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Original Article

The most appropriate cut-off point of anthropometric indices in predicting the incidence of metabolic syndrome and its components

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A B S T R A C T

Introduction: The association of individuals' anthropometric indices with their development of metabolic syndrome (MetS) has been investigated in several studies. Taking into account the ethnic differences, this study aimed to determine the most appropriate cut-off points of anthropometric indices in predicting the incidence of MetS and its components in Ahvaz.

Methods: This study is part of a cohort study conducted at the Diabetes Research Center of Ahvaz Jundishapur University of Medical Sciences on a population of over 20 in Ahvaz during 2009–2014. Of the 592 patients, 505 patients who were not diagnosed with MetS in 2009, were entered into this study. The data analyzed involved demographic information including age and sex, anthropometric information including height, weight, waist circumference (WC), hip circumference (HC) and the ratios between them, laboratory data including blood levels of Triglyceride (TG), Fasting plasma glucose (FPG) and High-density lipoprotein cholesterol (HDL-C), and clinical data including systolic(S) and diastolic(D)blood pressure(BP). After 5 years, the subjects were re-evaluated for MetS based on the National Cholesterol Education Program – Adult Treatment Panel III (NCEP-ATP III) criteria and the most appropriate cut-off points of anthropometric indices for the prediction of the incidence of MetS using the Receiver Operative Characteristic (ROC) curves were obtained.

Results: Waist-to-Height Ratio (WHtR) index with a cut-off point of 0.53 followed by WC with a cut-off point of 87.5 cm had the highest power to predict the incidence of MetS. The cut-off points of WC and Body mass index (BMI) were respectively 89.5 cm and 26 kg/m2 for men, and 83.5 cm and 27.5 kg/m2 for women. All anthropometric indices were able to predict the components of this syndrome (with the exception of low HDL-C). The cut-off point of WC in predicting High FBS, High TG and High BP was 84.5, 84.8, and 86.5 cm, respectively.

Conclusion: Overall, it seems that given its ease of measurement, the WC index is preferred to other indices for predicting the incidence of MetS and its components in clinical screening.

1. Introduction

Metabolic syndrome is a set of associated risk factors of a metabolic origin, which seems to directly contribute to the development of atherosclerotic cardiovascular diseases and Type 2 diabetes [1]. This syndrome was first introduced in 1988 by Reaven et al. who called it Syndrome X [2]. Several definitions have been put forward by different groups and organizations, including the NCEP ATP III [3] and the International Diabetes Federation (IDF) [4] generally, a combination of 3 (or more) key criteria including abdominal obesity, insulin resistance, glucose intolerance and diabetes, increased TG, HDL-C and Hypertension (HTN) are regarded as the necessary diagnostic indices in any definition. The syndrome is associated with a 2-fold increase in cardiovascular outcomes, a 1.5-fold increase in all causes of death [5] and a 3-fold increase in the risk of diabetes [6]. Insulin resistance and hyperinsulinemia are the hallmarks of MetS [7]. Overweight and obesity are the major risk factors for this syndrome [8]. The first step in determining the degree of obesity is the calculation of the BMI, which is easy and reliable to calculate, and depends on the body fat percentage [9] and is commonly used to evaluate generalized obesity, but is not reliable for evaluating the body fat distribution. Diagnosis of abdominal obesity that is associated with

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cardiovascular metabolic consequences [10,11] is evaluated by various methods, including measurement of the WC, and the waist to hip ratio (WHR). High WC is considered as ≥102 cm in men, and ≥88 cm in women [12], but ethnic diversity in its cut off (which is a predictor of high risk), shows that the definition of obesity in Asia, North America, or Europe is obviously different [7]. For example, in Asian men, the waist circumference is ≥ 90 cm while in Asian women, it is ≥ 80 cm [13] The WHR shows an intra-abdominal fat tissue that, like the WC, varies according to race, age and sex [14,15]. Another anthropometric index is WHtR which has been shown to be a strong predictor of metabolic syndrome in some studies [16,17]. Some ethnic populations have more or less sensitivity to the accumulation of visceral fat in proportion to a certain amount of total body fat, and thus the definition of high-risk abdominal obesity should be based on different populations in the world [7]. Given the ethnic differences in susceptibility to obesity and the health risks posed by it, and in view of the fact that various studies have reached controversial results regarding the practical value and predictive power of anthropometric indices for the identification of MetS and risk factors for cardiovascular disease, the World Health Organization (WHO) has recommended that in different populations, anthropometric cut-off points for that population would be adopted [18].

