

# Association of anthropometric indices with cardiovascular disease risk factors among adults: a study in Iran

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## Aims

Cardiovascular diseases (CVDs) are the leading cause of death in the world. Many modifiable risk factors have been reported to synergistically act in the development of CVDs. We aimed to compare the predictive power of anthropometric indices, as well as to provide the best cut-off point for these indicators in a large population of Iranian people for the prediction of CVDs and CVD risk factors.

## Methods and results

All the data used in the present study were obtained from Khuzestan comprehensive health study (KCHS). Anthropometric indices, including BMI (body mass index), WC (waist circumference), HC (hip circumference), WHR (waist-to-hip ratio), WHtR (waist-to-height ratio), ABSI (a body shape index), as well as CVD risk factors [dyslipidaemia, abnormal blood pressure (BP), and hyperglycaemia] were recorded among 30 429 participants. WHtR had the highest adjusted odds ratios amongst anthropometric indices for all the risk factors and CVDs. WC had the highest predictive power for dyslipidaemia and hyperglycaemia [area under the curve (AUC) = 0.622, 0.563; specificity 61%, 59%; sensitivity 69%, 60%; cut-off point 87.95, 92.95 cm, respectively], while WHtR had the highest discriminatory power for abnormal BP (AUC = 0.585; specificity 60%; sensitivity 65%; cut-off point 0.575) and WHR tended to be the best predictor of CVDs (AUC = 0.527; specificity 58%; sensitivity 64%; cut-off point 0.915).

## Conclusion

In this study, we depicted a picture of the Iranian population in terms of anthropometric measurement and its association with CVD risk factors and CVDs. Different anthropometric indices showed different predictive power for CVD risk factors in the Iranian population.

## Keywords

Obesity • Cardiovascular disease risk factors • Anthropometric indices • Cardiovascular diseases

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## Implications for practice

- Waist-to-height ratio seems to be a good predictor of cardiometabolic risk factors.
- Cut-off points for anthropometric indices are different in different world regions.
- These cut-off points vary widely regarding age and sex in the Iranian population.

## Introduction

Cardiovascular diseases (CVDs) are the leading cause of death in the world with a predicted 25 million deaths from CVDs in 2020.<sup>1</sup> Many modifiable risk factors for CVDs including obesity, diabetes, blood pressure (BP), and blood lipid profiles have been reported to synergistically act in the development of CVDs.<sup>2</sup>

Obesity is now being considered as a major public health issue in all the age groups globally.<sup>3</sup> The prevalence of obesity has been increasing strikingly for the past four decades to reach the mean percentage of 19.5% of adults worldwide in 2017<sup>4</sup> and it is now considered as the most prevalent metabolic disorder in many countries,<sup>5</sup> including high-, medium-, and low-income countries.<sup>6</sup> Iran, as a developing country, is also concerned with this public health issue. The prevalence of obesity is estimated to be 21.7% with an increasing trend in the population above the age of 18 years.<sup>7</sup> Furthermore, previous reports have consistently shown the close association between adipose tissue distribution and the risk of diabetes, hyperlipidaemia, hypertension, and CVD.<sup>8</sup>

Anthropometry is defined as the assessment of body composition, which describes body mass, size, shape, and fat distribution.<sup>9</sup> Many anthropometrical indices were introduced and used in the initial screening of obesity and other related conditions.<sup>10</sup>

Body mass index (BMI) is the most alleged useful epidemiological index suggested by WHO to define obesity; however, it lacks the capability to describe the body fat distribution.<sup>11</sup> Other indicators such as waist circumference (WC), hip circumference (HC), waist-hip ratio (WHR), and waist-to-height ratio (WHtR) are among the indices which provide more information regarding abdominal and visceral obesity.<sup>12</sup> A body shape index (ABSI) is also a novel index, which is believed to better predict mortality and CVDs than that of BMI or WC in whites.<sup>13</sup>

The association between anthropometric indices and CVD risk factors have been studied in many previous reports, especially in Asian countries; however, there is no consensus regarding the best anthropometric index for predicting CVD risk factors. Studies have postulated that depending on the population, gender, age, and ethnic group, the predictive power of anthropometric indices may vary widely.<sup>14</sup> For instance, WHtR has been proposed as the best predictor of hypertension in men for elderly age group in some countries, such as Taiwan,<sup>15</sup> and Korea,<sup>16</sup> while WHR has been shown to reliably predict hypertension in Argentinian men and women.<sup>17</sup> Also, the predictive power of these indices varies widely for different CVD risk factors in a single population. Liu *et al.*<sup>18</sup> showed that in Chinese population, WHtR is the best predictor for dyslipidaemia, hyperglycaemia, and CVDs. However, WC could more accurately predict abnormal BP in this population. While similar study was performed among the Iranian children and adolescents, which showed the superiority of WC and BMI to other indices in distinguishing CVD risk factors,<sup>19</sup> but they did not include adults. None of the previous studies

compared the discriminative power of different anthropometric indices for CVD and CVD risk factors among the Iranian population.

In this study, we aimed to compare the predictive power of six anthropometric indices (BMI, WC, HC, WHR, WHtR, and ABSI), as well as to provide the best cut-off points for these indicators in a large population of Iranian people for the prediction of CVDs and CVD risk factors.

## Materials and methods

### Study population

All the data used in the present study were obtained from Khuzestan comprehensive health study (KCHS) during 2016 to 2018. KCHS is a large community-based cross-sectional study evaluating several aspects of health status among 30 506 Iranian adults (aged 20–65 years) with a diverse socio-economic status from 29 counties of Khuzestan province located in the southwest of I.R. Iran. In brief, a multi-stage random sampling method was used. The whole province was first stratified into 29 counties and then clustered into 1079 clusters (including 780 urban and 299 rural). Seventy-seven patients were excluded from the final analysis due to missing data in the principle demographic information and the history of CVDs. Household health records were used to select participants in each cluster. The ethics committee of our institute (Digestive Diseases Research Institute) approved the KCHS study protocol.

