Comparison of anthropometric indices as predictors of the risk factors for cardiovascular disease in Iran: The PERSIAN Guilan Cohort Study

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Abstract

Objective: This study was conducted to assess the prevalence of central and general obesity and compare nine anthropometric indices as predictors of the risk factors for cardiovascular disease (CVD) in Iranian adults.
Methods: A total of 10,520 adults between ages 35 and 70 years old who were referred to the PERSIAN Guilan Cohort Study were included in this study. Anthropometric indices, including body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), waist-to-hip ratio (WHR), conicity index, hip circumference (HC), waist-to-hip-to-height ratio (WHHR), body adiposity index, and a body shape index (ABSI), were measured using the standard methods. The risk factors for CVD (diabetes mellitus, hypertension, and out-of-range lipid profiles) were defined by laboratory tests and medical history. The odds ratio of the risk factors based on a unit increase in anthropometric indices was examined by an adjusted logistic model.
Results: The mean of all anthropometric indices was higher in women than in men ($p<0.01$). After adjusting for confounders, the risk of diabetes mellitus, hypertension, and hypertriglyceridemia increased with an increase in all anthropometric indices. The highest risk of diabetes mellitus and hypertriglyceridemia was found in higher WHHR. The highest risk of low high-density lipoprotein cholesterol (HDL-C) and high low-density lipoprotein cholesterol (LDL-C) was found in an increase in the WHR and ABSI, respectively.
Conclusion: Our findings emphasize higher levels of general and central obesity in adults in the north of Iran. The WHHR and WHtR seem to be more valuable indices than BMI and WC for predicting distinct risk factors for CVD. However, the WHR was the strongest index for the prediction of high LDL-C/HDL-C ratio.
Keywords: anthropometry indices, obesity, cardiovascular disease, central obesity

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Introduction

Obesity and overweight are significant health problems worldwide. It often leads to a negative effect on health and is a major risk factor for the development of chronic diseases. Numerous studies have shown that obesity is an important cause of mortality around the world (1-3).

It is estimated that by 2030, up to 57.8% of adults worldwide would suffer from being overweight or obese (4). The total rate of obesity in Iran, based on a systematic review study,

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HIGHLIGHTS

- A total of 10.520 adults between ages 35 and 70 years old were included in this study.
- Anthropometric indices were measured using the standard methods.
- After adjusting for confounders, the risk of diabetes mellitus, hypertension, and hypertriglyceridemia increased with an increase in all anthropometric indices.
- The WHHR and WHtR seem to be more valuable indices than BMI and WC for predicting distinct risk factors for CVD.

was estimated as 21.7% for people above 18 years of age (5). The findings of a national study emphasize a high prevalence of obesity among people who live in different regions of Iran (4). Obesity is also a major health problem in Iran. Based on mortality data, obesity and overweight were the most significant causes of recorded mortalities that had been attributed to chronic diseases in Iran in 2002 (5). There are different techniques to measure obesity. Body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), waist-to-hip ratio (WHR), conicity index (CI), hip circumference (HC), waist-to-hip-to-height ratio (WHHR), body adiposity index (BAI), and a body shape index (ABSI) are regarded as the most popular indices that are used for measuring central or general obesity (6).

Up to now, the association of anthropometric indices of obesity with chronic disease and all-cause mortality is still controversial (7). Observational studies have reported differential relationships between the different anthropometric indices of obesity and risk for chronic disease or mortality, and a J- or U-shaped or positive linear relationship for different anthropometric indices has been reported (8-11). Some studies confirm that ethnicity and geographic area can influence the association between anthropometric indices and chronic disease, and based on recent studies, the same anthropometric obesity measures cannot be used across all ethnic groups (6, 12, 13).

Considering the lack of reliable data about the prevalence of general and central obesity in adults in the north of Iran and the effect of ethnicity and geographic area on the association between anthropometric indices and chronic diseases (12) and noticing that cardiovascular disease (CVD) is the leading cause of death worldwide and Iran possibly has a higher burden relative to other countries in this region (14), this study was conducted to investigate the prevalence of general and central obesity in adults in the north of Iran and determine the associations of different anthropometric indices with risk factors for CVD, based on the data of the PERSIAN Guilan Cohort Study (PGCS).

