ANTHROPOMETRIC INDICES IN ASSOCIATION WITH CARDIOMETABOLIC RISK FACTORS: FINDINGS OF THE ISFAHAN HEALTHY HEART PROGRAM

Nizal Sarrafzadegan[(1)], Roya Kelishadi[(2)], Alireza Najafian[(3)], Alireza Khosravi[(4)], Ahmad Bahonar[(5)], Sedigheh Asgary[(6)], Gholamhossein Sadri[(7)], Ahmad Amani[(8)], Babak Eshrati[(9)]

Abstract

BACKGROUND: Obesity is increasing worldwide, but the debate about the most valid index associated with its health hazards remains unresolved. This study aimed to compare four main anthropometric indices by gender, to determine the best index in predicting cardiometabolic risk factors and to find their cutoff values in the population studied.

METHODS: This study was a cross-sectional community-based study performed on a representative sample of 12,514 adults (aged ≥19 years) selected via 2-stage random cluster sampling from 3 cities in Iran. Partial correlation and ROC curve analyzes were used to determine the best anthropometric indices and their cutoff values.

RESULTS: The study population comprised 6123 males and 6391 females. In both genders, waist circumference (WC) had the highest correlation with cardiometabolic risk factors (6 of 8 risk factors in men and 7 of 8 risk factors in women). ROC analyses showed that in males, the largest area under curve (AUC) was obtained for waist-to-stature ration (WSR) in most risk factors (6 of the 10) followed by body mass index (BMI) and waist-to-height ratio (WHR) with largest AUC (3 of the 10). The corresponding figure for females was obtained for WSR (9 of the 10) followed by BMI and WHR (1 of 10). Optimal cutoff values computed for combination of 3 major risk factors (including diabetes mellitus, hypertension and dyslipidemia) revealed that in males and females, respectively, the cutoff values were 21.9 and 23.5 kg/m^2 for BMI, 80.70 and 84.70 cm for WC, 0.85 and 0.86 for WHR and 0.47 and 0.53 for WSR.

CONCLUSION: WSR could be a valid anthropometric index for predicting cardiometabolic risk factors, and it has less variation than other indices among populations with ethnic differences in body size and fat distribution.

Keywords: Anthropometry, Cardiovascular Risk Factors, Iran, Obesity.

***ARYA Atherosclerosis Journal* 2010, 5(4): 152-162**

Date of submission: 15 Oct 2009, *Date of acceptance:* 20 Des 2009

Introduction

It is widely agreed that chronic non-communicable diseases (CNCDs) are escalating much more rapidly in developing than in industrialized countries.[1] Clustering of metabolic risks increases the risk and mortality of cardiovascular disease

1-Professor of Medicine, Isfahan Cardiovascular Research Center Isfahan, Iran
2- Associate Professor of Pediatrics, Pediatric Preventive Cardiology Department, Isfahan Cardiovascular Research Center, Isfahan University of Medical Sciences, Isfahan, Iran
3- MD, Cardiologist, Isfahan Cardiovascular Research Center, Isfahan Cardiovascular Research Center, Isfahan, Iran
4- Cardiologist, Assistant Professor, Isfahan Cardiovascular Research Center, Isfahan, Iran
5- Executive Manager of Isfahan Cardiovascular Research Center (ICRC), WHO Collaborating Center, Isfahan University of Medical Sciences, Isfahan, Iran
6- Associate Professor of Pharmacognosy, Isfahan Cardiovascular Research Center, Applied Physiology Research Center, Isfahan University of Medical Sciences, Isfahan, Iran
7- PhD, Community Medicine, Research Management Office, Isfahan University of Medical Sciences, Isfahan, Iran
8- General Practitionner, Markazi Province Health Center, Arak, Iran
9- Epidemiologist, Markazi Province Health Center, Arak, Iran
Corresponding author: Roya Kelishadi MD, E-mail: kelishadi@med.mui.ac.ir

(CVD), and all cause mortality.[2]

Obesity is a health risk frequently associated with complications such as type 2 diabetes, dyslipidemia, high blood pressure, abnormal fibrinolysis and CVD.[3]

Population-based studies concerning the correlation of anthropometric indices and the cardiometabolic risk factors have documented that even in young age, abdominal or upper body fat carries an increased risk for metabolic complications such as dyslipidemia, and high fasting glucose, as well as for high blood pressure.[4]

Obesity is reaching to a global epidemic, but the debate about the most valid anthropometric index related to its health hazards remains unresolved.[5]

Both body mass index (BMI) and waist circumference (WC) are well-documented anthropometric indices in association with adverse cardiometabolic outcomes of obesity.[6]

Body mass index (BMI) is perhaps the index most thoroughly studied and its relation with cardiometabolic risk factors and outcomes have been well elucidated by cross-sectional and prospective studies.[7] However, as this index cannot distinguish fat from muscle mass, nor can it represent the fat.

Distribution, there are increasing doubts about the appropriateness of this overall obesity index in predicting CVDs. New anthropometric indices are being suggested from time to time; evidence is mounting for anthropometric indices related to abdominal obesity such as WC, waist-to-hip ratio (WHR), waist-to-stature ratio (WSR), as well as indexes as abdominal sagittal diameter (ASD) that are more sensitive but not feasible to be measured in population-based studies.[8]

There is a growing body of evidence that the Asian populations are predisposed to visceral or abdominal obesity;[9] given that they have smaller body size, notably shorter statures than Western populations do, considering the ratio of different measures might reach to a more appropriate index than simple measures as WC.

