

Prevalence of Metabolic Syndrome in Overweight and Obese Patients and Their Measurement of Neck Circumference: A Cross-sectional Study

Ayesha A. Hai¹, Sundus Iftikhar², Saba Latif¹, Fivzia F. Herekar³, Sana Javed¹, Muhammad Junaid Patel¹

1. Internal Medicine, The Indus Hospital, Karachi, PAK 2. Statistical and Training Unit, The Indus Hospital, Karachi, PAK 3. Internal Medicine and Infectious Diseases, The Indus Hospital, Karachi, PAK

✉ Corresponding author: Ayesha A. Hai, ayesha.hai@hotmail.com

Abstract

Background

The utilization of neck circumference (NC) as a valuable tool to evaluate metabolic syndrome (MetS) is still unclear. MetS has been extensively reported worldwide mainly due to the increasing trend of central obesity and the risk of developing coronary artery disease. In Pakistan, its incidence is reported to be between 18% and 49% among the urban population.

Methods

This cross-sectional study was conducted at the Indus Hospital, Karachi, Pakistan; in total, 392 patients (body mass index [BMI] >23 kg/m², age ≥18 years, both genders) were recruited through consecutive sampling, and informed consent was obtained.

Results

The majority of patients were females ($n = 344$, 87.8%), and the mean \pm SD of age and NC of all patients was 50.5 ± 9.6 years and 38 ± 4.6 cm, respectively. The majority ($n = 375$, 95.7%) of patients were found to have MetS, with 90% of both males and females having NC ≥ 38 cm and 34 cm, respectively.

Conclusion

The prevalence of MetS was found to be very high in overweight and obese patients. Moreover, the majority of patients with MetS were found to have higher NC.

Categories: Endocrinology/Diabetes/Metabolism, Internal Medicine

Keywords: metabolic syndrome, overweight, obese

Introduction

Globally, the burden of overweight and obesity has been increasing substantially affecting almost 30% of the entire world population [1]. Overweight and obesity are defined as an excessive accumulation of body fat or weight that exceeds the age- and gender-specific reference limits leading to ill health and a high incidence of non-communicable diseases such as metabolic syndrome (MetS) [1-2]. Pakistan ranks ninth among the world's most obese nations [1].

MetS is a serious health condition that can lead to several chronic, non-communicable diseases such as cardiovascular disease and diabetes mellitus [3]. MetS is a combination of at least three of the following five metabolic abnormalities: 1) elevated waist circumference (cutoff for Asians: ≥ 90 cm/35.4 inches in men and ≥ 80 cm/31.5 inches in women), 2) elevated triglycerides (TG; ≥ 150 mg/dL), 3) reduced high-density lipoprotein (HDL; < 40 mg/dL in men and < 50 mg/dL in women), 4) elevated blood pressure (systolic blood pressure [SBP] ≥ 130 mmHg or diastolic blood pressure [DBP] ≥ 85 mm Hg) or hypertensive, and 5) elevated fasting blood glucose level (≥ 100 mg/dL or 5.6 mmol/L) or diabetic [4].

There are several criteria for diagnosing MetS, of which the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) and the International Diabetes Federation (IDF) are the most widely used criteria in Pakistan due to their reliability [5-6]. According to these criteria, the prevalence of MetS in Pakistan over the last decade is reported to be 35% to 64% [7-8]. According to the report of the Global Burden of Disease (GBD), the disability-adjusted life years (DALYs) attributable to risk factors associated with the

How to cite this article

Hai A A, Iftikhar S, Latif S, et al. (November 10, 2019) Prevalence of Metabolic Syndrome in Overweight and Obese Patients and Their Measurement of Neck Circumference: A Cross-sectional Study. Cureus 11(11): e6114. DOI 10.7759/cureus.6114

Received 10/15/2019

Review began 10/17/2019

Review ended 11/04/2019

Published 11/10/2019

© Copyright 2019

Hai et al. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 3.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

diagnosis of MetS have dramatically increased over the past two decades [9]. The report revealed that in 2010, high BMI and diabetes ranked sixth among the various leading risk factors and non-communicable diseases contributing to DALYs [9].