Methods

Subjects

The present cross-sectional study was conducted within the framework of the PGCS, a study performed on 10,520 men and women aged between 35 and 70 years in Some'e Sara County (including urban areas and 39 villages), which is located in northern Iran, from October 8, 2014, to January 20, 2017, as part of the Prospective Epidemiological Research Studies in Iran (PERSIAN). The sampling and data collection methods had been previously described in detail (15-19).

Ethical consideration

This study was approved by the Ethics Committee of Guilan University of Medical Sciences in Iran (approval number: IR.GUMS.REC.1398.374).

At baseline, trained health workers walked door-to-door in rural and urban areas to inform individuals of the study and its objectives. Accurate local demographic information was obtained using census data. Research interviewers selected individuals, registered their contact information, and determined their geographic location (20, 21). The exclusion criteria included inability to attend the clinic for physical examination, mental retardation, and unwillingness to participate in the study. Blood pressure was measured twice in each arm after 10-min intervals in sitting position using Richter auscultatory sphygmomanometers (MTM Munich, Germany). Moreover, 1-min pulse rates were evaluated.

Anthropometric indices

In this study, we measured various anthropometric indices (BMI, WC, HC, WHtR, WHR, WHHR, CI, BAI, and ABSI). Trained health-care providers measured anthropometric data, including weight, height, WC, and HC, in a health center. Since measurement errors/biases were least in the morning, anthropometrics were acquired with the participants still fasting. Before weight measurement, weighing scale calibration was performed with 5-kg weights. Moreover, the removal of excess clothes and shoes was recommended to assure accurate measurements. Height was measured while the participants were standing against a wall with their heels and buttocks in contact with the wall. BMI was calculated as weight (in kg) divided by height squared (in m^2). A BMI of 25 kg/m^2 or more was defined as overweight, while that of 30 kg/m^2 or more was characterized as obese. WC and HC were measured to the nearest 0.1 cm using a flexible metric measuring tape with the participants in a standing position. HC was measured at the level of the maximum extension of the buttocks posteriorly in a horizontal plane. WC was determined, in duplicate, at the midpoint between the lowest costal ridge and upper border of the iliac crest. Based on the national cutoff in men and women, a cutoff point of ≥95 cm was considered for WC (22). WHtR, WHR, or WHHR was calculated as WC divided by height, HC, or both in meters, and CI was calculated using the following formula:

$$\text{Conicity index}= \frac{\text{Waist circumference (m)}}{0.109\sqrt{\frac{\text{Weight (kg)}}{\text{Height (m)}}}}$$

As proposed, BAI was calculated as HC (cm) divided by (height (m))$^{1.5}$ minus 18 (23).

ABSI expressing WC and height in m and weight in kg was calculated using the following formula (24):

$$\frac{WC}{BMI^{2/3}\times Height^{1/2}}$$

Blood measurements

For each participant, samples of fasting blood were collected by trained technicians and labeled. Blood samples were transferred in a cold box to the laboratory of the cohort center to assess fasting blood sugar, triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and total cholesterol (TC). The LDL-C/HDL-C ratio was also calculated. Hypertension was defined as a systolic blood pressure (SBP) ≥140 mm Hg and/or a diastolic blood pressure (DBP) ≥90 mm Hg, a prior diagnosis of hypertension by a health professional that one had high BP, or the use of antihypertensive drugs (25).

Diabetes was defined as fasting blood glucose level equal to or higher than 126 mmol/L, on medication for elevated blood glucose level, or with a history of diagnosis of diabetes (26). According to the expert panel of a national cholesterol education program, the practical action points for considering an association between lipid profile levels and the risk of developing CVD were calculated, with TC >200 mg/dL, TG >150 mg/dL, LDL-C >130 mg/dL, and HDL-C <40 mg as the risk factors for CVD (27). Moreover, a LDL-C/HDL-C ratio cutoff point of <2 was considered high risk (28).

Statistical analysis

The statistical analyses were performed by SPSS software version 16 (SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test and histograms were used to test the normality of variables. The t-test and Wilcoxon rank sum Test, wherever applicable, were used to compare the descriptive characteristics for continuous variables, and the chi-square test was applied for categorical variables. The correlation between anthropometric measures and risk factors for CVD was first analyzed using the Pearson correlation method. The odds ratio (OR) of each risk factor according to one unit increase in each anthropometric index was assessed by a multiple logistic regression model that was adjusted for several confounders (age, gender, place of residence, marital status, educational years, and smoking). Furthermore, the adjusted OR of the risk factors for CVD with each increase in standard deviation (SD) of the anthropometric measures and indices was analyzed. A p value <0.05 was considered statistically significant.

