Diabetes and Obesity International Journal
ISSN: 2574-7770

Frequency of Metabolic Syndrome According to Optimal Cut-Points for Body Mass Index in Saudi Population

Khalid S Aljabri[1]*, Samia A Bokhari[1], Muneera A Alshareef[1], Patan M Khan[1] and Bandari K Aljabri[2]

[1]Department of Endocrinology, King Fahad Armed Forces Hospital, Jeddah, Kingdom of Saudi Arabia

[2]College of medicine, Um Al Qura University, Kingdom of Saudi Arabia

Research Article

Volume 3 Issue 3

Received Date: August 06, 2018

Published Date: August 22, 2018

DOI: 10.23880/doij-16000184

***Corresponding author:** Khalid SJ Aljabri, Department of Endocrinology, King Fahad Armed Forces Hospital, Jeddah, Kingdom of Saudi Arabia, PO Box 9862, Jeddah 21159, Kingdom of Saudi Arabia, Tel: +966590008035; Email: khalidsaljabri@yahoo.com

Abstract

Background and Objective: The prevalence of metabolic syndrome (MetS) are increasing worldwide. Body mass index (BMI) cut-off for MetS can vary. The objective of this study is to identify the optimal BMI cut-off that is associated with MetS.

Methods: For the present study, we analyzed participants who are equal to or older than 18 years old. A total of 5498 were analyzed at the present study. Patients were recruited from the population of the primary health care department at King Fahad Armed Forces Hospital. Metabolic risk factors were defined using the 2006 International Diabetes Federation criteria. We collected data personal interview and electronic medical chart review. Physician and nurse interviewers measured the weight (kg) and height (cm) of the participants and BMI was calculated. Receiver operating characteristic curve analysis was used to obtain the optimal sensitivity and specificity using different BMI cut-off values to predict the presence of diabetes.

Results: Of the 5498 participants analyzed, 2049 (37.3%) were male and 3449 (62.7%) were female with female to male ratio 1.7:1. Age was 42.7 ± 15.8 (minimum 18 years and maximum 105 years). MetS was present in 1967 cases (35.8%) where 673 cases (38.8%) were male and 1204 cases (61.2%) were female with female to male ratio 1.6:1, P=0.08. Males were significantly older than females in MetS patients (45.5±12.8 vs. 36.1±13.3 respectively, p<0.0001). BMI was significantly higher in MetS patients (31.9±6.6 vs. 28.3±6.7 respectively, p<0.0001). Optimal BMI cut-off values ranged from 28.50 to 29.50 in total population, 27.50 to 28.50 in male and from 28.50 to 29.50 in female. The AUC was 0.615 (95% CI, 0.590-0.639) in male and 0.686 (95% CI, 0.668-0.704) in female. Regression analysis showed that the risk of MetS was significantly increased at BMI values as low as ≤15.0 kg/m^2 and increased progressively as BMI increased for both genders. Applying this criterion to identify the cut-off values resulted in improvements in sensitivity, false negative rate and worsening in specificity and false positive rate. A very small false negative rate ranging from 0.001 to 0.005 resulted by using these lower BMI cut-offs.

Conclusion: The diagnostic usefulness of BMI alone in defining obesity in patients with MetS is limited among men and women Saudi adults.

Keywords: Metabolic syndrome; Body Mass Index

Introduction

Metabolic syndrome (MetS) is a cluster of metabolic factors that increases the risk of cardiovascular disease (CVD) morbidity and mortality and type 2 diabetes mellitus (T2DM) [1-5]. MetS increases the risk of developing T2DM by three-fold and cardiovascular disease by two-fold, and it has become a major public health challenge around the world [6]. It has been proposed that the association between body mass index (BMI) and the development of T2DM is more complex than a mere a dose-response relationship [7,8]. These factors not only lead to reduced quality of life given their protracted nature, they also lead to premature death [9]. The first official definition of MetS put forward by a working group of the World Health Organization (WHO) in 1999, a number of different definitions have been proposed [10]. Presently, there are three sets of criteria for MetS: the International Diabetes Federation (IDF), the revised National Cholesterol Education Program and the Modified WHO [11].

Obesity is a complex disorder, where genetic predisposition interacts with environmental exposures to produce a heterogeneous phenotype [12]. Obesity is a well-known risk factor for developing T2DM, hypertension, dyslipidaemia and CVD and it was estimated to be the fifth leading cause of mortality at a global level, causing approximately 2.8 million deaths per year [1,13-15]. Although BMI is commonly used to measure somatic obesity, recent findings have reported its conflicting association with CVD and obesity-related health risks [16,17]. The prevalence of MetS is on the rise due to the obesity epidemic [1]. There are many individuals who are not categorized as obese based on BMI but are predisposed to MetS [18]. Screening for MetS among these non-obese individuals is often ignored, as they are assumed to be healthy. The literature shows that normal weight individuals could have MetS, placing them at elevated risk for chronic diseases that are typically associated with elevated BMI [19]. Evidence also suggests that an abnormal metabolic profile, rather than high BMI, is associated with higher risk of diabetes and CVD [20].

Studies from different countries and ethnicities have different conclusions regarding the cut-off points to diagnose obesity and hence MetS [21-23]. Researchers believe that ethnic and racial variation among population from different regions might need different cut-off points and/or use of different anthropometric measurement to diagnose obesity and MetS [23,24]. As a known risk factor of T2DM, high BMI (> 30 kg/m^2) is associated with 3–10 times greater risk of developing T2DM compared to low BMI (< 25 kg/m^2) [25-30]. Although this index has advantages in clinical and epidemiological practice, as a non-invasive and low-cost method, its predictive value for chronic diseases has been questioned, especially when applied to certain population groups [31-33]. Asians are more likely to have a higher percentage of body fat at lower BMI than Europeans, which may lead to the greater prevalence of cardiovascular disease risk factors at a relatively lower BMI in Asian populations [34-36]. The World Health Organization suggests that the cut-off values for public health action for Asians are BMI values ≥23 kg/m2 to represent an increased risk of CVD and BMI values ≥27·5 kg/m2 to represent a high risk of cardiovascular disease [35].

