NECK CIRCUMFERENCE AS A MEASURE OF OBESITY AMONG NEWLY DIAGNOSED TYPE 2 DIABETES IN YOUNG ADULTS
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ABSTRACT

BACKGROUND
Recent studies have shown that neck circumference (NC) is correlated with obesity and other cardiovascular risk factors. Being easy to measure, it may be useful in identifying individuals at risk for cardiometabolic disorders. The objective of the study was to determine the relationship between NC with BMI and waist circumference (WC) in the assessment of obesity in young adult population with new onset diabetes.

METHODS
117 consecutive subjects with new onset type 2 diabetes in the age group 18-44 years were included in the study. Sociodemographic characteristics, anthropometric and biochemical measurements were carried out using standard techniques. Pearson Product Movement Correlation Coefficient was used to find out correlation with other measures of obesity and ROC curve to determine its optimal cut off values.

RESULTS
Mean NC in males was significantly higher than in females. Pearson correlation showed that NC had a significant positive correlation with BMI (r 0.68, 0.49) and WC (r 0.63, 0.73) for both sexes. The strongest correlation was with WC followed by BMI. The cut off value of neck circumference when compared with BMI in defining obesity was 38.2 cm in males and 34.2 cm in females. The cut off value of neck circumference with waist circumference in males was 38.2 cm.

CONCLUSIONS
NC is a potential, inexpensive, easily measured, and non-invasive valid initial clinical screening tool for evaluating central and generalised obesity.

KEYWORDS
Neck Circumference, Obesity, Type 2 Diabetes, Young Adults


BACKGROUND
According to WHO, 65% of the world population live in countries where overweight and obesity kill more people than underweight. Body Mass Index (BMI) and waist circumference (WC) are considered as the traditional measures of generalized and abdominal obesity respectively. Obesity calculated by BMI can misclassify a significant number of individuals because of its relatively high specificity and low sensitivity. BMI fail to differentiate between fat and muscle mass and, does not account for regional fat distribution. Clothing is one major perturbing factor complicating the measurement of waist circumference. WC measurement is difficult in certain religious groups, those with marked obesity and in females. Accuracy of its measurement also may be affected by respiratory movement, abdominal gas, fullness after a meal, pregnancy and thick clothing.

Neck circumference (NC), a new anthropometric parameter representative of upper body obesity, has been reported to be more convenient for screening overweight/obesity than BMI or Waist Circumference. Being a proxy of upper body subcutaneous fat, NC is a novel, discrete and pathogenic fat depot both independent of and synergetic with visceral adipose tissue. NC may be an additional anthropometric surrogate marker for insulin resistance and obesity just like waist circumference and BMI. Various studies also suggests a positive relation between NC and central obesity. Upper body fat distribution has been considered as a risk factor for cardiovascular disease. NC was significantly and independently associated with cardio metabolic risk factors in a well-defined apparently healthy population.
to identify metabolic syndrome in community level. Upper body subcutaneous fat is responsible for a much larger proportion of systemic free fatty acid release than visceral fat, particularly in obese individuals, and is lipolytically more active than lower body adipose tissue. Lipolytic activity of upper body fat may mediate this relationship with lipid metabolism and glucose homeostasis. Insulin resistance relates better with subcutaneous truncal fat compared to intraperitoneal fat. Upper body subcutaneous fat is a novel, easily measured adipose depot, which is an important predictor of diabetic risk. Development of structures in the neck are completed by the end of puberty. Any change in NC after this is attributed to increase in fat mass in soft tissue space. NC measurement is easy to perform, convenient, reliable, quick, and inexpensive and is associated with cardio metabolic risks beyond that of BMI and WC. There is different cutoff values for BMI and WC for different ethnic groups. Similarly, differences in body size among different populations might clarify the heterogeneity of the cut off values for NC, which is the case for other standard anthropometric measures like BMI and WC. Differences in mean age of study participants, sample size and definition of cut off value for overweight/obesity and abdominal obesity are also contributing to different cut off value for NC in different populations.

The objective of the study was to explore the relationship between NC and traditional measures of obesity, and to find out respective optimal cut off values for neck circumference that define overweight/obesity in young male and female participants with new onset type 2 diabetes mellitus.