Waist circumference (WC) is commonly used to define central obesity and plays a vital role in diagnosing obesity and MetS. The measurement of WC may be significantly influenced by various measuring methods, weather conditions, particularly winter, and interday variations that might affect the abdominal wall and abdominal cavity [10]. Literature has shown that the heterogeneity in body structure and abdominal tissues depend on not only age and gender but also ethnicity [11]. Hence, the IDF has now proposed lower cut-off values for WC for some ethnicities [11]. Moreover, BMI, which is considered as another valuable tool to assess overweight and obesity, does not evaluate fat distribution; hence, it cannot always assess the individual risk of endocrine and metabolic complications.

Therefore, several studies have been carried out to assess the alternative anthropometric measure for diagnosing overweight, obesity, and MetS. Recently, researchers have greatly focused on NC, a parameter of upper-body adiposity. NC is a simpler, relatively new and practical anthropometric indicator that is not affected by the postprandial abdominal distension or by respiratory movements and can be particularly useful in specific populations such as morbidly obese people, patients in bed rest, and pregnant women [9].

NC has been shown to be promising in diagnosing overweight and obesity and is also significantly associated with cardiovascular disease, SBP and DBP, and TG, total cholesterol, and fasting blood sugar levels; NC is also a predictor of obstructive sleep apnea syndrome in the Framingham study [7,12-13].

Moreover, recent studies have also reported a significant and positive correlation between NC and MetS [14-15]. A study done in Pakistan in 2016 has reported a higher NC in the MetS group in comparison to the non-MetS group [14]. Additionally, the study reported NC ≥ 38 cm and ≥ 34 cm as the optimal cutoff values for the diagnosis of MetS in males and females, respectively [14]. However, a systematic review and meta-analysis done in 2018 reported significant positive associations between NC and the various factors of MetS but has reported no association between the two [16].

We aimed to conduct this study to assess the prevalence of MetS owing to the dearth of local literature reporting the current burden of MetS in Pakistan. Also, this study intended to gauge the optimal cutoff values of NC provided by Hingorjo MR et al. [17].

Materials And Methods

This cross-sectional study was conducted at the Indus Hospital, Karachi (TIH), a free-of-cost tertiary care facility. A priori sample size was calculated using OpenEpi software (Open Source Epidemiologic Statistics for Public Health, Version 3.01) with the following assumptions: MetS prevalence of 49% and the desired precision of 5% [7]. The required sample size was estimated to be 384. All patients of either gender and age ≥ 18 years presenting to the outpatient clinics or admitted in the medical unit with BMI > 23 kg/m² as per the Asian criteria and had given informed consent were included in the study through non-probability consecutive sampling [18].

Patients with clinical or laboratory evidence of cardiac failure (stage C and D), liver failure, hyper or hypothyroidism, known congenital syndromes that lead to obesity, or on systemic steroids were excluded from the study.

Data on socio-demographic characteristics, such as age, gender, comorbidities, anthropometric variables (height, weight, BMI, NC, WC), and blood pressure, were gathered. MetS screening tool used by the Department of Mental Health, Missouri was used to assess MetS [17]. Recent biochemical profiles of individual patients such as fasting plasma glucose, TC, LDP, TG, and HDP levels were extracted from the Hospital Information Management System (HIMS) of TIH. All data were recorded on a pre-designed questionnaire.

Blood pressure was measured using the auscultatory method, which uses a mercury sphygmomanometer and stethoscope for determining the SBP and DBP based on the appearance and disappearance of Korotkoff sounds, respectively. Two readings for SBP and DBP were taken and their average value was used in the analysis. Anthropometric measurements were measured using a soft flexible measuring tape. WC was measured in centimeters at the midpoint between the lowest rib and the highest point of the iliac crest. NC was measured at the level of the lower part of thyroid cartilage (just below Adam's apple) along a horizontal line in centimeters, with readings up to 1 decimal place.

Data analysis procedure

Data were entered on REDCap software (RedCap v9.1.0, Vanderbilt University) and analyzed using SPSS

version 24.0 (IBM Corp, Armonk, NY). All the quantitative variables such as age, SBP and DBP, and biochemical parameters were assessed for normality and reported as mean \pm SD or median (interquartile range [IQR]) as appropriate. The categorical variables were reported as frequencies and percentages. The prevalence of MetS was calculated using the criteria. Pearson or Kendall Tau-b correlation were used as appropriate to assess the relationship between NC and components of MetS. *P*-value <0.05 was considered significant.