To obtain an anthropometric index cut-off point, cross-sectional study design (especially for WC) has often been used in most studies, and few studies have been conducted as a prospective study to evaluate these indices in the incidence of MetS. Therefore, given the high prevalence of this syndrome in Iran which is 25% according to the ATP III criterion, and 30% according to IDF criteria [19] and 22.8% in Ahvaz according to ATP III criteria [20], this community-based cohort study was conducted to determine the cut-off points of anthropometric indices used to predict the incidence of MetS and its components in the adult population of Ahvaz.

2. Method

This study was part of a cohort study conducted at the Diabetes Research Center of Ahvaz Jundishapur University of Medical Sciences on a population of over 20 in Ahvaz during 2009–2014. The sampling method used was randomized clustered sampling. The data were recorded in a questionnaire including demographic information and medical history (age and sex, history of diabetes, hypertension, dyslipidemia and related drug use), anthropometric information (height, weight, WC, HC and ratios between them), laboratory information (TG, FPG and HDL-C), and clinical data (SBP and DBP). Of the 592 subjects, 505 subjects who met the inclusion criteria (age> 20, with no MetS, severe physical deformity, end stage cancer and pregnancy), entered this study and were evaluated for the variables mentioned. After 5 years, the subjects were re-evaluated for MetS and the appropriate cut-off points were obtained for anthropometric indices.

This study was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences.

BP was measured after 15 min of rest in sitting position from the right arm twice at a minimum of 30-min using a standard mercury pressure gauge, and the mean of the two measurements was considered as reference. The subjects were weighed with minimum clothing and barefoot with the aid of an analogue scales while their height was measured as they stood barefoot and sideways to the wall with their shoulders touching the wall, by using a tape measure. WC was measured from the midpoint between the lowest rib and upper lateral border of the right iliac crest, and HC was considered at the point with the maximum hip diameter.

The venous blood sample was taken after 12 h of fasting, and the necessary tests were performed at the Diabetes Research Center Laboratory.

MetS was diagnosed according to the NCEP/ATPIII criterion, which includes 3 or more of the following criteria:

- WC ≥ 102 cm in men and ≥88 cm in women.
- FPG ≥100 mg/dl or drug treatment for elevated blood glucose.
- TG ≥ 150 mg/dl or drug treatment for elevated TG.
- HDL-C < 40 mg/dl in men and <50 mg/dl in women or drug treatment for low HDL-C.
- SBP ≥130 mm Hg and/or DBP ≥85 mm Hg or drug treatment for elevated BP.

3. Statistical analysis

To determine the differentiation power of each anthropometric index for predicting the incidence of metabolic syndrome and its appropriate cut-off point, ROC (Receiver Operating Characteristic) analysis was used, and sensitivity, specificity, Youden index, and area under the curve (AUC) of ROC for each index and their comparison were examined in order to determine the diagnostic accuracy of each index. The significance levels of the above tests were considered to be less than 0.05. Data analysis was performed using SPSS version 22 and STAT 13.

4. Results

Out of the 592 initial participants in 2009, 87 (14.7%) patients who had MetS were excluded and 505 were enrolled (Diagram 1). Of these, 257 (50.9%) were men with a mean age of 43.4 ± 14.3 years and 248 (49.1%) were women with a mean age of 39.5 ± 11.9 years.

At the end of the study, 100 (19.8%) patients developed MetS [46 (46%) males and 54 (54%) females].

The incidence of MetS increased with age, and the highest incidence of MetS (31.6%) was among those over the age of 60 (p-Value: 0.003). MetS was reported in 17.9% of men and 21.7% of women.