### Anthropometric indices measurements

Anthropometric measurements were performed by well-trained examiner using standardized protocols and devices in the morning. Weight was measured with normal light cloth to the nearest 0.1 kg using the Seca 762 mechanical flat scale (Seca, Germany). Height, WC, and HC were measured to the nearest 0.1 cm using the Seca 206 body metre measuring tape with wall stop, and Seca 203 circumference measuring tape, respectively. WHR, WHtR, and ABSI were calculated using the following formula:<sup>20</sup>

- (1)  $\text{WHR} = \text{WC (cm)} / \text{HC (cm)}$
- (2)  $\text{WHtR} = \text{WC (cm)} / \text{Height (cm)}$
- (3)  $\text{ABSI} = \frac{\text{WC (m)}}{\text{BMI}^{\frac{1}{3}} \times \text{Height (m)}^{\frac{2}{3}}}$

BP (systolic and diastolic) was measured using Riester sphygmomanometers (Germany). Measures were collected twice (5 and 10 min after rest) in a sitting position and the mean was used in the analyses. The measurements were repeated in case of more than 5 mmHg difference between the two measurements.

### Blood sampling

Blood samples were collected after fasting for 12 h. Then, fasting blood sugar (FBS), triglyceride (TG), cholesterol (Chol), and high-density lipoproteins (HDLs) were measured by BT 1500 autoanalyzer (Biotechnica Instruments, Italy) using commercial kits (Pars Azmun, Iran). Low-density lipoproteins was calculated using Friedewald equation [ $\text{LDL-c (mg/dL)} = \text{TC (mg/dL)} - \text{HDL-c (mg/dL)} - \text{TG (mg/dL)} / 5$ ].

**Table 1** Baseline characteristics of the participants

Characteristics	Total population (N = 30 429)	CVDs <sup>a</sup> (N = 1773)	No CVDs (N = 28 656)	P-value
Gender (male)	10 876 (35.7)	698 (39.4)	10 178 (35.5)	<0.001
Age	41.7 ± 11.9	52.7 ± 9.4	41.0 ± 11.7	<0.001
Ethnicity				0.085
Fars	5604 (18.4)	365 (20.6)	5239 (18.3)	
Arab	14 903 (49.1)	843 (47.6)	14 060 (49.2)	
Lor and Bakhtiari	9634 (31.7)	551 (31.1)	9083 (31.8)	
Turk and Kurd	226 (0.7)	10 (0.6)	216 (0.8)	
Education				<0.001
Illiterate	6591 (21.7)	643 (36.3)	5948 (20.8)	
Elementary to high school	15 683 (51.5)	836 (47.1)	14 847 (51.9)	
University degree	8150 (26.8)	294 (16.6)	7856 (27.4)	
Residence				<0.001
Urban	22 231 (73.1)	1423 (80.3)	20 808 (72.6)	
Rural	8198 (26.9)	350 (19.7)	7848 (27.4)	
Smoking (yes)	3297 (10.8)	293 (16.5)	3004 (10.5)	<0.001
Use of alcohol (yes)	648 (2.1)	37 (2.1)	611 (2.1)	0.898
Physical activity				<0.001
Low	9427 (31.0)	727 (41.2)	8700 (30.4)	
Middle	13 038 (42.9)	687 (39.0)	12 351 (43.2)	
High	7905 (26.0)	349 (19.8)	7556 (26.4)	
Positive family history of CVD	8990 (29.5)	779 (43.9)	8211 (28.6)	<0.001
Glucose-lowering drugs	603 (2.0)	134 (7.6)	469 (1.64)	<0.001
Antihypertensive drugs	920 (3.0)	267 (15.1)	653 (2.3)	<0.001
Lipid-lowering drugs	445 (1.5)	164 (9.2)	281 (1.0)	<0.001
Dyslipidaemia <sup>b</sup>	25 715 (85.6)	1537 (87.4)	24 178 (85.5)	0.027
Abnormal BP <sup>c</sup>	8068 (26.5)	1118 (63.1)	6950 (24.2)	<0.001
Hyperglycaemia <sup>d</sup>	14 031 (46.7)	1197 (67.9)	12 834 (45.3)	<0.001
FBS (mg/dL)	110.6 ± 47.6	137.2 ± 71.7	108.9 ± 45.2	<0.001
Cholesterol (mg/dL)	193.1 ± 47.5	190.2 ± 49.4	193.3 ± 47.3	0.007
HDL (mg/dL)	50.9 ± 11.8	49.1 ± 11.7	51.1 ± 11.8	<0.001
LDL (mg/dL)	113.8 ± 37.0	108.9 ± 40.8	114.1 ± 36.7	<0.001
TG (mg/dL)	151.4 ± 102.1	170.1 ± 100.2	150.2 ± 102.1	<0.001
SBP <sup>e</sup> (mmHg)	115.8 ± 15.1	123.8 ± 18.0	115.3 ± 14.7	<0.001
DBP <sup>f</sup> (mmHg)	74.3 ± 11.1	79.1 ± 12.4	74.0 ± 11.0	<0.001
HC (cm)	103.3 ± 10.2	105.2 ± 10.7	103.2 ± 10.2	<0.001
WC (cm)	92.5 ± 13.4	98.3 ± 12.9	92.2 ± 13.3	<0.001
BMI	27.6 ± 5.3	29.2 ± 5.4	27.5 ± 5.3	<0.001
WHR	0.89 ± 0.08	0.93 ± 0.08	0.89 ± 0.08	<0.001
WhtR	0.57 ± 0.09	0.61 ± 0.08	0.57 ± 0.08	<0.001
ABSI	0.0798 ± 0.0065	0.0819 ± 0.0062	0.0797 ± 0.0065	<0.001

ABSI, a body shape index; BMI, body mass index; HC, hip circumference; WC, waist circumference; WHR, waist-to-hip ratio; WhtR, waist-to-height ratio.

