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RESEARCH ARTICLE

Neck circumference as an anthropometric parameter for obesity/overweight in type 2 diabetes mellitus

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ABSTRACT

Background: Diabetes mellitus type 2 and obesity are interdependent chronic disorders. Various anthropometric parameters (body mass index [BMI], waist circumference [WC], and waist-hip ratio [WHR]) have been used to determine body fat accumulation, which are useful as predictors of diabetes mellitus, metabolic syndrome, and other cardiovascular risks. Upper body fat deposition is another locus of body fat which has been the area of active research with important cardiovascular and metabolic consequences. Neck circumference (NC) is a simple and easy to use anthropometric parameter which can be a useful indicator of upper body fat distribution. **Aims and Objectives:** This study was done to study the usefulness of NC as a measure of obesity/overweight in Type 2 diabetes patients. **Materials and Methods:** This cross-sectional study was done at a rural tertiary care hospital in North India. 400 patients of diabetes mellitus were enrolled for the study. Anthropometric parameters (NC, BMI, WC, and W/H ratio) and cardiometabolic parameters (blood pressure, lipid profile, and blood glucose) were measured in all the subjects. **Results:** In both males and females, NC was significantly higher in overweight/obese patients than normal-weight patients ($P < 0.01$). Significant positive correlation was observed between NC and other anthropometric parameters (including BMI, WC, and WHR) and cardiometabolic factors (including systolic blood pressure, diastolic blood pressure, total cholesterol, and low-density lipoprotein cholesterol). **Conclusion:** NC is a convenient and effective tool to predict overweight/obesity in Type 2 diabetes mellitus patients.

KEY WORDS: Neck Circumference; Obesity; Body Mass Index; Diabetes Mellitus

INTRODUCTION

Type 2 diabetes mellitus is characterized by the presence of uncontrolled hyperglycemia, peripheral resistance to insulin, and relative impairment in insulin secretion. Diabetes has fast emerged as an epidemic in both developed and developing countries. As per epidemiological estimates, the total population with diabetes worldwide is projected to rise from 171 million in 2000 to 366 million in 2030.[1] India is among the worst affected by this epidemic and is having a very large diabetic population. Population growth, aging, rapid urbanization, sedentary lifestyle, and increased prevalence of obesity are the major environmental factors contributing to this diabetic epidemic. Obesity especially central obesity is an established risk factor for the development of insulin resistance and Type 2 diabetes mellitus. Since obesity and type 2 diabetes mellitus are so much related to each other, the term "diabesity" is used.[2,3]

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Overweight and obesity are defined as excessive body fat accumulation resulting in adverse health of the individual. They are major risk factors for a number of chronic

diseases, including diabetes, cardiovascular disorders, and stroke. WHO defines people as overweight if their body mass index (BMI) is between 25 and 30 kg/m^2, and BMI >30 kg/m^2 is regardedas obesity.[4] In the Indian population, expert guidelines have suggested lower BMI values to define obesity and overweight. These guidelines define overweight as BMI of 23–24.9 kg/m^2 and obesity as BMI of >25 kg/m^2.[5]

Various anthropometric parameters have been used to determine body fat accumulation, which can be used as good predictors of diabetes mellitus, metabolic syndrome, and other cardiovascular risks. BMI is an established parameter in evaluation and grading of obesity. Waist circumference (WC) and waist-to-hip ratio (WHR) are other commonly used anthropometric parameters to determine central body fat. These parameters are used to determine central or visceral adiposity.

Upper body fat deposition is another locus of body fat which has been the area of recent research. Studies have shown that an important contribution to the free fatty acids in the circulation is from the upper body adipose tissue. Therefore, it is believed that upper body adipose tissue may have important cardiovascular and metabolic consequences.[6]

Neck circumference (NC) is a simple, convenient and easy to use anthropometric parameter which can be a useful indicator of upper body fat distribution. It is also more practical and likely better measure when used in special populations such as morbidly obese people, patients in bed rest, and pregnant women. Use of NC as a predictor of obesity, metabolic syndrome, and cardiovascular risk is an area of active research.[7,8] Very few studies have evaluated the use of NC in Indian diabetic population.[9] Therefore, this study was undertaken to assess the use of NC as an anthropometric measurement to predict obesity/overweight (defined as per Indian consensus guidelines) in patients of Type 2 diabetes mellitus at a rural tertiary care centre in North India.