Participants with MetS, at the outset of the study had an average age of 45.9 ± 12.5 and non-affected individuals had an average age of 13.3 ± 40.4 years (p value: 0.0001). Men and women with MetS have a higher TG level at the onset of the study compared to non-affected subjects. Except for BMI in women, the difference in other anthropometric indices between the two groups of patients with and without MetS at the onset of the study in both sexes was statistically significant (Table 1). Compared to women, men had a higher average for most components of the MetS (WC, BP, FPG and TG) but had a lower average HDL-C.

BMI and HC in women (27.5 ± 6.7 kg/m^2 and 103.2 ± 9.5 cm, respectively) were higher than those in men (25.7 ± 3.67 kg/m^2 and 100.0 ± 8.8 cm, respectively) (P = 0.001), and WHR was higher in men (0.88 ± 0.07) than in women (0.79 ± 0.07) (P = 0.0001) (Table 1).

The mean of all anthropometric indices in year 2014 in subjects with MetS was significantly higher compared with 2009 (Table 2). At the end of the study, all anthropometric indices and MetS components in people with this syndrome were significantly higher than those in non-affected individuals in both sexes. WHtR index with a cut-off point of 0.53 (61% sensitivity and 62% specificity) had the maximum AUC (0.66.7; 95% CI: 0.606–0.728) in the whole population, but for women WC index with a cut-off point of 83.5 cm (70% sensitivity and 60% specificity), AUC (0.671; 95% CI: 0.590–0.751) and the Youden index (0.3) had the highest efficiency in predicting the incidence of MetS. The BMI cut-off point was higher in women (27.5 kg/m^2) than in men (26 kg/m^2) (Table 3). Fig. 1 show ROC curves of anthropometric indices in predicting the

Table 1
Baseline anthropometric and laboratory characteristics of subjects who developed MetS or not at follow-up.

Variable	Sex	Free MetS	p-value	Newly MetS	p-value
SBP	Male	115.7 ± 12.1	0.0001	117.9 ± 11.8	0.07
	Female	111.4 ± 13.2		112.8 ± 16.7	
	total	113.7 ± 12.8	-	115 ± 13.6	0.386
DBP	Male	72.6 ± 10.5	0.001	73.8 ± 10.1	0.07
	Female	68.8 ± 11.4		69.6 ± 11.8	
	total	70.8 ± 11.1	-	71.4 ± 11.2	0.649
FPG	Male	98.5 ± 30.0	0.16	112.5 ± 45.8	0.04
	Female	94.5 ± 27.3		97.5 ± 16.3	
	Total	96.6 ± 28.8	-	104.5 ± 34	0.021
TG	Male	151.0 ± 81.7	0.002	223.3 ± 146.3	0.005
	Female	125.8 ± 89.6		154.5 ± 81.3	
	total	138.9 ± 86	-	187 ± 120	0.0001
-C	Male	54 ± 13.5	0.0001	52.1 ± 12.7	0.029
HDL	Female	61.9 ± 16.0		57.5 ± 11.1	
	total	57.8 ± 15.2	-	54 ± 12.1	0.079
WC	Male	87.7 ± 9.7	0.0001	94.9 ± 11.0	0.001
	Female	81.9 ± 10.4		87.8 ± 10.7	
	total	84.9 ± 10.5	-	91.2 ± 11.4	0.0001
HC	Male	100.0 ± 8.8	0.001	103.8 ± 8.4	0.09
	Female	103.2 ± 9.5		107.0 ± 10.7	
	total	101.6 ± 9.3	-	105.5 ± 9.7	0.0001
WHR	Male	0.88 ± 0.07	0.0001	0.91 ± 0.07	0.0001
	Female	0.79 ± 0.07		0.82 ± 0.06	
	total	0.84 ± 0.08	-	0.87 ± 0.08	0.002
WHtR	Male	0.51 ± 0.06	0.47	0.56 ± 0.07	0.79
	Female	0.52 ± 0.07		0.55 ± 0.07	
	total	0.51 ± 0.07	-	0.55 ± 0.07	0.0001
BMI	Male	25.7 ± 3.6	0.001	27.8 ± 4.5	0.27
	Female	27.5 ± 6.7		28.9 ± 5.7	
	total	26.6 ± 5.4	-	28.4 ± 4.9	0.003

Values are expressed as mean ± SD.MetS: Metabolic syndrome; SBP: Systolic blood pressure; DBP: diastolic blood pressure; FPG: Fasting plasma glucose; TG: Triglyceride; HDL-C: High-density lipoprotein cholesterol; WC: waist circumference; HC: hip circumference; WHR: Waist-to-Hip Ratio; WHtR: Waist-to-Height Ratio; BMI: Body mass index.