<sup>a</sup>Cardiovascular diseases including a self-reported history of cardiovascular disease (coronary heart disease or heart failure or other cardiovascular diseases) or documented established diagnosis of cardiovascular diseases.

<sup>b</sup>Dyslipidaemia was defined with the presence of one of the following criteria: (i) cholesterol level greater than 200 mg/dL and/or LDL-C level greater than 100 mg/dL, (ii) triglyceride level greater than 150 mg/dL, or (iii) high-density lipoprotein-cholesterol (HDL-C) lower than 40 mg/dL in men and 50 mg/dL in women.

<sup>c</sup>Abnormal blood pressure (BP) was defined as self-reported history of hypertension or SBP ≥ 130 and/or DBP ≥ 85 mmHg.

<sup>d</sup>Hyperglycaemia was defined as fasting blood glucose FBS ≥ 100 mg/dL or 5.6 mmol/L or a self-reported history of diabetes.

<sup>e</sup>Systolic blood pressure.

<sup>f</sup>Diastolic blood pressure.

### Definition of risk factors

Abnormal BP was defined as self-reported history of hypertension or systolic BP (SBP) ≥ 130 and/or diastolic BP (DBP) ≥ 85 mmHg (in

concordance with American Heart Association).<sup>21</sup> Dyslipidaemia was defined with the presence of one of the following criteria [based on American College of Cardiology/American Heart Association

(ACC/AHA) Guideline on the Primary Prevention of Cardiovascular Disease and Iranian National Reports on dyslipidaemia<sup>22,23</sup> (converted into local units)

- (1) Cholesterol level greater than 200 mg/dL and/or LDL-C level greater than 100 mg/dL;
- (2) Triglyceride level greater than 150 mg/dL; and
- (3) High-density lipoprotein cholesterol (HDL-C) lower than 40 mg/dL in men and 50 mg/dL in women.

Hyperglycaemia was defined as fasting blood glucose FBS  $\geq$  100 mg/dL or 5.6 mmol/L or a self-reported history of diabetes or glucose lowering drug use consistent with past medical history (in concordance with American Diabetes Association).<sup>24</sup> Patients were classified as having CVDs regarding a self-reported history of CVD (coronary heart disease or heart failure or other CVDs) or documented, established diagnosis of CVDs.

## Statistical analysis

Data were expressed as mean  $\pm$  standard deviation or frequency and percentage, as appropriate. Means and percentage were compared using two-sided *t*-tests and  $\chi^2$  test, respectively. Unconditional logistic regression model was used to evaluate associations of anthropometric indices with CVDs and CVD risk factors. Multiple regression models were used to adjust for potential confounding factors such as sociodemographic variables (age, sex, residence, and education levels), lifestyle characteristics (physical activity, smoking status, opium used), and family history of chronic diseases, history of taking lipid-lowering, glucose-lowering, and anti-hypertensive drugs on the odds ratio (OR).

Cut-off value was determined between each anthropometrical index and cardiometabolic risk factors and CVDs by the receiver operating characteristic (ROC) curve, which was quantified by the area under the ROC curve (AUC). The Youden's index was used to determine the optimal cut-off point of each index.

Furthermore, we performed two subgroup analyses based on sex and age group. Patients were divided into two age group (1:  $\leq$ 40 years and 2:  $>$ 40 years). All reported *P*-values were two-sided and  $<0.05$  was considered significant. All analyses were performed in STATA software, version 12.0 (Stata Corp, College Station, TX, USA) and R (3.5.3).

## Results

We included 30 429 participants (35.7% male) in this study. Table 1 shows the demographic characteristics of the participants. Participants with CVDs were significantly different from participants without CVDs in terms of gender, age, education, residence, smoking, physical activity, and family history of CVDs (*P*-value  $< 0.001$ ). Dyslipidaemia, abnormal BP, and hyperglycaemia were significantly more popular among participants with CVDs (Table 1). Laboratory results were higher among CVD cases (*P*-value  $< 0.001$ ), except total cholesterol and LDL levels, which were higher in healthy adults (*P*-value = 0.007 and  $< 0.001$ , respectively). All the anthropometric indices were higher among CVD subjects (*P*-value  $< 0.001$ ).

Table 2 illustrates univariable and multivariable model for the association between adiposity indices and CVD risk factors and CVDs. The adjusted ORs were lower than non-adjusted ORs generally. WHtR had the highest adjusted ORs amongst anthropometric indices for all the risk factors and CVDs. Also, ORs were generally higher for dyslipidaemia.

**Table 2** Odds ratios regarding two models for the association of cardiovascular disease risk factor and anthropometric indices

Outcomes	Model 1 Odds ratio (95% CI)	Model 2 Odds ratio (95% CI)
Dyslipidaemia <sup>a</sup>		
BMI	1.144 (1.136–1.153)	1.118 (1.109–1.127)
WC	1.054 (1.052–1.057)	1.045 (1.042–1.048)
HC	1.056 (1.053–1.060)	1.047 (1.043–1.051)
WHR	1.846 (1.776–1.920)	1.656 (1.582–1.733)
WHtR	2.347 (2.248–2.450)	2.019 (1.925–2.118)
ABSI	1.435 (1.365–1.508)	1.171 (1.109–1.235)
Abnormal BP <sup>b</sup>		
BMI	1.086 (1.080–1.090)	1.069 (1.063–1.075)
WC	1.049 (1.047–1.051)	1.032 (1.029–1.035)
HC	1.032 (1.030–1.034)	1.030 (1.027–1.034)
WHR	2.136 (2.063–2.212)	1.437 (1.380–1.497)
WHtR	2.039 (1.975–2.106)	1.653 (1.590–1.719)
ABSI	1.846 (1.771–1.924)	1.236 (1.177–1.298)
Hyperglycaemia <sup>c</sup>		
BMI	1.069 (1.064–1.074)	1.043 (1.038–1.048)
WC	1.034 (1.032–1.036)	1.020 (1.018–1.022)
HC	1.027 (1.025–1.030)	1.020 (1.017–1.022)
WHR	1.613 (1.568–1.660)	1.245 (1.205–1.287)
WHtR	1.674 (1.628–1.722)	1.344 (1.301–1.388)
ABSI	1.439 (1.389–1.491)	1.111 (1.068–1.155)
CVDs <sup>d</sup>		
BMI	1.056 (1.047–1.065)	1.026 (1.016–1.036)
WC	1.033 (1.030–1.037)	1.012 (1.007–1.016)
HC	1.018 (1.013–1.023)	1.011 (1.006–1.016)
WHR	1.809 (1.706–1.918)	1.133 (1.056–1.214)
WHtR	1.700 (1.611–1.794)	1.190 (1.114–1.272)
ABSI	1.687 (1.568–1.814)	1.042 (0.960–1.136)

