

Anthropometric cutoff values for predicting metabolic syndrome in a Saudi community: from the SAUDI-DM study

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BACKGROUND: The prevalence of metabolic syndrome varies widely by ethnicity and by the criteria used in its definition.

OBJECTIVE: To identify the optimal cutoff values for waist circumference (WC), waist-to-hip ratio (WHR) and body mass index (BMI) for identifying metabolic syndrome among the Saudi population.

DESIGN: Nationwide household cross-sectional population-based survey.

SETTING: Thirteen health sectors in Saudi Arabia.

SUBJECTS AND METHODS: We used data for subjects in the Saudi Abnormal Glucose Metabolism and Diabetes Impact Study (SAUDI-DM), which was conducted from 2007 to 2009. Using International Diabetes Federation (IDF) criteria, metabolic syndrome and its different components were assessed using anthropometric measurements, blood pressure, fasting plasma glucose, triglycerides and HDL cholesterol. Receiver operating characteristic (ROC) curves were generated to assess sensitivity and specificity for different cutoff values of WC, WHR, and BMI. The Youden index was used to calculate the optimal cutoff value for each anthropometric measurement.

MAIN OUTCOME MEASURE(S): Optimal cutoff value for WC, WHR, and BMI for identifying the risk of metabolic syndrome.

RESULTS: The prevalence of two or more risk factors for metabolic syndrome was observed in 43.42% of the total cohort of 12 126 study participants ≥ 18 years of age. The presence of two or more risk factors were significantly higher among men (46.81%) than women (40.53%) ($P < .001$). The optimal cutoff values for WC, WHR, and BMI were 92 cm, 0.89, and 25 kg/m² for men and 87 cm, 0.81 and 28 kg/m² for women for identifying the risk of metabolic syndrome. The prevalence of elevated triglycerides, blood pressure, and fasting plasma glucose significantly increased with age for both genders.

CONCLUSIONS: The proposed WC cutoff values were better than WHR and BMI in predicting metabolic syndrome and could be used for screening people at high risk for metabolic syndrome in the Saudi population.

LIMITATIONS: No direct measure of body fatness and fat distribution, cross-sectional design.

Saudi Arabia has the highest prevalence of diabetes in the Middle East and North Africa.¹ The country is also known for having a high prevalence of other components related to metabolic syndrome, including hypertension, dyslipidemia, and central obesity.²⁻⁴ The prevalence of metabolic syndrome worldwide varies widely depending on ethnicity and criteria

applied to define metabolic syndrome.⁵ The main difference between the two widely accepted set of criteria: (the National Cholesterol Education Program, Third Adult Treatment Panel III (ATPIII)^{6,7} and the International Diabetes Federation (IDF) criteria⁸ is the definition of central obesity. In the IDF definition, the cutoff values for waist circumference (WC) are lower and are ethnic-

specific. Waist circumference is affected by factors like gender, age, and ethnicity.⁹⁻¹¹ This ethnicity related variation has recently pressured many national and international organizations to propose their own specific cutoff points, especially when the currently proposed ATP III and IDF cutoff values for WC and other anthropometric measurements including waist-hip ratio (WHR) and body mass index (BMI) have been based on studies in Western populations that may not be appropriate for other ethnic groups.¹²

There is currently enough evidence that Asians should have lower waist circumference cutoff values for defining metabolic syndrome than Americans and Europeans since they have an increased risk of morbidity and mortality associated with lower BMI and WC cutoff values.¹³⁻¹⁶ The same could be true for the Arab ethnic group. Although there are limited data for assessing the optimal cutoff values for WC, WHR, and BMI among Arabs, the available data from different Middle Eastern and North African countries including Iraq,¹⁷ Oman,¹⁸ Qatar,¹⁹ Jordan,²⁰ Egypt²¹ and Tunisia²² unexpectedly have shown wide variations in these anthropometric cutoff values. This inter-ethnicity variation warrants the determination of the optimal cutoff values for WC, as an integral component of metabolic syndrome, based on population specific data that can be used in defining this medical condition. This would be in line with the WHO recommendation for establishing country specific cutoff points for WC when defining metabolic syndrome.²³

Other anthropometric measurements including WHR and BMI are used in the definition of metabolic syndrome based on WHO 1999 criteria;²⁴ however, each measurement has its own limitations. Even though WHR is more consistent across different ethnicities and would provide a better prediction for disease risk, the measurement of WC is much easier and more convenient than hip circumference measurement for practical considerations.²³ BMI is less sensitive compared to WC and WHR in assessing abnormal body fat distribution.²⁵⁻²⁷ Despite these limitations, determining the country specific optimal cutoff points for those two measurements would help researchers in their respective countries in reporting a more appropriate prevalence of metabolic syndrome.

Since there are no previous studies that have looked into the cutoff values for WC, WHR and BMI to identify risk for metabolic syndrome in the Saudi population, the main aim of this study was to determine the optimal cutoff values for those three anthropometric measurements in this population using data from The Saudi Abnormal Glucose Metabolism and Diabetes Impact Study (SAUDI-DM).²⁸

PATIENTS AND METHODS

Study population

SAUDI-DM was a nationwide household cross-sectional population-based survey using a multistage stratified cluster sampling technique conducted from 2007 to 2009. Sampling took into consideration the urban to rural ratio in the 13 administrative regions in Saudi Arabia: Bahah, Aljouf, Northern border, Asir, Hail, Jizan, Madinah, Makkah, Najran, Qassim, Riyadh, Eastern, and Tabuk.²⁸ The study was conducted through primary healthcare centers by trained physicians and nurses by recruiting family members of Saudi nationals from every third house in the selected areas. All family members who were available during the visit of the survey team were recruited regardless of their age, gender or diabetes status, excluding participants who refused to participate or were not present during the recruitment visit.²⁸ A total of 87417 participants were recruited. Adjustment for age, area of residency and gender distribution led to the exclusion of 34047 (38.95%) participants. Of the remaining 53370 (61.05%), the current analysis further excluded 23523 (44.08%) subjects who were <18 years of age, 549 (1.09%) pregnant females, and 17172 (32.18%) subjects who did not have a lipid assessment, leaving 12126 subjects aged ≥18 years.

Anthropomorphic data collection

After obtaining consent from the eligible subjects, the data were collected using a pre-designed questionnaire that consisted of general demographic information including age and gender, in addition to diabetes history, hypertension and dyslipidemia. Each subject was assessed for weight and height in a standing position without shoes and wearing light clothing using an Adam's weighing scale (model MDW-250L, with capacity of 250 kg and reliability of 0.1 kg, Oxford CT USA) wherein the height was expressed in centimeters (cm) and weight in kilograms (kg). WC was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest based on the WHO STEP wise approach to surveillance (STEPS) protocol²⁹ while the hip circumference was measured around the widest portion of the buttocks in a standing position wearing light clothing and looking straight ahead with arms at the sides and feet adherent to each other.³ The measuring tape was kept horizontal during the measurement of the hip and waist circumference. All measurements were rounded to the nearest 1 decimal point. BMI was calculated by dividing weight (kg) to height in square meters (m²). A mercury sphygmoma-

nometer (Baumanometer, Model 0320, W.A. Baum Co., Inc. USA) was used to measure the blood pressure for each subject in a sitting position. Measurements were repeated twice at least 5 minutes apart, and the average of the two readings was used for data analysis.

Biochemical assessment

All subjects were asked to report to the nearest primary care center after more than 10 hours of overnight fasting and after which venous blood sampling was collected using a sodium fluoride tube. Plasma was stored at -20 degrees centigrade. All blood samples were sent to the central laboratory at the Strategic Center for Diabetes Research in the capital city of Riyadh. The blood glucose assessment was done using glucose oxidase/oxidase method while blood lipids were measured using the esterase oxidase/oxidase method for serum cholesterol, and the glycerokinase oxidase/oxidase method for HDL, LDL and triglycerides, which were performed in an RX Daytona clinical chemistry analyzer by Randox (UK).

Definition of metabolic risk factors

Metabolic risk factors were defined using the 2006 IDF criteria³⁰ that define elevated triglyceride (TG) as ≥ 150 mg/dL (≥ 1.7 mmol/L) and reduced HDL cholesterol as < 40 mg/dL (< 1.03 mmol/L) for men and as < 50 mg/dL (< 1.29 mmol/L) for women. Elevated blood pressure was defined when the systolic blood pressure (SBP) was ≥ 130 mm Hg and/or diastolic blood pressure (DBP) was ≥ 85 mm Hg in addition to receiving any medication for hypertension. Abnormal glucose metabolism was considered when fasting plasma glucose (FPG) was ≥ 100 mg/dL (≥ 5.6 mmol/L) or when patients were known to have type 2 diabetes. A combination of two or more of these risk factors was used to assess cutoff values for WC, WHR and BMI. This study was approved by the Institutional Review Board (IRB) at the College of Medicine, King Saud University.

Statistical analysis

Data were analyzed using SPSS statistical package version 21. Continuous variables were expressed as mean and standard deviation (SD), and categorical variables were expressed as percentages. The *t* test was used for continuous variables and the chi-square test for categorical variables. Imputation, based on a regression model, was used to estimate missing data. Receiver operating characteristic (ROC) curves were used to plot true positive (sensitivity) against false positive (1-specificity) rates. ROC analysis was used to quantify how accurately medical diagnostic tests (or systems) might discriminate

between a diseased and "nondiseased" patient state. The area under the curve (AUC) is an indication of how well a parameter distinguishes a diagnostic state (presence of absence of metabolic syndrome in this case). The Youden index, a commonly used measure of overall diagnostic effectiveness which is the maximum vertical distance or difference between the ROC curve and the diagonal or chance line, was calculated to determine the optimal cutoff values for WC, WHR, and, BMI. A *P* value of less than .05 was used as the level of significance.

RESULTS

In the 12 126 subjects from the SAUDI-DM study, men were significantly older and had higher mean body weight than women (**Table 1**). The mean values for weight, height, WC, WHR, TG, FPG, SBP and DBP were significantly greater in men than those found in women, while only the mean values of BMI, hip circumference and HDL cholesterol were lower in men than women. Additionally, the prevalence of all metabolic syndrome risk factors (elevated triglycerides, reduced HDL cholesterol, elevated blood pressure, elevated fasting glucose) was higher in men compared with women, except for reduced HDL cholesterol. Men had a higher prevalence of two or more risk factors for metabolic syndrome than women (46.81% versus 40.53%, $P < .001$). The proportion of subjects with metabolic risk factors also increased with age in both the genders except for reduced HDL cholesterol, which was similar across age groups (**Figure 1**). The prevalence of two or more metabolic syndrome risk factors in both genders increased in a linear pattern by age from around 20% to more than 70% (**Figure 1**).

Metabolic parameters by anthropometric category

In both genders, mean values of all metabolic parameters increased in a linear pattern with increasing BMI values, except for HDL cholesterol, which decreased with increasing BMI (**Appendix 1**). A similar relationship was seen with WC and WHR except for WHR values > 0.95 , in which the prevalence of metabolic syndrome risk factors decreased compared with the preceding WHR value of 0.9-0.95. The mean values for triglycerides increased linearly, but mean HDL cholesterol decreased with increasing values of WC or WHR.

The proportion of both men and women with two or more risk factors increased about threefold from the lowest to the highest categories of BMI (**Figure 2**), and about twofold from the lowest to the highest categories of WC (**Figure 3**). For WHR, the proportion also doubled although it declined for women with WHR > 0.95

Table 1. Characteristics of the population of the The Saudi Abnormal Glucose Metabolism and Diabetes Impact Study by sex.

Clinical and demographic variables	Total 12 126	Men 5571 (45.9%)	Women 6555 (54.1%)	P
Age (years)	35.74 (15.00)	36.05 (15.20)	35.47 (14.82)	.035
Weight (kg)	71.38 (18.31)	76.07 (18.56)	67.40 (17.11)	<.001
Height (cm)	160.31 (10.24)	166.86 (8.88)	154.74 (7.71)	<.001
Body mass index (kg/m ²)	27.81 (7.06)	27.35 (6.77)	28.20 (7.28)	<.001
Waist circumference (cm)	87.02 (16.72)	89.71 (17.11)	84.75 (16.03)	<.001
Hip circumference (cm)	99.07 (16.81)	98.66 (16.81)	99.41 (16.8)	.014
Waist:hip ratio	0.88 (0.12)	0.91 (0.11)	0.86 (.12)	<.001
Triglyceride (mmol/L)	1.62 (1.15)	1.83 (1.30)	1.45 (.98)	<.001
HDL cholesterol (mmol/L)	0.97 (0.32)	0.89 (0.32)	1.03 (.32)	<.001
Fasting plasma glucose (mmol/L)	5.68 (2.44)	5.83 (2.63)	5.55 (2.27)	<.001
Systolic blood pressure (mm Hg)	117.72 (13.76)	119.69 (13.08)	116.04 (14.09)	<.001
Diastolic blood pressure (mm Hg)	76.13 (8.64)	77.29 (8.38)	75.15 (8.73)	<.001
Risk factors for metabolic syndrome				
Elevated triglyceride, n (%)	3959 (32.65)	2263 (40.62)	1696 (25.87)	<.001
Reduced HDL cholesterol, n (%)	9531 (78.6)	4155 (74.58)	5376 (82.01)	<.001
Elevated blood pressure, n (%)	3344 (27.58)	1784 (32.02)	1560 (23.8)	<.001
Elevated fasting plasma glucose, n (%)	4439 (36.61)	2250 (40.39)	2189(33.39)	<.001
≥2 risk factors, n (%)	5265 (43.42)	2608 (46.81)	2657 (40.53)	<.001

Values are mean (standard deviation) unless indicated otherwise. The t test was used for continuous variables and the chi-square test for categorical variables. HDL: high-density lipoprotein.

(Figure 4 and Appendix 1).

Optimal cutoff values for metabolic risk factors

The optimal cutoff values for two or more risk factors are shown in **Table 2**, along with the sensitivity and specificity, and the Youdin index. The optimal cutoffs and other parameters for each metabolic risk factor are in **Appendices 2-4**.

In the area under the curve corresponding to the optimal cutoff points for anthropometric parameters in both genders, WC had the highest AUC value compared with WHR and BMI, especially in women as shown in **Figure 5**.

DISCUSSION

Waist circumference is an important component of metabolic syndrome definition. Numerous studies have demonstrated different cutoff values for waist circumference that warrant establishing country- or region-specific cutoff points.²³ The Saudi cohort in our study was used to determine the optimal gender-specific cutoff points of WC, WHR, and BMI for predicting two or more risk factors of metabolic syndrome. These cutoff points yielded the highest Youden index values. The optimal cutoff value of WC for identifying two or more risk factors of metabolic syndrome in the Saudi population was 92 cm for men and 87 cm for women, which lies within the WHO recommended range.²³ This

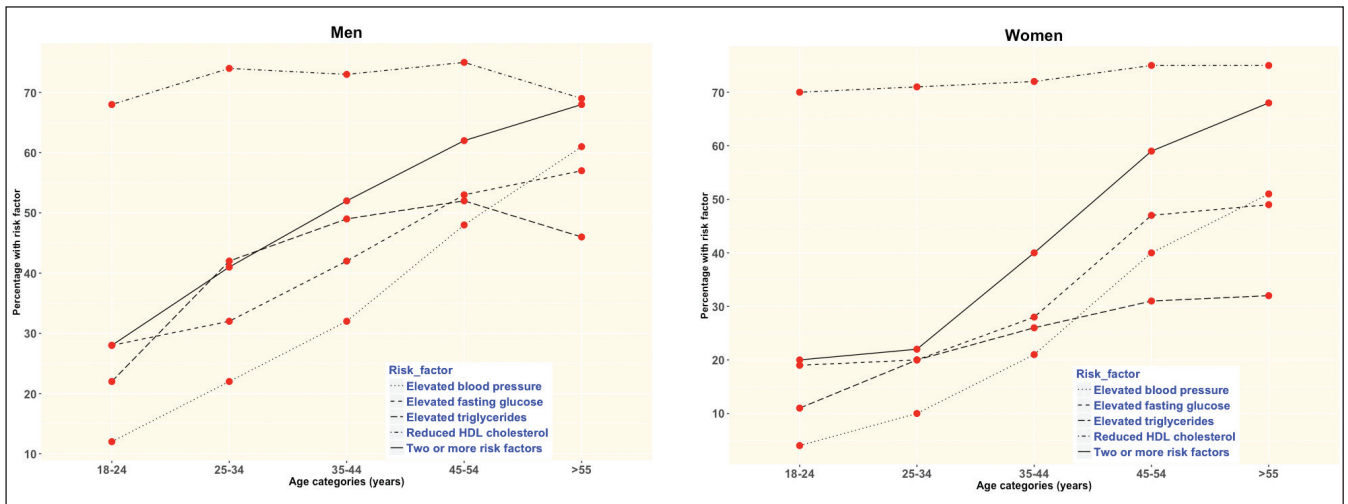


Figure 1. The prevalence of metabolic syndrome risk factors according to age groups for men and women.

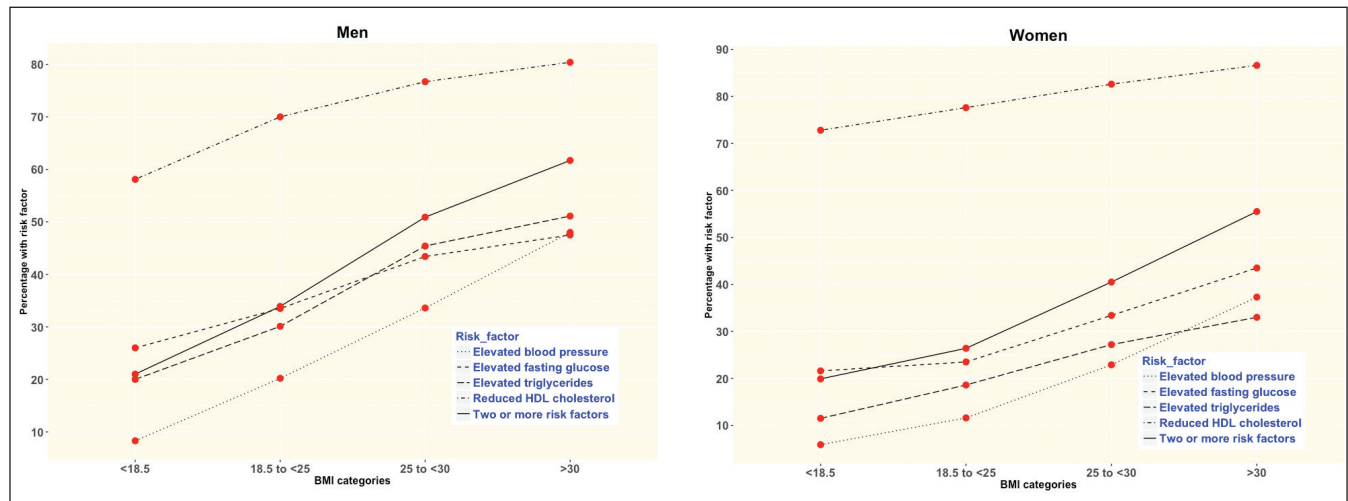


Figure 2. The prevalence of metabolic syndrome risk factors according to body mass index categories for men and women.

Table 2. Optimal cutoff values for identifying metabolic syndrome by the presence of two or more risk factors among Saudi men and women.

Risk factor	Cut-off value	Sensitivity	Specificity	Youden index
Men				
Body mass index	25	73.7	48.9	22.6
Waist circumference	92	57.3	67.4	24.65
Waist:hip ratio	.89	69.4	48.7	18.1
Women				
Body mass index	28	62.1	62.9	24.9
Waist circumference	87	61.0	65.6	26.62
Waist:hip ratio	.81	75.5	40.4	15.9

Body mass index in kg/m²; waist circumference in centimeters.