Table 2
Comparison of anthropometric and laboratory characteristics of people who developed MetS in baseline and follow-up.

Variable	Baseline	Follow-up	p-value
SBP	115 ± 13.6	126.5 ± 17.5	0.0001
DBP	71.4 ± 11.2	78.5 ± 18.9	0.002
FPG	104.5 ± 34	119.4 ± 41.0	0.002
TG	187 ± 120	198.2 ± 109.3	0.22
HDL	54 ± 12.1	44.0 ± 9.8	0.0001
WC	91.2 ± 11.4	97.6 ± 10.6	0.0001
HC	105.5 ± 9.7	108.7 ± 11.9	0.01
WHR	0.87 ± 0.08	0.09 ± 0.09	0.001
WHtR	0.55 ± 0.07	0.58 ± 0.07	0.001
BMI	28.4 ± 4.9	29.5 ± 5.3	0.01

Values are expressed as mean ± SD.MetS: Metabolic syndrome; SBP: Systolic blood pressure; DBP: diastolic blood pressure; FPG: Fasting plasma glucose; TG: Triglyceride; HDL-C: High-density lipoprotein cholesterol; WC: waist circumference; HC: hip circumference; WHR: Waist-to-Hip Ratio; WHtR: Waist-to-Height Ratio; BMI: Body mass index.

incidence of MetS in men and women, respectively.

Among anthropometric indices, none had a superiority over others in predicting non-adipose components of MetS, with the exception of the WC index, which was the best index in predicting the incidence of high TG level (≥150 mg/dl). To predict high FPG (≥100 mg/dl) and high TG level, WHR and WC had the highest AUC, respectively, and as with the prediction of high BP (≥130/85), WC and WHtR had the highest AUC. None of the anthropometric indicators were efficient in predicting the incidence of low HDL-C level (<40 mg/dl in men and <50 mg/dl in women) (P value = 0.06) (Table 4).

WHR with a cut-off point of 0.85 in the age group of 20–29 years, WHtR with a cut-off point of 0.53 in the age group of 30–39 and 49-40 years, HC with a cut-off point of 103.5 cm in the age group of 50–59 and WHR with a cut-off point of 0.89 in the group of 60–69 had the highest AUCs (Table 5).

5. Discussion

In this study, the incidence of MetS was 19.8% (21.7% of women and 17.9% of men developed this syndrome), which was similar to the result obtained in Zabetian et al.'s study [21] on a population of over 20 years of age in Tehran showing an incidence of 20.6% for this syndrome (men: 18.4%; women: 23.1%). all anthropometric indices had an AUC higher than 0.5, indicating their importance in predicting the incidence of MetS. People with MetS were more obese and older, and had a significantly higher TG and FPG levels. Several studies have shown a higher prevalence of MetS in older people, including Kuk and Arden, who reported that in individuals over 65 years of age, the prevalence of MetS is twice that of people under the age of 25 [22].

The WHtR index with a cut-off point of 0.53 had the greatest power in predicting the incidence of MetS in the population as a whole, followed by WC with a cut-off point of 87.5 cm. Similarly, in the working population of Spain [23], the WHtR with a cut-off point of 0.54 had the best prediction. In Pavanello et al.'s study [24] conducted in Italy, WHtR ≥ 0.5 had the greatest sensitivity in determining the syndrome in both sexes. According to Wang et al.'s study [25], in the Chinese population of 40–65 years of age, BMI and AVI (Abdominal volume index) were stronger in men and women, respectively, and of course, there were no significant difference between these two indices and WC. The cause of the difference was probably due to differences in the age range of the subjects studied and the different types of anthropometric indices in the two studies. To the best of our knowledge, we could not find a similar study in Iran, comparable to ours, and most studies determined cut-off points cross-sectionally in the diagnosis of this syndrome. In Latifi et al.'s study [26] in Ahvaz, WHtR with a cut-off point of 0.54 in women, and WC with a cut-off point of 91.5 cm in men were more efficient in predicting the MetS, which is practically consistent with the results of our prospective study, and it seems logical to find lower cut-off points of indices in prospective studies compared to cross-sectional studies, and this suggests the importance of their clinical value prior to the development of the syndrome. In a study aimed at predicting the incidence of cardiovascular diseases, Hadaegh et al. [27] obtained WHtR with a cut-off point of 0.55 for men and 0.62 for women, which is clearly higher than the figures obtained in our study, and this could be due to differences in study design or demographic variability.

According to our results, the three indices WHtR, WHR, and WC were almost similar in their power to predict MetS although WHtR was slightly stronger. On the other hand, in women, the WC index with a cut-off point of 83.5, was the most efficient predictor of the MetS, followed by WHtR. In Malaysia, WC had a more power of differentiation in women than WHR, but was not significantly better than BMI [28]. Of course, WHtR was not studied in this cross-sectional study. In Hajian-Tilaki [29] conducted in Babol, north of Iran, BMI had a slightly higher differentiation power than WC and WHtR in men, whereas in women, the power of differentiation of WC and WHtR was higher than that of BMI and WHR, and these results about women are similar to the present study.

In our study, the cut-off point of WC was 89.5 cm for men and 83.5 cm for women, which is higher than the cut-off point obtained in a Chinese population (84 cm for men and 80 cm for women) [25], and the one obtained for a Spanish population [23] (Men: 91.75 cm; Women: 85.75 cm), which is probably due to ethnic, geographical

Table 3
AUCs and Cut-off points for anthropometric indices in predicting the incidence of MetS.

Anthropometric index	Sex	AUC*(95% CI)	Cut off point	Sensitivity (%)	Specificity(%)	Youden index
WC	Male	0.675(0.584-0.766)	89.5	62	61	0.20
	Female	0.671(0.590-0.751)	83.5	70	60	0.30
	Total	0.653(0.593-0.713)	87.5	61	60	0.21
HC	Male	0.61(0.516-0.797)	100.5	60	51	0.11
	Female	0.626(0.542-0.710)	105.5	57	65	0.22
	Total	0.622(0.561-0.684)	102.8	60	58	0.18
WHR	Male	0.679(0.589-0.768)	0.90	63	63	0.26
	Female	0.639(0.554-0.724)	0.80	62	60	0.22
	Total	0.601(0.537-0.664)	0.84	63	54	0.17
WHtR	Male	0.685(0.594-0.775)	0.53	64	62	0.26
	Female	0.647(0.563-0.731)	0.53	61	62	0.23
	Total	0.667(0.606-0.728)	0.53	61	62	0.23
BMI	Male	0.637(0.549-0.726)	26.0	60	59	0.19
	Female	0.612(0.521-0.699)	27.5	60	59	0.19
	Total	0.625(0.564-0.687)	26.7	60	59	0.19

*: P-Value < 0.05. AUC: Area under the curve; CI: Confidence interval; MetS: Metabolic syndrome; WC: waist circumference; HC: hip circumference; WHR: Waist-to-Hip Ratio; WHtR: Waist-to-Height Ratio; BMI: Body mass index.