Model 1: unadjusted model.

Model 2: adjusted for age, gender, location of residence, education level, physical activity, use of smoking, use of opium, family history of diabetes, family history of hypertension, family history of cardiovascular diseases, use of antihypertensive drugs, use of lipid-lowering drugs, and use of glucose-lowering drugs.

ABSI, a body shape index; BMI, body mass index; HC, hip circumference; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

<sup>a</sup>Dyslipidaemia was defined with the presence of one of the following criteria: (i) cholesterol level greater than 200 mg/dL and/or LDL-C level greater than 100 mg/dL, (ii) triglyceride level greater than 150 mg/dL, or (iii) high-density lipoprotein-cholesterol (HDL-C) lower than 40 mg/dL in men and 50 mg/dL in women.

<sup>b</sup>Abnormal blood pressure (BP) was defined as self-reported history of hypertension or SBP  $\geq$  130 and/or DBP  $\geq$  85 mmHg.

<sup>c</sup>Hyperglycaemia was defined as fasting blood glucose FBS  $\geq$  100 mg/dL or 5.6 mmol/L or a self-reported history of diabetes.

<sup>d</sup>Cardiovascular diseases including a self-reported history of cardiovascular disease (coronary heart disease or heart failure or other cardiovascular diseases) or documented established diagnosis of cardiovascular diseases.

Adjusted ORs of anthropometric indices ranged from 1.118–2.019, 1.069–1.653, 1.043–1.344, 1.026–1.190 for dyslipidaemia, abnormal BP, Hyperglycaemia, and CVDs, respectively.

Table 3 demonstrates the ORs for anthropometric indices classified by gender and age groups. ORs were generally higher among men, except WHtR in the association with CVDs. WHtR still had the

**Table 3** Adjusted odds ratios for the association of cardiovascular disease risk factor and anthropometric indices stratified by sex and age group

Outcome	Sex		Age Groups	
	Male (N = 10 876)	Female (N = 19 553)	20 ≤ age ≤ 40 years	Age > 40 years
Dyslipidaemia <sup>a</sup>				
BMI	1.136 (1.120–1.151)	1.107 (1.097–1.117)	1.169 (1.157–1.181)	1.055 (1.043–1.068)
WC	1.051 (1.046–1.057)	1.041 (1.037–1.044)	1.060 (1.056–1.064)	1.027 (1.022–1.032)
HC	1.058 (1.051–1.065)	1.041 (1.036–1.046)	1.070 (1.065–1.076)	1.017 (1.011–1.023)
WHR	1.969 (1.807–2.144)	1.520 (1.440–1.604)	1.844 (1.743–1.952)	1.528 (1.419–1.646)
WHtR	2.330 (2.134–2.543)	1.858 (1.754–1.968)	2.581 (2.425–2.747)	1.485 (1.377–1.600)
ABSI	1.329 (1.187–1.489)	1.109 (1.043–1.180)	1.236 (1.157–1.321)	1.215 (1.109–1.333)
Abnormal BP <sup>b</sup>				
BMI	1.081 (1.070–1.091)	1.060 (1.052–1.068)	1.091 (1.080–1.101)	1.058 (1.051–1.065)
WC	1.033 (1.029–1.037)	1.029 (1.026–1.033)	1.040 (1.036–1.044)	1.031 (1.028–1.034)
HC	1.040 (1.035–1.046)	1.024 (1.021–1.028)	1.044 (1.039–1.049)	1.022 (1.018–1.026)
WHR	1.470 (1.369–1.578)	1.401 (1.332–1.474)	1.578 (1.471–1.692)	1.570 (1.496–1.650)
WHtR	1.760 (1.644–1.884)	1.567 (1.492–1.645)	1.874 (1.752–2.003)	1.688 (1.610–1.770)
ABSI	1.278 (1.161–1.408)	1.203 (1.136–1.275)	1.316 (1.206–1.435)	1.417 (1.338–1.501)
Hyperglycaemia <sup>c</sup>				
BMI	1.052 (1.043–1.062)	1.038 (1.032–1.044)	1.047 (1.040–1.054)	1.047 (1.040–1.054)
WC	1.027 (1.023–1.030)	1.015 (1.013–1.018)	1.018 (1.015–1.021)	1.026 (1.023–1.029)
HC	1.029 (1.024–1.034)	1.015 (1.012–1.018)	1.023 (1.019–1.026)	1.019 (1.015–1.022)
WHR	1.449 (1.359–1.544)	1.169 (1.124–1.215)	1.180 (1.128–1.235)	1.464 (1.398–1.534)
WHtR	1.551 (1.460–1.649)	1.253 (1.206–1.302)	1.319 (1.261–1.379)	1.500 (1.433–1.569)
ABSI	1.494 (1.369–1.630)	1.020 (0.975–1.067)	1.048 (0.991–1.108)	1.318 (1.247–1.392)
CVDs <sup>d</sup>				
BMI	1.024 (1.006–1.043)	1.026 (1.014–1.039)	1.024 (0.999–1.051)	1.026 (1.015–1.037)
WC	1.010 (1.003–1.017)	1.012 (1.007–1.018)	1.010 (1.000–1.021)	1.015 (1.011–1.020)
HC	1.013 (1.004–1.022)	1.010 (1.004–1.016)	1.012 (1.000–1.025)	1.009 (1.003–1.014)
WHR	1.075 (0.950–1.219)	1.148 (1.054–1.250)	1.110 (0.932–1.323)	1.296 (1.204–1.396)
WHtR	1.210 (1.072–1.366)	1.176 (1.085–1.274)	1.125 (0.950–1.333)	1.318 (1.227–1.414)
ABSI	1.078 (0.905–1.283)	1.023 (0.927–1.129)	0.980 (0.788–1.219)	1.253 (1.145–1.371)