MATERIALS AND METHODS

This cross-sectional study was conducted on 400 patients of Type 2 diabetes mellitus (in the age group of 20–80 years) coming in outpatient/inpatient settings in the Department of General Medicine, Maharishi Markandeshwar Institute of Medical Sciences and Research, Mullana, Ambala. The study was conducted over a total duration of 6 months after taking approval from the Institutional Ethics Committee.

Inclusion Criteria

The following criteria were included in this study:
1. Patients diagnosed with Type 2 diabetes mellitus.
2. Age >20 years.

Exclusion Criteria

The following criteria were excluded from the study:
1. Patients having goiter.
2. Patients with renal or hepatic dysfunction.
3. Patients with any cognitive/psychiatric illness like schizophrenia.
4. Diagnosed case of Cushing syndrome, any pituitary/adrenal disorder, or any patient taking long-term corticosteroids.
5. Pregnant females.

Each eligible participant was explained about the aims and objectives of the study, and a written informed consent was taken before his/her inclusion in the study. Detailed present and medical history was recorded, followed by a thorough physical examination in all the subjects. Demographic data including age and sex of the patients were recorded. Blood pressure was measured in sitting position after 5 min of rest with a standard sphygmomanometer. Blood samples were obtained from all the subjects to measure fasting blood sugar and lipid profile.

Overweight and obesity were defined as per the recent consensus guidelines for Asian Indian population.[5] Patients with BMI of 23–24.9 kg/m^2 were taken as overweight, while patients with BMI >25 kg/m^2 were defined as obese.

All anthropometric parameters were measured as per the standard guidelines in a fasting state.[10] All measurements were obtained using a non-elastic measuring tape. Height was measured using Harpenden Stadiometer to the nearest centimeter. The subject was requested to stand upright without any shoes with back against the wall, heels together and eyes directed forward. Weight was measured with single standardized weighing scale available at MMIMSR, with the same machine to be used for all the subjects. BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). WC was measured at the approximate midpoint between the lower margin of the last palpable rib and the top of the iliac crest, in standing position after normal expiration. Hip circumference (HC) is the perimeter at the level of the greatest posterior protuberance of the gluteals. WHR was calculated from WC and HC.

NC was obtained with the subject sitting with head in the horizontal plane position. A measuring tape was applied around the neck below the laryngeal prominence and perpendicular to the long axis of the neck. The minimal circumference was measured and recorded to the nearest 0.1 cm.

Statistical Analysis

The data for continuous variables were expressed as mean ± standard deviation, and categorical data were expressed as frequencies and percentages. Student *t*-test was applied

to analyze statistical difference for continuous variables. Pearson's correlation coefficient was used to correlate NC with other anthropometric and metabolic parameters. $P < 0.05$ was considered as statistically significant. Reciever operator curve (ROC) analysis was done to measure the area under curve (AUM) and cutoff values. All statistical analysis was performed using SPSS statistical software version 21.0.

RESULTS

Table 1 shows a comparison of demographic, anthropometric, and metabolic parameters between male and female diabetic patients. NC was significantly higher in male subjects (37.04 ± 2.61) as compared to females (35.60 ± 2.41) ($P < 0.01$).

The comparison of NC between normal weight (BMI <23 kg/m^2) and overweight and obese (BMI>23 kg/m^2) was done for male and female subjects as shown in Table 2. Out of 172 male diabetic patients, 88 (51.2 %) were overweight/obese. Similarly, 132 (57.9 %) female subjects (n = 228) were overweight/obese. In both males and females, NC was significantly higher in overweight/obese patients than normal-weight patients ($P < 0.01$).

Tables 3 and 4 show the correlation analysis of NC with various anthropometric and metabolic parameters in male and female subjects, respectively. In male subjects, NC correlated significantly with weight, height, BMI, WC, HC, W/H ratio, systolic blood pressure (SBP), and diastolic blood pressure (DBP). Similarly, in females, a significant correlation was seen between NC and Weight, BMI, WC, HC, W/H ratio, SBP, DBP, total cholesterol (TC), and low-density lipoprotein cholesterol (LDL-C).