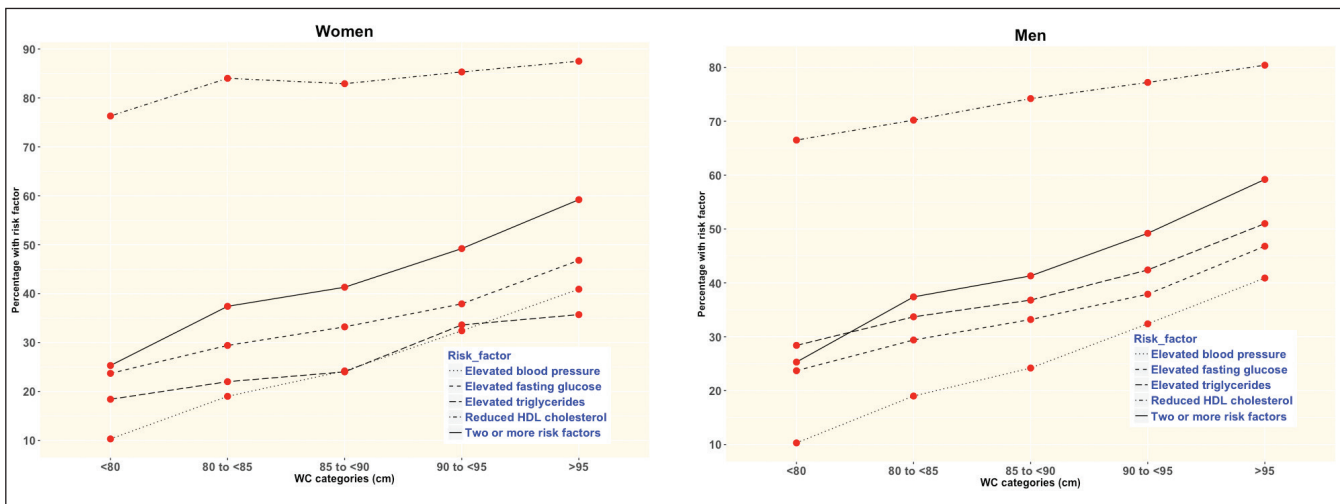


Figure 3. The prevalence of metabolic syndrome risk factors according to waist circumference categories for men and women.

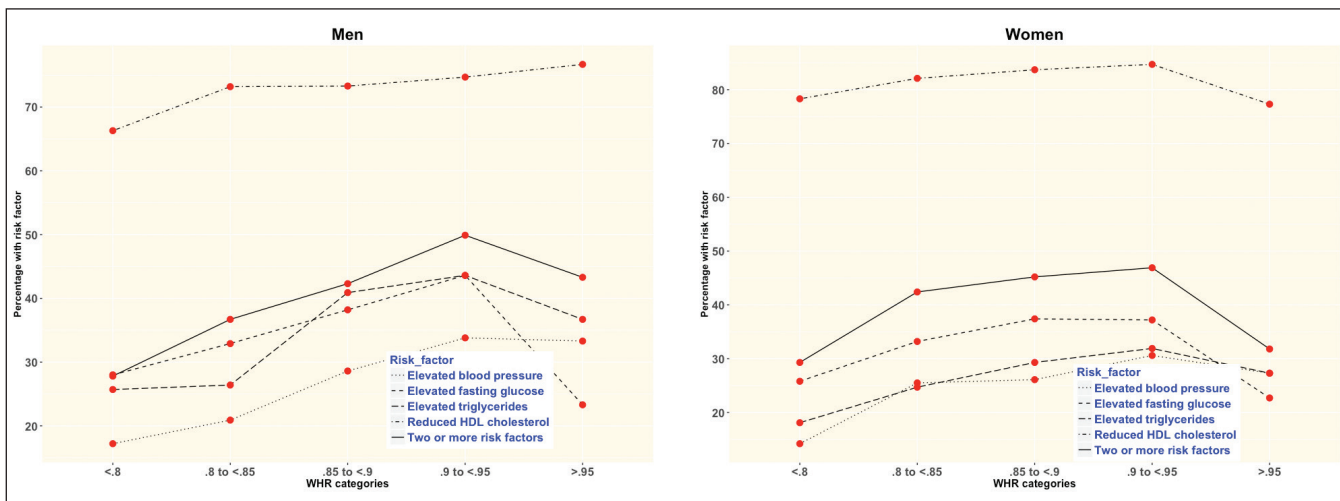


Figure 4. The prevalence of metabolic syndrome risk factors according to waist-to-hip ratio categories for men and women.

proposed cutoff value for the Saudi population is similar to data reported in other studies from individuals of the same ethnicity (Arabs) (Table 3). Using the Youden index methodology as in the current study, Qataris reported a WC cutoff value of 99.5 cm in men and 91 cm in women,¹⁴ while Iraqis reported WC cutoff values at 99 cm for men and at 97 cm for women.¹² The discrepancies could be due to either different statistical approaches or to different clinical methods used in measuring WC. Another factor may be the definition of cardiovascular risk. In Oman, for instance, two or more risk factors are used in the definition,¹⁸ while in Qatar three or more risk factors are used;¹⁹ however, all the proposed cutoff values lie in the reported WHO range

for Middle Eastern countries.²³

The WC cutoff values for the Saudi population are similar to those for Caucasians. In Latin America, 94 cm in men and 91 cm in women have been reported.³¹ However, these values were higher than the WC cutoff values reported from South and South East Asia that ranged between 71.5 cm for Chinese women and 95.1 cm for South Asian men.²³ This difference in the WC cutoff values between different ethnic groups could be explained by ethnic differences in socioeconomic status, physical activities, lifestyle and cultural factors that could affect the body composition of each population that consequently uses the WC as a surrogate for abdominal fat.²⁰

Table 3. Comparison between the optimal cutoff values for waist circumference for identifying metabolic syndrome among different Arab countries.