BMI is a valuable tool in clinical care and public health research to identify individuals who are at a significantly higher risk for obesity-associated diseases. However, evidence regarding whether different cut-off BMI values are appropriate in Saudi Arabia and gulf countries are insufficient [37-41]. On the other hand, several studies have attempted to determine the optimal cut-off values for BMI to predict various CVD risk factors based on data from either small-scale or cross-sectional studies. Most of the available data indicate that a cut-off BMI value is needed for the general population in Saudi Arabia. The objective of this study is to identify the optimal BMI cut-off that is associated with MetS

Methods

We analyzed 5498 participants who are equal to or older than 18 years old. All cases were from the population of the primary health at King Fahad Armed Forces Hospital. All data were collected by personal interview and on the basis of a review of electronic medical records. Physician and nurse interviewers measured and recorded weight (kg) and height (cm). Metabolic risk factors were defined using the 2006 IDF criteria that define elevated triglyceride as ≥150 mg/dL (≥1.7 mmol/L) and reduced high density lipoprotein cholesterol as <40 mg/dL (<1.03 mmol/L) for male and as <50 mg/dL (<1.29 mmol/L) for female. [24] Elevated blood pressure was defined when the systolic blood pressure was ≥130 mm Hg and/or diastolic blood pressure was ≥85 mm Hg in addition to receiving any medication for hypertension. Abnormal glucose metabolism was considered when HbA1c (≥5.7) 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 BMI.

Statistical Analysis

Unpaired t-test analysis and Chi square (X^2) test (categorical data comparison) were used between variables to estimate the significance of different between groups for demographic and clinical laboratory were used for. The optimal sensitivity and specificity using different BMI cut-off values to predict the presence of MetS were examined by receiver operating characteristic curve (ROC) analysis. A greater area under the curve (AUC) indicates better predictive capability. An AUC=0.5 indicates that the test performs no better than chance, and an AUC=1.0 indicates perfect discrimination. An ideal test is one that reaches the upper left corner of the graph (100% true positives and no false positives). To determine the optimal BMI cutoff points, we computed and searched for the shortest distance between any point on the curve and the top left corner on the y-axis. Distance was estimated at each one-half unit of BMI according to the equation:

Distance in ROC curve=$(1-\text{sensitivity})^2+(1-\text{specificity})^2$

[42,43]. Additional criteria were also used to select cut-offs, including the greater sum of sensitivity and specificity, the smallest misclassification rate, and the significant associations between BMI and risk factors based on the logistic regression. Diagnostic performance of BMI in predicting MetS was assessed by calculating AUC, sensitivity, specificity, likelihood ratios, false positive, false negative and the total misclassification rate. All results are presented as mean ± standard deviation or percentage, where applicable. Data analysis was performed in each gender separately. BMI was stratified in unit of 0.5 for both gender. We consider a BMI <15.0 as the reference. The independent relationship between the stratified BMI and the odds ratio of having MetS were analyzed using logistic regression. All statistical analyses were performed using SPSS Version 22.0. The difference between groups was considered significant when P<0.05.

Results

Of the 5498 participants analyzed, 2049 (37.3%) were male and 3449 (62.7%) were female with female to male ratio 1.7:1. Age was 42.7 ± 15.8 (minimum 18 years and maximum 105 years), Table 1. MetS was present in 1967 cases (35.8%) where 673 cases (38.8%) were male and 1204 cases (61.2%) were female with female to male ratio 1.6:1, P=0.08. Males were significantly older than females in MetS patients (45.5 ± 12.8 vs. 36.1 ± 13.3 respectively, p<0.0001). BMI was significantly higher in MetS patients (31.9 ± 6.6 vs. 28.3 ± 6.7 respectively, p<0.0001).

Parameters		Total	Metabolic syndrome		P value
			Present	Absent	
n (%)		5498	1967 (35.8)	3531 (64.2)	
Gender	Male	2049 (37.3)	673 (38.8)	1286 (36.4)	0.08
	Female	3449 (62.7)	1204 (61.2)	2245 (63.6)	
Age (years)		42.7 ± 15.8	45.5 ± 12.8	36.1 ± 13.3	<0.0001
Body mass index (kg/m^2)		29.6 ± 6.9	31.9 ± 6.6	28.3 ± 6.7	<0.0001

Table 1: Population characteristics (means ± SD or number (%)).

Table 2 displays details of the diagnostic performance of BMI in detecting MetS using optimal BMI cut-off values based on the shortest distance in ROC curve. Optimal BMI cut-off values ranged from 28.50 to 29.50 in total population, 27.50 to 28.50 in male and from 28.50 to 29.50 in female. The AUC was 0.615 (95% CI, 0.590-0.639) in male and 0.686 (95% CI, 0.668-0.704) in female, Figure 1.

Parameters	Area under curve (95% CI)	Cut-offs BMI kg/m^2	Sensitivity	Specificity	False positive rate	False negative rate	Positive likelihood ratio	Negative likelihood ratio	Misclassification rate
Total	0.659 (0.645-0.674)	29.0	0.63	0.64	0.36	0.37	0.98	0.58	0.73
Male	0.615 (0.590-0.639)	28.0	0.57	0.53	0.47	0.43	1.08	0.81	0.90
Female	0.686 (0.668-0.704)	29.5	0.66	0.64	0.34	0.36	1.03	0.53	0.70

Table 2: Diagnostic performance of BMI in detecting metabolic syndrome using optimal BMI cut-off values based on the shortest distance in ROC curves in Saudi adults.

Table 3 shows the predictive value of BMI in detecting MetS using BMI cut-off values based on the lowest significant association between BMI and the risk factors from the logistic regression analysis. Regression analysis showed that the risk of MetS was significantly increased at BMI values as low as $\leq$15.0 kg/m^2 and increased progressively as BMI increased for both genders, Table 4. Applying this criterion to identify the cut-off values resulted in improvements in sensitivity, false negative rate and worsening in specificity and false positive rate. A very small false negative rate ranging from 0.001 to 0.005 resulted by using these lower BMI cut-offs.

