

Neck circumference: A supplemental tool for the diagnosis of metabolic syndrome

Mozaffer Rahim Hingorjo,¹ Sitwat Zehra,² Erum Imran,³ Masood Anwar Qureshi⁴

Abstract

Objective: To explore the usefulness of neck circumference as a supplemental tool for diagnosing metabolic syndrome while identifying its cut-off values.

Methods: This case-control study was conducted at Dr. Essa's Laboratory and Diagnostic Centre, Karachi, from December 2014 to April 2015, and comprised subjects with and without metabolic syndrome aged between 35 and 65 years regardless of their diabetic status. Evaluation was done for metabolic syndrome by measuring anthropometric, clinical and biochemical parameters according to the criteria proposed by the International Diabetes Federation. Variables in both cases and controls were correlated with neck circumference and its cut-off values were determined for diagnosing metabolic syndrome. SPSS 20 was used for statistical analysis.

Results: Of the 215 subjects enrolled, 164(76.28%) were selected. Of them, 83(50.61%) were cases and 81(49.39%) were controls. Moreover, 90(55%) of them were men and 74(45%) were women. The overall mean age was 51.15 ± 10.36 years (range: 35 to 65 years). The mean neck circumference was 36.13 ± 2.14 cm and 31.59 ± 1.18 cm in normal-weight men and women, respectively, compared with 40.0 ± 2.13 cm and 35.75 ± 2.74 cm among obese men and women.

The neck circumference correlated best with waist circumference in men ($p=0.001$) and with body surface area in women ($p=0.001$). The area under the curve of neck circumference for metabolic syndrome was 0.760 for men ($p<0.001$) and 0.631 for women ($p<0.05$). Optimal neck circumference cut-off points to determine metabolic syndrome were ≥ 38 cm for men and ≥ 34 cm for women. The odds ratio for metabolic syndrome was 12.44 (95% confidence interval: 4.13-37.41) among male cases and controls compared to 3.34 (1.26-8.80) among women.

Conclusion: Neck circumference strongly correlated with adiposity indices and had a definite cut-off point. It can therefore be used as a useful adjunct for clinical screening of metabolic syndrome.

Keywords: Neck circumference, Waist circumference, Metabolic syndrome, Obesity, Diabetes mellitus. (JPMA 66: 1221; 2016)

Introduction

Metabolic syndrome (MS) is the name given to a cluster of disorders that increase the chance of developing cerebrovascular and coronary artery disease (CAD). The prevalence of MS is increasing throughout the world, which may be due to a rise in central or abdominal obesity, an important diagnostic variable in the definition of MS. The prevalence of MS in the United States is 34% according to the data compiled by National Health and Nutrition Examination Survey (NHANES) 1999-2006.¹ Its prevalence in Pakistan according to various studies is stated to be between 18-46%.^{2,3} In studies conducted locally and internationally, the prevalence rate of MS is higher in diabetic population.⁴⁻⁶ Early diagnosis of MS

prevents development of complications reducing the morbidity and mortality related to this disease.

Currently, the waist circumference (WC) is used to measure central obesity. However, its cut-off points are yet to be established as there are wide variations in accordance to geographic and racial differences. Waist circumference varies with the phases of respiration and fullness of stomach. Furthermore, there are disparities in the locations used for measuring WC which may produce error in the diagnosis of MS. Deposition of fat around the neck is a unique place that depicts upper body subcutaneous adipose tissue. Measurement of neck circumference (NC) has been identified as a reliable tool that can supplement WC. It is easy to measure, reproducible and not affected by phases of respiration or stomach fullness. However, it has yet to be decided whether NC is a better indicator of central obesity than WC.⁷⁻⁹

The current study was planned to identify the usefulness of NC in diagnosing abdominal obesity and metabolic syndrome. We also intended to define NC cut-off points

^{1,3}Department of Physiology, Jinnah Medical & Dental College, ²Dr. A. Q. Khan Institute of Biotechnology & Genetic Engineering, University of Karachi, ⁴Department of Physiology, Dow International Medical College, Dow University of Health Sciences, Karachi, Pakistan.

Correspondence: Mozaffer Rahim Hingorjo.
Email: muzaffer_rahim@hotmail.com

for the development of MS. Because of lack of local studies in this regard, we believe this study will add to the current literature, especially in terms of NC cut-off points obtained.

Subjects and Methods

This case-control study was conducted at Dr. Essa's Laboratory and Diagnostic Centre in Karachi from December 2014 to April 2015, and comprised subjects with and without metabolic syndrome aged between 35 and 65 years regardless of their diabetic status. Subjects having active infection, inflammatory disorder, cancer, thyroid dysfunction, end-stage hepatic/renal/cardiac failure and diabetics on insulin were excluded. Written informed consent was taken from each subject and the investigations were carried out according to the principles outlined in the Declaration of Helsinki as revised in 2008. The study was approved by the research and ethical committee of Jinnah Medical and Dental College, Karachi.

Anthropometric indices of obesity were measured

Weight was measured to the nearest 0.1 kg using digital scale and height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Body Mass Index (BMI) was then calculated as a ratio of weight (kg) and height (m²). Waist circumference (WC) was measured in the standing position, to the nearest 0.1 cm, midway between the iliac crest and lower border of rib cage, at the end of normal expiration. Hip Circumference (HC) was similarly measured while standing, to the nearest 0.1 cm at the widest part of hip. Waist-Hip Ratio (WHR) and Waist-Height Ratio (WHtR) were calculated by dividing the WC with HC and height, respectively. The neck circumference (NC) was taken below the level of thyroid cartilage, perpendicular to the vertical axis of the neck.

Conicity index (C index),^{10,11} a measure of central obesity which is used to calculate WC for a given height and weight, was determined by:

$$Cindex = WC(m) \div 0.109 \times / (Wt(kg) \div Ht(m))$$

The body surface area (BSA) was determined by

$$BSA = \sqrt{(Wt \times Ht)} \div 60$$

Abdominal volume index (AVI),¹² another measure of central obesity, was determined by:

$$AVI = [2WC^2 + 0.7(WC - HC)^2] \div 1000$$

To determine body fat percent (BF%), skin fold thickness

was measured at specified places using Fat-O-Meter. Using log of this value, body density (D) was estimated and used to calculate BF% as below:

$$\text{Males} = (4.97 \div D) - 4.52$$

$$\text{Females} = (4.81 \div D) - 4.34$$

Metabolic syndrome was defined as according to the criteria suggested by International Diabetes Federation (IDF).¹³ This includes central obesity measured by ethnicity specific cut-off points of WC (males: 90 cm, females: 80cm) plus any two of the following four criteria: High blood pressure (systolic 130mmHg or diastolic 85mmHg) or taking medicines for previously diagnosed hypertension; Triglycerides 150mg/dL or taking specific treatment for it; Decreased high-density lipoprotein(HDL) cholesterol (males: < 40mg/dL, females: < 50mg/dL) or taking specific treatment for it; and fasting plasmagluucose 100mg/dL or previously diagnosed type 2 diabetes mellitus.

(If fasting plasma glucose is ≥ 100 mg/dL, an oral glucose tolerance test should be done, however, it is not needed to diagnose metabolic syndrome.)

Fasting venous blood sample were drawn, after an overnight fast of 10 to 14 hours, to measure levels of glucose, glycated haemoglobin (HbA1c), lipid profile, insulin and leptin. After centrifugation, serum was separated and immediately stored at -80 degree Celsius until analysed by commercially available kits. Levels of human insulin were detected using highly sensitive sandwich enzyme-linked immunosorbent assay (ELISA). The kit used for determination of serum insulin was DRG® Insulin ELISA (EIA-2935), having sensitivity or minimum detection limit of 1.76 µIU/mL. The inter-assay and intra-assay coefficients of variation (CV) of the kit were 2.6% and 2.9%, respectively. Serum leptin was similarly determined using highly sensitive sandwich ELISA (EIA-2395; DRG Instruments GmbH, Germany), with a sensitivity to detect a minimum level of 1.0 ng/ml. The intra-assay and inter-assay CV of the kit were 6.91% and 8.66%, respectively.

SPSS 20 was used for statistical analysis. The results were expressed as mean $\pm$ SD. Pearson's correlation coefficient was used to determine the relation between neck circumference and variables of metabolic syndrome. A p-value < 0.05 was considered significant. Odds ratios (ORs) and 95% confidence intervals (CIs) were determined for NC against MS and its individual components. Receiver operating characteristic (ROC) curves were constructed and cut-off points were determined to evaluate the accuracy of NC as a predictor of MS.

Results

Of the 215 subjects enrolled, 164(76.28%) were selected. Of them, 83(50.61%) were cases and 81(49.39%) were controls. There were 90(55%) men and 74(45%) women in the study, with a mean age of 51.15±10.36 years (range: 35 to 65 years). The mean age of men was 52.82±10.47 years and that of women was 49.12±9.90 years. Among men, the mean age of controls and cases was 50.56±10.82 and 55.65±9.40 years, respectively ($p=0.021$). Among women, the mean age of controls was 43.67±8.22 and that of cases was 53.04±9.19 years ($p<0.001$). The respective values for mean systolic blood pressure were 130.12±15.1 mmHg and 138.97±16.6 among men controls and cases ($p=0.009$) compared to 125.58±15.5 and 149.39±24.5 among women ($p<0.001$). Similarly, the diastolic blood pressure among men was 81.68±10.80 mmHg in controls and 84.40±9.42 in cases ($p=0.212$), whereas the respective values were 78.35±7.94 and 85.14±12.08 among women ($p=0.007$). Among men, the mean insulin level of controls was 4.67±4.84 µIU/ml and that of cases was 9.68±10.16 ($p=0.002$); the values were 6.40±7.19 and 10.29±8.78 among women ($p=0.046$). Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), a measure

of insulin resistance, was 3.36±3.23 in males and 3.97±3.69 in females in the MS group compared to 1.71±2.29 and 1.76±1.95 among controls ($p<0.01$). Serum leptin, a measure of adiposity, was 6.62±5.41 and 12.14±8.80 ng/ml among men controls and cases ($p<0.001$) compared to 29.30±20.10 and 29.89±21.12 among women ($p=0.904$) (Table-1).

The mean NC in normal weight subjects was 36.13±2.14 cm in men and 31.59±1.18 cm in women. However, it was 40.0±2.13 cm and 35.75 ± 2.74 cm, respectively, among obese men and women. Pearson's correlation in men was best for WC ($p<0.001$) and AVI ($p<0.001$; both markers of central obesity. In women, the correlation value of NC correlated best with BSA ($p<0.001$, BMI ($p<0.001$), WC ($p<0.001$) and AVI ($p<0.001$).

The area under the ROC curve (95% CI) for NC and MS was 0.76 (0.66, 0.85) for males and 0.63 (0.50, 0.76) for females. The cut-off values obtained for NC to diagnose MS were 37.9 cm in males (sensitivity 0.875, specificity 0.640) and 34.0 cm in females (sensitivity 0.535, specificity 0.710). The corresponding cut-off values for WC and BMI with respect to MS were 93.25 cm and 24.93 kg/m², respectively, in males and 96.50 cm and 26.53 kg/m² in females.

Table-1: Descriptive characteristics of the study population.

Variables	Controls (n = 50)	Males MS (n = 40)	p value	Controls (n = 31)	Females MS (n = 43)	p value
Age, years	50.56 (10.82)	55.65 (9.40)	0.021*	43.67 (8.22)	53.04 (9.19)	<0.001***
BMI, kg/m ²	23.65 (3.90)	26.74 (3.31)	<0.001***	26.28 (4.41)	28.45 (5.37)	0.069
WC, cm	91.75 (11.54)	101.85 (7.54)	<0.001***	91.50 (8.79)	99.76 (11.17)	0.001***
HC, cm	96.97 (7.63)	103.05 (9.37)	0.001***	105.64 (8.76)	107.93 (10.6)	0.329
WHR	0.94 (0.06)	0.99 (0.05)	<0.001***	0.86 (0.05)	0.92 (0.07)	<0.001***
WHtR	0.53 (0.06)	0.60 (0.04)	<0.001***	0.58 (0.05)	0.63 (0.06)	<0.001***
NC, cm	37.05 (2.73)	39.62 (2.20)	<0.001***	33.12 (2.98)	35.04 (2.85)	0.006**
C-Index	1.32 (0.08)	1.39 (0.06)	<0.001***	1.30 (0.07)	1.37 (0.08)	<0.001***
BSA, m ²	1.80 (0.18)	1.88 (0.18)	0.039*	1.68 (0.17)	1.73 (0.21)	0.278
AVI, L	17.14 (4.33)	20.88 (3.14)	<0.001***	17.06 (3.15)	20.23 (4.49)	0.001***
BF, %	24.02 (5.06)	28.68 (3.82)	<0.001***	36.19 (5.41)	40.94 (5.77)	<0.001***
SBP, mmHg	130.12 (15.1)	138.97 (16.6)	0.009**	125.58 (15.5)	149.39 (24.5)	<0.001***
DBP, mmHg	81.68 (10.80)	84.40 (9.42)	0.212	78.35 (7.94)	85.14 (12.08)	0.007**
LDL-C, mg/dl	111.61 (26.4)	98.26 (35.09)	0.042*	113.35 (24.6)	121.46 (34.9)	0.271
HDL-C, mg/dl	43.04 (4.29)	42.12 (5.16)	0.358	44.25 (3.94)	43.09 (4.11)	0.227
TGL, mg/dl	155.40 (84.6)	163.84 (82.2)	0.635	120.58 (52.3)	154.27 (61.1)	0.015*
FPG, mg/dl	133.20 (79.5)	144.07 (51.8)	0.457	115.48 (38.7)	156.65 (49.6)	<0.001***
Insulin, µIU/ml	4.67 (4.84)	9.68 (10.16)	0.002**	6.40 (7.19)	10.29 (8.78)	0.046*
HOMA-IR	1.71 (2.29)	3.36 (3.23)	0.005**	1.76 (1.95)	3.97 (3.69)	0.003**
Leptin, ng/ml	6.62 (5.41)	12.14 (8.80)	<0.001***	29.30 (20.10)	29.89 (21.12)	0.904

MS: metabolic syndrome. BMI: body mass index. WC: waist circumference. HC: hip circumference. WHR: waist-to-hip ratio. WHtR: waist-to-height ratio. NC: neck circumference. C-Index:conicity index.

BSA: body surface area. AVI: abdominal volume index. BF: body fat percent. SBP: systolic blood pressure. DBP: diastolic blood pressure. LDL-C: low-density lipoprotein cholesterol.

HDL-C: high-density lipoprotein cholesterol. TGL: triglyceride. FPG: fasting plasma glucose. UA: uric acid.

Note: Unpaired Student's t-test was used to compare means between controls and MS in male and female subjects. Values expressed as mean (SD). * $p<0.05$, significant; ** $p<0.01$, very significant;

*** $p<0.001$, extremely significant.

Table-2: Odds ratio between metabolic syndrome components and neck circumference.

	Cases Odds	Male Controls Odds	Total Odds Ratio (95% CI)	Cases Odds	Female Controls Odds	Total Odds Ratio (95% CI)
MS	7.0	0.56	12.44*** (4.13-37.41)	1.93	0.57	3.34** (1.26-8.80)
HTN	2.0	0.95	0.86 (0.36-2.05)	1.38	0.84	1.63 (0.61-4.34)
WC	4.75	0.51	9.18*** (3.43-24.58)	6.0	0.34	17.40*** (5.53-57.12)
TGL	2.46	0.87	2.81* (1.17-6.72)	1.20	1.15	1.04 (0.41-2.60)
HDL-C	2.80	0.92	3.02* (1.22-7.46)	1.31	1.05	1.24 (0.49-3.10)
FPG	2.0	0.83	2.40* (0.99-5.78)	1.63	0.33	4.90* (1.40-17.13)

Note: Values presented as odds or odds ratio (95% CI). *p<0.05, significant; **p<0.01, very significant; ***p<0.001, extremely significant.

MS: metabolic syndrome. WC: waist circumference. HTN: hypertension. HDL-C: high-density lipoprotein cholesterol. TGL: triglyceride. FPG: fasting plasma glucose. OR: odds ratio. CI: confidence interval.

Table-3: Neck Circumference cut-off points for Metabolic Syndrome.

Author/s	Year	Place of Study	Age (years)	Neck Circumference	
				Male	Female
Yan Q et al ⁷	2014	East China	> 65	38 cm	35 cm
Yang GR et al ⁸	2010	China	20 - 80	39 cm	35 cm
Zhou JY et al ¹⁶	2013	China	20 - 85	37 cm	≥ 33 cm
Onat A et al ¹⁸	2009	Turkey	55 ± 12	39 cm	35 cm
Hoebel et al ¹⁹	2012	South Africa	25 - 45	39 cm	32 cm
		(Urban African)	45 - 65	35 cm	35 cm
		South Africa	25 - 45	40 cm	34 cm
		(Caucasian)	45 - 65	41 cm	33 cm
Kumar NV et al ²⁰	2014	India	> 35	> 37 cm	> 34 cm
Ang NS & Raboca JC ²¹	2011	Philippines	49 ± 11	≥ 40 cm	33.8 cm
Hasan HS ²²	2012	Iraq	30 - 68	≥ 38 cm	34 cm
FerrettiRde L et al ²³	2015	Brazil	10 - 17	34.25 cm*	31.25 cm*
				37.95 cm†	32.65 cm†
Limpawattana P et al ²⁴	2015	Thailand	50	39 cm	33 cm
This Study	2015	Pakistan	30 - 65	38 cm	≥ 34 cm

*Overweight. †Obesity.

The odds ratio for MS was 12.44 (95% CI: 4.13-37.41) among men cases and controls compared to 3.34 (1.26-8.80) among women. The ratio for WC was 9.18 (3.43-24.58) among men and 17.40 (5.53-57.12) among women (Table-2).