**METHODS**

**Inclusion Criteria**

Adult men and women aged between 18-44 years who fulfil the American Diabetes Association (ADA) criteria for diagnosis of type 2 diabetes mellitus.

**Exclusion Criteria**

Type 1 diabetes, Gestational Diabetes, other specific types of diabetes, unclear types of diabetes and subjects with Cushing’s disease, goiter/thyroid nodules, cervical lymphadenopathy, cystic/ mass lesions in the neck, any anatomical abnormality of the neck, those on long term corticosteroids, and pregnant women as well as those who had a chronic disease that may affect the metabolic status or body composition (e.g., thyroid or hypothalamic disease, chronic hepatitis, cirrhosis, cancer), participants who were bed ridden and those with incomplete data or not willing to give consent were excluded from the study.

**Study Period**

January 2016 to January 2019.

**Study Population**

All consecutive subjects (adult men and women) aged between 18-44 years who have visited General Medicine or Diabetology departments of Sree Gokulam Medical College & Research Foundation with FPG >126 mg/dL. Fasting was defined as no caloric intake for at least 8h. In the absence of unequivocal hyperglycaemia, result was confirmed by repeat testing.

**Data Collection Methods**

After identification of eligible study participants, informed consent was taken and those who gave written informed consent were interviewed using a structured Performa. Socio demographic characteristics, anthropometric and biochemical measurements were carried out using standard techniques.

117 consecutive subjects with new onset type 2 diabetes in the age group 18-44 years (early-onset type 2 diabetes) who visited a tertiary care hospital outpatient department were included in the study. The cases were ascertained using internationally accepted ADA criteria. The measurements were done by a qualified, trained, single investigator.

Height was measured with the commercial fixed stadiometer corrected to 0.1 cm with the subject standing with arms at the sides, heels touching the rod with head held erect and the plane passing through the lower border of orbit and Frankfurt plane parallel. Digital scale weighing machine corrected to 0.5 Kg was used to measure body weight. Machine was checked for zero error prior to each measurement. BMI was calculated by dividing body weight in Kg by height in meters squared. Waist circumference in centimeter was measured in horizontal plane midway between the inferior margin of the ribs and the superior border of the iliac crest, using a standard inelastic measuring tape at the end of gentle expiration. Measurements were taken thrice, and the median was taken in all cases.

NC was measured in subjects standing upright with their faces kept straight and shoulders relaxed but not hunched in the middle of the neck between the mid-cervical spine and mid-anterior neck to within 1 mm using a non-stretchable plastic tape. The superior border of tape measure was placed just below the laryngeal prominence and applied perpendicular to the long axis of the neck. Plastic tape was calibrated weekly, to ensure validity. In subjects with laryngeal prominence, NC was taken just below the prominence. After ensuring confidentiality of the information, data were collected by the investigator himself to minimize the inter observer bias. Mean of two readings was used for analysis.

**Statistical Analysis**

Data were entered in MS Excel spread sheet. The data was cleaned, and completeness of data was checked. Continuous variables are represented as arithmetic mean ± standard deviation and categorical data as numbers (percentage). Pearson’s correlation coefficient was used to evaluate the association of NC with other anthropometric indices. By considering the area under the curve (AUC) of the receiver operator characteristic (ROC) curves, the association of neck circumference with obesity indices were evaluated and determined its sex- and age-specific optimal cut off points in
association with obesity. AUC: 0.5, AUC: 0.5–0.65 and AUC: 0.65–1.0 were interpreted as equal to chance, moderately and highly accurate tests, respectively. To determine an appropriate cut off point of NC to predict incidence of obesity, an ROC curve analysis was done regarding the subjects' BMI as the outcome variable and neck circumference as the exposure. The appropriate cut off of NC was defined by calculating Youden’s J statistics (sensitivity + specificity − 1) for each cut off measure of NC. The maximum value of Youden’s index was taken as the appropriate cut off value. All analyses were performed using IBM SPSS for Windows version 20. A two-tailed P value <.05 was considered significant in all analyses.