Parameters	Area under curve (95% CI)	Cut-offs BMI kg/m^2	Sensitivity	Specificity	False positive rate	False negative rate	Positive likelihood ratio	Negative likelihood ratio	Misclassification rate
Total	0.659 (0.645-0.674)	16.0	0.997	0.012	0.988	0.003	1.01	0.23	0.99
Male	0.615 (0.590-0.639)	17.0	0.999	0.013	0.987	0.001	1.01	0.08	0.99
Female	0.686 (0.668-0.704)	17.0	0.995	0.031	0.969	0.005	1.03	0.16	0.97

Table 3: Diagnostic performance of BMI in detecting metabolic syndrome using optimal BMI cut-off values based on the significant association using logistic regression in Saudi adults.

BMI (kg/m^2)	Total		Male		Female	
	Odd ratio (95% C I)	P	Odd ratio (95% C I)	P	Odd ratio (95% C I)	P
<15.0	16.3 (2.1-125.7)	0.007	-	-	16.1 (2.1-124.9)	0.008
15.0-15.9	10.9 (3.3-36.5)	<0.0001	-	-	9.9 (2.9-33.7)	<0.0001
16.0-16.9	23.4 (5.6-98.1)	<0.0001	-	-	18.6 (4.4-79.3)	<0.0001
17.0-17.9	19.9 (6.1-64.8)	<0.0001	15.6 (1.9-125.6)	0.01	19.9 (4.7-84.3)	<0.0001
18.0-18.9	11.5 (5.1-25.8)	<0.0001	9.0 (1.9-42.5)	0.005	11.7 (4.5-30.1)	<0.0001
19.0-19.9	8.6 (4.5-16.4)	<0.0001	10.4 (2.8-38.1)	<0.0001	6.9 (3.3-14.5)	<0.0001
20.0-20.9	10.8 (6.0-19.6)	<0.0001	8.5 (2.3-31.4)	0.001	11.2 (5.8-21.7)	<0.0001
21.0-21.9	6.1 (3.9-9.6)	<0.0001	2.4 (1.1-5.2)	0.02	11.5 (5.8-23.0)	<0.0001
22.0-22.9	5.5 (3.5-8.5)	<0.0001	2.4 (1.1-5.1)	0.02	9.4 (4.9-17.9)	<0.0001
23.0-23.9	3.9 (2.7-5.7)	<0.0001	2.3 (1.1-4.7)	0.03	4.7 (3.0-7.4)	<0.0001
24.0-24.9	3.6 (2.6-5.1)	<0.0001	2.1 (1.1-4.2)	0.04	4.4 (2.9-6.6)	<0.0001

25.0-25.9	3.0 (2.2-4.3)	<0.0001	1.6 (0.8-3.1)	0.2	4.2 (2.7-6.5)	<0.0001
26.0-26.9	2.3 (1.7-3.2)	<0.0001	1.3 (0.7-2.5)	0.4	3.1 (2.1-4.8)	<0.0001
27.0-27.9	2.0 (1.5-2.7)	<0.0001	1.2 (0.6-2.2)	0.6	2.6 (2.7-3.8)	<0.0001
28.0-28.9	2.3 (1.7-3.1)	<0.0001	1.4 (0.7-2.6)	0.3	2.8 (1.9-4.1)	<0.0001
29.0-29.9	2.0 (1.5-2.7)	<0.0001	1.2 (0.6-2.3)	0.5	2.3 (1.6-3.4)	<0.0001
30.0-30.9	1.6 (1.2-2.2)	0.003	1.1 (0.6-2.2)	0.7	1.7 (1.2-2.5)	0.006
31.0-31.9	1.7 (1.2-2.3)	0.001	1.1 (0.6-2.2)	0.6	1.8 (1.2-2.6)	0.002
32.0-32..9	1.6 (1.2-2.2)	0.003	1.0 (0.5-2.0)	0.9	1.8 (1.3-2.7)	0.001
33.0-33.9	1.2 (0.9-1.7)	0.2	0.9 (0.4-1.7)	0.7	1.3 (0.9-1.7)	0.2
34.0-34.9	1.2 (0.8-1.6)	0.4	1.0 (0.5-2.1)	0.9	1.1 (0.8-1.6)	0.5
35.0-35.9	1.2 (0.9-1.8)	0.3	0.7 (0.3-1.5)	0.4	1.4 (0.9-2.1)	0.1
36.0-36.9	0.9 (0.6-1.3)	0.5	0.9 (0.4-2.0)	0.8	0.9 (0.6-1.6)	0.8
37.0-37.9	1.3 (0.9-2.1)	0.2	0.6 (0.3-1.4)	0.2	1.2 (0.8-2.0)	0.4
38.0-38.9	1.1 (0.7-1.6)	0.8	0.9 (0.4-2.2)	0.9	1.0 (0.6-1.7)	0.9
39.0-39.9	1.5 (1.0-2.4)	0.08	0.9 (0.3-2.5)	0.8	1.7 (1.0-2.8)	0.05

Table 4: Risk of metabolic syndrome associated with increasing BMI in Saudi adults based on regression analysis.

