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

Chitra Selvan, Deep Dutta¹, Anubhav Thukral², Titli Nargis³, Manoj Kumar², Satinath Mukhopadhyay², Subhankar Chowdhury²

Department of Endocrinology, MS Ramaiah Medical College, Bengaluru, Karnataka, ¹Department of Endocrinology, Post Graduate Institute of Medical Education and Research, Dr. Ram Manohar Lohia Hospital, New Delhi, ²Department of Endocrinology, Institute of Post Graduate Institute of Medical Education and Research, Seth Sukhial Kamani Memorial Hospital, ³PhD Scholar, Indian Institute of Chemical Biology, Kolkata, West Bengal, India

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.¹¹ Metabolic syndrome (MetS) refers to a conglomeration of cardiovascular risk factors that identifies a cohort of individuals with increased risk of cardiovascular morbidity.¹² Asian Indians are ethnically predisposed to increased cardiovascular morbidity.¹³ 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.¹⁴ Visceral adipose tissue (VAT) has traditionally been linked with increased cardiovascular risk.¹⁵ BMI, waist...
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%) 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/m²). 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, Nishnomaya, 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 Spearmans'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,
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 sexes [Table 5]. NHtHR 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, NHtHR 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%)
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.\(^6\) However, it has been observed that a significant proportion of patients with cardiovascular disease with normal WC, thereby highlighting its shortcomings.\(^10\) 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.\(^27\) Hence, this fat may have a significant contribution to genesis of insulin resistance and dyslipidemia.\(^7\) 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.\(^10,18-28\) 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 3: Relation between anthropometric indices after adjusting for age in males and females

| Parameter | NC* | WC | NHR* | BMI |
|-----------|-----|----|------|-----|
| Males (n=258) |    |    |      |     |
| NC*       | 0.742* | 1   | 0.858* | 0.744* |
| WC        | 0.180 | 0.713 | 1   |     |
| NHR*      | 0.112 | 0.057 | 1   |     |
| BMI       | 0.852 | 0.009 | 1   |     |
| Females (n=193) |    |    |      |     |
| NC*       | 0.713* | 1   | 0.852* | 0.682* |
| WC        | 0.180 | 0.713 | 1   |     |
| NHR*      | 0.112 | 0.057 | 1   |     |
| BMI       | 0.852 | 0.009 | 1   |     |

Pearson’s correlation coefficient calculated; *Not normally distributed; Spearman’s correlation coefficient calculated; \( P < 0.05 \) considered statistically significant; \( \text{NHtR}: \) Neck height ratio, WC: Waist circumference, NC: Neck circumference, BMI: Body mass index.

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

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

Pearson’s correlation coefficient calculated; *Not normally distributed, Spearman’s correlation coefficient calculated; \( P < 0.05 \) considered statistically significant; \( \text{NHtR}: \) Neck height ratio, WC: Waist circumference, NC: Neck circumference, BMI: Body mass index.
Table 5: Area under the ROC by different anthropometric indices as predictor of metabolic syndrome and cardio-metabolic risk factors (n=451)

|            | NC (AUC (95%CI)) | P value | WC (AUC (95%CI)) | P value | NHtR (AUC (95%CI)) | P value | BMI (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 (0.442-0.587) | 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. Hypertriglyceridemia 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. The same cut-off was proposed by Yang et al. for diagnosing MetS in the Chinese population. 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. 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.

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.

Acknowledgments
The authors are grateful to the staff of the department of endocrinology for their support during fieldwork and patient recruitment, which made this work possible.

Financial support and sponsorship
This study was funded by a research grant from Research Society of Study of Diabetes in India, West Bengal chapter.

Conflicts of interest
There are no conflicts of interest.

REFERENCES
1. Morris NJ, Wang SL, Stevens LK, Fuller JH, Keen H. Mortality and causes of death in the WHO multinational study of vascular disease in diabetes. Diabetologia 2001;44 Suppl 2:S14-21.
2. Bonora E, Targher G, Formentini G, Calcaterra F, Lombardi S, Marinis F, et al. The metabolic syndrome is an independent predictor of cardiovascular disease in type 2 diabetic subjects. Prospective data from the Verona diabetes complications study. Diabet Med 2004;21:52-8.
3. Mohan V, Sandeep S, Deepa R, Shah B, Varghese C. Epidemiology of type 2 diabetes: Indian scenario. Indian J Med Res 2007;125:217-30.
4. Yajnik CS, Yudkin JS. The VY paradox. Lancet 2004;363:163.
5. Fujimoto WY, Bergstrom RW, Boyko EJ, Chen KW, Leonetti DL, Newell-Morris L, et al. Visceral adiposity and incident coronary heart disease in Japanese-American men. The 10-year follow-up results of the Seattle Japanese-American community diabetes study. Diabetes
Selvan, et al.: Neck-height ratio and metabolic syndrome

6. Dutta D, Mukhopadhyay S. Comment on Anjana et al. Incidence of diabetes and prediabetes and predictors of progression among Asian Indians: 10-year follow-up of the Chennai urban rural epidemiology study (CURES). Diabetes Care 2015;38:1441-1448. Diabetes Care 2015;38:e146.

7. Dutta D, Mondal SA, Choudhuri S,Maisnam I, Hasanoor Reza AH, Bhattacharya B, et al. Vitamin-D supplementation in prediabetes reduced progression to type 2 diabetes and was associated with decreased insulin resistance and systemic inflammation: An open label randomized prospective study from Eastern India. Diabetes Res Clin Pract 2014;103:e18-23.

8. Dutta D, Maisnam I, Shrivastava A, Sinha A, Ghosh S, Mukhopadhyay P, et al. Serum Vitamin-D predicts insulin resistance in individuals with prediabetes. Indian J Med Res 2013;138:853-60.

9. Dutta D, Mondal SA, Kumar M, Hasanoor Reza AH, Biswas D, Singh P, et al. Serum fetuin-A concentration predicts glycaemic outcomes in people with prediabetes: A prospective study from eastern India. Diabet Med 2014;31:1594-9.

10. Dutta D, Choudhuri S, Mondal SA, Mukherjee S, Chowdhury S. Urinary albumin: Creatinine ratio predicts prediabetes progression to diabetes and reversal to normoglycemia: Role of associated insulin resistance, inflammatory cytokines and low Vitamin D. J Diabetes 2014;6:316-22.

11. Martin ML, Jensen MD. Effects of body fat distribution on regional lipolysis in obesity. J Clin Invest 1991;88:609-13.

12. Sjöström CD, Håkangård AC, Lissner L, Sjöström L. Body compartment and subcutaneous adipose tissue distribution – Risk factor patterns in obese subjects. Obes Res 1995;3:9-22.

13. Ben-Noun L, Laor A. Relationship of neck circumference to cardiovascular risk factors. Obes Res 2003;11:226-31.

14. Ben-Noun L, Sohar E, Laor A. Neck circumference as a simple screening measure for identifying overweight and obese patients. Obes Res 2001;9:470-7.

15. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: An American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation 2005;112:2735-52.

16. Gupta R, Deedwania PC, Gupta A, Rastogi S, Panwar RB, Kohari K. Prevalence of metabolic syndrome in an Indian urban population. Int J Cardiol 2004;97:257-61.

17. Aswathappa J, Garg S, Kutty K, Shankar V. Neck circumference as an anthropometric measure of obesity in diabetics. N Am J Med Sci 2013;5:28-31.

18. Katmarzyk PT, Janssen I, Ross R, Church TS, Blair SN. The importance of waist circumference in the definition of metabolic syndrome: Prospective analyses of mortality in men. Diabetes Care 2006;29:404-9.

19. Yang GR, Yuan SY, Fu HJ, Wen G, Zhu LX, Bu XL, et al. Neck circumference positively related with central obesity, overweight, and metabolic syndrome in Chinese subjects with type 2 diabetes: Beijing community diabetes study 4. Diabetes Care 2010;33:2465-7.

20. Stabe C, Vasques AC, Lima MM, Tambascia MA, Pareja JC, Yamanaka A, et al. Neck circumference as a simple tool for identifying the metabolic syndrome and insulin resistance: Results from the Brazilian metabolic syndrome study. Clin Endocrinol (Oxf) 2013;78:874-81.

21. Sjöström CD, Lissner L, Sjöström L. Relationships between changes in body composition and changes in cardiovascular risk factors: The SOS intervention study. Swedish obese subjects. Obes Res 1997;5:519-30.

22. Preis SR, Massaro JM, Hoffmann U, D’Agostino RB Sr., Levy D, Robins SJ, et al. Neck circumference as a novel measure of cardiometabolic risk: The Framingham heart study. J Clin Endocrinol Metab 2010;95:3701-10.

23. Onat A, Hergenç G, Yüksel H, Can G, Ayhan E, Kayla Z, et al. Neck circumference as a measure of central obesity: Associations with metabolic syndrome and obstructive sleep apnea syndrome beyond waist circumference. Clin Nutr 2009;28:46-51.

24. Zhou JY, Ge H, Zhu MF, Wang LJ, Chen L, Tan YZ, et al. Neck circumference as an independent predictive contributor to cardio-metabolic syndrome. Cardiovasc Diabetol 2013;12:76.