Similar to many other developing countries, the epidemiologic transition along with rapid lifestyle changes made Iranians prone to CVD and their risk factors. Our previous studies showed a considerably high prevalence of coronary heart disease[10] and their risk factors[11] in our community. Hence, determining the best anthropometric index predicting such disorders is necessary for epidemiologic studies, as well as routine physical examinations and measurements in primary health care services.

Present study aims to compare the aforementioned anthropometric indices (BMI, WC, WHR and WSR) by gender, to determine the best index in predicting cardiometabolic risk factors and to find their cutoff values in a large representative sample of Iranian population.

Materials and Methods

This cross-sectional study was performed as the baseline survey of a preventive community trial in 3 cities in central Iran, entitled Isfahan Healthy Heart Program (IHHP), the details of which have been previously published,[12-13] and here we report its methods in brief.

Study Participants

Ethics committees and other relevant national regulatory organizations approved the study. Written informed consent was obtained from participants after full explanation of the study protocol.

We considered two provincial cities of Isfahan and Najaf-Abad with populations of 1,895,856 and 275,084, respectively, as venues of intervention. We considered Arak, a provincial city located 375 km northwest of Isfahan with a population of 668,531, as the reference area because of socioeconomic, demographic, health profile similarities to the intervention areas. The populations of the three cities were studied for major CNCD risk factors, as well as the related risk behaviors. Furthermore, we performed continuous surveillance of disease data registry (myocardial infarction, stroke, cancers, etc) in order to identify appropriate and feasible interventions to be scaled up to the national level.

By conducting quota sampling, the study population was stratified by their living area (urban vs. rural) according to regional population distribution as per the national population census in 1999.

The project team conducted this baseline survey of 12,514 randomly selected adults aged ≥ 19 years via 2-stage random cluster sampling. Initially, they randomly selected census blocks from each city and divided them into clusters, each with approximately 1000 households. They randomly selected approximately 5 to 10 of households within these clusters for enumeration. After enumeration, they randomly selected one of the eligible individuals aged ≥ 19 years per household, providing that he or she had Iranian nationality, was mentally competent and not pregnant. We calculated the sample size and divided it into different age groups (19-25, 25-34, 35-44, 45-54, 55-64 and ≥ 65 years) in both sexes according to the distribution in the community.

We doubled the total number owing to our use of the cluster method. Considering the missing rate, we calculated the total number of 12,600 for the 3 cities. The urban-to-rural ratio in Iran is approximately 68/32, and in the cities of Isfahan, Najaf-Abad and Arak it was 90/10, 60/40 and 66/34, respectively. It should be mentioned that in Iran, all places with a population of at least 10000 and having municipality are considered as urban area.

Physical examination

Our team conducted a structured interview using a standardized questionnaire to obtain information on demographic and socioeconomic aspects. A trained team of physicians performed physical examinations using standardized and zero-calibrated instruments. They measured blood pressure (BP) twice in a seated position and recorded the average of two readings for the first and fifth Korotkoff sounds as systolic and diastolic pressures (SBP, DBP), respectively.

They measured height barefoot in standing position to the nearest 0.5 cm using a secured metal ruler, and measured weight in light clothing using calibrated scales. In addition, they measured waist circumference (WC) at a level midway between the lower rib margin and the iliac crest to the nearest half-centimeter.

Laboratory examinations

Trained nurses obtained the participants' blood samples by venipuncture from the left antecubital vein after 12 hours of fasting. They kept all blood samples frozen at -20°C to be assayed within 72 hours at the central laboratory of ICRC, which is under external national and international quality control. The results from the laboratories highly correlated with each other. Serum total cholesterol (TC), triglycerides (TG) and fasting plasma glucose (FPG) measured enzymatically using an auto-analyzer (Eppendorf, Germany) and determined serum HDL cholesterol (HDL-C) after precipitation of low-density and very low-density lipoproteins with dextran sulfate-magnesium.[14-15] Serum low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald equation[16] in subjects with TG < 400 mg/dL, and used standard kits in other cases. The 2-hour post load plasma glucose test (2hpp) was performed by two times of venous blood sampling (in fasting state and 2 hours after drinking a glucose solution) in all participants other than the known cases of diabetes mellitus.

Definition of cardiometabolic risk factors

The metabolic syndrome and its components were defined according to the Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III or ATPIII).[17] Serum triglyceride level (TG) more than 200 mg/dL, HDL-C less than 50 mg/dL for female and less than 40 for male, FBG more than 126 mg/dL, impaired glucose tolerance between 140 and 200 mg/dL, LDL-C more than 170 mg/dL and total cholesterol more than 200 mg/dL were considered as abnormal values.

Considering that the ATP III criteria for hypertension consist of simultaneous systolic and diastolic high BP, the definition of the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure which includes isolated high SBP or DBP (SBP > 140 or DBP > 90 mmHg)[18] was also used for dividing subjects in normotensive and hypertensive groups for comparison of the prevalence of the metabolic syndrome components between them.

Statistical analysis

The data were collected and stored in a computer database. A trained team checked the recorded information for missing values and data entry errors.