Figure 1a and b shows the ROC curves for NC and overweight/obesity (BMI>23 kg/m^2) in males and females, respectively. The AUM and best cutoff values for NC and overweight/obesity were calculated. The AUC for NC and overweight/obesity (BMI >23 kg/m^2) was 0.728 (95% confidence interval [CI], 0.653–0.803) for males and 0.793 (95% CI, 0.736–0.850) for females, respectively.

DISCUSSION

Upper body subcutaneous fat is a unique fat deposition which may confer additional cardiovascular and metabolic risk, above and beyond the central visceral body fat.[6] NC is a novel anthropometric parameter which is a measure of upper body fat deposit.[7] It has also been shown to correlate with abdominal visceral fat.[11] Recent research has shown that NC can be useful as a predictor of cardiometabolic risk, obesity, and insulin resistance in addition to standard parameters such as BMI, WC, and WHR in different populations.[8,12-16] A study done on a large Chinese population showed that there is a significant positive correlation between NC and other cardiometabolic risk factors and it is an independent predictor of cardiometabolic risks beyond the classical

Table 1: Comparison of demographic, anthropometric, and metabolic parameters between male and female diabetic patients

Parameters	Males (n=172)	Females (n=228)	P value
Age (years)	53.67±7.20	53.73±8.24	0.946
Weight (kg)	70.70±11.04	65.38±11.09	<0.01*
Height (cm)	1.70±0.06	1.62±0.06	<0.01*
BMI (kg/m^2)	24.44±4.29	25.03±4.37	0.178
WC (cm)	87.03±8.43	85.02±10.90	<0.05*
HC (cm)	95.58±8.48	94.49±10.61	0.270
WHR	0.90±0.042	0.89±0.038	<0.01*
NC (cm)	37.04±2.61	35.60±2.41	<0.01*
SBP (mm Hg)	135.49±14.58	133.42±16.64	0.196
DBP (mm Hg)	82.88±8.56	82.31±9.59	0.538
FBS (mg/dl)	146.75±35.24	150.38±38.07	0.330
TC (mg/dl)	174.73±38.14	162.99±38.92	<0.01*
TG (mg/dl)	159.42±43.03	157.33±56.21	0.684
HDL-C (mg/dl)	40.59±9.24	35.41±10.42	<0.01*
LDL-C (mg/dl)	95.92±31.03	95.66±33.27	<0.01*

*P<0.05 Statistically significant. BMI: Body mass index, WC: Waist circumference, HC: Hip circumference, WHR: Waist-hip ratio, NC: Neck circumference, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, FBS: Fast blood sugar, TC: Total cholesterol, TG: Triglycerides, HDL-C: High-density lipoprotein cholesterol, LDL-C: Low-density lipoprotein cholesterol

Table 2: Comparison of NC values between non-obese, overweight, and obese patients of Type 2 diabetes

Gender	BMI status (kg/m^2)	NC (cm)		P value
		N	Mean±SD	
Males	BMI<23	84	35.93±1.727	<0.01*
	BMI>23	88	38.10±2.861	
Females	BMI<23	96	34.18±1.930	<0.01*
	BMI>23	132	36.64±2.197	

*P<0.01 Highly significant, Data analyzed by t-test. SD: Standard deviation, BMI: Body mass index, NC: Neck circumference

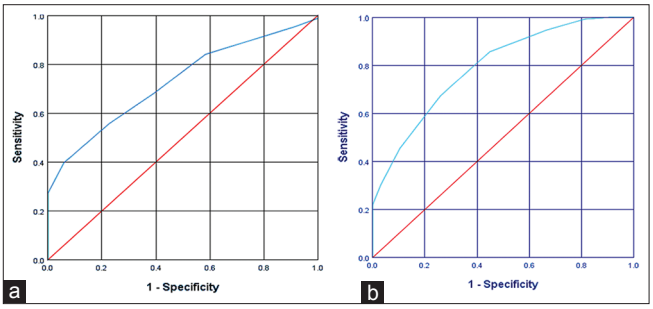

Figure 1: (a) Reciever operator curve (ROC) curve for neck circumference and overweight/obesity (body mass index [BMI]>23 kg/m^2) in males. (b) ROC curve for neck circumference and overweight/obesity (BMI>23 kg/m^2) in females