RESULTS

### Table 1. Distribution of BMI, Waist Circumference and Neck Circumference According to Gender

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male N=68 (58.1%)</th>
<th>Female N=49 (41.9%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (Kg/m^2)</td>
<td>Mean SD</td>
<td>Mean SD</td>
</tr>
<tr>
<td></td>
<td>26.47 3.49</td>
<td>28.35 4.47</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>97.05 9.05</td>
<td>97.77 12.18</td>
</tr>
<tr>
<td>Neck circumference (cm)</td>
<td>38.76 2.76</td>
<td>35.55 2.98</td>
</tr>
</tbody>
</table>

In the present study, 68 (58.1%) of the study participants were males and 49 (41.9%) were females. Mean age of male and female participants were 35.4±6.3 years and 37.6± 5.8 years respectively. Males developed type 2 diabetes at an earlier age than females. Mean BMI was 27.3±4.0 Kg/m^2 (male 26.5±3.5 Kg/m^2, female 28.3±4.5 Kg/m^2). Females were more obese than males. The mean waist circumference was 97.4±10.4 cm (male 97.1±9.0 cm, female 97.8±12.2 cm). The mean neck circumference was 37.4±3.3 cm (male 38.8±2.8 cm, female 35.5±2.98 cm). 80.9% males and 100% females were having abdominal obesity. Male participants had larger neck size than females 38.8±2.8 cm versus 35.5±2.98 cm.

### Table 2. Distribution of Generalized and Abdominal Obesity According to Gender

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (N=68)</th>
<th>Female (N=49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI 18.5-22.9 Kg/m^2</td>
<td>10 (14.71) 6 (12.24)</td>
<td>44 (64.71) 36 (73.47)</td>
</tr>
<tr>
<td>BMI ≥25 Kg/m^2</td>
<td>14 (20.58) 7 (14.29)</td>
<td>55 (80.9) 100 (100)</td>
</tr>
<tr>
<td>WC ≥ 90 cm</td>
<td>-</td>
<td>49 (100)</td>
</tr>
<tr>
<td>WC ≥ 80 cm</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

BMI 18.5-22.9 Kg/m^2 - Normal Weight
BMI 23-24.9 Kg/m^2 - Overweight
BMI ≥25 Kg/m^2 - Obesity
WC ≥ 90 cm (in male) & ≥ 80 cm (in female) - Abdominal obesity.

The mean BMI of the participants was 27.3 Kg/m^2 (male 26.5 Kg/m^2, female 28.4 Kg/m^2). 17.95% were overweight (male 20.6%, female 14.3%) and 68.4% were obese (male 64.7%, female 73.5%). Only 10 (14.7%) males and 6 (12.2%) females had normal BMI (18.5-22.9 Kg/m^2). 13 (19.1%) of males had normal waist circumference (< 90 cm). All the female participants irrespective of BMI status had abdominal obesity (WC ≥ 80 cm).

### Table 3. Mean Waist and Neck Circumference According to BMI Categories in Both Genders

<table>
<thead>
<tr>
<th>BMI (Kg/m^2)</th>
<th>Male WC (cm)</th>
<th>Male NC (cm)</th>
<th>Female WC (cm)</th>
<th>Female NC (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.5-22.9</td>
<td>88.05</td>
<td>35.30</td>
<td>87.58</td>
<td>32.42</td>
</tr>
<tr>
<td>23-24.9</td>
<td>90.61</td>
<td>37.54</td>
<td>87.00</td>
<td>32.92</td>
</tr>
<tr>
<td>≥25</td>
<td>101.15</td>
<td>39.93</td>
<td>101.50</td>
<td>36.58</td>
</tr>
</tbody>
</table>

Anthropometric measurements according to BMI are summarized in Table 3. Mean NC of subjects with normal BMI was 33.86 cm. Waist and neck circumference among different BMI categories shows that, Overweight-Obese subjects had a higher waist and neck circumference compared with normal weight subjects.

The Correlation Coefficient of neck circumference with BMI in females was + 0.489 (95% CI 0.210-0.745) p value <0.001.

The Correlation Coefficient of neck circumference with BMI in males after controlling the effect of age was +0.681 (95% Confidence Interval 0.579-0.771) p value <0.001.
Figure 3. Correlation between Waist Circumference and Neck Circumference - Male

The Correlation Coefficient of neck circumference with waist circumference was +0.627 (95% CI 0.482-0.738) p value <0.001.