Author	Year	Country	Statistical approach	WC cutoff values (cm)		WHR cutoff values		BMI cutoff values (kg/m ²)	
				Men	Women	Men	Women	Men	Women
Al-Rubeaan et al	Current	Saudi Arabia	Youden index	92	87	0.89	0.81	25	28
Al-Lawati et al ¹⁸	2001	Oman	Shortest distance	80	84.5	0.91	0.91	23.2	26.8
Mansour et al ¹⁷	2006	Iraq	Youden index	99	97	-	-	-	-
Khader et al ²⁰	2009	Jordan	Youden index	88.5-91.8	84.5-88.5	0.88-0.90	0.80-0.83	26.2-27.2	27.2-30.0
Bener et al ¹⁹	2012	Qatar	Youden index	99.5	91.0	0.90	0.88	28.0	28.4

The current study highlights that using the proposed WC cutoff values of NECP ATP III criteria^{6,7,32} will underestimate the prevalence of metabolic syndrome in the Saudi population. At the same time, if IDF criteria for Asians³³ were used in this society, it would underestimate the prevalence of metabolic syndrome among men and overestimate this prevalence among women. Therefore, the current study shall serve as a reference for providing accurate cutoff values for anthropometric measurements that could be used in future studies that aim to define metabolic syndrome in the Saudi population.

The cutoff values for WHR in the Saudi cohort were 0.89 and 0.81 for men and women respectively, which is lower than what has been reported among Qataris¹⁹ at 0.90 and 0.88 for men and women respectively, and Omanis¹⁸ at 0.91 for both men and women, but higher than what has been proposed for Jordanians at 0.88 for men and 0.82 for women.²⁰ When comparing our results with Caucasians, we had a lower WHR for men (0.89 versus 0.95) but a higher WHR for women (0.84 versus 0.80).³⁴ The proposed cutoff points for WHR in the current study are close to the proposed cutoff values used in the WHO 1998 definition of metabolic syndrome,³⁵ at 0.89 versus 0.90 for men and 0.84 versus 0.85 for women. Although WHR was claimed by Welborn et al,³⁶ to be a good predictor for morbidity and mortality, it is difficult to interpret biologically and any change in body fat distribution may produce little or no change in the ratio.³⁷ Additionally, a reduction in body weight is usually associated with the reduction in both waist and hip circumferences, but not necessarily a change in WHR. A decrease in WHR might not be related to a

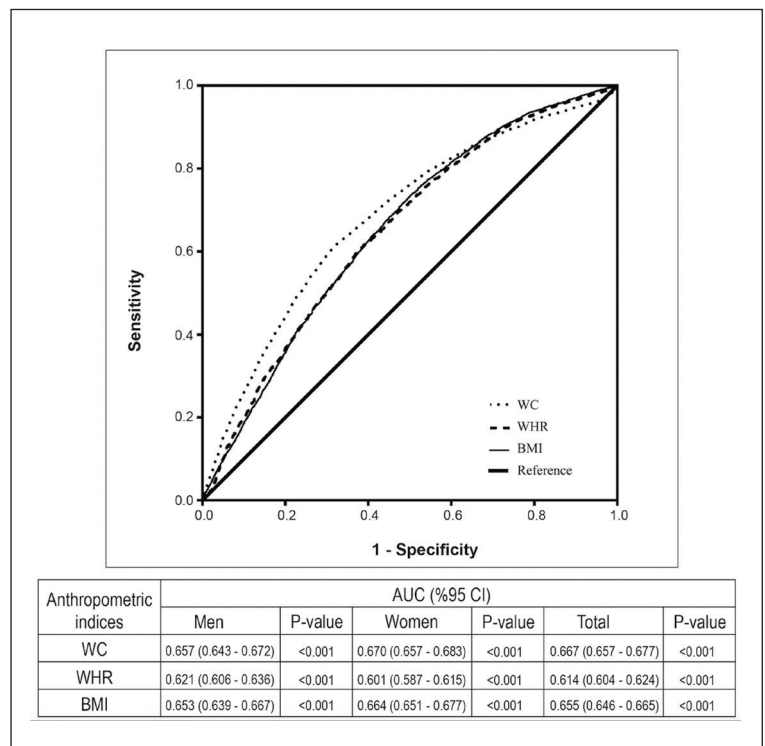


Figure 5. Area under the receiver operating characteristic curves (AUC) for waist circumference (WC), waist to hip ratio (WR), and body mass index (BMI) for total subjects and both genders.