Odds ratios were adjusted for age, gender, location of residence, education level, physical activity, use of smoking, use of opium, family history of diabetes, family history of hypertension, family history of cardiovascular diseases, use of antihypertensive drugs, use of lipid-lowering drugs, and use of glucose-lowering drugs.  
ABSI, a body shape index; BMI, body mass index; HC, hip circumference; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.  
<sup>a</sup>Dyslipidaemia was defined with the presence of one of the following criteria: (i) cholesterol level greater than 200 mg/dL and/or LDL-C level greater than 100 mg/dL, (ii) triglyceride level greater than 150 mg/dL, or (iii) high-density lipoprotein-cholesterol (HDL-C) lower than 40 mg/dL in men and 50 mg/dL in women.  
<sup>b</sup>Abnormal blood pressure (BP) was defined as self-reported history of hypertension or SBP ≥ 130 and/or DBP ≥ 85 mmHg.  
<sup>c</sup>Hyperglycaemia was defined as fasting blood glucose FBS ≥ 100 mg/dL or 5.6 mmol/L or a self-reported history of diabetes.  
<sup>d</sup>Cardiovascular diseases including a self-reported history of cardiovascular disease (coronary heart disease or heart failure or other cardiovascular diseases) or documented established diagnosis of cardiovascular diseases.

highest ORs compared to other anthropometric indices among men and women.

WHtR had the highest ORs amongst anthropometric indices in both age groups, except the OR for dyslipidaemia in the age Group 2, which was higher for WHR. The comparison of ORs between age groups was heterogeneous. Generally, the ORs were higher among age Group 1 in association with dyslipidaemia and abnormal BP, while they were generally higher among age Group 2 in association with hyperglycaemia and CVDs.

Table 4 shows the discriminatory power of anthropometric indices for the prediction of CVD risk factors and CVDs. WC had the highest predictive power for dyslipidaemia and hyperglycaemia (AUC = 0.622, 0.563; specificity 61%, 59%; sensitivity 69%, 60%; cut-off point

87.95, 92.95 cm, respectively), while WHtR had the highest discriminatory power for abnormal BP (AUC = 0.585; specificity 60%; sensitivity 65%; cut-off point 0.575) and WHR tended to be the best predictor of CVDs (AUC = 0.527; specificity 58%; sensitivity 64%; cut-off point 0.915).

Table 5 compares the predictive power of anthropometric indices between men and women. WC was the best predictor for dyslipidaemia in men (AUC = 0.620; specificity 60%; sensitivity 71%; cut-off point 88.05 cm). However, WHR was superior to others in terms of predictive power for hyperglycaemia, and CVDs in men (AUC = 0.563, 0.529; specificity 61%, 59%; sensitivity 59%, 63%; cut-off point 0.925, 0.935, respectively) and WC and WHR had almost the same discriminatory power for abnormal BP (AUC = 0.583, 0.583;



**Table 4** AUCs and optimal cut-off points for anthropometric indices regarding cardiovascular risk factors

Outcome	AUC (95% CI)	Cut-off point	Specificity	Sensitivity
Dyslipidaemia <sup>a</sup>				
BMI	0.608 (0.598–0.618)	24.68	0.54	0.74
WC	0.622 (0.612–0.632)	87.95	0.61	0.69
HC	0.584 (0.574–0.595)	98.25	0.53	0.71
WHR	0.600 (0.589–0.610)	0.875	0.58	0.65
WHtR	0.618 (0.608–0.628)	0.535	0.60	0.69
ABSI	0.526 (0.515–0.537)	0.077	0.45	0.67
Hyperglycaemia <sup>b</sup>				
BMI	0.542 (0.534–0.549)	26.38	0.50	0.64
WC	0.563 (0.556–0.570)	92.95	0.59	0.60
HC	0.534 (0.527–0.541)	102.15	0.55	0.56
WHR	0.557 (0.550–0.564)	0.905	0.60	0.57
WHtR	0.558 (0.551–0.566)	0.565	0.58	0.61
ABSI	0.527 (0.520–0.534)	0.081	0.61	0.50
Abnormal BP <sup>c</sup>				
BMI	0.559 (0.550–0.567)	27.52	0.57	0.61
WC	0.583 (0.574–0.591)	92.55	0.57	0.69
HC	0.547 (0.538–0.555)	102.15	0.53	0.60
WHR	0.572 (0.563–0.580)	0.905	0.59	0.67
WHtR	0.585 (0.577–0.593)	0.575	0.60	0.65
ABSI	0.538 (0.530–0.546)	0.078	0.45	0.73
CVDs <sup>d</sup>				
BMI	0.506 (0.492–0.520)	27.39	0.52	0.61
WC	0.520 (0.506–0.535)	90.35	0.45	0.75
HC	0.497 (0.483–0.511)	102.35	0.50	0.57
WHR	0.527 (0.513–0.541)	0.915	0.58	0.64
WHtR	0.523 (0.509–0.537)	0.575	0.55	0.66
ABSI	0.513 (0.499–0.527)	0.079	0.43	0.72

Models were adjusted for age, gender, location of residence, education level, physical activity, use of smoking, use of opium, family history of diabetes, family history of hypertension, family history of cardiovascular diseases, use of antihypertensive drugs, use of lipid-lowering drugs, and use of glucose-lowering drugs. ABSI, a body shape index; BMI, body mass index; HC, hip circumference; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

<sup>a</sup>Dyslipidaemia was defined with the presence of one of the following criteria: (i) cholesterol level greater than 200 mg/dL and/or LDL-C level greater than 100 mg/dL, (ii) triglyceride level greater than 150 mg/dL, or (iii) high-density lipoprotein-cholesterol (HDL-C) lower than 40 mg/dL in men and 50 mg/dL in women.

