chinese population.[19] Zhou *et al.* in another study from a different part of China suggested lower cut-offs for 37 cm and 33 cm for identifying MetS in males and females, respectively.[24] The lower cut-offs observed in our study in part can be explained by the lower median NC among our study subjects. Different ethnicity and body composition of different populations evaluated in different studies may explain this difference. Our study proposed for the 1st time cut-offs for NHtR in predicting MetS. A NHtR of >21.17 cm/m for men and >20.48 cm/m for women were the best predictors for identifying MetS. Overall NHtR had a better odds ratio for predicting MetS as compared to NC. Among patients of MetS with normal WC, 75% and 50% of males and females respectively had NHtR above the suggested cut-offs, highlighting that NHtR may be a better predictor of MetS.

Limitations of this study include the cross-sectional design, which prevents us from establishing causality. NC was used as surrogate for upper body subcutaneous tissue, which however was not quantified by an imaging modality in our study. The higher prevalence of MetS observed in our study, as compared to previously reported literature may in part be explained by the opportunistic screening done during patient recruitment.

To summarize it may be said that our study reinforced the previous observation of NC being a good predictor of MetS and other related cardiovascular risk factors in Asian Indians. Our study demonstrated for the 1st time the reliability of NHtR as a predictor of MetS and its components and highlighted that NHtR is perhaps an even better index than NC with regards to cardiovascular risk prediction.

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Conflicts of interest

There are no conflicts of interest.

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