Results

A total of 392 patients were included in the study, and the majority of patients 344 (87.8%) were females. The mean \pm SD age and NC of all the patients were 50.5 ± 9.6 years and 38 ± 4.6 cm, respectively (Table 1).

	n (%)
Gender	
Male	48 (12.2)
Female	344 (87.8)
Total	392 (100)
Ethnicity	
Sindhi	26 (6.6)
Balochi	8 (2)
Urdu speaking	185 (47.2)
Punjabi	72 (18.4)
Pathan	35 (8.9)
Others	66 (16.8)
Total	392 (100)
Occupation	
Professional	11 (2.8)
Technicians and associate professionals	1 (0.3)
Clerical support workers	8 (2)
Service and sales workers	3 (0.8)
Skilled agricultural, forestry and fishery workers	2 (0.5)
Craft and related trades workers	3 (0.8)
Housewife	303 (77.3)
Others	61 (15.6)
Total	392 (100)
Comorbids	
Hypertensive	309 (84.4)
IHD	31 (8.5)
Dyslipidemia	224 (61.2)
Diabetes	300 (82)
Others	135 (36.9)
Metabolic syndrome	
Non-metabolic syndrome	12 (3.1)
Metabolic syndrome	366 (93.4)
Unknown	14 (3.6)

TABLE 1: Characteristics of the study participants

IHD, ischemic heart disease

More than three-quarters of the patients (n = 303; 77.3%) were homemakers, while 89 (22.7%) patients were doing any kind of job. Furthermore, comorbidities were present in all the patients. The most common comorbidity was hypertension (n = 309; 84.4%) followed by diabetes (n = 300; 82%) and dyslipidemia (n = 224; 61.2%).

Moreover, results showed that 366 (93.4%) of the patients has MetS, 12 (3.1%) were non-MetS, and 14 (3.6%) had unknown status due to incomplete information about the components of MetS (Table 2).

Characteristics	Metabolic syndrome		Overall	P-value
	No (n = 7)	Yes (n = 375)		
Age (in years)				
Mean ± SD	47.2 ± 13.5	50.5 ± 9.5	50.5 ± 9.6	0.749 [†]
Min-Max	30 to 60	24 to 79	24 to 79	
Median (IQR)	55.5 (33 to 60)	50 (45 to 56)	50 (45 to 56)	
Height (cm)				
Mean ± SD	156.7 ± 7	154 ± 7.9	154.1 ± 7.9	0.249 [†]
Min-Max	145 to 167.6	103 to 180	103 to 180	
Median (IQR)	157.5 (152.5 to 160)	153 (149.5 to 158)	153 (150 to 158.8)	
Weight (kg)				
Mean ± SD	78.8 ± 13.7	77.5 ± 13.4	77.6 ± 13.5	0.571 [†]
Min-Max	60.4 to 95	50 to 130	50 to 130	
Median (IQR)	80 (61.5 to 91)	75 (68 to 84)	75 (68 to 84.9)	
BMI				
Mean ± SD	32 ± 4.6	32.7 ± 5.7	32.8 ± 5.7	0.946 [†]
Min-Max	25.1 to 37.6	23.2 to 75.4	23.2 to 75.4	
Median (IQR)	33.1 (28.5 to 36.7)	31.9 (29.1 to 35.2)	31.9 (29.1 to 35.3)	
Waist circumference (cm)				
Mean ± SD	39.8 ± 4.5	43 ± 7	43.2 ± 7.7	0.080 [†]
Min-Max	36 to 47	32 to 142	32 to 142	
Median (IQR)	38.8 (36 to 45)	42.3 (40 to 45)	42.2 (40 to 45)	
Neck circumference (cm)				
Mean ± SD	37.2 ± 2.8	37.9 ± 3.9	38 ± 4.6	0.667 [†]
Min-Max	33 to 40.6	29 to 78.7	29 to 88.9	
Median (IQR)	36.8 (35.6 to 40.6)	38.1 (35.6 to 40.6)	38.1 (35.6 to 40.6)	
Systolic blood pressure (mm of Hg)				
Mean ± SD	115.3 ± 9.6	129.6 ± 16.6	129.3 ± 16.5	0.009 ^{*†}
Min-Max	100 to 130	90 to 190	90 to 190	
Median (IQR)	117 (110 to 120)	130 (120 to 140)	130 (120 to 140)	
Diastolic blood pressure (mm of Hg)				
Mean ± SD	71.4 ± 3.8	78.8 ± 10.8	78.6 ± 10.7	0.038 ^{*†}
Min-Max	70 to 80	60 to 110	60 to 110	