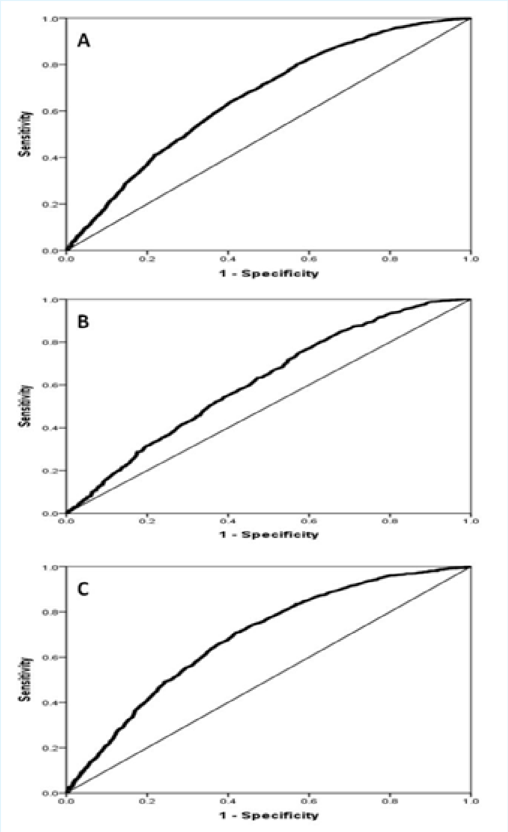

Figure 1: ROC curve showing the performance of BMI in predicting diabetes (A: metabolic syndrome in total population, B: metabolic syndrome in male, C: metabolic syndrome in female).

Discussion

In this hospital-based cohort of Saudi adults, we showed that individuals with a BMI of ≤16.0 kg/m^2 have been significantly at higher risk of developing MetS with optimal BMI cut-off points of 29.5 kg/m2 in women and 28.0 kg/m2 in men. Our findings also higher to those of other studies conducted in Asian countries [44-54].

MetS is an asymptomatic, pathophysiological state characterised by obesity, insulin resistance, hypertension, dysglycaemia, and dyslipidaemia. The current study shows the prevalence of MetS to be 35.8% according to the IDF criteria, when BMI cutoff values have been implemented [55]. The prevalence of MetS in Saudi Arabia and gulf countries ranged from 33.7% to 40.5% using the same IDF criteria [41,56,57]. The prevalence of MetS was higher with age which was consistent with other studies [58-60]. Our sample shows that female had a higher prevalence of MetS (62.7%) than male (37.3 %), a finding contrary to that of Flowers, et al. who found that males had a higher prevalence using the same MetS criteria and ascribed the sex differences to the protective effect of oestrogen [61,62].

The use of BMI with optimal cut-off points for diagnosis of obesity is important to establish consequent public health policies, treatment protocols and to determine the correct optimal cut-off points of BMI for each population. In 2004, the WHO consultation group stated that based on the existing data, Asians may have higher chances of acquiring disease at a BMI cut-off once presumed as low risk for obesity related disease (< 25 kg/m^2) and since then multiple studies have been conducted in the Asian region to evaluate the best threshold of BMI regarding risk of disease [63]. Majority of the studies point to the fact that Asians have a higher risk of developing MetS and CVD and have a higher percent of body fat, compared to their peer Caucasians living in the US and Europe with a similar BMI [64]. In one study in the eastern province of Saudi Arabia among a large population of adults over 30 years old, BMI cut-offs for detecting hypertension and diabetes were defined as 28.5 kg/m^2 and 29.5 kg/m^2 for men and 30.5 kg/m^2 and 31.5 kg/m^2 for women, although their ROC analysis did not show these cut-off points as having clinical value. Al-Lawati, et al. in 2008, reported the optimum BMI cut-off for the Omani Arab population as 23.2 kg/m^2 and 26.8 kg/m^2 for men and women older than 20 years old, respectively [38,39]. In another study evaluating BMI based on metabolic risk factors conducted in Guatemala, as a developing country, they documented BMI cut-offs as 24.7–26.1 kg/m^2 for men and 26.5–27.6 kg/m^2 for women. In a sample of the Chinese population Dong and colleagues evaluated 3006 individuals [65].

They documented a cut-off of 25 kg/m^2 for men and 24.5 kg/m^2 for women as appropriate for the prediction of metabolic syndrome in the Chinese population. For the Malaysian population, one study in 2009 , based on their definition of cardiovascular risk as hypertension, dyslipidemia and diabetes, reported a BMI cut-off of 23.5 and 24.9 kg/m2 for men and women, respectively [66]. Wannamethee, et al. in a prospective study in 2010, found that a BMI of between 28–29 kg/m2 for men and a BMI of 29–30 kg/m2 was optimal for the diagnosis of diabetes in a large sample of residence within the UK [67]. Pan et al. compared the accumulation of different risk factors including hypertension, diabetes, hypertriglyceridemia and hypercholesterolemia considering a similar positive predictive value between a Taiwanese population and a non-Hispanic Caucasian population from the US [46]. They found that with a similar positive predictive value, risk factors are much more prevalent in the Taiwanese population. One of the confounding factors that influence the difference in cut-off points among studies, other than ethnic differences, could be the different age groups selected for the studies. Age can change body composition regarding total and distribution of body fat and the metabolic factors [68].

BMI cut-off points defined by the WHO, are based on the risk factors associated with development of disease, mostly CVD. In light of the WHO expert consultation in 2004, it has become evident that a single BMI cut-off is unlikely to represent an equal accumulation of different risk factors for non-communicable disease among all ethnic groups and different populations worldwide [63,69,70]. The optimum BMI for definition of disease has been a subject of great consideration among different researches. Studies have shown that Asians are likely to have a higher percent of adipose tissue, especially visceral adiposity, at lower BMI cut-off points than that reported by the WHO as standard cut-off points, which is based on studies in European and American populations [66,71]. A BMI of >30 kg/m^2, as defined by the WHO criterion was found to be less sensitive for predicting individual metabolic risk factors for MetS in both genders [54]. The important caveat is the BMI cut-off value selected. Our results, and those of others, show that it may not be appropriate to use the BMI cut-offs developed for certain other groups (e.g. European Americans or African Americans) for Saudi population since Saudis seem to experience metabolic abnormalities at lower BMI [72-75]. The suggestion to use different cut-off values is not new. Other studies have also called for lower BMI cut-offs [76]. BMI cut-off values of 25.0 kg/m^2 and 30.0 kg/m^2, derived from European populations, are associated with increased co-morbidities in Saudi population and are clearly too high to use. They underestimate the prevalence of MetS and obfuscate the large numbers of Saudis who evince metabolic abnormalities at theses higher BMI cut-offs. Some researchers have called for an even lower BMI cut-off (21.0 kg/m^2) for overweight in Asians, but this suggestion has failed to gain consensus [77-79].

In our study, the risk of MetS associated with each BMI level was estimated, adjusting for other covariates. To assess the impact of the other covariates, we estimated an unadjusted logistic regression model with BMI level as the only covariate. The Odd Ratios (OR), which approximate the relative risks in the nested case-control analysis, are listed in Table 4. BMI cut-off of 16.0 kg/m^2 was associated with the highest unadjusted and adjusted prevalence ratio particularly in females. The unadjusted ORs were slightly higher than the adjusted ORs. This implies that some factors, such as age and gender, are associated with both increased BMI and increased risk of MetS, but the impact of these factors on the association between BMI and risk of MetS is limited. Moreover, BMI values were clinically measured in the current study, compared with BMI calculated from self reported height and weight in those earlier studies. Self reported weight and height considerably underestimate the individuals' measured BMI and may thus have weakened the association between obesity and risk of MetS and/or biased the estimated results [80,81]. Self reported diabetes has high specificity and positive predictive value but low sensitivity [82]. This may explain the higher OR associated with BMI levels in the current study compared to other report [83].

The overall performance of the ROC curve can be quantified by estimating the AUC which ranged from 0.59 to 0.70, Table 2. An area of 1.0 is perfect and an area <0.5 is considered non-informative. Our results indicated that the ROC analysis was close to a non-informative test as shown in the Figure 1. ROC curve analysis showed that the corresponding sensitivities and specificities were poor (<0.63 and <0.64, respectively). This indicates that the percentage of people identified as having the risk factors and the percentage of people who were identified as not being at risk were less than 63% of total population. Both positive likelihood ratio and negative likelihood ratio were close to 1.0, indicating a minimal increase in the likelihood of the presence of the risk factor if the test is positive and a minimal decrease in the likelihood if the test is negative. The false positive and false negative rates were high and close to each other in both women and men. Several reasons may explain the weakness of BMI as a tool to classify obesity in the Saudi Arabian population. First, BMI does not reflect fatness uniformly in all populations and different ethnic groups [76]. This may suggest the importance of including a measure of abdominal obesity in classifying obesity in Saudi populations. Second, the short stature of Saudi women could be limiting the usefulness of BMI in this population [37].

The overall misclassification was high and exceeded 90% of the total population across all the selected BMI cut-off points. Most of the other previous studies that have been conducted in non-Caucasian populations did not assess the misclassification rate [84-87]. However, one study conducted in Asian Indians indicated a high overall misclassification rate, particularly in women [76]. Those authors concluded that the BMI did not accurately predict overweight in that population. This is not the first study to suggest the presence of a significantly increased risk of MetS at BMI values less than 25. However, the use of such low cut-offs would lead to large misclassification of healthy people as being at risk, as indicted by the high values of sensitivities and false positive rates. This fact that could cause unnecessary and costly diagnostic testing. Overall the total misclassification rate was unacceptably high, even with the use of different BMI cut off points. These findings illustrate the significant limitations in using BMI alone for obesity diagnosis in the Saudi Arabian population.

Our results should be interpreted in light of the study's limitations. First, most of the patients enrolled were already on treatment for hypertension, diabetes and hypercholesterolaemia, which imposed some limitations on the study. We tried to overcome these by obtaining the necessary sample size and by using data documented before treatment. Finally, as this was a hospital-based, retrospective study, the findings do not represent the whole Saudi population or the local community. Further larger population-based studies are necessary to support our findings. Another limitation of the present study was having considered only overall obesity (assessed by BMI) and not abdominal obesity (measured by waist circumference), which is known to bear a close relationship with the target diseases.

Conclusion

The diagnostic usefulness of BMI alone in defining obesity in patients with MetS is limited among men and women Saudi adults.

Acknowledgments

We are grateful to the staffs from the Primary care department at King Fahad Armed Forces Hospital for their valuable contributions in data collection. The authors have no conflict of interest to disclose.

References

1. Liberopoulos EN, Mikhalidis DP, Elisaf MS (2005) Diagnosis and management of the metabolic syndrome in obesity. Obes Rev 6(4): 283-296.

2. National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood 0Cholesterol in Adults (Adult Treatment Panel III) (2002) Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation 106(25): 3143-3421.

3. Bener A, Mohammad AG, Ismail AN, Zirie M, Abdullatef WK, et al. (2010) Gender and age-related differences in patients with the metabolic syndrome in a highly endogamous population. Bosn J Basic Med Sci 10(3): 210-217.

4. Scott L (2003) Diagnosis, prevention and intervention for the metabolic syndrome. American Journal of Cardiology 99(1A): 35i–42i.
5. Moller DE, Kaufman KD (2005) Metabolic syndrome: a clinical and molecular perspective. Annual Review of Medicine 56: 45-62.
6. Zimmet P, Maglian D, Matsuzawa Y, Alberti G, Shaw J (2005) The metabolic syndrome: a global public health problem and a new definition. J Atherosclera Thromb 12(6): 259-300.
7. Brochu M, Tchernof A, Dionne IJ, Sites CK, Eltabbakh GH, et al. (2001) What are the physical characteristics associated with a normal metabolic profile despite a high level of obesity in postmenopausal women? J Clin Endocrinol Metab 86(3): 1020-1025.
8. Karelis AD, Faraj M, Bastard JP, St-Pierre DH, Brochu M, et al. (2005) The metabolically healthy but obese individual presents a favorable inflammation profile. J Clin Endocrinol Meta 90(7): 4145-4150.
9. Asfaw A (2008) The effects of obesity on doctor-diagnosed chronic diseases in Africa: empirical results from Senegal and South Africa. J Public Health Policy 27(3): 250-264.
10. Marchesini G, Forlani G, Cerrelli F, Manini R, Natale S, et al. (2004) WHO and ATPIII proposals for the definition of the metabolic syndrome in patients with Type 2 diabetes. Diabet Med 21(4): 383-387.
11. Tan BT, Kantilal HK, Singh R (2008) Prevalence of metabolic syndrome among Malaysians using the International Diabetes Federation, National Cholesterol Education Program and Modified World Health Organisation Definitions. Mal J Nutr 14(1): 65-77.
12. Comuzzie AG, Williams JT, Martin LJ, Blangero J (2001) Searching for genes underlying normal variation in human adiposity. J Mol Med 79(1): 57-70.
13. Yusuf S, Hawken S, Ounpuu S, Dans T, Avezum A, et al. (2004) Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. Lancet 364(9438): 937-952.
14. Klein S, Allison DB, Heymsfield SB, Kelley DE, Leibel RL, et al. (2007) Waist circumference and cardiometabolic risk: a consensus statement from Shaping America’s Health: Association for Weight Management and Obesity Prevention; NAASO, The Obesity Society; the American Society for Nutrition; and the American Diabetes Association. Am J Clin Nutr 85(5): 1197-1202.
15. WHO (2016) Obesity and Overweight. World Health Organization.
16. Hsieh SD, Yoshinaga H, Muto T, Sakurai Y, Kosaka K (2002) Health risks among Japanese men with moderate body mass index. Int J Obes Relat Metab Disord 24(3): 358-362.
17. Wang J, Russell-Aulet M, Mazariegos M, Burastero S, Thornton J, et al. (1992) Body fat by dual photon absorptiometry (DPA): comparisons with traditional methods in Asians, Blacks and Caucasians. Am J Hum Biol 4(4): 501-510.
18. Ruderman N, Chisholm D, Pi-Sunyer X, Schneider S (1998) The metabolically obese, normal-weight individual revisited. Diabetes 47(5): 699-713.
19. Wildman RP, Muntner P, Reynolds K, McGinn AP, Rajpathak S, et al. (2008) The obese without cardiometabolic risk factor clustering and the normal weight with cardiometabolic risk factor clustering: prevalence and correlates of 2 phenotypes among the US population (NHANES 1999-2004). Arch Intern Med 168(15): 1617-1624.
20. Meigs JB, Wilson PW, Fox CS, Vasan RS, Nathan DM, et al. (2006) Body mass index, metabolic syndrome, and risk of type 2 diabetes or cardiovascular disease. J Clin Endocrinol Metab 91(8): 2906-2912.
21. Park SH, Choi SJ, Lee KS, Park HY (2009) Waist circumference and waist-to-height ratio as predictors of cardiovascular disease risk in Korean adults. Circulation Journal 3(9): 643-1650.
22. Ko KP, Oh DK, Min H, Kim CS, Park JK, et al. (2012) Prospective study of optimal obesity index cutoffs for predicting development of multiple metabolic risk factors: the korean genome and epidemiology Study. Journal of Epidemiology 22(5): 433-439.
23. Gharipour M, Sarrafzadegan N, Sadeghi M, Andalib E, Talaie M, et al. (2013) Predictors of metabolic syndrome in the iranian population: waist

circumference, body mass index, or waist to hip ratio? Cholestrol 2013: 198384.

24. Alberti KG, Zimmet P, Shaw J (2006) Metabolic syndrome-a new world-wide definition. A consensus statement from the International Diabetes Federation. Diabetic Medicine 23(5): 469-480.

25. Chan JM, Rimm EB, Colditz GA, Stampfer MJ, Willett WC (1994) Obesity, fat distribution, and weight gain as risk factors for clinical diabetes in men. Diabetes Care 17(9): 961-969.

26. Colditz GA, Willett WC, Stampfer MJ, Manson JE, Hennekens CH, et al. (1990) Weight as a risk factor for clinical diabetes in women. Am J Epidemiol 132(3): 501-513.

27. de Mutsert R, Sun Q, Willett WC, Hu FB, van Dam RM (2014) Overweight in early adulthood, adult weight change, and risk of type 2 diabetes, cardiovascular diseases, and certain cancers in men: a cohort study. Am J Epidemiol 179(11): 1353-1365.

28. Nagaya T, Yoshida H, Takahashi H, Kawai M (2005) Increases in body mass index, even within non-obese levels, raise the risk for type 2 diabetes mellitus: a follow-up study in a Japanese population. Diabet Med 22(8): 1107-1111.

29. Perry IJ, Wannamethee SG, Walker MK, Thomson AG, Whincup PH, et al. (1995) Prospective study of risk factors for development of non-insulin dependent diabetes in middle aged British men. BMJ 310(6979): 560-564.

30. Wannamethee SG, Shaper AG, Walker M (2005) Overweight and obesity and weight change in middle aged men: impact on cardiovascular disease and diabetes. J Epidemiol Community Health 59(2): 134-139.

31. Hubbard VS (2002) Defining overweight and obesity: what issues? Am J Clin Nutr 72(5): 1067-1068.

32. Ko GTC, Tang J, Chan JCN, Wu MMF, Wai HPS, et al. (2001) Lower body mass index cut-off value to define obesity in Hong Kong Chinese: an analysis based on body fat assessment by bioeletrical impedance. Br J Nutr 85(2): 239-2342.

33. Long AE, Prewitt TE, Kaufman JS, Rotimi CN, Cooper RS, et al. (1998) Weight-height relationships among eight populations of West African origin: the case against constant BMI standards. Int J Obes Relat Metab Disord 22(9): 842-846.

34. Deurenberg P, Deurenberg-Yap M, Guricci S (2002) Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. Obes Rev 3(3): 141-146.

35. WHO Expert Consultation (2004) Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 363(9403): 157-163.

36. Chen YM, Ho SC, Lam SS, Chan SS (2006) Validity of body mass index and waist circumference in the classification of obesity as compared to percent body fat in Chinese middle-aged women. Int J Obes (Lond) 30(6): 918-925.

37. Almajwal AM, Al-Baghli NA, Batterham MJ, Williams PG, Al-Turki KA, et al. (2009) Performance of body mass index in predicting diabetes and hypertension in the Eastern Province of Saudi Arabia. Annals of Saudi Medicine 29(6): 437-445.

38. Al-Lawati JA, Jousilahti P (2007) Body mass index, waist circumference and waist-to-hip ratio cut-off points for categorisation of obesity among Omani Arabs. Public Health Nutr 11(1): 102-108.

39. Al-Lawati JA, Barakat NM, Al-Lawati AM, Mohammed AJ (2008) Optimal cut-points for body mass index, waist circumference and waist-to-hip ratio using the Framingham coronary heart disease risk score in an Arab population of the Middle East. Diabetes Vasc Dis Res 5(4): 304-309.

40. Al-Nozha M, Al-Khadra A, Arafah MR, Al-Maatouq MA, Khalil MZ, et al. (2005) Metabolic syndrome in Saudi Arabia. Saudi Med J 26(12): 1918-1925.

41. Khalid Al-Rubeaan, Nahla Bawazeer, Yousuf Al Fars (2018) Prevalence of metabolic syndrome in Saudi Arabia - a cross sectional study. BMC Endocrine Disorders 18(1): 16.

42. Shan Kuan Z, Zi Mian W, Stanley H, Moonseong H, Faith M, et al. (2002) Waist circumference and obesity-associated risk factors among whites in the third National Health and Nutrition Examination Survey: Clinical action thresholds. Am J Clin Nutr 76(4): 743-749.

43. Weng X, Liu Y, Ma J, Wang W, Yang G, et al. (2006) Use of body mass index to identify obesity-related metabolic disorders in the Chinese population. Eur J Clin Nutr 60(8): 931-937.

44. Ko GT, Chan JC, Cockram CS, Woo J (1999) Prediction of hypertension, diabetes, dyslipidaemia or albuminuria using simple anthropometric indexes in Hong kong Chinese. Int J Obes Relat Metab Disord 23(11): 1336-1342.

45. (2006) The IDF Consensus Worldwide Definition of the Metabolic Syndrome. In: International Diabetes Federation.

46. Pan WH, Flegal KM, Chang HY, Yeh WT, Yeh CJ et al. (2004) Body mass index and obesity-related metabolic disorders in Taiwanese and US whites and blacks: implications for definition of overweight and obesity for Asians. Am J Clin Nutr 79(1): 31-39.

47. Zhou BF, Cooperative Meta-Analysis Group of the Working Group on Obesity in China (2002) Predictive values of the body mass index and waist circumference for the risk factors of certain related diseases in Chinese adults-study on optimal cut-off points of body mass index and waist circumference in Chinese adults. Biomed Environ Sci 15(1): 83-96.

48. Li G, Chen X, Jang Y, Wang J, Xing X, et al. (2002) Obesity, coronary artery disease risk factors and diabetes in Chinese: an approach to the criteria of obesity in the Chinese population. Obes Rev 3(3): 167-172.

49. Vikram NK, Pandey RM, Misra A, Sharma R, Devi JR, et al. (2003) Non-obese (body mass index < 25 kg/m2) Asian Indians with normal waist circumference have high cardiovascular risk. Nutrition 19(6): 503-509.

50. Misra A, Vikram NK, Gupta R, Pandey RM, Wasir JS, et al. (2006) Waist circumference cutoff points and action levels for Asian Indians for identification of abdominal obesity. Int J Obes (Lond) 30(1): 106-111.

51. Deurenberg-Yap M, Chew SK, Deurenberg P (2002) Elevated body fat percentage and cardiovascular risks at a low body mass index levels among Singaporean Chinese, Malays and Indians. Obes Rev 3(3): 209-215.

52. Hara K, Matsushita Y, Horikoshi M, Yoshiike N, Yokoyama T, et al. (2006) A proposal for the cutoff point of waist circumference for the diagnosis of metabolic syndrome in the Japanese population. Diabetes Care 29(5): 1123-1124.

53. Ito H, Nakasuga K, Ohshima A, Maruyama T, Kaji Y, et al. (2003) Detection of cardiovascular risk factors by indices of obesity obtained from anthropometry and dual-energy X-ray absorptiometry in Japanese individuals. Int J Obes Relat Metab Disord 27(2): 232-237.

54. Bee YT, Haresh KK, Rajibans S (2008) Prevalence of metabolic syndrome among Malaysians using the International Diabetes Federation, National Cholesterol Education Program and Modified World Health Organisation Definitions. Mal J Nutr 14(1): 65-77.

55. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, et al. (2009) Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation 120(16): 1640-1605.

56. Malik M, Razig SA (2008) The prevalence of the metabolic syndrome among the multiethnic population of the United Arab Emirates: a report of a national survey. Metab Syndr Relat Disord 6(3): 177-186.

57. Bener A, Zirie M, Musallam M, Khader YS, Al-Hamaq AO (2009) Prevalence of metabolic syndrome according to adult treatment panel III and international diabetes federation criteria: a population-based study. Metab Syndr Relat Disord 7(3): 221-229.

58. Meigs JB, Wilson PW, Nathan DM, D'Agostino RB Sr, Williams K, et al. (2003) Prevalence and characteristics of the metabolic syndrome in the San Antonio Heart and Framingham Off spring Studies. Diabetes 52(8): 2160-2167.

59. Villegas R, Perry IJ, Creagh D, Hinchion R, O'Halloran D (2003) Prevalence of the metabolic syndrome in middle‐aged men and women. Diabetes Care 26(11): 3198‐3199.

60. Irwin ML, Ainsworth BE, Mayer‐Davis EJ, Addy CL, Pate RR, et al. (2002) Physical activity and the

metabolic syndrome in a tri‑ethnic sample of women. Obes Res 10(10): 1030‑1037.

61. Flowers E, Molina C, Mathur A, Prasad M, Abrams L, et al. (2010) Prevalence of metabolic syndrome in South Asians residing in the United States. Metab Syndr Rel Disord 8(5): 417-423.

62. Alberti KGMM, Zimmet P, Shaw J (2006) Metabolic syndrome-a new world-wide definition. A Consensus Statement from the International Diabetes Federation. Diabet Med 23(5): 469-480.

63. WHO Expert Consultation (2004) Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 363(9403): 157-163.

64. Pan WH, Yeh WT (2008) How to define obesity? Evidence-based multiple action points for public awareness, screening, and treatment: an extension of Asian-Pacific recommendations. Asia Pac J Clin Nutr 17(3): 370-374.

65. Dong X, Liu Y, Yang J, Sun Y, Chen L (2011) Efficiency of anthropometric indicators of obesity for identifying cardiovascular risk factors in a Chinese population. Postgrad Med J 87(1026): 251-256.

66. Zaher ZM, Zambari R, Pheng CS, Muruga V, Ng B, et al. (2009) Optimal cut-off levels to define obesity: body mass index and waist circumference, and their relationship to cardiovascular disease, dyslipidaemia, hypertension and diabetes in Malaysia. Asia Pac J Clin Nutr 18(2): 209-216.

67. Wannamethee SG, Papacosta O, Whincup PH, Carson C, Thomas MC, et al. (2010) Assessing prediction of diabetes in older adults using different adiposity measures: a 7 year prospective study in 6,923 older men and women. Diabetologia 53(5): 890-898.

68. Nascimento H, Catarino C, Mendonca D, Oliveira P, Alves AI, et al. (2015) Comparison between CDC and WHO BMI z-score and their relation with metabolic risk markers in Northern Portuguese obese adolescents. Diabetology & metabolic syndrome 7: 32.

69. Chang Y, Ryu S, Suh BS, Yun KE, Kim CW, et al. (2012) Impact of BMI on the incidence of metabolic abnormalities in metabolically healthy men. Int J Obes (Lond) 36(9): 1187-1194.

70. Worachartcheewan A, Nantasenamat C, Isarankura-Na-Ayudhya C, Pidetcha P, Prachayasittikul V (2010) Lower BMI cutoff for assessing the prevalence of metabolic syndrome in Thai population. Acta Diabetol 47(S1): 91-96.

71. Zeng Q, He Y, Dong S, Zhao X, Chen Z, et al. (2014) Optimal cut-off values of BMI, waist circumference and waist: height ratio for defining obesity in Chinese adults. Br J Nutr 112(10): 1735-1744.

72. Snehalatha C, Viswanathan V, Ramachandran A (2003) Cutoff values for normal anthropometric variables in asian Indian adults. Diabetes Care 26(5): 1380-1384.

73. Lear SA, Toma M, Birmingham CL, Frohlich JJ (2003) Modification of the relationship between simple anthropometric indices and risk factors by ethnic background. Metabolism 52(10): 1295-1301.

74. Jayasinghe SR, Jayasinghe SH (2009) Variant metabolic risk factor profile leading to premature coronary disease: time to define the syndrome of accelerated atherocoronary metabolic syndrome in Asian Indians. Singapore Med J 50(10): 949-955.

75. Chowdhury B, Lantz H, Sjostrom L (1996) Computed tomography-determined body composition in relation to cardiovascular risk factors in Indian and matched Swedish males. Metabolism 45(5): 634-644.

76. Dudeja V, Misra A, Pandey RM, Devina G, Kumar G, et al. (2001) BMI does not accurately predict overweight in Asian Indians in northern India. Br J Nutr 86(1): 105-112.

77. Vasudevan D, Stotts AL, Mandayam S, Omegie LA (2011) Comparison of BMI and anthropometric measures among South Asian Indians using standard and modified criteria. Public Health Nutr 14(5): 809-816.

78. Misra A, Misra R, Wijesuriya M, Banerjee D (2007) The metabolic syndrome in South Asians: continuing escalation & possible solutions. Indian J Med Res 125(3): 345-354.

79. Misra A, Wasir JS, Vikram NK (2005) Action and research are needed for evaluation of optimal definitions of anthropometric parameters and metabolic syndrome for Asians. Diabetes Res Clin Pract 68(2): 178-179.

80. Burkhauser RV, Cawley J (2008) Beyond BMI: the value of more accurate measures of fatness and obesity in social science research. J Health Econ 27(2): 519-529.

81. Plankey MW, Stevens J, Flegal KM, Rust PF (1997) Prediction equations do not eliminate systematic error in self-reported body mass index. Obes Res 5(4): 308-314.

82. Saydah SH, Geiss, Tierney E, Benjamin SM, Engelgau M, et al. (2004) Review of the performance of methods to identify diabetes cases among vital statistics, administrative, and survey data. Ann Epidemiol 14(7): 507-516.

83. Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, et al. (2003) Prevalence of obesity, diabetes, and obesity-related health risk factors. JAMA 289(1): 76-79.

84. Nguyen TT, Adair LS, He K, Popkin BM (2008) Optimal cutoff values for overweight: using body mass index to predict incidence of hypertension in 18- to 65-year-old Chinese adults. J Nutr 138(7): 1377-1382.

85. Chen YM, Ho SC, Lam SS, Chan SS (2006) Validity of body mass index and waist circumference in the classification of obesity as compared to percent body fat in Chinese middle-aged women. Int J Obes 30(6): 918-925.

86. Pongchaiyakul C, Nguyen TV, Kosulwat V, Rojroongwasinkul N, Charoenkiatkul S, et al. (2006) Defining obesity by body mass index in the Thai population: an epidemiologic study. Asia Pac J Clin Nutr 15(3): 293-299.

87. Tazeen HJ, Nish C, Gregory P (2006) Prevalence of overweight and obesity and their association with hypertension and diabetes mellitus in an Indo-Asian population. CMAJ 175(9): 1071-1077.