reduction in cardiovascular risk factors.³⁸

Based on the ROC curve analysis, the optimal cutoff values for BMI among our subjects was ≥ 25 kg/m² for men and ≥ 28 kg/m² for women. The proposed values for BMI in the current study are lower than that for Qataris,¹⁹ where they reported BMI cutoff values of 28

kg/m² and 28.4 kg/m² for men and women, respectively, and for Jordanians,²⁰ with reported BMI cutoff values of 27.2 and 30 kg/m² for men and women, respectively. However, our proposed cutoff points were higher than what has been reported among Omanis at 23.2 kg/m² and 26.8 kg/m² for men and women, respectively.¹⁸ It is noteworthy that the proposed cutoff for BMI among men at 25 kg/m² in this study is less than the increased risk category according to WHO recommendations for appropriate BMI for an Asian population, while the BMI cutoff for women at 28 kg/m² is under the very high risk category for an Asian population.³⁹ The current study reported significantly higher BMI among women while reporting a significantly lower WC than men. This observation is similar to the findings among Jordanians²⁰ and could be explained by the fact that men are mostly taller than women, especially when the BMI calculation is mainly dependent on the net body weight and height, regardless of the distribution of muscle and bone mass.²⁰

The best anthropometric index for identifying metabolic syndrome is still controversial and varied widely depending on the studied population⁴⁰ and ethnicity.⁴¹ In some populations including Australia, Canada, and Japan, the WHR was the best indicator for cardiovascular risk factors compared to BMI,⁴²⁻⁴⁴ while in another Iranian study, WC was superior to BMI and WHR in predicting cardiovascular risk factors.⁴⁵ On the other hand, among a Chinese population, the three indicators were equally useful for detecting metabolic syndrome.⁴⁶ In the current study WC yielded the highest AUC followed by BMI, and then WHR. This finding indicates that WC is the best anthropometric indicator for identifying metabolic syndrome among the Saudi population. This finding is also in consistent with data reported from cross-sectional studies among an Iranian population,⁴⁵ white and African American populations,⁴⁷ and a Qatari population where the WC was reported as the most powerful indicator for predicting metabolic syndrome.¹⁹

The superiority of WC in identifying metabolic syndrome compared with BMI could be due to the fact that WC is better correlated with abdominal fat and strongly associated with cardiovascular risk factors than BMI.⁴⁸ This is in addition to the reportedly poor ability of BMI to discriminate between excess adipose tissue and high lean muscle mass, and therefore failing to account for body fat distribution.⁴⁹ In addition, aging results in a decreased standing posture that can inaccurately increase the BMI by 1.5 kg/m² in men and 2.5 kg/m² in women,

despite a minimal change in body weight.^{50,51} In addition to its superiority, WC has been acknowledged by WHO as the easiest and most efficient anthropometric measurement for fatness and fat location.⁵²

The current study also shows that the mean values for cardiovascular risk factors as well as the prevalence increase with higher cutoff values for the three anthropometric measurements (BMI, WC, and WHR). This linear association of BMI and WC with cardiovascular risk factors is consistent with data reported from China and Korea.^{53,54}

A strength of the current study is that it is the only source of optimal cutoff values for WC, WHR, and BMI for identifying metabolic syndrome among the Saudi population. The study is also nationwide, representing adults aged ≥ 18 years from all 13 administrative rural and urban regions of Saudi Arabia. Thus, the results of the current study could be generalized to the full adult population of Saudi Arabia.

Since WC, BMI and WHR are surrogates for body fatness and fat distribution, the present study is limited primarily by not having a direct measure of the body fatness and fat distribution. However, those direct measures are complicated and might not be cost-effective in population-based studies. A second limitation of this study is the cross-sectional design that might have affected the temporality and therefore limited the ability to draw causal inferences. Therefore, prospective studies are needed to provide stronger evidence and predictive power from anthropometric measures for metabolic syndrome.

We conclude that WC is the best predictor for metabolic syndrome in the Saudi population. The proposed cutoff values for the three anthropometric measures are lower than the values in the ATP III or IDF criteria. Therefore, the proposed cutoff values from the current study could be used for screening people at high risk for metabolic syndrome. Future studies should be conducted to assess the prevalence of metabolic syndrome based on the newly proposed cutoff values for central obesity.

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Conflict of interest

The authors declared no competing interests.

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