Median (IQR)	70 (70 to 70)	80 (70 to 90)	80 (70 to 90)	
Fasting blood glucose				
Mean ± SD	96.9 ± 15.7	147.8 ± 61.3	145.8 ± 61	
Min-Max	87 to 130	43 to 438	43 to 438	0.001 [†]
Median (IQR)	90 (87 to 104)	132 (108 to 167.3)	129.5 (106 to 165.5)	
Total cholesterol				
Mean ± SD	185.4 ± 36.7	167.3 ± 44.1	167.8 ± 43.6	
Min-Max	129 to 226	53 to 314.1	53 to 314.1	0.281 [†]
Median (IQR)	197 (138.7 to 206)	166 (135 to 196)	166.2 (136 to 197)	
Triglyceride				
Mean ± SD	90.3 ± 28.4	167.7 ± 81.1	164.9 ± 80.8	
Min-Max	65 to 135	27 to 604.7	27 to 604.7	0.001 [†]
Median (IQR)	80 (65 to 118)	150 (116.3 to 195.8)	147 (115 to 193.5)	
HDL				
Mean ± SD	55 ± 11.7	38.5 ± 9.7	39.1 ± 10.3	
Min-Max	41 to 69.8	14 to 91	14 to 91	0.001 [†]
Median (IQR)	57 (42.3 to 69)	37.1 (32 to 43.5)	38 (32.5 to 44)	
LDL				
Mean ± SD	119.3 ± 35.5	110.1 ± 38.6	110.3 ± 38.2	
Min-Max	63 to 157	25 to 228	25 - 228	0.398 [†]
Median (IQR)	128 (78.6 - 151)	105 (81 to 137.7)	106 (81.2 to 137)	
VLDL-Cholesterol				
Mean ± SD	18 ± 5.8	34 ± 18.5	33.4 ± 18.4	
Min-Max	13 to 27	5 to 206	5 to 206	0.001 [†]
Median (IQR)	16 (13 to 24)	30 (23 to 39.3)	29 (23 to 39)	
Non-HDL Cholesterol				
Mean ± SD	130.4 ± 40	129.1 ± 42.2	128.8 ± 41.9	
Min-Max	69 to 169	35 to 273	35 to 273	0.736 [†]
Median (IQR)	140 (80 to 162)	127 (97 to 155.3)	127.5 (97 to 155.2)	
HbA1c				
Mean ± SD	5.4 ± 0.6	8 ± 2	7.9 ± 2	
Min-Max	4.6 to 6.3	4.1 to 14.9	4.1 to 14.9	0.000 ^{***†}
Median (IQR)	5.4 (4.8 to 6)	7.5 (6.4 to 9.2)	7.5 (6.3 to 9.1)	
Comorbid				
Hypertensive	2 (28.6)	316(84.3) ^a	324 (82.7)	
IHD	0(0)	32 (8.5)	33 (8.4)	
Dyslipidemia	6 (85.7)	224(60.3)	233 (59.4)	0.000 ^{***†}
Diabetes	1 (14.3)	303(80.8) ^a	304 (77.6)	

Others	5 (71.4)	141(37.6)	154 (39.3)
--------	----------	-----------	------------

*P-value<0.05, **P-value<0.0001, † Independent Sample T-test, ‡ Mann-Whitney U test, † Chi-square test

TABLE 2: Characteristics of the study participants with and without metabolic syndrome

SD, standard deviation; IQR, interquartile range; IHD, ischemic heart disease, HDL, high-density lipoprotein; HbA1c, glycated hemoglobin

It was observed that 90% of both males and females had NC ≥ 38 cm and 34 cm, respectively, and the optimal cutoff values were provided by Hingorjo MR et al. [16]. Also, females had lower NC than males (mean ± SD: 37.5 ± 3.7 cm vs 41.4 ± 3.2 cm, p < 0.0001).

Additionally, no significant linear correlation was between NC and HbA1C, total cholesterol, LDL, non-HDL cholesterol, fasting blood glucose levels, and SBP and DBP. A significant weak positive correlation was observed between NC and WC, VLDL cholesterol, and TG; however, a significant weak negative correlation was observed between NC and female gender and HDL (Table 3).