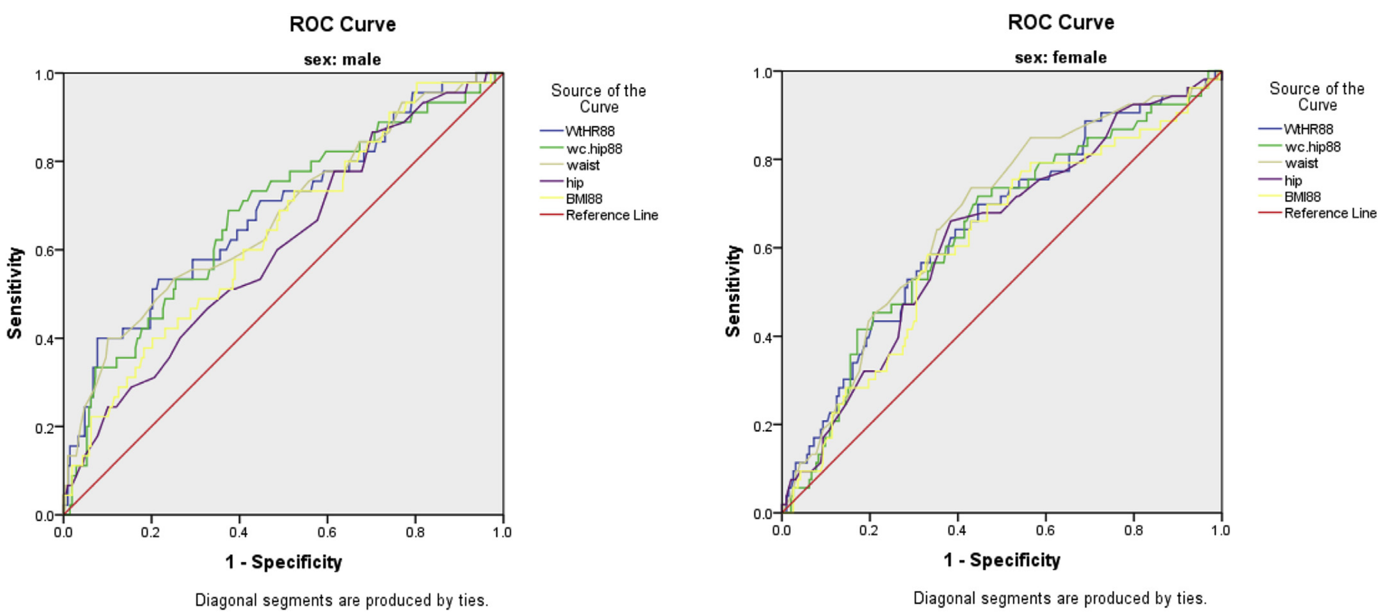

Fig. 1. ROC Curves of anthropometric indices in predicting the incidence of MetS in men (right) and female (left).

and lifestyle differences. The cut-off point obtained in this study is lower than the one obtained in a population of Ahvaz in a cross-sectional study by Latifi et al. [26]. It is about 2 cm smaller for both sexes, which may suggest that the use of cut-off points obtained in cross-sectional studies as opposed to those obtained in incidence studies may delay the prevention efforts for this syndrome. Esteghamati et al. [30] reported the most appropriate cut-off point of WC for predicting the multiple risk factors of MetS in a population of Tehran, which was 91.5 cm for men and 85.5 cm fir women. Veghari et al. [31] found that the cut-off point of WC for MetS was higher in Turkmen as compared to non-Turkmens (90.5 and 89.5 cm, respectively), which shows the effect of racial differences. According to their results, the cut-off points for all components of metabolic syndrome in Turkmens were higher than those of non-Turkmens (except for cholesterol). The association of WC with high BP, blood glucose, and dyslipidemia was also reported in this study.

The cut-off point of BMI obtained in the current study was higher in women (27.5 kg/m^2 versus 26 kg/m^2 in men), and was overall lower than those obtained in Hadaegh et al. [27] (men: 26.95 kg/m^2; women: 29.19 kg/m^2, for the prediction of cardiovascular diseases) were lower, but higher than those obtained for the population of Babol (25.3 and 25.4 kg/m^2, for men and women respectively), which could be due to the difference in study design, studied outcomes, regional differences, and lifestyle. The cut-off point of WHR obtained in the present study was 0.9 and 0.8, for men and women, respectively, which was lower than that of Hadaegh [27] in Tehran (men: 0.95; women: 0.9), and the one obtained by Obeidat et al. [32] in Jordan (men: 0.94; women: 0.86). Analysis of the results from different age groups showed that different cut-off points should be used for different age groups. The age group of 20–29 years had the lowest cut-off point in all anthropometric indices. WC (cut-off point: 91.5 cm) and WHR (cut-off point: 103.5) had the highest cut-off points in the age group of 59-50 years, while BMI (cut-off point: 28 kg/m^2) and HC (cut-off point: 105.5 cm) in the age group of 30–39 years had the highest cut-off points, which was similar to the results obtained in Wang et al. [33].

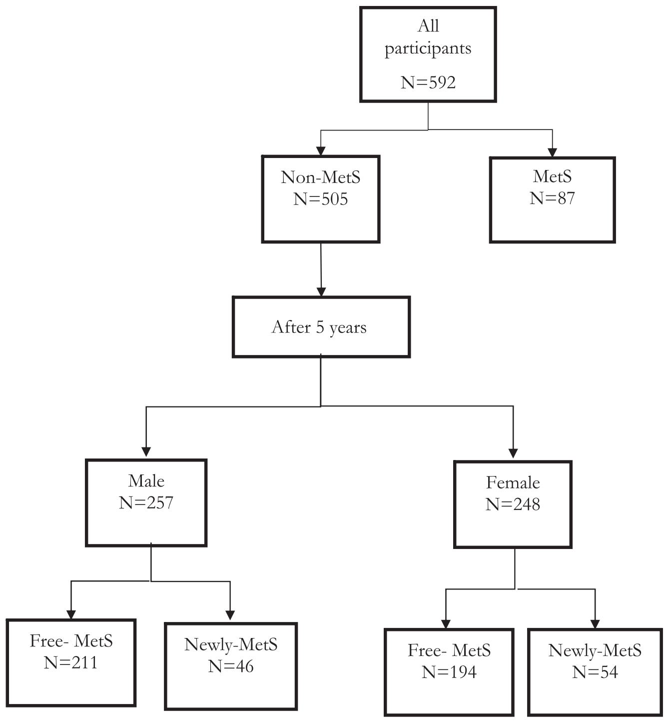

Diagram 1. Flow graph of individual recruitment. (MetS: Metabolic syndrome).

In this study, we investigated the anthropometric indices in predicting the incidence of non-adipose components of the MetS and their cut-off points. Overall, all indices had the ability to predict the incidence of these components except for low HDL-C.

None of the anthropometric indicators in our study were able to predict the incidence of low HDL-C, and this was similar to the results of Wang et al. [25]. However, they found no index with sufficient power of differentiation to predict the incidence of high blood sugar, but in our study, WHtR and WC had the highest AUC for the prediction of high FPG. The cut-off point of WC for the incidence of high FPG was 84.5 cm and that of WHtR was 0.52. The cut-off point of WC reported by Veghari et al. [31], for high FPG was 108.75 and 100.5 cm for Turkmens and non-Turkmens.

In predicting the incidence of High TG, the WC with a cut-off point of 84.8 cm had the highest predictive power compared to other indices, whereas in predicting High BP, WHtR and WC with cut-off points 0.52 and 86.5 cm, respectively had the highest AUC. In Wang et al. [25]., BMI and AVI had a significant predictive power for high-TG in men, but their predictive power was not significant for other components in both sexes. According to gharipour et al. [34], the cut-off point of WC in Iranian men for predicting High TG was 94.5 cm.

Overall, it seems that given its ease of measurement, the WC index is a better option for predicting the incidence of non-adipose components of the metabolic syndrome in clinical settings. A similar result was obtained in Wang et al. [33], in which WC had the strongest link with the total risk factors in both sexes. In examining

Table 4
Cut-off points and AUCs for anthropometric indices in predicting the incidence of MetS components.

Anthropometric index	Cut off(S/SP) AUC*(95% CI)			
	High FPG	High TG	Low HDL-C	High BP
WC	84.5(65/50) 0.672(0.560-0.694)	84.8(61/53) 0.682(0.490-0.652)	82.8(62/43) 0.474(0.418-0.531)	86.5(63/60) 0.648(0.589-0.707)
HC	100.5(60/46) 0.581(0.560-0.694)	99.5(63/40) 0.528(0.445-0.611)	98.5(65/30) 0.456(0.400-0.512)	102.8(61/58) 0.590(0.528-0.653)
WHR	0.82(60/45) 0.58(0.510-0.65)	0.84(61/59) 0.586(0.510-0.650)	0.82(60/62) 0.474(0.418-0.529)	0.84(63/60) 0.638(0.576-0.700)
WHtR	0.52(60/58) 0.622(0.555-0.690)	0.51(61/51) 0.622(0.555-690)	.50(60/48) 0.488(0.431-0.544)	0.52(61/61) 0.645(0.586-0.705)
BMI	25.6(60/47) 0.567(0.499-0.634)	25.6(60/50) 0.548(0.460-0.628)	24.8(60/35) 0.492(0.436-0.549)	26.5(60/60) 0.603(0.542-0.665)

* P Value is 0.06 for Low HDL-C in all indices, and >0.05 for other components. AUC: Area under the curve; MetS: Metabolic syndrome; S: Sensitivity; SP: Specificity; CI: Confidence interval; FPG: Fasting plasma glucose; TG: Triglyceride; HDL-C: High-density lipoprotein cholesterol; BP: Blood pressure; WC: waist circumference; HC: hip circumference; WHR: Waist-to-Hip Ratio; WHtR: Waist-to-Height Ratio; BMI: Body mass index.

Table 5
Cut-off points and AUCs for anthropometric indices in predicting the incidence of MetS in different age groups.

Age categories (years)	Cut off (S/SP) AUC*(95% CI)				
	WC	HC	WHR	WHtR	BMI
20–29	75.5(58/45) 0.534(0.350-0.718)	98.5(67/40) 0.541(0.344-0.738)	0.85(67/63) 0.693(0.556-0.831)	0.46(66/43) 0.543(0.369-0.716)	23.8(67/43) 0.528(0.343-0.713)
30–39	84.5(74/47) 0.628(0.494-0.762)	105.5(63/60) 0.630(0.492-0.769)	0.83(63/35) 0.537(0.393-0.681)	0.53(63/62) 0.658(0.523-0.794)	28(68/61) 0.644(0.511-0.778)
40–49	87.5(63/56) 0.603(0.483-0.723)	101.5(63/49) 0.578(0.454-0.703)	0.87(63/49) 0.535(0.421-0.649)	0.53(70/54) 0.658(0.536-0.781)	27(63/64) 0.632(0.506-0.757)
50–59	91.5(63/88) 0.641(0.521-0.760)	103.5(70/60) 0.657(0.539-0.774)	0.91(67/60) 0.634(0.515-0.754)	0.56(63/64) 0.625(0.497-0.754)	27.3(63/55) 0.599(0.477-0.722)
60–69	88.5(64/61) 0613(0.416-0.810)	100.5(64/52) 0.619(0.415-0.822)	0.89(82/74) 0.828(0.690-0.967)	0.54(64/52) 0.630(0.434-0.827)	26.7(64/57) 0.615(0.416-0.814)

* P Value > 0.05. AUC: Area under the curve; MetS: Metabolic syndrome; S: Sensitivity; SP: Specificity; CI: Confidence interval; WC: waist circumference; HC: hip circumference; WHR: Waist-to-Hip Ratio; WHtR: Waist-to-Height Ratio; BMI: Body mass index.

the power of each component of the MetS in predicting its incidence, TG and WC had the most pronounced role in predicting MetS with an AUC of nearly 0.655.

Study strengths: The main strength of this study lies in its prospective design for determining anthropometric cut-off points and their role in the development of MetS and its components, which places it among the few valuable studies conducted in this field.

Study limitations: Our study did not consider the changes in anthropometric indicators during the 5 years and their effect on the development of metabolic syndrome.

6. Conclusion

According to the results we obtained from a 5-year prospective study, WHtR with a cut-off point of 0.53 followed by WC with a cut-off point of 87.5 cm have the predictive power to determine the incidence of MetS. WC and BMI were 89.5 cm and 26 kg/m^2 for men, and 83.5 cm and 27.5 kg/m^2 for women, respectively. All anthropometric indices had the ability to predict the incidence of the components of the syndrome (except for low HDL-C). The cut-off point of WC for High TG, High FPG, and High BP was 84.5, 84.8 and 86.5 cm, respectively. To put it in a nutshell, it seems that considering the ease of its measurement, the WC index is a better option for predicting the incidence of MetS. and its components in clinical screening.

Suggestions: More prospective studies with larger sample sizes on different ethnic groups comparing different diagnostic criteria for the MetS. are needed in order to achieve the best indicators and cut-off points for clinical use and successful prevention of this syndrome.

Conflicts of interest

The authors declare that they have no competing interests.

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Authors contributions

All of authors contributed equally to this work.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2019.07.009.

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