<sup>b</sup>Hyperglycaemia was defined as fasting blood glucose FBS  $\geq$  100 mg/dL or 5.6 mmol/L or a self-reported history of diabetes.

<sup>c</sup>Abnormal blood pressure (BP) was defined as self-reported history of hypertension or SBP  $\geq$  130 and/or DBP  $\geq$  85 mmHg.

<sup>d</sup>Cardiovascular diseases including a self-reported history of cardiovascular disease (coronary heart disease or heart failure or other cardiovascular diseases) or documented established diagnosis of cardiovascular diseases.

specificity 54%, 53%; sensitivity 68%, 71%; cut-off point 92.95 cm, 0.915, respectively). However, in women WC was the best predictor for hyperglycaemia and abnormal BP (AUC = 0.566, 0.586; specificity 60%, 44%; sensitivity 58%, 77%; cut-off point 92.55, 89.65 cm, respectively). Moreover, WHtR was the best predictor for dyslipidaemia (AUC = 0.620; specificity 55%; sensitivity 74%; cut-off point 0.535), and WHR was the best predictor for CVDs (AUC = 0.528; specificity 61%; sensitivity 65%; cut-off point 0.895).

Table 6 compares the predictive power of anthropometric indices between age groups. In the younger age group, WC was the best predictor for all CVD risk factors and CVDs. However, in the older age group, WHR was superior to other indices for the prediction of dyslipidaemia, hyperglycaemia, and CVDs (AUC = 0.586, 0.588, 0.569; specificity 43%, 54%, 43%; sensitivity 69%, 58%, 69%; cut-off point 0.895, 0.925, 0.915, respectively), while WHtR was the best predictor of abnormal BP (AUC = 0.612; specificity 52%; sensitivity 65%; cut-off point 0.585).

## Discussion

To the best of our knowledge, this is the first population-based study to assess the predictive power of anthropometric indices for CVD risk factor and CVDs among the Iranian population. We found higher ORs for WHtR compared to other indices in the total population (especially for dyslipidaemia and abnormal BP). Also, all ORs were higher among men compared to women.

Many studies in different world regions (the USA, China, and Taiwan) showed the superiority of WHtR to other indices in predicting CVD risk factors.<sup>15,25,26</sup> Many reasons can justify this superiority. First, WHtR is not affected greatly by race, age, and gender.<sup>27</sup> Second, it can differentiate between body fat and muscular tissue, while factors such as BMI cannot represent fat distribution and may overestimate the risk of CVDs in the population with higher weight due to more muscular tissue.<sup>28</sup> The cut-off point for this index is also controversial. In our study, the cut-off point was lower for men (ranged 0.505–0.545 in men, and 0.535–0.595 in women). Other studies conducted in southeast Asia proposed lower cut-off points for both men and women compared to ours.<sup>15,28</sup> These cut-off points are considered to be somewhat different in different world regions; however, previous studies in the Iranian population confirmed higher cut-off points of WHtR compared to Chinese population (as proposed to be 0.52 in men and 0.56 in women by Zafari et al.<sup>29</sup> in the Iranian population). Many factors including different percentage of body fat, variation in the level of leptin, life style, and genetic differences can contribute to diverse cut-off points worldwide.<sup>30,31</sup>

We found higher ORs among men, which can be justified by other modifiable risk factor (including smoking and drinking) and different fat and muscle distribution.<sup>18</sup> Visceral fat is more dominant in men, which has a stronger association with metabolic diseases and justifies higher ORs in men.<sup>30</sup> A recent study among Lebanese population also showed that abdominal adiposity indicators functioned better than BMI in predicting metabolic syndrome in men, while in women, BMI, WC, and WHtR were all acceptable predictors.<sup>32</sup>

We also found different results in different age groups. We found that ORs associated with dyslipidaemia and abnormal BP decreased by age, while ORs associated with hyperglycaemia and CVDs increased. Others studies also showed age-specific differences.<sup>33</sup> Many underlying mechanisms may play a role in this difference, including losing muscle mass with age and concentration of fat distribution.<sup>34</sup> For instance, our results have showed that ORs associated with abnormal BP drops with age, consistent with the result of Ononamadu et al.,<sup>10</sup> which showed lower ORs after 40 years of age. Studies also showed weaker association of BP with body composition indices in elderly age group compared to youth. These interactions

**Table 5** AUCs and optimal cut-off points for anthropometric indices regarding cardiovascular risk factors stratified by sex

Outcome	Male				Female			
	AUC (95% CI)	Cut-off point	Specificity	Sensitivity	AUC (95% CI)	Cut-off point	Specificity	Sensitivity
Dyslipidaemia <sup>a</sup>								
BMI	0.611 (0.594–0.627)	23.18	0.48	0.81	0.609 (0.597–0.622)	24.80	0.52	0.76
WC	0.620 (0.604–0.637)	88.05	0.60	0.71	0.619 (0.606–0.631)	87.95	0.63	0.66
HC	0.589 (0.572–0.606)	96.85	0.51	0.74	0.585 (0.571–0.597)	100.75	0.58	0.65
WHR	0.596 (0.579–0.612)	0.885	0.52	0.74	0.591 (0.578–0.604)	0.875	0.65	0.57
WHtR	0.619 (0.602–0.635)	0.505	0.55	0.77	0.620 (0.608–0.633)	0.535	0.55	0.74
ABSI	0.528 (0.510–0.546)	0.078	0.41	0.73	0.524 (0.510–0.537)	0.075	0.38	0.72
Hyperglycaemia <sup>b</sup>								
BMI	0.534 (0.522–0.546)	24.91	0.45	0.69	0.543 (0.534–0.552)	27.28	0.53	0.63
WC	0.559 (0.548–0.572)	93.25	0.59	0.60	0.566 (0.557–0.575)	92.55	0.60	0.58
HC	0.525 (0.513–0.537)	102.35	0.63	0.49	0.537 (0.528–0.546)	104.75	0.60	0.51
WHR	0.563 (0.551–0.575)	0.925	0.61	0.59	0.559 (0.550–0.568)	0.885	0.58	0.59
WHtR	0.549 (0.536–0.561)	0.535	0.54	0.66	0.557 (0.548–0.565)	0.595	0.49	0.61
ABSI	0.530 (0.518–0.542)	0.081	0.60	0.56	0.527 (0.518–0.536)	0.078	0.48	0.61
Abnormal BP <sup>c</sup>								
BMI	0.551 (0.537–0.565)	26.42	0.58	0.61	0.555 (0.545–0.566)	27.40	0.47	0.69
WC	0.583 (0.569–0.596)	92.95	0.54	0.68	0.586 (0.576–0.597)	89.65	0.44	0.77
HC	0.538 (0.524–0.552)	101.05	0.57	0.58	0.545 (0.534–0.555)	103.85	0.51	0.59
WHR	0.583 (0.569–0.596)	0.915	0.53	0.71	0.577 (0.567–0.587)	0.895	0.56	0.67
WHtR	0.573 (0.560–0.587)	0.545	0.58	0.66	0.577 (0.566–0.587)	0.575	0.47	0.76
ABSI	0.544 (0.531–0.558)	0.081	0.59	0.59	0.541 (0.531–0.551)	0.079	0.48	0.68
CVDs <sup>d</sup>								
BMI	0.506 (0.480–0.531)	24.87	0.39	0.74	0.506 (0.488–0.523)	27.63	0.53	0.68
WC	0.524 (0.499–0.549)	90.75	0.42	0.75	0.520 (0.501–0.537)	90.35	0.53	0.75
HC	0.498 (0.472–0.524)	97.15	0.33	0.74	0.495 (0.479–0.513)	103.85	0.54	0.61
WHR	0.529 (0.504–0.553)	0.935	0.59	0.63	0.528 (0.510–0.545)	0.895	0.61	0.65
WHtR	0.523 (0.497–0.548)	0.545	0.52	0.69	0.520 (0.501–0.538)	0.595	0.63	0.68
ABSI	0.518 (0.495–0.541)	0.081	0.59	0.60	0.512 (0.494–0.529)	0.078	0.45	0.72

Models were adjusted for age, location of residence, education level, physical activity, use of smoking, use of opium, family history of diabetes, family history of hypertension, family history of cardiovascular diseases, use of antihypertensive drugs, use of lipid-lowering drugs, and use of glucose-lowering drugs.  
ABSI, a body shape index; BMI, body mass index; HC, hip circumference; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.  
<sup>a</sup>Dyslipidaemia was defined with the presence of one of the following criteria: (i) cholesterol level greater than 200 mg/dL and/or LDL-C level greater than 100 mg/dL, (ii) triglyceride level greater than 150 mg/dL, or (iii) high-density lipoprotein-cholesterol (HDL-C) lower than 40 mg/dL in men and 50 mg/dL in women.  
<sup>b</sup>Hyperglycaemia was defined as fasting blood glucose FBS ≥ 100 mg/dL or 5.6 mmol/L or a self-reported history of diabetes.  
<sup>c</sup>Abnormal blood pressure (BP) was defined as self-reported history of hypertension or SBP ≥ 130 and/or DBP ≥ 85 mmHg.  
<sup>d</sup>Cardiovascular diseases including a self-reported history of cardiovascular disease (coronary heart disease or heart failure or other cardiovascular diseases) or documented established diagnosis of cardiovascular diseases.

may be justified by other mechanism of hypertension in the elderly rather than just fat distribution.<sup>35</sup> We also found acceptable discriminatory power of WC for the prediction of CVD risk factors in younger age groups. Other studies have also showed the superiority of WC to WHR and BMI among youth.<sup>19</sup> One recent study in 2019 among Chinese population revealed that WC had the strongest predictive power for determining cardiometabolic risk among adults.<sup>36</sup> We interestingly found higher level of total cholesterol and LDL-C in patients without CVDs. This issue is still controversial. Previous studies reported weak association between total cholesterol and degree of atherosclerosis.<sup>37</sup> The level of cholesterol is also an important factor, as some studies found no correlation between total cholesterol and degree of atherosclerosis when those with total cholesterol

above 350 mg/dL were excluded.<sup>37</sup> Another evidence for this casual correlation is exposure-response in cholesterol-lowering drugs. Evidence shows no benefit on the arteries of patients taking these drugs. Same results are also provided to show no association between LDL-C and degree of atherosclerosis.<sup>37</sup> We also could show the association of ABSI with CVD risk factors and CVDs; however, in the Iranian population, it was not superior to other indices. Bozorgmanesh et al.<sup>38</sup> in a prospective cohort study showed the superiority of ABSI to BMI, WHR, and WHtR; however, it could not improve the predictability of the Framingham algorithm. This inconsistency may stem from different study designs. ABSI was introduced to predict mortality in follow-up studies. We performed a cross-sectional study; however, we accept that prospective studies

**Table 6** AUCs and optimal cut-off points for anthropometric indices regarding cardiovascular risk factors stratified by age group

Outcome	20 ≤ age ≤ 40 years				Age > 40 years			
	AUC (95% CI)	Cut-off point	Specificity	Sensitivity	AUC (95% CI)	Cut-off point	Specificity	Sensitivity
Dyslipidaemia <sup>a</sup>								
BMI	0.681 (0.669–0.692)	24.68	0.64	0.67	0.556 (0.539–0.572)	24.28	0.31	0.83
WC	0.685 (0.674–0.696)	82.95	0.58	0.71	0.578 (0.562–0.596)	89.35	0.41	0.75
HC	0.660 (0.649–0.671)	98.25	0.60	0.68	0.529 (0.512–0.546)	97.65	0.33	0.76
WHR	0.630 (0.618–0.641)	0.875	0.70	0.51	0.586 (0.569–0.603)	0.895	0.43	0.69
WHtR	0.684 (0.673–0.695)	0.505	0.59	0.71	0.574 (0.557–0.591)	0.535	0.35	0.80
ABSI	0.533 (0.521–0.545)	0.075	0.39	0.69	0.533 (0.517–0.549)	0.079	0.42	0.65
Hyperglycaemia <sup>b</sup>								
BMI	0.557 (0.547–0.566)	27.22	0.63	0.48	0.550 (0.540–0.559)	27.24	0.48	0.63
WC	0.563 (0.553–0.573)	90.35	0.62	0.50	0.585 (0.576–0.595)	94.55	0.52	0.62
HC	0.555 (0.545–0.565)	100.55	0.50	0.60	0.535 (0.525–0.544)	101.25	0.46	0.62
WHR	0.544 (0.533–0.554)	0.885	0.61	0.47	0.588 (0.579–0.598)	0.925	0.54	0.58
WHtR	0.560 (0.549–0.569)	0.555	0.62	0.47	0.583 (0.574–0.593)	0.575	0.48	0.66
ABSI	0.511 (0.501–0.521)	0.075	0.34	0.70	0.551 (0.542–0.561)	0.081	0.48	0.60
Abnormal BP <sup>c</sup>								
BMI	0.617 (0.602–0.632)	27.70	0.65	0.53	0.569 (0.560–0.579)	27.52	0.48	0.63
WC	0.636 (0.621–0.651)	89.95	0.58	0.66	0.604 (0.594–0.613)	95.15	0.53	0.63
HC	0.612 (0.597–0.626)	102.35	0.57	0.61	0.548 (0.538–0.558)	102.05	0.48	0.60
WHR	0.599 (0.585–0.613)	0.857	0.56	0.64	0.602 (0.592–0.611)	0.915	0.48	0.67
WHtR	0.631 (0.616–0.645)	0.565	0.66	0.51	0.612 (0.603–0.621)	0.585	0.52	0.65
ABSI	0.542 (0.528–0.556)	0.078	0.50	0.62	0.564 (0.554–0.573)	0.081	0.50	0.61
CVDs <sup>d</sup>								
BMI	0.547 (0.506–0.589)	26.39	0.53	0.58	0.529 (0.513–0.544)	27.39	0.43	0.63
WC	0.554 (0.513–0.594)	95.45	0.72	0.40	0.555 (0.540–0.570)	98.25	0.58	0.52
HC	0.541 (0.501–0.582)	100.75	0.47	0.67	0.510 (0.495–0.526)	102.35	0.45	0.58
WHR	0.534 (0.495–0.573)	0.885	0.58	0.47	0.569 (0.554–0.584)	0.915	0.43	0.69
WHtR	0.546 (0.505–0.587)	0.575	0.68	0.43	0.566 (0.551–0.581)	0.575	0.41	0.70
ABSI	0.503 (0.467–0.539)	0.073	0.22	0.82	0.545 (0.529–0.559)	0.081	0.49	0.59

Models were adjusted for age, gender, location of residence, education level, physical activity, use of smoking, use of opium, family history of diabetes, family history of hypertension, family history of cardiovascular diseases, use of antihypertensive drugs, use of lipid-lowering drugs, and use of glucose-lowering drugs.

ABSI, a body shape index; BMI, body mass index; HC, hip circumference; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

<sup>a</sup>Dyslipidaemia was defined with the presence of one of the following criteria: (i) cholesterol level greater than 200 mg/dL and/or LDL-C level greater than 100 mg/dL, (ii) triglyceride level greater than 150 mg/dL, or (iii) high-density lipoprotein-cholesterol (HDL-C) lower than 40 mg/dL in men and 50 mg/dL in women.

<sup>b</sup>Hyperglycaemia was defined as fasting blood glucose FBS ≥ 100 mg/dL or 5.6 mmol/L or a self-reported history of diabetes.

<sup>c</sup>Abnormal blood pressure (BP) was defined as self-reported history of hypertension or SBP ≥ 130 and/or DBP ≥ 85 mmHg.

<sup>d</sup>Cardiovascular diseases including a self-reported history of cardiovascular disease (coronary heart disease or heart failure or other cardiovascular diseases) or documented established diagnosis of cardiovascular diseases.

are needed to show the hazard ratio of different anthropometric indices.

A recent study by Li *et al.*<sup>39</sup> also showed that anthropometric indices are not effective screening methods for paediatric cardiometabolic risk factors, even in obese or overweight children. Thus, further studies are needed among children and adolescents to evaluate the role of these predictors, which was beyond the scope of this article.

In this study, we depicted a picture of the Iranian population in terms of anthropometric measurement and the association with CVD risk factors and CVDs. To our knowledge, this is the most comprehensive study performed in the Iranian population with a big sample size and many different aspects. Also, we controlled the results

for many factors including physical activity level. This study indeed has some limitation. Participants were selected from a single province (although with diverse ethnicities), and the generalization of the results to the whole Iranian population should be performed cautiously. Also, this study was a cross-sectional one and casual effects cannot be inferred from the results.

In this study, we depicted a picture of the Iranian population in terms of anthropometric measurement and the association with CVD risk factors and CVDs. Different anthropometric indices possess different predictive power for CVD risk factors in the Iranian population. The predictive power of anthropometric indices varies widely according to age and sex.



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## Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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