	Unadjusted correlation coefficient	P-value	Adjusted correlation coefficient
Females	-0.329	0.000**	-
BMI	0.184	0.000**	0.201**
Waist circumference in cm	0.290	0.000**	0.293**
TG	0.107	0.020*	0.112
HDL	-0.123	0.008*	-0.087
VLDL cholesterol	0.106	0.023*	0.109
HBA_RESULT	0.069	0.138	0.088
Total cholesterol	-0.068	0.140	-0.051
LDL	-0.069	0.134	-0.058
Non-HDL cholesterol	-0.039	0.394	-0.030
Fasting blood glucose	0.037	0.422	0.059
Systolic (mm of Hg)	0.019	0.695	0.011
Diastolic (mm of Hg)	0.002	0.966	-0.012

*P-value<0.05, **P-value<0.0001, Kendall Tau-b correlation

TABLE 3: Correlation of neck circumference with various variables

BMI, body mass index; TG, triglyceride; HDL, high-density lipoprotein; VLDL, very low density lipoprotein; LDL, low-density lipoprotein

On the contrary, NC was found to be significantly positively correlated with BMI and WC only adjusting for gender (Table 3).

Discussion

The National Nutrition Health Survey (2018) of Pakistan reported a high prevalence of overweight and obesity in adolescents, young adults, and women of reproductive age [19]. Moreover, the prevalence of MetS has increased two folds over the last 10 years in Pakistan, indicating that these two are the emerging public health issues in Pakistan that require urgent attention of healthcare providers to restrain their increasing incidence [7-8]. Although Pakistan is facing an epidemic of obesity and MetS, no recent literature is available

assessing the burden of MetS in general as well as in the overweight and obese population.

In this study, we found a very high prevalence of MetS (95.7%) in our overweight and obese patients in comparison to the previous studies done in Pakistan [5,7-8,20]. Also, in our study, the majority of patients were diabetic and hypertensive, which is one of the diagnostic components of MetS. Ahmed A et al. (2012) reported 91.9% prevalence of MetS in type 2 diabetic patients, whereas other studies reported a high prevalence of overweight and obesity among MetS patients [5,7,19]. Moreover, a wide variation in the prevalence of MetS has been reported in various developing countries, i.e., from 7.9% to 39% [21]. This enormous heterogeneity in the prevalence could be due to the different criteria used for MetS, ethnic variations, genetics, environmental and cultural differences, study settings, and other risk factors. Also, patients presenting to the Indus Hospital belong to low- and middle socioeconomic groups that could account for the high prevalence of MetS. Literature reports an association between low socioeconomic status (SES) and MetS as people belonging to low SES are less educated, have low healthcare knowledge, and less leisure-time physical activity and may be unemployed [22-23].

Furthermore, our study revealed that more than 90% of our study participants had NC greater than or equal to the optimal cut-off values provided by Hingorjo MR et al. [17]. Thus, this indicates that these cut-off values can be used to screen MetS in the Pakistani population, thereby reducing the diagnostic testing. Several studies have reported the use of NC for identifying obesity and MetS by various criteria in different populations [10,15,18,24-25].

Additionally, we found a significant positive association between NC and VLDL and TG. This result is also supported by a recent systematic review and meta-analysis [16]. Some of the components of MetS in our study were not significantly correlated with NC, which include HbA1c, SBP and DBP, TC, LDL, non-HDL, and fasting glucose levels, whereas Bochaliya et al., Cho et al., Ben-Noun, and Ataie Jafari showed significant association of these aforementioned variables with NC [23,26-28]. It was also shown by Ravikiran et al. that the risk of cardiovascular diseases and MetS among South Asians increased due to an increase in fat mass of intra-abdomen, body, and truncal subcutaneous and ectopic deposition, such as the region of the neck [29]. In our study, BMI and WC were significantly associated with NC. The significant association between NC and BMI and WC was observed in other studies as well, which identified NC as an efficient tool for the identification of patients with obesity and MetS [10,30]. Therefore, our study is in agreement with other studies that suggest NC as a good predictor of obesity and MetS.

Limitations

Since this study was a cross-sectional study, we could not establish an association between MetS and NC. We suggest either a longitudinal or a case-control study to establish any relationship between MetS and NC. Secondly, this is a single-center, hospital-based study with the majority of patients being females. Thirdly, in this study, we have included all the overweight and obese patients, out of which almost two-thirds were both diabetic and hypertensive, which are the components contributing to MetS due to which we found a very high prevalence of MetS. We recommend further community-based studies to assess the burden of the disease.