After tidying up the data, statistical analyses were performed using the SPSS statistical package for Windows (SPSS Inc., Chicago, USA) at $p < 0.05$.

Two statistical methods, partial correlation and Receiver Operator Characteristic (ROC) curve analyses, were used to determine the best anthropometric index.

Partial correlations were performed between anthropometric indices and cardiometabolic risk factors after adjusting for age.

ROC analyses were used to calculate the area under curve (AUC) between each cardiovascular risk factor and anthropometric index.

Each value of an anthropometric index was used as a cutoff value to calculate its sensitivity and specificity in classifying cardiometabolic risk factors.

The ROC curve is a plot of the sensitivity against 1-specificity for each cutoff value, and the area under curve (AUC) is an indicator of how good the anthropometric indices can distinguish a positive test outcome. AUC ranges from 0 to 1, with 0.5 (diagonal line) indicating that the anthropometric index has no predictive power and 1 indicating perfect power. After determining that which one was the best anthropometric index, the optimal cutoff value was denoted by the value that had the largest sum of sensitivity and specificity.[19]

Results

The study population comprised 6123 males and 6391 females. The mean age had no significant difference in terms of gender (38.9 ± 15.2 years in males and 38.8 ± 14.7 years in females.

The anthropometric and metabolic characteristics of the study population according to gender are presented in Table1. It shows that males had higher height and weight, whereas females had higher levels of BMI, WC and WSR. The mean serum total-, LDL- and HDL-cholesterol were higher in females than in males, while males had higher mean TG values.

WHR, SBP, DBP) and FBS had no significant difference in terms of gender. The prevalence of high TG and low HDL-C levels was significantly higher in males than in females, and high cholesterol level was more prevalent in females. Diabetes and metabolic syndrome were significantly more common in females but this difference was not significant for hypertension between them (Table 2).

In both genders, significant correlations were documented between the four anthropometric indices studied. The correlation of BMI was significant with WC ($r = 0.6$ in both genders), WHR ($r = 0.3$ in males and $r = 0.1$ in females), and WSR ($r = 0.7$ in both genders).

Age adjusted partial correlation coefficients between anthropometric indices and cardiometabolic risk factors are presented in Table 3. In males, WC had the highest coefficient in 6 of 8 risk factors, followed by BMI in 4 risk factors. Similarly, in females WC had highest coefficient in 7 of 8 risk factors followed by BMI in 3 risk factors; in addition, WSR had highest correlation (equal to WC coefficient) with LDL-C and HDL-C.

Table 1. Characteristics of the study population by gender: IHHP

	Men (n = 6123)		Women (n = 6391)		P
	Mean ± SD	CI 95%	Mean ± SD	CI 95%	
Age (years)	38.9±15.2	38.13-38.95	38.8±14.7	37.96-38.71	0.47
Weight (Kg)	71.5±12.4	70.7-71.4	65.2±12.7	64.6-65.3	<0.0001
Height (cm)	170.9±8.5	170.7-171.2	156.6±7.9	56.4-156.8	<0.0001
Body mass index (kg/m^2)	24.5± 4.8	24.27-24.52	26.7±5.9	26.47-26.78	<0.0001
Waist circumference (cm)	88.4±12.1	87.7-88.36	92.6±14.1	92.03-92.76	<0.0001
Waist-to-stature ratio	0.51±0.07	0.514-0.518	0.59±0.09	0.589-0.594	<0.0001
Waist-to-hip ratio	0.89±0.08	0.894-0.899	0.90±0.09	0.900-0.905	0.2
Systolic blood pressure (mmHg)	115.3±17.6	114.7-115.9	114.6±20.4	113.9-115.3	0.14
Diastolic blood pressure (mmHg)	75.5±10.3	75.10-75.8	75.2±11.5	74.8-75.6	0.3
Total cholesterol (mg/dL)	194.65±57.7	190.7-193.6	202.5±54.8	199.3-202.1	<0.0001
LDL-C (mg/dL)	114.3±41.3	113.2-115.4	122±41.8	120.9-123.1	<0.0001
HDL-C (mg/dL)	45.4±11.74	44.9-45.5	48.5±13.4	48.1-48.8	<0.0001
Triglycerides (mg/dL)	178.58±120	158.6-162.8	162±99.9	148.9-152.8	0.000
Fasting plasma glucose (mg/dL)	83.51±29.8	81-82.4	82.02±33.5	81.4-82.9	0.38
2-hour post load plasma glucose (mg/dL)	96.8±47.4	94.1-96.5	105.5±53.4	102.7-105.3	<0.0001

Table 2. Prevalence of cardiometabolic risk factors according to gender: IHHP

	Men(n = 6123)	Women(n = 6391)	P
	n (%)	n (%)	
Hypertension (14)	987(18.7)	1136(18.9)	0.07
Total cholesterol >200 mg/dL	2459(40.2)	2965(46.4)	<0.0001
LDL-C> 170 mg/dL	692(11.31)	980(15.3)	<0.0001
Low HDL-C*	746(12.5)	460(7.4)	<0.0001
Triglycerides >200 mg/dL	1755(29.2)	1582(25.1)	<0.0001
Fasting plasma glucose>125 mg/dL	311(5.2)	402(6.4)	0.004
140<2-hpp<200 mg/dL	250(4.2)	424(6.8)	<0.0001
Metabolic syndrome[17]	623(10.7)	2145(35)	<0.0001

* HDL < 40 mg/dL for men and HDL < 50 mg/dL for women were considered as low level.
2-hpp: 2-hour post load plasma glucose test.