Figure 4. Correlation between Waist Circumference and Neck Circumference - Female

The Correlation Coefficient (r) of neck circumference with waist circumference was +0.725 (95% CI 0.510-0.856) p value <0.001.

Figure 5. BMI vs. Neck Circumference - Male

The cut off value of neck circumference when compared with BMI in male was 38.2 cm. Sensitivity 75, Specificity 83.3, Youden's J statistic 583. Area under Curve (AUC) .849. (95% CI .758-.93) p value <0.001.

Figure 6. BMI vs. Neck Circumference - Female

The cut off value of neck circumference in female when compared with BMI was 34.2 cm. Sensitivity 86.1, Specificity 84.6, Youden's J statistic .707) AUC .913 (95% CI .827-1.000), p value <0.001.

Figure 7. Waist Circumference vs. Neck Circumference - Male

The cut off value of Neck circumference with Waist Circumference in male was 38.2 cm. Sensitivity 65.5, Specificity 92.3, Youden’s J statistic .578. AUC .820 (95% CI 0.703-0.938) p value <0.001.

DISCUSSION

The present study shows that NC has significant positive correlation with BMI and WC. A study in young Chinese population also showed moderate correlation of NC with BMI and WC. It concludes that, NC may not be a good tool for screening individuals with central obesity, but may be a simple and valuable tool for screening individuals with overweight/obesity, especially in females. But the present study shows more correlation of NC with WC especially in female participants. It may be because, Indians have more abdominal obesity with similar BMI when compared with other populations. Cut off value in Chinese for overweight/obesity was 37.4 cms and 32.2 cms and, for central obesity 37.1 cms and 32.6 cms in males and females respectively. In a study by Jagadamba et al, NC ≥36 cm in diabetics and ≥37 cm in non-diabetics was the best cut off value to determine subjects with central obesity. Study by
Hingorjo et al suggests that NC of ≥ 35.5 cm in men and ≥32 cms in women should be considered the cutoff point for overweight/obesity. A study in Saudi subjects found that a NC ≥39.25 cm for men and ≥34.75 cm for women were the best cutoff levels for identifying subjects with central obesity. CC with BMI 0.5, with WC 0.7 in male and 0.5 in female. These cutoff levels for NC were associated with a significantly increased risk for diabetes, dyslipidemia, and hypertension. Significant positive correlation with BMI and WC were also reported in young adults from Bosnia and India (with BMI r 0.7, 0.53, with WC 0.48, 0.38 in males and females, r with BMI 0.81). In Bosnian adults, Cut off value of NC was 36cm, 38 cm, 30.9 cms and 33 cms in males and females respectively for overweight and obesity. Study by Liubov Ben-Noun et al showed that Men with NC <37 cm and women with NC<34 cm do not require additional evaluation. Patients above these levels require a more comprehensive evaluation of their overweight or obesity status. The present study also shows similar results. Study by Verma M et al also showed that NC correlated positively with body weight and WC. NC was found to have good discriminatory power with cutoff values of 36.55 cm for males and 34.05 cm for females, with maximum sensitivity and specificity to predict overweight and obesity in comparison to direct body fat percentage estimation on ROC analysis. (Mean value of NC in male was 34.90±3.94 which was higher than that of the female 33.65±3.81 cm. Correlation with BMI was 0.6 in men and 0.5 in women.)

A study in Bangladeshis adults showed moderate correlation of NC with BMI and WC. (r of BMI 0.5 in male and 0.4 in female, with WC 0.6 for male and 0.4 in female. Best cut off value for overweight was ≥34.7 cm in male and >31.7 in female, ≥35.2 and ≥34.2 cm in male and female for obesity, ≥35.2 and ≥31.2 cm for WC in male and female respectively.) An Egyptian study showed that a NC ≥ 38 cms in men and ≥36 cm in women were the best cut off points for determining subjects with overweight. Different cut offs in our study compared with western studies may be because of difference in criteria used to define generalised and abdominal obesity.