Conclusions

A very high prevalence of MetS was observed among overweight and obese patients in this study. Moreover, NC can be used as a screening tool for MetS.

Additional Information

Disclosures

Human subjects: Consent was obtained by all participants in this study. Interactive research development institutional review board issued approval IRD_IRB_2018_05_010. The above-referenced human subjects research project has been approved by the IRD-IRB. This approval is limited to the activities described in the study protocol and extends to the performance of these activities at each respective site identified in the application for IRB Review. It is inclusive of all previously approved documents. As principal investigator for a study involving human subjects, you assume certain responsibilities, specifically: 1. You will conduct the study according to the protocol approved by the IRB. As the PI, you will be accountable for your own research and the protection of human subjects. You will ensure, at all times, that you have the appropriate resources and facilities to conduct the study. You will ensure that all research personnel involved in the conduct of the study have been appropriately trained on the protection of human subjects, in addition to the study procedures. 2. Any unanticipated problems involving risks to participants or others will be reported to the IRB in accordance to the IRB policy. Changes in approved research initiated without IRB approval to eliminate apparent immediate hazards to the participant, are to be reported to the IRB. 3. Any changes in your research plan must be submitted to the IRB for review and approval prior to implementation of the change. Proposed changes in approved research cannot be initiated without IRB approval, except when

necessary to eliminate apparent immediate hazards to participants. 4. A Progress Report for continuing review or a Study Closure Form, as applicable, must be submitted to the IRB administration by the administrative due date in order to allow sufficient time for review/closure to be completed prior to the expiration date. Failure to attain continued renewal by the expiration date will result in the study being assigned an inactive status, whereby all research activities including data analysis must stop immediately. .

Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Acknowledgements

We acknowledge Dr Naila Baig-Ansari, Chair, Indus Hospital Research Center for helping us in the entire research process.

References

1. Siddiqui M, Hameed R, Nadeem M, et al.: Obesity in Pakistan; current and future perceptions . J Curr Trends Biomed Eng Biosci. 2018, 17:001-004.
2. Hingorjo MR, Qureshi MA, Mehdi A: Neck circumference as a useful marker of obesity: a comparison with body mass index and waist circumference. J Pak Med Assoc. 2012, 62:36.
3. Herningtyas EH, Ng TS: Prevalence and distribution of metabolic syndrome and its components among provinces and ethnic groups in Indonesia. BMC Public Health. 2019, 19:377-10. <https://doi.org/10.1186/s12889-019-6711-71>
4. Liu J, Grundy SM, Wang W, et al.: Ethnic-specific criteria for the metabolic syndrome: evidence from China . Diabetes Care. 2006, 29:1414-1416.
5. Ahmed A, Khan TE, Yasmeen T, Awan S, Islam N: Metabolic syndrome in type 2 diabetes: comparison of WHO, modified ATP III & IDF criteria. J Pak Med Assoc. 2012, 62:569-574.
6. Basit A, Shera AS: Prevalence of metabolic syndrome in Pakistan. Metab Syndr Relat Disord. 2008, 6:171-175.
7. Iqbal Hydrie MZ, Shera AS, Fawwad A, Basit A, Hussain A: Prevalence of metabolic syndrome in urban Pakistan (Karachi): comparison of newly proposed International Diabetes Federation and modified Adult Treatment Panel III criteria. J Metab Syndr. 2009, 7:119-124.
8. Ali NS, Khuwaja AK, Adnan Ur R, Nanji K: Retrospective analysis of metabolic syndrome: prevalence and distribution in executive population in urban Pakistan. Int J Family Med. 2012, 2012: 649383. [10.1155/2012/649383](https://doi.org/10.1155/2012/649383)
9. The Global Burden of Disease: Generating Evidence, Guiding Policy. South Asia Regional Edition . (2013). Accessed: November 7, 2019: http://www.healthdata.org/sites/default/files/files/data_for_download/2013/WorldBank_SouthAsia/IHME_GBD_World
10. Lin S, Hu L, Li P, et al.: Utility of neck circumference for identifying metabolic syndrome by different definitions in Chinese subjects over 50 years old: a community-based study. J Diabetes Res. 2018, 2018:3708939.
11. Sagun G, Oguz A, Karagoz E, Filizer AT, Tamer G, Mesci B: Application of alternative anthropometric measurements to predict metabolic syndrome. Clinics (Sao Paulo). 2014, 69:347-353.
12. Verma M, Rajput M, Sahoo SS, Kaur N: Neck circumference: independent predictor for overweight and obesity in adult population. Indian J Community Med. 2017, 42:209-213.
13. Silva CdCd, Zambon MP, Vasques ACJ, et al.: Neck circumference as a new anthropometric indicator for prediction of insulin resistance and components of metabolic syndrome in adolescents: Brazilian Metabolic Syndrome study. Revista Paulista de Pediatria. 2014, 32:221-229.
14. Kurtoglu S, Hatipoglu N, Mazicioglu MM, Kondolot M: Neck circumference as a novel parameter to determine metabolic risk factors in obese children. Eur J Clin Invest. 2012, 42:623-630.
15. Luo Y, Ma X, Shen Y, et al.: Neck circumference as an effective measure for identifying cardio-metabolic syndrome: a comparison with waist circumference. Endocrine. 2017, 55:822-830.
16. Namazi N, Larijani B, Surkan PJ, Azadbakht L: The association of neck circumference with risk of metabolic syndrome and its components in adults: A systematic review and meta-analysis. Nutr Metab Cardiovasc Dis. 2018, 28:657-674. [10.1016/j.numecd.2018.03.006](https://doi.org/10.1016/j.numecd.2018.03.006)
17. Hingorjo MR, Zehra S, Imran E, Qureshi MA: Neck circumference: a supplemental tool for the diagnosis of metabolic syndrome. J Pak Med Assoc. 2016, 66:1221-1226.
18. Llido L, Mirasol R: Comparison of body mass index based nutritional status using WHO criteria versus "Asian" criteria: report from the Philippines. J Parenter Enteral Nutr. 2011, 1-8.
19. Pakistan National Nutrition Survey 2018 - Key Findings Report . (2018). Accessed: November 7, 2018: <https://www.unicef.org/pakistan/media/1951/file/Final%20Key%20Findings%20Report%202019.pdf>.
20. Jahan F, Qureshi R, Borhany T, Hamza HB: Metabolic syndrome: frequency and gender differences at an out-patient clinic. J Coll Physicians Surg Pak. 2007, 17:32.
21. Yu S, Guo X, Yang H, Zheng L, Sun Y: An update on the prevalence of metabolic syndrome and its associated factors in rural northeast China. BMC Public Health. 2014, 14:877-10.
22. Yang X, Tao Q, Sun F, Zhan S: The impact of socioeconomic status on the incidence of metabolic syndrome