In the ROC analyses conducted among males, the largest AUC was obtained for WSR in most risk factors (6 of the 10) followed by BMI and WHR with largest AUC in 3 (factors had equal AUC with other anthropometric indices in some cases). In females, the best anthropometric index was WSR with largest AUC in 9 of the 10 risk factors followed by BMI and WHR (1 of 10) (Table 4).

The optimal cutoff values of the anthropometric indices in relation to each cardiometabolic risk factor in males and females are presented in Table 5.

The cutoff values in males ranged from 19.9 to 29.3 kg/m^2 for BMI, 73.7 to 80.7 cm for WC, 0.81 to 0.85 for WHR and 0.43 to 0.47 for WSR. The corresponding figures for females were 20.4 to 23.5 kg/m^2, 75.7 to 84.7cm, 0.78 to 0.86 and 0.45 to 0.53.

Optimal cutoff values were also computed for combination of 3 major risk factors (including diabetes mellitus, hypertension and dyslipidemia) and revealed that in males and females, respectively, the cutoff values were 21.9 and 23.5 kg/m^2 for BMI, 80.70 and 84.70 cm for WC, 0.85 and 0.86 for WHR and 0.47 and 0.53 for WSR.

Discussion

In this population-based study, we found that although anthropometric indices are significantly inter-related, and are all associated with cardiometabolic risk factors, but WSR was the best in predicting these risk factors. This finding is suggested to be being, at least in part, because of ethnic differences in terms of body size and fat deposition. The anthropometric indices proposed in Western

Table 3. Age-adjusted partial correlation coefficients between cardiometabolic factors and anthropometric indices: IHHP

	Males				Females			
	WC	BMI	WHR	WSR	W.C	BMI	WHR	WSR
TC	0.12*	0.15*	0.08*	0.12*	0.17*	0.13*	0.12*	0.16*
LDL-C	0.07*	0.08*	0.06*	0.07*	0.13*	0.1*	0.11*	0.13*
HDL-C	-0.09*	-0.09*	-0.03	-0.07*	-0.04*	-0.03	-0.03	-0.04
TG	0.31*	0.31*	0.18*	0.28*	0.27*	0.24*	0.15*	0.25*
FPG	0.1*	0.07*	0.06*	0.09*	0.07*	0.07*	0.03	0.06*
2-hpp	0.08*	0.04*	0.08*	0.08*	0.05*	0.05*	0.04	0.04*
SBP	0.19*	0.15*	0.08*	0.16*	0.19*	0.14*	0.12*	0.17*
DBP	0.18*	0.15*	0.09*	0.14*	0.15*	0.16*	0.07*	0.13*

*P<0.05
BMI: Body mass index (kg/m^2); WC: Waist circumference (cm); WSR: Waist-to-stature ratio; WHR: Waist-to-hip ratio; TC: Total cholesterol (mg/dL); TG: Triglycerides (mg/dL); FBG: Fasting plasma glucose (mg/dL); 2-hpp: 2-hour post load plasma glucose test; SBP: Systolic blood pressure (mmHg); DBP: Diastolic blood pressure (mmHg).

Table 4. Area under the receiver operating characteristic curve for anthropometric indices as predictors of cardiometabolic risks factors by gender: IHHP.

	Area under the receiver operating characteristic curve							
	BMI		WC		WHR		WSR	
	Males	Females	Males	Females	Males	Females	Males	Females
Metabolic syndrome	0.81(0.8-0.83)	0.72(0.71-0.74)	0.78(0.85-0.88)	0.75(0.74-0.77)	0.8(0.78-0.82)	0.70(0.69-0.71)	**0.86(0.85-0.88)**	**0.76(0.75-0.77)**
Hypertension	0.65(0.63-0.67)	0.66(0.64-0.67)	0.67(0.67-0.70)	0.68(0.66-0.70)	0.68(0.66-0.7)	0.67(0.65-0.69)	**0.70(0.68-0.72)**	**0.70(0.69-0.72)**
Hypertriglyceridemia	**0.74(0.73-0.75)**	0.07(0.67-0.71)	0.72(0.70-0.73)	0.71(0.69-0.72)	0.67(0.66-0.69)	0.66(0.65-0.68)	0.72(0.70-0.73)	**0.72(0.70-0.73)**
Low HDL	**0.56(0.54-0.58)**	**0.52(0.50-0.55)**	0.55(0.53-0.58)	0.5(0.48-0.53)	0.54(0.52-0.56)	0.48(0.46-0.51)	0.54(0.52-0.56)	0.49(0.46-0.52)
FPG>126	0.68(0.65-0.71)	0.65(0.62-0.68)	0.73(0.7-0.76)	0.68(0.65-0.70)	0.73(0.71-0.76)	0.67(0.64-0.70)	**0.75(0.72-0.77)**	**0.69(0.66-0.71)**
140<2-hpp<200	0.65(0.61-0.68)	0.60(0.57-0.63)	0.67(0.64-0.70)	0.59(0.56-0.62)	**0.69(0.66-0.72)**	0.59(0.56-0.62)	**0.69(0.66-0.73)**	**061(0.58-0.63)**
SBP>140 mmHg	0.62(0.59-0.66)	0.63(0.61-0.66)	0.67(0.64-0.71)	0.66(0.63-0.69)	**0.70(0.67-0.73)**	0.66(0.63-0.69)	**0.70(0.67-0.73)**	**0.67(0.65-0.70)**
DBP>90 mmHg	0.63(0.6-0.66)	0.62(0.6-0.65)	0.67(0.64-0.70)	0.63(0.60-0.66)	**0.67(0.65-0.70)**	**0.64(0.61-0.67)**	0.67(0.64-0.70)	**0.64(0.61-0.67)**
Diabetes	0.68(0.65-0.71)	0.65(0.62-0.67)	0.73(0.70-0.76)	0.69(0.66-0.71)	0.74(0.71-0.77)	0.68(0.65-0.70)	**0.75(0.72-0.78)**	**0.70(0.67-0.72)**
Dyslipidemia	**0.66(0.65-0.67)**	0.65(0.64-0.66)	0.66(0.64-0.67)	0.65(0.64-0.67)	0.62(0.60-0.64)	0.62(0.61-0.64)	0.65(0.64-0.66)	**0.66(0.65-0.67)**

The best index is marked as bold.
Definitions and abbreviations are the same as those in Table 3.

Table 5. Optimal cutoff value, sensitivity, specificity and likelihood ratios of anthropometric indices for predicting cardiometabolic risk factors according to gender: IHHP.

	BMI				WC				WHR				WSR			
	Cut-off	Se	SP	LR	Cut-off	Se	SP	LR	Cut-off	Se	SP	LR	Cut-off	Se	SP	LR
Males																
Diabetes	21.50	0.90	0.73	3.3	80.7	0.91	0.70	3	0.85	0.90	0.70	3	0.47	0.93	0.70	3.1
Dyslipidemia	29.3	0.90	0.78	4.1	74.7	0.91	0.82	5	0.81	0.90	0.79	4.3	0.43	0.90	0.78	4.1
SBP>140 mmHg	21	0.90	0.77	2.7	79.7	0.90	0.74	3.5	0.85	0.91	0.70	3	0.46	0.90	0.71	3.1
DBP>90 mmHg	21	0.90	0.77	2.7	77.7	0.91	0.80	4.5	0.85	0.90	0.70	3	0.46	0.90	0.73	3.3
FPG>126 mg/dL	21.2	0.90	0.70	3	80.7	0.90	0.70	3	0.85	0.94	0.70	3.1	0.47	0.93	0.70	3.1
High TG	21.1	0.94	0.70	3.1	78.7	0.92	0.71	3.2	0.84	0.90	0.70	3	0.45	0.92	0.70	3.1
High TC	20.6	0.90	0.76	3.7	75.5	0.90	0.81	4.7	0.82	0.90	0.79	4.3	0.44	0.90	0.76	3.7
Low HDL-C	19.9	0.90	0.86	6.4	73.7	0.91	0.89	8.3	0.81	0.90	0.86	6.4	0.43	0.90	0.86	6.4
High LDL-C	20.3	0.90	0.83	5.3	76.7	0.90	82	5	0.83	0.90	0.77	3.9	0.44	0.90	0.79	4.3
140<2-hpp<200	20.1	0.90	0.85	6	77.7	0.90	0.80	4.5	0.85	0.91	0.70	3	0.46	0.90	0.75	3.6
Metabolic syndrome	21.6	0.96	0.70	3.2	79.7	0.97	0.73	5.7	0.85	0.96	0.70	3.2	0.46	0.97	0.70	3.2
Hypertension	21.1	0.90	0.75	3.6	78.7	0.90	0.76	6.4	0.84	0.90	0.75	3.6	0.45	0.97	0.70	3.2
3-Risk factors (diabetes, hypertension, dyslipidemia)	21.9	0.93	0.70	3.1	80.7	0.97	0.71	3.3	0.85	0.96	0.70	3.2	0.47	0.98	0.70	3.3
Females																
Diabetes	23.01	0.90	0.72	3.20	84.7	0.92	0.71	3.2	0.84	0.90	0.75	3.6	0.53	0.92	0.70	3.1
Dyslipidemia	21.7	0.90	0.75	3.6	77.7	0.91	0.79	4.3	0.8	0.90	0.81	4.7	0.50	0.90	0.72	3.2
SBP>140 mmHg	22.7	0.90	0.74	3.5	83.5	0.90	0.72	3.2	0.85	0.90	0.71	3.1	0.53	0.90	0.70	3
DBP>90 mmHg	22.2	0.90	0.78	4.1	79.7	0.92	0.86	3.8	0.84	0.90	0.76	3.7	0.51	0.9	0.78	4.1
FPG>126 mg/dL	23.1	0.90	0.72	3.2	84.7	0.90	0.70	3	0.84	0.90	0.74	3.5	0.53	0.91	0.70	3
High TG	22.7	0.92	0.70	3.1	82.7	0.91	0.70	3	0.83	0.90	0.73	3.3	0.52	0.92	0.70	3.1
High TC	21.9	0.90	0.73	3.3	78.9	0.90	0.77	2.7	0.81	0.90	0.79	4.3	0.50	0.90	0.75	3.6
Low HDL-C	20.4	0.95	0.89	8.6	75.7	0.90	0.88	4.1	0.78	0.90	0.90	9	0.47	0.90	0.88	7.5
High LDL-C	22.2	0.90	0.76	3.7	79.7	0.90	0.80	4.5	0.82	0.90	0.80	4.5	0.51	0.90	0.77	3.9
140<2-hpp<200	21.6	0.90	0.82	4.1	76.7	0.90	0.86	6.4	0.80	0.90	0.84	5.6	0.49	0.90	0.83	5.3
Metabolic syndrome	22.3	0.94	0.70	3.1	79.7	0.98	0.73	3.6	0.84	0.91	0.70	3	0.46	0.97	0.70	3.2
Hypertension	22.5	0.90	0.74	3.5	81.5	0.91	0.74	3.5	0.84	0.90	0.72	3.2	0.45	0.90	0.74	3.5
3-Risk factors (diabetes, hypertension, dyslipidemia)	23.5	0.94	0.70	3.1	84.7	0.97	0.71	3.3	0.86	0.97	0.70	3.2	0.53	0.96	0.70	3.2

Definitions and abbreviations are the same as those in Table 3.

countries with taller populations might be not applicable in other ethnicities, and consequently the necessity of using different cutoff values for anthropometric measures in different populations. The priority of WSR in predicting cardiometabolic risk factors is suggested to be because it includes two anthropometric measures of WC and height which have large ethnic differences; hence by providing the ratio of these measures, it can be applicable in different ethnic group. There are several advantages for WSR to make it the best indicator of cardiovascular risks in health promotion. WSR has been shown to be a good indicator of abdominal visceral fat,[20] cardiometabolic factors, CVDs and mortality both in cross-sectional[21-23] and cohort studies.[24] Practically, as both waist circumference and stature are easy to measure, WSR as a ratio of the two can be easily calculated no matter what unit of measurement was used.[25]
Our finding is consistent with some previous studies mostly conducted among South Asians. A population-based study in Hong Kong Chinese[25] and a study among Singaporean women,[26] found that WSR might be the best anthropometric index in relation to cardiometabolic risk factors. A study in Japan showed that WSR is more sensitive than BMI or WC to evaluate clustering of coronary risk factors among non-obese men and women.[23] However, some studies in Western countries found that other anthropometric indexes have better correlation with CVD risk factors than WSR has. A study among Canadians revealed that WC and BMI correlated most closely with blood pressure and plasma lipids.[27] In the study of Zhu et al. among Americans of three race–ethnicity groups, WC followed by BMI were the most sensitive anthropometric indexes in predicting CVD risk.[28]

Contrary to a previous population-based study among Iranians found that WHR is a better screening measure for cardiometabolic risk factors in Iranian men[29] and women,[30] we documented a weak correlation for this index among both genders. This disagreement between the findings of these studies in a same ethnic group might be because our study comprised urban and rural residents of three cities, and was representative of a general population, whereas the aforementioned study included only the urban residents of the Metropolitan Tehran.

As mentioned before, we used two major statistical methods of partial correlation and ROC analysis to find the best anthropometric indices. In selecting the best anthropometric index as a screening tool for cardiovascular risks, some previous studies have compared the correlation coefficients between risk factors and the indices.[31-32] Based on this method, in our study, WC had the highest coefficient in both genders. But, as stated by Ho et al., correlation coefficients could not be a valid method in comparing indices to choose the best one as a screening tool because this method suffers from the drawback that the anthropometric indices are highly correlated.[25] Furthermore, ROC analyses, have long been used in other situations to compare the efficacy of screening tools and to determine the optimal cutoff values.[33-34] Using latter method in the current study revealed that WSR was the best anthropometric index in predicting cardiometabolic risk factors.

In our study, findings of partial correlation and ROC analysis documented that in both genders, BMI was inferior to WC and WSR in predicting cardiometabolic risk factors, however it was significantly correlated with these two indices.

Among males, WSR was the best predictor for cardiovascular risk factors followed by BMI and WHR with similar strength, whereas among females, none of the indices were comparable to WSR in predicting cardiometabolic risk factors. These findings are consistent with the notion that abdominal obesity is more directly related to CVD risks than overall obesity as indicated by BMI. Furthermore, BMI cannot distinguish fat from muscle mass, and hence risks tend to be overstated in muscular athletes and understated in older persons whose muscle mass is replaced by fat to varying degrees.[35] We would suggest to consider WSR in future population-based studies and routine physical examinations in primary health care settings, nonetheless we should acknowledge that WC has the advantage of being a the simplest index as it involves only one measurement.

The increased health risks associated with

obesity have been found to occur in Asians at lower BMIs, hence different cutoff values are suggested for BMI and WC in various Asian populations.[36]

In the present study, BMI cutoff values for combination of 3 major cardiometabolic risk factors were 21.9 and 23.5 kg/m^2 for males and females, respectively.

A study on Asian population proposed as cutoff value of 23 kg/m^2 for BMI in both genders,[35] a study in Hong Kong Chinese has supported this value and documented the cutoff value of 23.4 kg/m^2 for both genders.[25] A study in China[37] and a study in Thailand[38] confirmed that a BMI cutoff value of 23 might be appropriate for use in identification of high risk of obesity-related metabolic disorders. An optimal cut-off value of 23.6 for BMI in males and 22.1 in females is suggested for Taiwanese population.[39] A study in Tunisia found that the optimum BMI cut-off points for predicting cardiovascular risk factors were 24 kg/m^2 in men and 27 kg/m^2 in women.[40] Noteworthy to state that the cut-off values obtained in South Asians did not differ in terms of gender, but the limited studies conducted in the Eastern Mediterranean region, as the Tunisian[40] and the current study documented higher BMI cutoff values for females. This is another confirmatory observation on ethnic differences in anthropometric indices and their association with cardiometabolic risk factors.

In the current study, a WC cutoff value of 80.7 cm was documented for males, and 84.7 cm for females. Other studies in Asian countries found different cut-off values; the appropriate WC cutoff value for central obesity for males and females, respectively is determined to be 78.2 and 74.7 cm in China,[25] 90 and 85 cm in Korea,[41] 80.5 and 71.5 cm in Taiwan ,[39] 81.5-84 and 76-80.5 cm in Thailand,[38] 85 cm for both genders in Tunisia,[40] 97 cm and 99 cm in Iraq[42] and 89 and 91cm in Iran.[43]

While studies among South Asians documented higher cutoff values for WC among males than in females, the study in Tunisia found similar cutoff values for both genders, and the studies in Iraq[42] and Iran[43] as well as the current study revealed higher cutoff values for females than males.

In addition to ethnic differences, sedentary lifestyle in females of this region, as documented in Iranian women[44-45] might be a contributing factor.

A study in Sweden revealed that immigrant women from Iran and Turkey are heavier than women born in Sweden and have a higher prevalence of abdominal obesity, an unfavorable lipid profile.[46] Another study among 30 migrants from Pakistan to the UK, 30 British-born British Pakistani women, and 25 British-born women of European origin found that British-born British Pakistani women had healthier levels of anthropometric indices and lipid profile, i.e. a lower WHR, lower mean TG levels, and higher mean HDL-C levels than migrant British Pakistani women did.[47] These findings confirm the gene-environment interaction in the development of the chronic diseases and their risk factors.

WSR cutoff values for combination of 3 major risk factors in present study were documented as 0.53 for males and 0.47 for females.

Some studies in Japan proposed 0.5 as optimal cutoff values for WSR both for males[22] and females.[23] Our finding is consistent with a study in Hong Kong that found WSR cutoff values of 0.48–0.51 in males and 0.49–0.52 in females for predicting hypertension, diabetes, dyslipidaemia and albuminuria.[5] Taking into consideration that in spite of considerable differences between the WC cutoff values obtained in the current study and those in South Asians, the cutoff points obtained for WSR are comparable in these populations, WSR can be a valid anthropometric index in different populations.

Study limitations

The main limitation of this study is its cross-sectional nature, the prediction of cardiometabolic risk factors by anthropometric indices should be interpreted with caution given the cross-sectional nature of the associations. The ongoing longitudinal part of IHHP will be able to assess the current findings.

Conclusion

We found that WSR could be a valid anthropometric index for predicting cardiometabolic risk

factors. It has less variation than other indices among populations with ethnic differences in body size and fat distribution. We suggest that WSR might be considered in epidemiologic studies, as well as physical examinations in primary health care settings.

Funding: This program was supported by a grant (No. 31309304) from the Iranian Budget and Planning Organization, as well as the Deputy for Health of the Iranian Ministry of Health and Medical Education, Isfahan Cardiovascular Research Centre and Isfahan Provincial Health Center, both affiliated to Isfahan University of Medical Sciences.

Ethical Approval: The study was approved by the Ethics Committee of Isfahan Cardiovascular Research Center, Isfahan University of Medical Sciences (ICRC-IUMS) (NIH Code: FWA 0000t8578).

Conflict of Interests

Authors have no conflict of interests.