Results

Out of the 10,520 adults who were enrolled in the study, 4,887 (46.5%) were men, and 5,633 (53.5%) were women. The general characteristics and anthropometric measurements of the participants are presented based on gender in Table 1.

A higher percentage of men had higher education degree (diploma and university grade), whereas a higher percentage of women were illiterate (p<0.001). The frequency of female smokers was very rare; however, approximately 37% of male participants were currently smokers (p<0.001). Mean±SD of all anthropometric indices (BMI, WC, HC, WHtR, WHR, WHHR, CI, BAI and ABSI) was higher in women than men (p<0.001). Approximately 39.9%, 32.7%, and 62.7% of participants were overweight, obese, and centrally obese, respectively. Although the frequency of overweight was higher in men, the frequency of general and central obesity was dramatically higher in women (p<0.001).

Table 2 represents the biochemical characteristics and risk factors for CVD in both genders. The means ± SD of SBP, DBP, TG, and LDL-C/ HDL-C ratio were higher in men, and the HDL-C level was higher in women (p<0.001). However, the frequency of most risk factors for CVD (diabetes mellitus, hypertension, and hypercholesterolemia (p<0.001) and high LDL-C (p<0.05) was higher in women. A higher percentage of men experienced hypertriglyceridemia and low HDL-C and LDL-C/HDL-C ratio (p<0.001).

Table 3 shows the Pearson correlation between anthropometric measures and indices and hematological factors. BMI and WC were correlated with almost all factors in both genders (p<0.001), except LDL-C that was only correlated in men (p<0.05). All indices were correlated with fasting blood glucose and SBP in all participants (p<0.001). Besides these two risk factors, in women, the DBP was correlated with all indices (p<0.001). However, in men, only SBP was correlated with all indices (p<0.001). The strongest correlation was found between BAI and SBP when both genders were merged together (r=0.7) (p<0.001); however, all other correlations were weak (r<0.3) either in all participants or in genders separately. Among the measures of general obesity, BMI (as an index for general obesity) was best correlated with the risk factors for CVD [three (TG, HDL-C, and LDL-C/HDL-C ratio) and four (diastolic BP, TC, HDL-C, and LDL-C/HDL-C ratio) out of the eight variables of the risk factors for CVD in women and men, respectively]. Among the central adiposity indices, WC was best correlated with the male gender [three (TC, HDL-C, LDL-C/HDL-C ratio) risk factors]. However, in women, there were not any distinct indices that could be best correlated with more than one risk factor [except WHtR that was best correlated with three (SDP, DBP, and TG) out of the studied risk factors].

The strongest correlation coefficients were for WHtR and CI in women (r=0.22) and BMI and WHR (r=0.26) in men. Among all indices, ABSI was not correlated with any of the risk factors for CVD when the samples were considered separately based on gender. However, it had the strongest correlation with HDL-C and LDL-C/HDL-C ratio in all studied population. In addition,

Table 1. General and anthropometric characteristics of the sample of men and women living in the north of Iran

	Total (n=10.520)		Women (n=5.633, 53.5%)		Men (n=4.887, 46.5%)		*P* value
	n	%	n	%	n	%	
Demographic and socioeconomic characteristics							
Age (years)							
35-44	3142	29.9	1712	30.4	1430	29.3	0.243
45-54	3852	36.6	2063	36.6	1789	36.6	
55-65	2730	25.9	1451	25.8	1279	26.2	
>65	796	7.6	407	7.2	389	8.0	
Place of residence							
Urban	4613	43.9	2551	45.3	2062	42.2	0.001
Rural	5907	56.1	3082	54.7	2825	57.8	
Marital status							
Married	9527	90.6	4794	85.1	4733	96.8	
Single, widow, divorced	993	9.4	839	14.9	154	3.2	<0.001
Education years							
Illiterate	1738	16.5	1232	21.9	506	10.4	
1-5 years of schooling	3312	31.5	1977	35.1	1335	27.3	
6-12 years of schooling	4832	45.9	2242	39.8	2590	53.0	
University/college	638	6.1	182	3.2	456	9.3	<0.001
Daily smoking (daily and sometimes)	1827	17.3	32	0.6	1795	36.7	<0.001
Anthropometric measurement and indices							
BMI (kg/m^2)[1]	28.14	5.08	29.92	5.11	26.08	4.20	<0.001
WC (cm)[1]	98.8	12.4	103.3	11.9	93.6	10.9	<0.001
HC (cm)[1]	1025	126	105.5[5]	13.5[6]	995	9.56	<0.001
WHtR1	0.61	0.09	0.66	0.07	0.55	0.06	<0.001
WHR1	0.93	0.06	0.97	0.06	0.94	0.06	0.008
WHHR (m^{-1})[1]	0.59	0.07	0.55	0.04	0.62	0.07	<0.001
CI	1.34	0.09	1.39	0.08	1.29	0.06	<0.001
BAI (%)	32.20	6.88	36.74	5.74	26.97	3.59	<0.001
ABSI ($m^{11/6}\ kg^{-2/3}$)[1]	0.08	0.00	0.08	0.00	0.08	0.00	<0.001
Overweight[2]	4198	39.9	2103	37.3	2095	42.8	<0.001
Obese[3]	3435	32.7	2647	47.0	788	16.1	<0.001
Centrally obese[4]	6594	62.7	4352	77.3	2242	45.9	<0.001

BMI - body mass index; WC - waist circumference; HC - hip circumference; WHtR - waist-to-height ratio; WHR - waist-to-hip ratio; WHHR - waist-to-hip-to-height ratio; CI - conicity index; BAI - body adiposity index; ABSI - a body shape index; [1]Variables are presented as mean and standard deviation (SD). [2]BMI ≥25.0. [3]BMI ≥30.0. [4]Waist circumference ≥95 cm (based on the national cutoff). [5]Median. [6]Interquartile range (IQR)

BAI and CI did not have the strongest correlation with the risk factors in men.

Table 4 represents the adjusted ORs of the risk factors for CVD according to a unit increase in SD of the anthropometric measures and indices. The highest ORs were found for diabetes mellitus [OR, 1.38; 95% confidence interval (CI), 1.12–1.51] and hypertriglyceridemia (OR, 1.33; 95% CI, 1.11–1.52) by each unit increase in WHHR. Each unit increase in WHtR was related with the highest OR for hypertension (OR, 1.62; 95% CI, 1.41–1.83) and high TG (OR, 1.36; 95% CI, 1.22–1.51). Also, the highest risk of low HDL-C and high LDL-C was found for each unit increase in WHtR (OR, 1.52; 95% CI, 1.22–1.78) and ABSI (OR, 0.01; 95% CI, 0.00–0.22), respectively. The risk of diabetes mellitus, hypertension, and hypertriglyceridemia increased by each unit increase in all anthropometric measures and indices (p<0.01).

Discussion

This national study presents alarming rates of general and central obesity in adults in the north of Iran. The findings of this study indicate that the prevalence of overweight–obesity according to the BMI was 72.6% and that of central obesity ac-

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Table 2. Biochemical characteristics and risk factors for cardiovascular disease in the sample of men and women living in the north of Iran

	Total (n=10.520)		Women (n=5.633, 53.5%)		Men (n=4.887, 46.5%)		*P* value
Biochemical characteristics	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Fasting glucose (mg/dL)	104.56	37.17	105.11	38.77	103.92	35.24	0.102
Systolic blood pressure (mm Hg)	118.24	16.75	118.19	16.82	118.31	16.67	<0.001
Diastolic blood pressure (mm Hg)	76.97	11.01	76.84	10.91	77.12	11.12	<0.001
Triglycerides (mg/dL)	160.24	103.02	155.38	94.98	165.91	111.80	<0.001
Total cholesterol (mg/dL)	192.82	38.96	191.19	38.17	194.19	39.59	0.427
HDL-C (mg/dL)	48.39	10.98	49.99	11.09	46.52	10.52	<0.001
LDL-C (mg/dL)	112.87	32.05	112.15	31.73	113.46	32.31	0.256
LDL-C/HDL-C ratio	2.42	0.78	2.37	0.77	2.47	0.80	<0.001
Risk factors for cardiovascular disease							
	n	**%**	**n**	**%**	**n**	**%**	
Diabetes mellitus	2531	24.1	1542	27.3	989	20.2	<0.001
Hypertension	4543	43.2	2639	46.8	1904	38.9	<0.001
High total cholesterol	4121	39.2	2281	40.5	1840	37.7	<0.001
High triglycerides	4538	43.1	2312	41.0	2226	45.5	<0.001
Low HDL-C	2188	20.8	896	15.9	1292	26.4	<0.001
High LDL-C	2927	27.8	1622	28.8	1305	26.7	0.011
High LDL-C/HDL-C	4034	38.3	1930	34.3	2104	43.1	<0.001

HDL-C - high-density lipoprotein cholesterol; LDL-C - low-density lipoprotein cholesterol

cording to the WC and Iranian national cutoff points was 62.7%, which were considerably higher than those of previous studies in the northern part of Iran. In a population-based cross-sectional study in 2006, the overall prevalence rate of obesity and overweight in adults who were living in north of Iran was 53.6%, and the prevalence rate of central obesity was 28.3% (29).

In the present study, the prevalence of obesity and central obesity was higher in women. According to previous studies, the prevalence of greater BMI in women than in men has been reported in several countries, except in Europe (30). Factors related to lifestyle, hormone differences, and multiple pregnancies may therefore be the reasons for the high prevalence of obesity in women (31, 32).

This alarming rate of increase is not restricted to the north of Iran. Recent estimates show the prevalence of overweight and obesity to be increasing at a disturbing rate in other geographic areas of Iran (31, 33, 34). Also, the rate of overweight and obesity is dramatically increasing in other developed and developing countries (30, 35). In recent decades, with the improvement of living standards, overweight, and obesity have become a public health concern worldwide. The transition from a traditional to Western diet and adhering to sedentary lifestyle could be the main reasons of the escalating rates of weight gain in the developing countries such as Iran (36).

Our study shows that after adjusting for age, gender, place of residence, marital status, educational years, and smoking, the risk of diabetes mellitus, hypertension, and hypertriglyceridemia increased by each unit increase in all anthropometric indices. Although all indices generally demonstrated associations with cardiovascular risk factors, the WHHR most consistently showed the strongest associations with the risk factors for CVD, such as diabetes mellitus and hypertriglyceridemia, and the WHtR was more strongly associated with hypertension and high LDL-C/HDL-C ratio than other anthropometric indices. Previous studies on anthropometric indices and cardiovascular risk have shown conflicting results. Our results are in general agreement with those of the previous studies. The superiority of the WHR over BMI and WC in predicting CVD risk is also demonstrated in prospective studies (37-39). In a data from two prospective cohorts of health professionals in the US, the WHtR demonstrated statistically the best model fit and strongest associations with cardiovascular risk (40). In a number of studies, the WHtR was more strongly associated with hypertension, hypertriglyceridemia, hyperglycemia, and metabolic syndrome than BMI or WC in selected populations, primarily among Asian populations (40-43). In a cross-sectional survey, Su et al. (44) showed that the WHR, WHtR, and WC were strongly associated with cardiovascular risk in both genders. According to a study conducted in South Korea, the central obesity indices WC, WHR, and WHtR were better than BMI for the prediction of hypertension in middle-aged (40–69 years) Korean people (45). Another study in Jordan suggested

Table 3. Correlation between anthropometric indices and risk factors for cardiovascular disease

	BMI	WC	WHR	WHtR	WHHR	CI	BAI	ABSI
Overall								
Fasting glucose	0.05**	0.08**	0.12**	0.07**	0.07**	0.08**	0.03**	0.05**
Systolic blood pressure	0.16**	0.18**	0.23**	0.16**	0.16**	0.14**	0.7**	0.08**
Diastolic blood pressure	0.17**	0.17**	0.20**	0.12**	0.11**	0.08**	0.04**	0.01
Triglycerides	0.09**	0.09**	0.09**	0.05**	0.03**	0.02**	0.00	-0.002
Total cholesterol	0.04**	0.05**	0.03**	0.03**	0.03**	0.02**	0.03**	0.01
HDL-C	-0.05**	-0.05**	-0.03**	0.00	0.02*	0.02**	0.04*	0.05**
LDL-C	0.01	0.02**	0.01	0.00	0.01	0.006	0.01	0.03
LDL-C/HDL-C ratio	0.04**	0.05**	0.02*	-0.001	-0.006	-0.01	-0.02**	-0.03**
Women								
Fasting glucose	0.04**	0.08**	0.06**	0.10**	0.13**	0.09**	0.05**	0.10**
Systolic blood pressure	0.14**	0.19**	0.10**	0.21**	0.12**	0.22**	0.13**	0.14**
Diastolic blood pressure	0.18**	0.21**	0.09**	0.22**	0.11**	0.18**	0.14**	0.08**
Triglycerides	0.07**	0.07**	0.04	0.07**	0.0**	0.03*	0.04**	0.01
Total cholesterol	0.02	0.01	0.02	0.02*	0.02*	0.01	0.03*	0.01
HDL-C	-0.08**	-0.08**	-0.02	-0.02	-0.01	-0.001	0.01	0.01
LDL-C	0.00	0.00	0.01	0.01	0.00	0.01	0.02	-0.01
LDL-C/HDL-C ratio	0.04**	0.04**	0.03**	0.02	0.01	0.00	0.00	-0.01
Men								
Fasting glucose	0.07**	0.08**	0.12**	0.08**	0.09**	0.06**	0.06**	0.02
Systolic blood pressure	0.22**	0.22**	0.26**	0.25**	0.23**	0.18**	0.19**	0.07**
Diastolic blood pressure	0.26**	0.24**	0.24**	0.24**	0.19**	0.13**	0.17**	0.00
Triglycerides	0.19**	0.18**	0.15**	0.12**	0.09**	0.09**	0.08**	-0.001
Total cholesterol	0.08**	0.09**	0.03**	0.04**	0.03**	0.03*	0.03**	0.01
HDL-C	-0.18**	-0.19**	-0.10**	-0.11**	-0.05**	-0.07**	-0.08**	-0.00
LDL-C	0.03*	0.04**	-0.003	0.01	0.00	0.01	0.01	0.01
LDL-C/HDL-C ratio	0.14**	0.16**	0.06**	0.09**	0.04**	0.06**	0.07**	0.01

Pearson correlation coefficient. **P*<0.05 ***P*<0.01. HDL-C - high-density lipoprotein cholesterol; LDL-C - low-density lipoprotein cholesterol

to choose the cutoff value of 0.6 in the WHtR for women and 0.57 for men to predict diabetes and hypertension (46).

Some meta-analysis reported interesting findings. Deng et al. (47) showed that the WHtR is a good indicator of discriminating those individuals at increased risk of hypertension, and in some cases, it is better than BMI, WC, and WHR. Based on this meta-analysis in China, the WHtR had the strongest association with hypertension risk (OR, 1.68; 95% CI, 1.29–2.19) (47). In a meta-analysis reported by Aune et al. from cohort studies, a higher BMI is associated with an increased risk of all-cause mortality (48). Data from the baseline survey of Isfahan Healthy Heart Program in 2000–2001 on randomly selected adults in the central part of Iran indicated that higher BMI and WC were significantly associated with hypertension, dyslipidemia, and diabetes mellitus (49). An adult population study in Singapore showed that BAI may function as a measure of overall adiposity but it was not a better indicator than BMI (50).

In the present study, ABSI had the strongest correlation with HDL-C and LDL-C/HDL-C ratio, and it was the solo index that was significantly related with higher odds of low LDL-C. ABSI expresses the excess risk from high WC in a convenient form that is complementary to BMI and other known risk factors (24). In a study on the US population, body shape, as measured by ABSI, appears to be a substantial risk factor for premature mortality in the general population derivable from basic clinical measurements (24). In a meta-analysis reported by Ji et al. (51) about the effectiveness of ABSI in predicting chronic diseases and mortality, ABSI was associated with an increase in the odds of hypertension by 13% and type 2 diabetes by 35% and an increase in CVD risk by 21% and all-cause mortality risk by 55% (51). In a longitudinal study in Spain, Moliner-Urdiales et al. (52) showed that to predict hypertension, BAI could be considered as an alternative to traditional body adiposity measures. In a study from the general population of Vitoria City in Brazil, Oliveira Alvim et al. suggested that the BAI is a useful tool for the risk assessment of type 2 diabetes mellitus in admixture populations (53). In a similar study conducted in north of Iran (Babol), the means of BMI, WC, WHR, and WHtR were significantly higher among diabetic individuals in both sexes.