- in a Taiwanese health screening population. *Int J Public Health*. 2012, 57:551-559.
23. Cho NH, Oh TJ, Kim KM, et al.: Neck circumference and incidence of diabetes mellitus over 10 years in the Korean Genome and Epidemiology Study (KoGES). *Sci Rep*. 2015, 5:18565-10.
 24. Joshipura K, Muñoz-Torres F, Vergara J, Palacios C, Pérez CM: Neck circumference may be a better alternative to standard anthropometric measures. *J Diabetes Res*. 2016, 2016:6058916.
 25. Vallianou NG, Evangelopoulos AA, Bountziouka V, et al.: Neck circumference is correlated with triglycerides and inversely related with HDL cholesterol beyond BMI and waist circumference. *Diabetes Metab Res Rev*. 2013, 29:90-97.
 26. Bochaliya RK, Sharma A, Saxena P, Ramchandani GD, Mathur G: To evaluate the association of neck circumference with metabolic syndrome and cardiovascular risk factors. *J Assoc Physicians India*. 2019, 67:60-62.
 27. Ben-Noun LL, Sohar E, Laor A: Neck circumference as a simple screening measure for identifying overweight and obese patients. *Obesity*. 2001, 9:470-477.
 28. Ataie-Jafari A, Namazi N, Djalalinia S, et al.: Neck circumference and its association with cardiometabolic risk factors: a systematic review and meta-analysis. *Diabetol Metab Syndr*. 2018, 10:72-10.
 29. Ravikiran M, Bhansali A, Ravikumar P, et al.: Prevalence and risk factors of metabolic syndrome among Asian Indians: a community survey. *Diabetes Res Clin Pract*. 2010, 89:181-188.
 30. Anothaisintawee T, Sansanayudh N, Thamakaisorn S, Lertrattananon D, Thakkinstian A: Neck circumference as an anthropometric indicator of central obesity in patients with prediabetes: a cross-sectional study. *BioMed Research International*. 2019, 2019: