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Cut-off values of obesity indices to predict coronary heart disease incidence by time-dependent receiver operating characteristic curve analysis in 10-year follow-up in study of Yazd Healthy Heart Cohort, Iran

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Original Article

Abstract

BACKGROUND: The current study aimed to determine the optimal cut-off of obesity indices for detecting coronary heart disease (CHD) in 10-year study of Yazd Healthy Heart Cohort (YHHC) in Iran.

METHODS: A total of 2000 individuals aged 20-74 years were enrolled. All participants without cardiovascular disease (CVD) had a full medical check-up at the start of the study. At the start of the study, a variety of obesity indices were assessed and calculated, including body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHpR), waist-to-height ratio (WHtR), A Body Shape Index (ABSI), abdominal volume index (AVI), body adiposity index (BAI), and body roundness index (BRI). Coronary artery bypass graft (CABG), percutaneous coronary intervention (PCI), myocardial infarction (MI), Rose Angina Questionnaire (RAQ) (chest pain) greater than 3, and electrocardiographic (ECG) changes in favour of the coronary artery disease (CAD) were considered as the CVD risks. A time-dependent receiver operating characteristic (ROC) curve with right-censored data and naive estimator was used to estimate the time-dependent sensitivity and specificity and the best cut-off of the anthropometric indices for CHD risk.

RESULTS: Overall, 1623 participants (818 men and 805 women) with mean and standard deviation (SD) of weight of 71.21 ± 12.94 kg were included. In a 10-year follow-up, 101 [59 (58.42%) men and 42 (41.58%) women] developed CVD event. WHpR demonstrated the largest area under the time-dependent ROC curve (AUC) of 0.65 and 0.63 as well as 95% confidence interval (CI) of 58.64-72.66 and 50.74-75.55 for men and women, respectively, in predicting CVD. Optimal WHpR cut-off was 0.93 and 0.92, respectively, for men and women.

CONCLUSION: WHpR index was superior to other obesity indices in predicting CHD.

Keywords: Cardiovascular Diseases; Anthropometry; ROC Curve

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Introduction

Over the past several decades, cardiovascular diseases (CVD) were increasing worldwide. In 2016, CVD was responsible for 17.9 million (31%) of all global deaths.[1] Alarming rise of cardiovascular risk factors such as excess of adiposity, particularly visceral adiposity, is responsible for the prevalence of CVD.[2] The World Health Organization (WHO) reported that obesity was linked to 4 million excess deaths worldwide.[3]

Several anthropometric indices are introduced to evaluate overweight and obesity. Body mass index (BMI) is a usual index that is widely used to classify weight gain and obesity.[4]

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Literature review showed that BMI could not accurately predict the presence of CVD risk factors or the incidence of heart disease in diverse populations.[5] Notably, the CVD risk factor related to central obesity has been observed to be higher than general obesity as measured by BMI.[6,7] The waist circumference (WC) has been shown to be closely linked to central obesity and modulate the limitations of BMI.[8] Studies showed that the predictive power of WC for predicting risk of CVD was enhanced when it was corrected by height and hip circumference (HC).[9] Many epidemiological studies proposed waist-to-height ratio (WHtR), as a more reliable predictor of CVD risks than WC.[10,11] Although general and central obesity are associated with many risk factors of CVD, WC is highly correlated with BMI and differentiating these indices as epidemiological risk factors can be difficult.[12] A Body Shape Index (ABSI) has been developed which has little correlation with height, weight, and BMI indices and a modest correlation with WC index.[13] In comparison to BMI and WHtR, ABSI was found to be a poor predictor of CVD risk.[14-16]

Additional anthropometric indices that aim to quantify obesity have recently been proposed, including the abdominal volume index (AVI),[9] body adiposity index (BAI),[17] and body roundness index (BRI).[15] In a cross-sectional study, the risk of coronary heart disease (CHD) was investigated by eight anthropometric indices of BMI, WC, waist-to-hip ratio (WHpR), WHtR, AVI, BAI, BRI, and ABSI. Results showed that in rural areas of China, ABSI index in men and WHtR and BRI in women were the best indicators for estimating CHD risk.[18]

Accurate identification of overweight and obese people allows healthcare professionals to propose prevention and treatment programs to those at the highest risk of CVD.[19] The receiver operating characteristic (ROC) is a well-established method for evaluating the predictive power of an anthropometric index in distinguishing between people experiencing CVD and those who do not.[20] The area under the ROC curve (AUC) is used to measure the performance of an anthropometric index for CVD incidence, with a higher AUC value indicating superior anthropometric index performance.[21] The classical ROC curve analysis supposes disease status for an individual as fixed over time; however, in practice, many disease outcomes are time-dependent. Individuals are initially without CVD but can succumb to disease during follow-up. The important point is that how well baseline anthropometric index can distinguish between individuals who become diseased and individuals who do not in a follow-up period. ROC curve as a function of time was introduced for such disease incidence setting.[22]

Nowadays, obesity as a global public health concern is associated with an increased risk of CVD. Various types of obesity are important. Research shows that sarcopenic obesity increases the morbidity and death rates of CVD.[23] Besides, reduction in abdominal obesity reduces the risk of CVD.[24] In Iran, 43% of deaths are attributed to CVD.[1] As presented by national data, not surprisingly, in Iran, 19% and 32% of adult men and women aged 18 and over have obesity, respectively.[1] This study was carried out on Iranian 20-74-year men and women to look into the relationship between anthropometric indices of BMI, WC, hip circumference, WpHR, WHtR, ABSI, AVI, BAI, and BRI and CVD during a 10-year follow-up in Yazd Healthy Heart Cohort (YHHC), Iran. The optimal cut-off of anthropometric indices was evaluated by time-dependent ROC curve analysis. The novel point of this research compared with most studies on Iranian people is the study of nine anthropometric indices in predicting incidence of CVD using time-dependent ROC curve analysis in YHHC.

Materials and Methods

Study population: A community-based prospective cohort (YHHC) on 2000 individuals from Yazd, Iran, was conducted from 2006 to 2016 to investigate the efficiency of anthropometric indicators in predicting CVD.[25]

Ethical reporting: This study was approved with reference number of IR.SSU.SPH.REC.1398.050 by the Ethics Committee of Shahid Sadoughi University of Medical Sciences, Yazd.

Before being enrolled in this study, all individuals signed informed permission in accordance with the ethical principles of Declaration of Helsinki.

Data measurement and calculation: At baseline, a trained interviewer collected information of all 2000 participants. The information included demographic information, family history of CVD and prior medical history of CVD, medication used, and information related to the diagnosis and treatment of CVD. Anthropometric indices of weight, height, WC, and HC were measured by the trained workers according to a standardized protocol and technique, while subjects were minimally clothed without shoes. Height was measured while shoulders were in a normal alignment and subjects stood without shoes in standing place. Weight was measured using digital scales and documented to the nearest 0.1 kg. WC was metered at a point midway between the lower rib margin and the iliac crest without any pressure applied to the body surface and HC was taken at the level of maximal gluteal protrusion over light clothing.[25]

Anthropometric indices of BMI, WHpR, and WHtR for each subject were calculated using the following formulas:[18]

BMI = Weight (kg)/height^2 (m)

WHpR = WC (cm)/HC (cm)

WHtR = WC (cm)/height (cm)

The ABSI was calculated using the formula:[13]

ABSI = WC (m)/[BMI$^{2/3}$ (kg/m^2) height$^{1/2}$ (m)]

AVI was calculated as:[26]

AVI = [2 WC^2 (cm) + 0.7 (WC – HC)^2]/1000

BAI was calculated as:[17]

BAI = [HC (m)/height$^{2/3}$ (m)] – 18

The formula was used to determine the BRI:[15]

BRI = 364.2 – 365.5 [1- π^{-2} WC^2 (m) height^{-2} (m)]$^{1/2}$

Time to event for each subject was defined as the time interval between the inclusion in the study and incidence of CVD, death caused by CVD, the date of the last follow-up, and/or date of death due to other causes, whichever had occurred earlier.

CVD definition: Detailed evaluation of the medical records of all participants (n = 2000) for their 10-year follow-up CVD status in YHHC was accomplished and data were collected for vital status and incidence of CVD. Vital status is defined as death from CAD, cerebrovascular accident (CVA), sudden cardiac death (SCD) death, or no cardiac death. Coronary artery disease (CAD) is the most common type of heart disease which is the most common cause of death in men and women. CVA is the medical term for a stroke, and it is a major cause of death. SCD is death due to a cardiovascular cause that occurs within one hour of the onset of symptoms.

To estimate the incidence of CVD, participants with any of the five following components were considered: (1) subjects with coronary artery bypass graft (CABG), (2) subjects with percutaneous coronary intervention (PCI), (3) subjects with myocardial infarction (MI), (4) subjects with Rose Angina Questionnaire (RAQ) (chest pain) greater than 3, and (5) subjects with electrocardiographic (ECG) changes in favour of the CAD.

Outcome measurements: All participants were followed up annually by a telephone call to ask about any medical event leading to hospitalization during the past year. In case of positive responses, related data were collected by a trained physician using hospital records. If the death occurred outside the hospital, data were collected from the death certificate, the report of forensic medicine, and if needed, a verbal autopsy from witnesses. The final diagnosis was recorded after being reviewed by an outcome confirmation committee. The adjudication committee consisted of the physician who collected the data, an internist, an epidemiologist, a cardiologist, an endocrinologist, and other experts invited as needed.

Statistical analysis: The baseline anthropometric indices of weight, height, WC, HC, BMI, WHpR, WHtR, ABSI, AVI, BAI, and BRI were presented as the mean and standard deviation (SD). The mean values of the baseline variables were compared between men and women as well as two groups with CVD and without CVD during 10-year follow-up using two-tailed independent t-test. P-value for trends was calculated.

The sensitivity of a standard ROC curve is defined as the likelihood of a diseased subject being anticipated to have the disease (true-positive), while the specificity is defined as the likelihood of a non-diseased subject being predicted to not have the disease (true-negative).[21] The cumulative sensitivity is the probability that a subject has a marker value greater than cut-off among those who experienced the event before time t, and the dynamic specificity is the probability that a subject has a marker value less than or equal to cut-off among those who are event-free beyond time t in time-dependent ROC curve analysis.[27]

Naive estimator under cumulative sensitivity and dynamic specificity (C/D) definition[21] was employed to calculate sensitivity, specificity, and AUC. The model included age, gender (men = 1, women = 2), failure (0 = right censor, 1 = event), a numeric vector with the follow-up times (time to event in days), and variable (a numeric vector with the prognostic variable of anthropometric indices of WC, HC, BMI, WHpR, WHtR, ABSI, AVI, BAI, and BRI at baseline) as independent variables. All statistical analyses were conducted using R software (version 3.5.1)[28] and statistical package ROCt[29] was used for data analysis, time-dependent ROC curves, and cut-off of anthropometric indices. Statistical significance was considered as P-value < 0.05 for all analyses.

The cut-off for anthropometric indices was assessed by the minimum value of ($\sqrt{|(1-\text{sensitivity})^2+(1-\text{specificity})^2|}$), in each male and female group.[30] The predictive power of different anthropometric indices for incidence of CVD was assessed by the AUC.

Results

Baseline characteristics of the study population: In this study, 2000 individuals of the community aged between 20 and 74 were recruited. Participants with history of CVD at baseline (n = 116) and those with missing data or those who immigrated to another city (n = 261) were excluded. From this overall group, a total of 1623 subjects (818 men and 805 women) were included in this study, of whom, 101 subjects [59 (58.42%) men and 42 (41.58%) women] at risk of CVD completed the 10-year follow-up (Table 1).

Table 1. Number and percentage of total sample and participants with cardiovascular disease (CVD)

Variable	Total sample n (%)	Participants with event n (%)
Subjects	1623 (100)	101 (6.22)
Sex		
Men	818 (50.40)	59 (58.42)
Women	805 (49.60)	42 (41.58)

The baseline characteristics of men and women were presented in table 2. The mean and SD of age, weight, height, WC, HC, BMI, WHpR, WHtR, ABSI, AVI, BAI, and BRI for men and women were presented. Average age besides ABSI of men were larger than women and average WC and AVI of women were larger than men without significant difference (P > 0.05). Furthermore, men had an average higher weight, height, and WHpR than women (P < 0.001). However, the mean values of anthropometric indices of HC, BMI, WHtR, BAI, and BRI were higher in women than men (P < 0.001).

There was a statistically significant difference between subjects with and without CVD, with respect to age (P < 0.001) with mean ± SD of 61.6 ± 10.15 and 47.24 ± 14.74, respectively, and participants with event were much older than subjects without CVD. Subjects with CVD had significantly higher anthropometric indices of WC, WHpR, WHtR, ABSI, AVI, and BRI (P < 0.05) than those without CVD (Table 3).

Comparison of the anthropometric indices for predicting CVD: To identify the anthropometric index that best predicted incidence of CVD, the time-dependent ROC curves of the anthropometric indices of WC, HC, BMI, WHpR, WHtR, ABSI, AVI, BAI, and BRI for the total sample and sex-stratified groups were plotted in figure 1. Table 4 provided the cut-off, sensitivity, specificity, and AUC of anthropometric indices for total sample (n = 1623), men (n = 818), and women (n = 805). As shown in figure 1, the AUCs of all anthropometric indices except HC were larger than 0.5. In general, the AUCs varied from 0.47 for HC to 0.65 for WHpR in total sample, from 0.52 for HC to 0.65 for WHpR in men, and from 0.43 for HC to 0.63 for WHpR in women. The AUC of HC index was the lowest and did not differ from 0.5 in total sample and sex-stratified groups, men and women (P > 0.05). Moreover, the AUC of BMI showed no significant differences with 0.5 (P > 0.05) and it was not a predictive variable for CVD. Besides, the AUCs of WC and AVI were greater than 0.5 in total sample and men, while no difference from 0.5 was observed in women, with P-value of 0.23 and 0.24, respectively. The AUCs of the other indices, WHpR, WHtR, and BRI, were greater than 0.5 (P < 0.05), implying that they were clinically significant predictors of CVD. In men and women, ABSI did not differ significantly from 0.5. BAI only differed significantly from 0.5 in men (P < 0.05).

Table 2. Baseline characteristics of study population (men and women)

Characteristics	Men (n = 818) (Mean ± SD)	Women (n = 805) (Mean ± SD)	P*
Age (year)	48.270 ± 15.210	48.000 ± 14.590	0.720
Weight (kg)	74.270 ± 12.220	68.100 ± 12.920	< 0.001
Height (cm)	172.130 ± 7.770	157.890 ± 7.170	< 0.001
WC (cm)	93.350 ± 11.570	94.000 ± 12.760	0.275
HC (cm)	101.280 ± 8.310	104.330 ± 10.860	< 0.001
BMI (kg/m^2)	25.060 ± 3.770	27.300 ± 4.760	< 0.001
WHpR	0.920 ± 0.079	0.900 ± 0.089	< 0.001
WHtR	0.540 ± 0.070	0.600 ± 0.080	< 0.001
ABSI	0.083 ± 0.006	0.080 ± 0.007	0.310
AVI	17.780 ± 4.280	18.130 ± 4.740	0.116
BAI	26.960 ± 4.240	34.710 ± 5.780	< 0.001
BRI	4.300 ± 1.430	5.480 ± 1.890	< 0.001

*T-test performed for anthropometric indices

BMI: Body mass index; WC: Waist circumference; HC: Hip circumference; WHpR: Waist-to-hip ratio; WHtR: Waist-to-height ratio; ABSI: A Body Shape Index; AVI: Abdominal volume index; BAI: Body adiposity index; BRI: Body roundness index; SD: Standard deviation

Table 3. Baseline characteristics of study population, cardiovascular disease (CVD)-positive group, and CVD-negative group

Characteristics	No CVD[1] (n = 1522) (Mean ± SD)	CVD[2] (n = 101) (Mean ± SD)	P[*]
Age (year)	47.240 ± 14.740	61.600 ± 10.150	< 0.001
Weight (kg)	71.210 ± 12.950	71.310 ± 12.950	0.939
Height (cm)	165.150 ± 10.380	163.830 ± 9.470	0.215
WC (cm)	93.450 ± 12.180	97.090 ± 11.580	0.004
HC (cm)	102.810 ± 9.820	102.530 ± 9.200	0.776
BMI (kg/m^2)	26.150 ± 4.450	26.530 ± 4.130	0.403
WHpR	0.910 ± 0.080	0.950 ± 0.080	< 0.001
WHtR	0.570 ± 0.080	0.590 ± 0.070	0.002
ABSI	0.080 ± 0.007	0.090 ± 0.007	< 0.001
AVI	17.870 ± 4.520	19.190 ± 4.340	0.004
BAI	30.780 ± 6.410	31.140 ± 5.690	0.578
BRI	4.850 ± 1.870	5.390 ± 1.580	0.004

[*]T-test performed for anthropometric indices; [1]Cardiovascular disease (CVD)-negative group: No cardiovascular diseases during 10-year follow-up; [2]CVD-positive group: With cardiovascular diseases during the 10-year follow-up
BMI: Body mass index; WC: Waist circumference; HC: Hip circumference; WHpR: Waist-to-hip ratio; WHtR: Waist-to-height ratio; ABSI: A Body Shape Index; AVI: Abdominal volume index; BAI: Body adiposity index; BRI: Body roundness index; CVD: Cardiovascular disease; SD: Standard deviation

WC was correlated with overall adiposity and it was used as a measure of abdominal obesity, which in turn, was strongly associated with cardiovascular risk.[31]

Table 4. The sensitivity, specificity, area under the curve (AUC), and cut-off of anthropometric indices

	Indices	SS	SP	AUC	Cut-off	P
Total (n = 1623)	BMI	0.63	0.48	0.54	25.46	0.140
	WC	0.63	0.48	0.57	93.00	< 0.010
	HC	0.53	0.45	0.47	101.00	0.250
	WHpR	0.70	0.55	0.65[*]	0.92	< 0.001
	WHtR	0.62	0.55	0.60[*]	0.57	< 0.001
	ABSI	0.55	0.57	0.57	0.08	0.010
	AVI	0.65	0.46	0.57[*]	17.30	0.010
	BAI	0.40	0.62	0.51	31.99	0.260
	BRI	0.55	0.62	0.60[*]	5.20	< 0.001
Men (n = 818)	BMI	0.54	0.66	0.59	26.40	0.090
	WC	0.59	0.58	0.60	95.00	0.010
	HC	0.61	0.51	0.52	101.00	0.450
	WHpR	0.67	0.59	0.65[*]	0.93	< 0.001
	WHtR	0.63	0.55	0.64[*]	0.55	< 0.001
	ABSI	0.52	0.57	0.56	0.08	0.360
	AVI	0.59	0.55	0.60[*]	18.08	0.020
	BAI	0.72	0.47	0.59	26.76	0.030
	BRI	0.63	0.53	0.63[*]	4.39	< 0.001
Women (n = 805)	BMI	0.71	0.37	0.50	24.84	0.860
	WC	0.63	0.44	0.53	93.00	0.230
	HC	0.80	0.25	0.43	96.00	0.170
	WHpR	0.62	0.59	0.63	0.92	0.040
	WHtR	0.69	0.47	0.59[*]	0.69	0.020
	ABSI	0.58	0.58	0.58	0.08	0.100
	AVI	0.63	0.43	0.53	17.52	0.240
	BAI	0.45	0.62	0.52	35.28	0.410
	BRI	0.74	0.47	0.59[*]	5.20	0.020

[*]Compared with the area under the curve (AUC) of waist circumference (WC), P-value is less than 0.05.
SS: Sensitivity; SP: Specificity; AUC: Area under the curve; BMI: Body mass index; WC: Waist circumference; HC: Hip circumference; WHpR: Waist-to-hip ratio; WHtR: Waist-to-height ratio; ABSI: A Body Shape Index; AVI: Abdominal volume index; BAI: Body adiposity index; BRI: Body roundness index

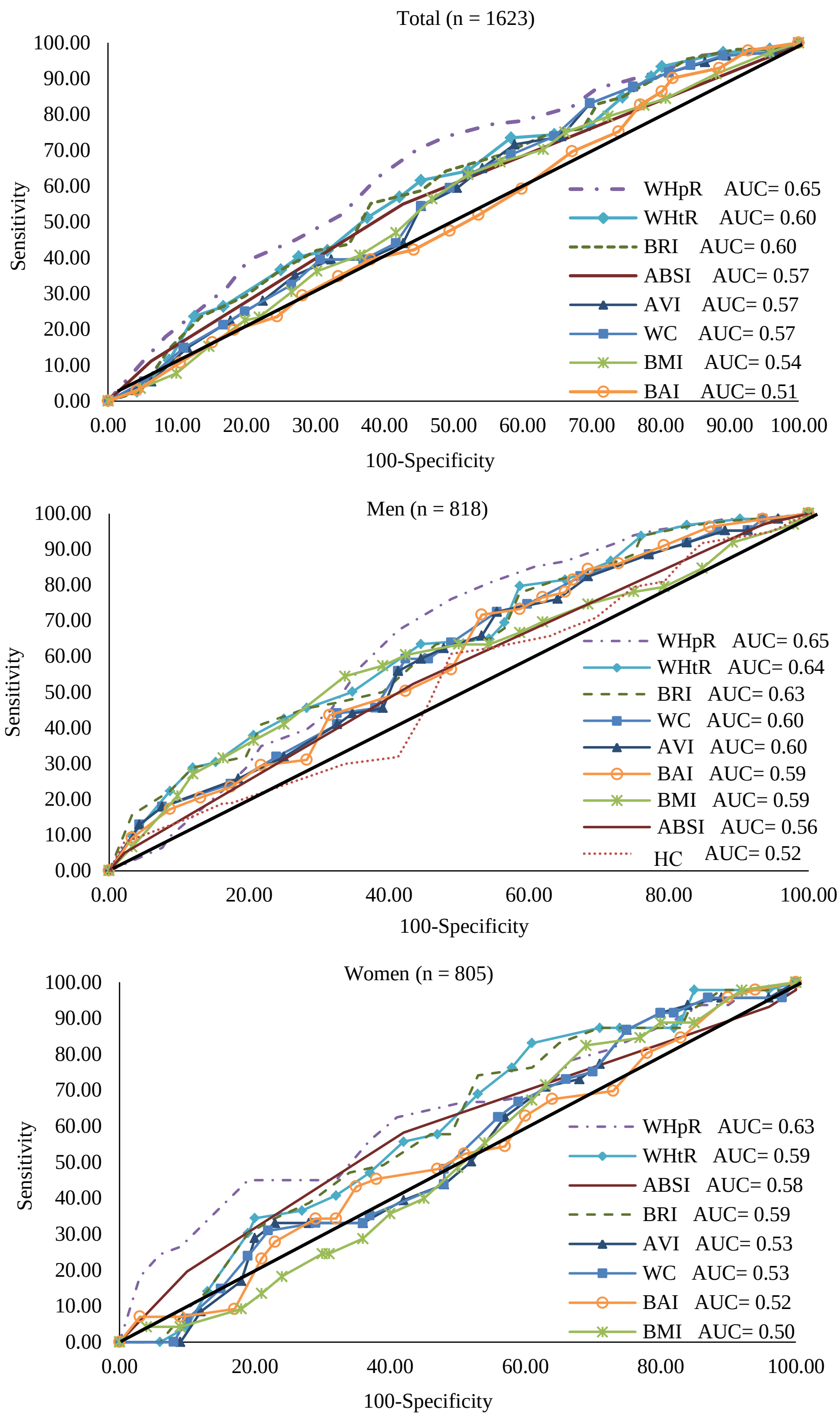

Figure 1. Time-dependent receiver operating characteristic (ROC) curve for anthropometric indices

(BMI: Body mass index; WC: Waist circumference; HC: Hip circumference; WHpR: Waist-to-hip ratio; WHtR: Waist-to-height ratio; ABSI: A Body Shape Index; AVI: Abdominal volume index; BAI: Body adiposity index; BRI: Body roundness index; AUC: Area under the curve)

Therefore, AUCs of anthropometric indices were compared with AUC of WC. WHpR, WHtR, AVI, and BRI significantly differed with WC in total sample besides men ($P < 0.05$). In women, WHtR and BRI significantly differed with WC. Furthermore, BMI, HC, ABSI, and BAI did not differ significantly from WC.

Table 4 also contains additional information on all of the anthropometric indices, such as cut-off, sensitivity, and specificity.

Discussion

The association between obesity and related chronic diseases such as CVD, diabetes, and cancer makes it crucial to be at the forefront of health problems. Screening and identification of obesity in an easy and accurate manner is the first step in planning for health. Abdominal obesity is one of the most major risk factors for CVD, according to the literature.[32] In addition, a large number of research showed the ability of indices obtained from a variety of anthropometric parameters in predicting CVD.[14,30-34] In this study, we estimated cut-off of nine anthropometric indices, BMI, WC, HC, WHpR, WHtR, ABSI, AVI, BAI, and BRI by time-dependent ROC curve analysis in determining the incident risk of CVD using a 10-year prospective YHHC data. The correlation between different anthropometric indices and CVD was examined by statistical analysis to choose the most suitable factor.

During the 10-year follow-up, among 1623 participant in Yazd, the number of cases with CVD (individuals with event during follow-up) was 101. In brief, the statistical results showed that the mean ± SD of age of the 101 participants in CVD-positive group was 61.60 ± 10.15 and the mean age for the CVD-negative group was 47.24 ± 14.74 years ($P < 0.001$). Mean values of anthropometric indices of BMI, WC, WHpR, WHtR, ABSI, AVI, BAI, and BRI in the CVD-positive group were higher compared to the CVD-negative one. As a consequence, people with CVD had a greater baseline visceral fat area than non-CVD participants, suggesting that abdominal visceral fat could be an excellent predictor of CVD, similar to earlier research.[32,35] Comparing anthropometric indices of HC, BMI, and BAI in table 3 showed no significant difference between CVD-positive and CVD-negative groups ($P > 0.05$). Anthropometric indices of WC, WHpR, WHtR, ABSI, AVI, and BRI differed significantly between CVD-positive and CVD-negative groups ($P < 0.05$).

BMI is used as a usual measure in overweight and obesity discrimination. Cut-off values of 25 and 30 kg/m^2 define overweight and obesity, respectively, in all populations for both men and women.[19] In a study over a median of 7.6-year follow-up in Iran, that was conducted on 1614 men and 2006 women free from CVD at baseline, BMI cut-off values for CVD prediction in men and women were 26.95 and 29.19 kg/m^2, respectively.[33] In our study, BMI cut-off values of 26.40 and 24.84 kg/m^2 were estimated for CVD prediction in men and women, respectively (Table 4). There is some evidence that BMI cut-offs are not useful in predicting the presence of cardiovascular risk factors or the incidence of heart disease in diverse populations.[5] Moreover, it was shown that BMI was not passively associated with the risk of CVD ($P > 0.05$).

Several studies have suggested that WC is a good indicator for predicting the risk of CVD,[36] while others have shown that WHpR is a better indicator for predicting the risk of CVD compared to WC and BMI.[33] The link between anthropometric indices of BMI, WC, and WHpR and CVD has been previously investigated.[37] WC cut-off of 90 cm was reported for Iranian men and women at risk of CVD but requiring only lifestyle change; it was predicted to be 95 cm for those at high risk for CVD events, requiring immediate intervention for CVD prevention.[38,39] Furthermore, we found that cut-off value of WC for predicting risk of CVD was 95 and 93 cm for men and women, respectively (Table 4). Consistent with the present study, Hadaegh et al. in Iran cited cut-off value of WC for predicting CVD equal to 94.5 cm for both male and female groups.[33]

The predictive power of WC index for risk of CVD is enhanced when it is corrected by height and HC.[9] Universal WC index cut-off is not appropriate for use worldwide; however, there may be general consistency in the cut-off value of WHpR for predicting CVD risk. WHpR cut-offs have been thoroughly investigated among Asian populations. Based on the available evidence, Lear et al. recommended cut-offs of 0.90 and 0.80 for Asian men and women, respectively.[40] Meta-analysis on the potential of anthropometric indices cut-off to predict CVD, using 38 cross-sectional and prospective studies with 105 to 137256 participants, showed that WC and WHpR better predicted CVD than BMI.[41] Hadaegh et al. in a population-based longitudinal study over a median of 7.6-year follow-up in Iranian adults predicted WHpR cut-off value of 0.95 and 0.90 for CVD incidence in men and women, respectively.[33] According to the results of our study, WHpR had the highest AUC among anthropometric indices (0.65 for men and 0.63 for women). Optimal cut-offs for predicting CVD were 0.93 and 0.92 for male and female groups, respectively, as well as 0.92 for total sample (Table 4). We found acceptable discriminatory power of

WHpR for the prediction of CVD in agreement with one recent study in a large population of Iranian people from the Khuzestan Comprehensive Health Study (KCHS) during 2016 to 2018. It was shown that WHpR with cut-off of 0.915 and AUC of 0.527 was the best predictor of CVD in KCHS.[42]

In a cross-sectional study on a sample of 11247 adults in China, older than 35 years of age, WHtR provided the largest AUC value of 0.7 in women with the optimal cut-off of 0.54.[18] WHtR cut-off value for predicting CVD in the present study was predicted as 0.55 and 0.69 in men and women, respectively (Table 4).

In both men and women, our findings revealed that WHpR and WHtR had superior overall predictive discrimination (as measured by AUC) for incidence of CVD than BMI and WC. It was shown that WHpR due to a higher AUC had a stronger predictive power of CVDs in both sexes. Yusuf et al. in a case-control study on 27000 participants from 52 countries reported that WHpR was a better predictor of cardiovascular events than BMI as a measure of central obesity.[6]

We also compared the AUCs of several anthropometric indices of ABSI, AVI, BAI, and BRI for predicting CVD (Table 4). In general, it was shown that ABSI outperformed BMI and WC in predicting all-cause mortality but underperformed in predicting chronic diseases.[16] In a cross-sectional study conducted on 9555 Iranian population aged more than 19 years, ABSI was a weak predictor for CVD risks.[14] In our study as presented in table 4, ABSI was not passively associated with the risk of CVD ($P > 0.05$). ABSI cut-off was evaluated as 0.08 for men and women.

According to the results of current study, AVI had the AUC of 0.60 and 0.53 with cut-offs of 18.08 and 17.52 among men and women, respectively. In a cross-sectional study on 300 men and non-pregnant women with CAD aged 18-60 years in Tehran, Iran, the AUC of AVI had the highest value of 0.72 and cut-off of 18.64 for CAD-positive group.[33]

Without any numerical adjustments, the BAI anthropometric index can be used to reflect body fat percentage (%BF) in men and women of different nationalities.[17] In a cross-sectional study on 1891 subjects, aged 21-74 years in Singapore, anthropometric indices and CVD risk factors were measured.[43] BAI consistently had lower correlation, AUC, and odd ratio values in comparison with BMI, WC, and WHtR. It was concluded that although BAI attempted to give an estimation of %BF, it did not distinguish the distribution of that body adiposity; BAI behaved similarly to BMI and had no additional value after evaluating BMI.[41] BAI cut-off obesity index for CVD risk factor in northeast China was estimated 25 and 30 for men and women, respectively.[44] In our study, BAI cut-offs were evaluated as 26.76 for men and 35.28 for women.

We investigated the performance of BRI index for CVD risk. BRI cut-offs of 4.39 for men and 5.20 for women were estimated in this study. It can be compared with the results of the study on participants in China in 2018, with optimal cut-off of 4.21 for women.[18]

This study found that there was a clear difference in HC, BMI, WHpR, WHtR, BAI, and BRI between men and women, implying that gender-specific reference values should be employed in clinical practice.

Conclusion

We estimated optimal cut-offs for BMI, WC, HC, WHpR, WHtR, ABSI, AVI, BAI, and BRI indices to predict Yazd adults at high risk for CVD. Statistical analysis provided healthy upper limits of anthropometric indices to keep the risk for CVD low. Central obesity criteria were good indices for predicting the risk of CVD. WHpR which indicates the anatomical and skeletal status of the body could be an excellent indicator for CVD. Therefore, WHpR was the best anthropometric index for the diagnosis of CVD for both male and female groups. In addition, WHtR outperformed other anthropometric indices in predicting CVD in both men and women.

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Conflict of Interests

Authors have no conflict of interests.

Authors' Contribution

All authors provided critical feedback and helped shape the research, analysis, and manuscript. AH and SJ designed the model, analyzed data, and drafted and revised the manuscript. SMN collected data, interpreted the results, and revised the manuscript.

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