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Table 4. Odds ratio of risk factors for cardiovascular disease by anthropometric indices[1]

	BMI	WC	WHR	WHtR	WHHR	BAI	ABSI
Diabetes mellitus	1.03 (1.02-1.05)**	1.02 (1.01-1.02)**	2.12 (1.54-2.79)**	1.22 (1.07-1.46)**	1.38 (1.12-1.51)**	1.01 (1.00-1.02)*	1.07 (1.40-4.02)*
Hypertension	1.09 (1.08-1.10)**	1.04 (1.03-1.04)**	1.78 (1.23-2.21)**	1.62 (1.41-1.83)**	1.34 (1.02-1.89)*	1.04 (1.03-1.05)**	258.89 (0.00-2.43)
High total cholesterol	1.02 (1.00-1.03)**	1.00 (0.99-1.00)	1.61 (0.93-2.79)	1.19 (0.95-1.35)	1.23 (0.95-1.63)	1.01 (1.00-1.03)**	0.00 (0.00-0.05)*
High triglyceride	1.03 (1.02-1.04)**	1.01 (1.01-1.02)**	1.13 (1.07-1.24)**	1.36 (1.22-1.51)**	1.33 (1.11-1.52)**	1.01 (1.00-1.02)**	0.00 (0.00-1.10)
Low HDL-cholesterol	1.02 (1.01-1.03)**	1.01 (1.00-1.01)**	1.28 (1.11-1.49)**	1.52 (1.22-1.78)**	1.23 (1.09-1.41)**	1.00 (0.98-1.01)	1.65 (0.00-3.77)
High LDL-cholesterol	1.00 (0.99-1.02)	0.99 (0.99-1.00)	1.05 (0.80-1.38)	1.00 (0.34-2.22)	0.95 (0.69-2.21)	1.00 (0.99-1.02)	0.00 (0.00-0.22)*
High LDL/HDL cholesterol ratio	1.05 (0.99-1.12)	1.03 (1.00-1.05)	1.18 (0.90-1.54)	1.11 (1.05-1.19)	1.02 (0.99-1.05)	1.04 (0.97-1.10)	1.90 (0.00-4.50)

BMI - body mass index; WC - waist circumference; HC - hip circumference; WHtR - waist-to-height ratio; WHR - waist-to-hip ratio; WHHR - waist-to-hip-to-height ratio; BAI - body adiposity index; ABSI - a body shape index. [1]Data are presented as odds ratio (95% confidence interval) adjusted for age, gender, place of residence, marital status, educational years, and smoking. *$P<0.05$, **$P<0.01$

This finding suggested that the overall WC and WHtR exhibited a slightly better discriminate performance than BMI for predicting the risk of diabetes in both men and women, particularly in women (54). The Olivetti Heart Study showed that WC was strongly correlated with hypertension (55).

Previous evidence showed that sex, race, ethnicity, and geographic area can influence the association between anthropometric indices and cardiovascular risk factors and confirmed that the same anthropometric obesity measure cannot be used across all ethnic groups (12, 56). It has been suggested that ethnicity influences specific fat storage, possibly explaining the relationship between ethnicity, adiposity, and CVD risk (57).

The strength and limitation of this study

The strength of this study was the large sample size that was representative of the population living in the north region of Iran from both rural and urban areas. Although some confounders such as age, gender, place of residence, marital status, educational years, and smoking were controlled in the model, some significant confounders such as total energy intake and physical activity were not adjusted.

Conclusion

In conclusion, new indices (e.g., BAI and ABSI) had no extra predicting value compared with the common indices (e.g., BMI and WC) in predicting the risk factors for CVD in adults in the north of Iran. Nevertheless ABSI may be the more appropriate index than other indices to predict high LDL-C. However, the WHHR and WHtR seem to be more valuable indices than BMI, WC, and WHR for predicting distinct risk factors such as diabetes mellitus and high TG (by WHHR), hypertension, and high LDL-C/HDL-C ratio (by WHtR) in their relation with the risk factors for CVD. Furthermore, the WHR was the strongest index for the prediction of high LDL-C/HDL-C ratio.

Details of ethics approval: This project was discussed and confirmed by the Ethics Committee of Guilan University of Medical Sciences (P/3/132/215) and informed written consent was obtained from each subject.

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