Study by Ruby Sharma et al showed positive correlation of NC with WC. (r 0.40 and 0.69; Cut off values 37.5 cms and 35.5 cms in young male and female adult participants). NC may be used collectively with other anthropometric tools to determine an individual's health risk. In another study, cut off value for NC reported was 36.5 cm in males and 32.5 cm in females. Correlation with BMI was 0.59 in males and 0.74 in females. Cut off >36.6 in males and >32.1 in females require additional evaluation for overweight/obesity status. In a study by Jagadamba et al, correlation of BMI was 0.6 and of WC was 0.7. NC in diabetics was significantly higher than in non-diabetics.

NC is considered as a simple time saving clinical tool for obesity detection. In an Iranian paediatric population, it was significantly correlated with indices of adiposity and could reliably identify children with general and abdominal obesity. Another Iranian study also showed similar results. (r with BMI 0.76, 0.73, with WC 0.77, 0.76 in males and females respectively). Cut off value with obesity in the study was ≥38.75 cm in males, ≥34.3 cms in females, with central obesity, ≥39.25 in males and, ≥34.5 in females.

Studies conducted in different part of world suggest that NC can be used as a simple initial screening measure of overweight and obesity. A significant and independent association was found between NC and overweight levels using multiple regression analysis in young adults. (Correlation Coefficient r with BMI was 0.53 in males, 0.58 in females, with WC 0.40 in males, and 0.62 in females.) A systematic review by Caroline Kroll et al suggests that, NC is an accurate tool for assessing overweight and obesity in males and females of different age groups and could be used to screen for excess body weight in routine medical practice or epidemiological studies. NC work better in women than men, probably because of differences in neck musculature.

NC is another way by which clinicians can assess degree of adiposity of patients as a measure of cardiovascular risk and make recommendations about reducing the risk. NC was also significantly associated with metabolic syndrome. Several studies have shown positive correlation between NC and SBP, DBP and glucose levels in both genders. NC has been reported as a marker of visceral adipose tissue, insulin resistance, sleep apnea and hypertension. Patients with abnormal NC should be screened for cardiovascular risk factors.

Neck circumference is associated with cardio metabolic risk factors, even after adjustment for visceral adipose tissue. Upper body subcutaneous fat accumulation in the neck appears to be associated with cardio metabolic risk beyond generalised adiposity. Upper body subcutaneous adipose tissue and visceral adipose tissue independently contribute to cardio metabolic risk. NC could suffice as a surrogate index of VAT in primary care setting. The Framingham Heart Study indicated that upper body subcutaneous fat measured as NC may be a unique, pathogenic fat deposit. NC was associated with CVD risk factors even after adjustment for VAT and BMI. (r with VAT 0.6, 0.7 with BMI 0.79, 0.80 in males and females respectively.) Systemic free fat concentrations are determined by upper body subcutaneous fat. NC was more strongly associated with adverse risk factor levels in women compared with men.

Waist circumference measurement may be difficult, particularly in situations due to cultural inhibitions, during winter period and in busy primary care setting. Women may not be comfortable in WC measurement by a male examiner. NC measurement is more useful in morbidly obese individuals, pregnant women and those bedridden.

Limitation of the study is that, NC is a proxy for upper body fat, but radiological measures to directly quantify this fat was not done. Sometimes the difficulty in locating the osseous structures causes a technical difficulty in measuring the NC in morbidly obese persons could limit the usefulness of this parameter in clinical practice.
CONCLUSIONS
A screening test for obesity detection must be simple, least cumbersome, easily feasible and non-invasive. NC as an additional measure of screening and monitoring tool for obesity is inexpensive, quick, easy to use and generally acceptable to both patients and health care providers. Measurement of NC may help in better identification and stratification of individuals at increased cardio metabolic risk. It is particularly useful in markedly obese patients, as BMI increases, waist circumference becomes a weaker marker of visceral adipose tissue. In pregnant women, it is useful, where traditional measures of obesity may be challenging or meaningless. NC may be used as a reliable index of obesity both in clinical practice and in epidemiological studies where it has a cultural advantage also. Training field health workers to detect obesity is easy for NC, as it is more socially acceptable. The present study shows that, neck circumference measurement is a valid potential clinical screening tool for detecting generalised and abdominal obesity in subjects with early-onset T2DM.

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