Discussion

We found NC to be highly correlated with all the anthropometric indices of obesity as well as with MS. The correlation with WC was of special significance due to the fact that central obesity measured by WC is the principal component in the diagnosis of MS. Furthermore, an NC value of ≥ 38 cm for men and ≥ 34 cm for women was the best cut-off point to determine subjects with MS.

An increased WC is identified as a first step in diagnosing metabolic syndrome. Waist circumference is chosen due to its close association with central obesity and

cardiometabolic risk factors. However, the site for measurement of WC varies among studies, such as, iliac crest, umbilicus, lower border of rib cage, and midway between rib cage and iliac crest.¹⁴ Furthermore, WC is affected by the state of stomach fullness and has to be taken at the end of normal expiration that again leads to variation in measurements. Neck circumference has been suggested by several studies to correlate strongly with measures of central obesity and does not require multiple readings to be taken for accuracy and reliability as opposed to WC.¹⁵ It can be measured at a single point, involves no breath holding and is not affected by prandial state. Also, it is a simple measure that can be taken without removal of clothing and is therefore convenient for both the examiner and the subject.

Our results showed that NC was highly sensitive in identifying obesity and could be used to predict MS as

well. Yan Q et al. in a cross-sectional study on 2,092 elderly Chinese subjects found NC to be highly correlated with anthropometric indices of obesity, such as BMI and WC as well as to MS.⁷ Another study in diabetic individuals aged 20 to 80 years found positive correlation of NC with obesity markers and MS.⁸ Zhou JY et al. examined a total of 4,201 male and female subjects between the ages of 20 to 85 years and found significant association of NC with cardio-metabolic risk factors. Furthermore, NC individually contributed to the prediction of MS risk factors beyond conventional anthropometric indices such as BMI, WC and WHR.¹⁶ In the Framingham Heart Study, 2,732 participants (mean age 57 years) were followed for 10 years for the development of each component of MS. It was found that NC positively correlated with a high fasting blood sugar level, hypertension, low HDL cholesterol and high triglyceride. The correlation of NC with type 2 diabetes remained strong even after adjustments for BMI and WC.¹⁷ Similar findings were reported by Onat et al. in Turkish subjects where NC proved better than WC in predicting the likelihood of MS.¹⁸

Hoebel et al. determined the NC cut-off associated with MS in a South African cohort. They compared the NC cut-off among young and old Caucasians and urban Africans. The cut-off value for Caucasians was higher than that for urban Africans in all age groups, especially in men, suggesting racial influence on distribution of fat and difference in body size.¹⁹

Kumar et al. conducted a cross-sectional study on South Indian population that was similar to our study. The correlation between NC and MS and its individual variables were strong as in our study.²⁰ Moreover, the cut-offs obtained for NC were same as those observed by our study, suggesting the need to develop standard values for local populations. These values can be used in demographic surveys to supplement other anthropometric indices for the diagnosis of obesity and its related disorders.

The international reference values for NC cut-off points are not yet available. Furthermore, the NC cut-off points for assessing MS have been variably described in different studies. This may be due to racial and geographical differences in the study populations as well as the methodology used for a particular study. The cut-off values obtained by our study were 38 cm for men and 34 cm for women and correspond well with other Asian studies²¹⁻²⁴ (Table-3) and a comparison of cut-off points in these studies showed higher values for men than for women.

An NC cut-off point corresponding with a high sensitivity

is important for screening purposes. Further tests having high specificity may need to be done later to identify false positive tests done in the first stage.

This study has some limitations. First, being a cross-sectional study, it was difficult to make a causal inference. Second, the sample size was not sufficiently large enough to estimate the prevalence of MS with adequate precision. Finally, due to convenience sampling, the results of the study could not be generalised to the entire population. Despite these limitations, we were able to make assumptions regarding the usefulness of NC in diagnosing obesity and MS.

Conclusion

NC was found to be a simple, yet reliable enough tool, that may supplement anthropometric indices used to diagnose abdominal obesity and MS. Due to its ease of measurement, it can be considered as a first step towards screening for metabolic disorders related to obesity. Further studies are required to establish the same relationship in the general population.

Acknowledgement

We are grateful to Dr. Shazia Nadeem, assistant professor physiology at the Ziauddin University, Karachi, for assistance in collecting data. We are also grateful to Essa Laboratories for providing us laboratory assistance.

Disclaimer: The abstract has not been presented or published in a conference, or published in an abstract book.

Conflict of Interest: None.

Source of Funding: None.

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