Table 3: Correlation of NC with other anthropometric parameters in male and female patients

Parameters	NC			
	Males		Females	
	Pearson coefficient *r*	*P* value	Pearson coefficient r	*P* value
Age	0.145	0.063	0.008	0.904
Weight (kg)	0.511	<0.001*	0.671	<0.001*
Height (cm)	–0.255	<0.001*	0.062	0.354
BMI (kg/m2)	0.587	<0.001*	0.621	<0.001*
WC (cm)	0.653	<0.001*	0.736	<0.001*
HC (cm)	0.621	<0.001*	0.705	<0.001*
WHR	0.187	0.014*	0.359	<0.001*

**P*<0.01 Highly significant. BMI: Body mass index, NC: Neck circumference, WC: Waist circumference, HC: Hip circumference, WHR: Waist-hip ratio

Table 4: Correlation of NC with metabolic parameters in male and female patients

Parameters	NC (males)		NC (females)	
	Pearson coefficient '*r*'	*P* value	Pearson coefficient '*r*'	*P* value
FBS (mg/dl)	0.037	0.630	0.054	0.417
TC (mg/dl)	0.121	0.115	0.173	0.009*
TG (mg/dl)	0.066	0.390	0.023	0.726
HDL-C (mg/dl)	0.118	0.123	0.231	<0.001*
LDL-C (mg/dl)	0.126	0.100	0.221	<0.001*
SBP (mm Hg)	0.317	<0.001*	0.262	<0.001*
DBP (mm Hg)	0.210	0.006*	0.283	<0.001*

**P*<0.01: Highly significant. NC: Neck circumference, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, FBS: Fast blood sugar, TC: Total cholesterol, TG: Triglycerides, HDL-C: High-density lipoprotein cholesterol, LDL-C: Low-density lipoprotein cholesterol

anthropometric parameters.[8] Similarly, in the San Juan Overweight Adults Longitudinal Study which included 1206 participants of 40–65 age group, NC was compared with other anthropometric measurements. NC showed similar or better associations with metabolic risk factors. In addition, it was more practical measurement than WC.[16]

In our study, we evaluated the usefulness of NC as a predictor of overweight/obesity in Indian patients diagnosed with Type 2 diabetes mellitus. Obesity/overweight was defined as per recent guidelines given for Asian Indian populations.[5] Our results showed that in both males and females, NC in obese/overweight subjects (BMI > 23 kg/m^2) was significantly higher than in normal-weight subjects (BMI < 23 kg/m^2) ($P < 0.01$). In correlation analysis of NC with other anthropometric parameters, the statistically significant correlation was found between NC and other parameters (BMI, WC, HC, and W/H ratio) in both male and female subjects. NC also showed significant correlation with cardiometabolic parameters including SBP, DBP, TC, and LDL-C. Our results were consistent with the results of previous studies done in diabetic populations.[9,17]

ROC analysis showed that the AUC for NC and overweight/obesity (BMI > 23 kg/m^2) was 0.728 (95% CI, 0.653–0.803) for males and 0.793 (95% CI, 0.736–0.850) for females. The best cutoff value of NC for identifying overweight/obesity was 37.5 cm for male subjects (sensitivity 55.7% and specificity 77.4%) and 35.5 cm for female subjects (sensitivity 67.4% and specificity 74%).

One important advantage of NC as an anthropometric tool is that it is easy to use, less time consuming, and less cumbersome. Unlike waist and HCs, it is a simple and convenient measurement which can be independently used as a predictor of overweight/obesity in different populations including diabetic patients.

Our study had some important limitations. Since our study was a single hospital based cross-sectional study, the results may not be generalized to other populations. This may also have resulted in an overestimation of correlation between the variables. Our study did not evaluate the possible effects of physical activity, dietary habits, socioeconomic status, and genetics on the NC in the diabetic patients.

CONCLUSION

Obesity and Type 2 diabetes mellitus are interdependent chronic disorders. Detection of obesity is based on anthropometric measurements. NC correlates well with other anthropometric parameters of obesity such as BMI,

WC, and WHR in both male and female subjects. Our study concluded that NC can be used as a convenient and effective tool to predict overweight/obesity in Type 2 diabetes mellitus patients.

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