References

1. Yusuf S, Reddy S, Ounpuu S, Anand S. Global burden of cardiovascular diseases: Part II. variations in cardiovascular disease by specific ethnic groups and geographic regions and prevention strategies. Circulation 2001; (104): 2855-64.
2. Isomaa B, Almgren P, Tuomi T, Forsén B, Lahti K, Nissén M, et al. Cardiovascular morbidity and mortality associated with the metabolic syndrome. Diabetes Care 2001; (24): 683-9.
3. Turner RC. The role of obesity in diabetes. Int J Obes Relat Metab Disord1992; 16 Suppl 2: S43-6.
4. Weiss R, Dufour S, Taksali SE, Tamborlane WV, Petersen KF, Bonadonna RC, et al. Prediabetes in obese youth: a syndrome of impaired glucose tolerance, severe insulin resistance, and altered myocellular and abdominal fat partitioning. Lancet 2003; 362(9388): 951-7.
5. Ko GT, Chan JC, Cockram CS, Woo J. Prediction of hypertension, diabetes, dyslipidaemia or albuminuria using simple anthropometric indexes in Hong Kong Chinese. Int J Obes Relat Metab Disord 1999; 23(11): 1136-42.
6. WHO. Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation. World Health Organ Tech Rep Ser 2000; (894): 1-253.
7. Hu FB, Wang B, Chen C, Jin Y, Yang J, Stampfer MJ, et al. Body mass index and cardiovascular risk factors in a rural Chinese population. Am J Epidemiol 2000; 151(1): 88-97.
8. Lemieux S, Prud'homme D, Bouchard C, Tremblay A, Després JP. A single threshold value of waist girth identifies normal-weight and overweight subjects with excess visceral adipose tissue. Am J Clin Nutr 1996; 64 (5): 685-93.
9. Hsieh SD, Yoshinaga H, Muto T, Sakurai Y. Anthropometric obesity indices in relation to age and gender in Japanese adults. Tohoku J Exp Med 2000; 191(2): 79-84.
10. Sarraf-Zadegan N, Sayed-Tabatabaei FA, Bashardoost N, Maleki A, Totonchi M, Habibi HR, et al. The prevalence of coronary artery disease in an urban population in Isfahan, Iran. Acta Cardiol 1999; 54(5): 257-63.
11. Sarraf-Zadegan N, Boshtam M, Rafiei M. Risk factors for coronary artery disease in Isfahan, Iran. Eur J Public Health 1999; 9(1): 41-4.
12. Sarraf-Zadegan N, Sadri G, Malek Afzali H, Baghaei M, Mohammadi Fard N, Shahrokhi S, et al. Isfahan healthy heart programme: a comprehensive integrated community-based programme for cardiovascular disease prevention and control. Design, methods and initial experience. Acta Cardiol 2003; 58(4): 309-20.
13. Sarrafzadegan N, Baghaei A, Sadri Gh, Kelishadi R, Malekafzali H, Boshtam M. Isfahan healthy heart program: Evaluation of comprehensive, community-based interventions for non-communicable disease prevention. Prevention and Control 2006; 2: 73-84.
14. Mc Namara JR, Schaefer EJ. Automated enzymatic standardized lipid analyses for plasma and lipid lipoprotein fractions. Clin Chem Acta 1987; 166: 1-8.
15. Warnick GR, Benderson J, Albers JJ. Dextran sulfate-magnesium precipitation procedure for quantitation of high-density lipoprotein cholesterol. Clin Chem 1982; 28: 1379-82.
16. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 1972; 18(6): 499-502.
17. National Institutes of Health, Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation 2002; 106(25): 3143-421.
18. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, et al. National heart, lung, and blood institute joint national committee on prevention, detection, evaluation, and treatment of high blood pressure; national high blood pressure education program coordinating committee. The seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. JAMA 2003; 289(19): 2560-72.

19. Farr BM, Shapiro DE. Diagnostic tests: distinguishing good tests from bad and even ugly ones. Infect Control Hosp Epidemiol 2000; 21(4): 278-84.

20. Ashwell M, Cole TJ, Dixon AK. Ratio of waist circumference to height is strong predictor of intra-abdominal fat. BMJ 1996; 313(7056): 559-60.

21. Ashwell M, Lejeune S, McPherson K. Ratio of waist circumference to height may be better indicator of need for weight management. BMJ 1996; 312(7027): 377.

22. Hsieh SD, Yoshinaga H. Abdominal fat distribution and coronary heart disease risk factors in men-waist/height ratio as a simple and useful predictor. Int J Obes Relat Metab Disord 1995; 19(8): 585-9.

23. Hsieh SD, Yoshinaga H. Waist/height ratio as a simple and useful predictor of coronary heart disease risk factors in women. Intern Med 1995; 34 (12): 1147-52.

24. Cox BD, Whichelow M. Ratio of waist circumference to height is better predictor of death than body mass index. BMJ 1996; 313(7070): 1487.

25. Ho SY, Lam TH, Janus ED. Hong Kong Cardiovascular Risk Factor Prevalence Study Steering Committee. Waist to stature ratio is more strongly associated with cardiovascular risk factors than other simple anthropometric indices. Ann Epidemiol 2003; 13(10): 683-91.

26. Pua YH, Ong PH. Anthropometric indices as screening tools for cardiovascular risk factors in Singaporean women. Asia Pac J Clin Nutr 2005; 14(1): 74-9.

27. Ledoux M, Lambert J, Reeder BA, Després JP. A comparative analysis of weight to height and waist to hip circumference indices as indicators of the presence of cardiovascular disease risk factors. Canadian heart health surveys research group. CMAJ 1997; 157 (Suppl 1): S32-8.

28. Zhu S, Heymsfield SB, Toyoshima H, Wang Z, Pietrobelli A, Heshka S. Race-ethnicity-specific waist circumference cutoffs for identifying cardiovascular disease risk factor. Am J Clin Nutr 2005; 81(2): 409-15.

29. Esmaillzadeh A, Mirmiran P, Azizi F. Waist-to-hip ratio is a better screening measure for cardiovascular risk factors than other anthropometric indicators in Tehranian adult men. Int J Obes Relat Metab Disord 2004; 28(10): 1325-32.

30. Azizi F, Esmaillzadeh A, Mirmiran P, Ainy E. Is there an independent association between waist-to-hip ratio and cardiovascular risk factors in overweight and obese women? Int J Cardiol 2005; 101(1): 39-46.

31. Ko GT, Chan JC, Woo J, Lau E, Yeung VT, Chow CC, et al. Simple anthropometric indexes and cardiovascular risk factors in Chinese. Int J Obes Relat Metab Disord 1997; 21(11): 995-1001.

32. Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N, et al. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. Int J Obes Relat Metab Disord 2000; 24(11): 1453-8.

33. Rankinen T, Kim SY, Pérusse L, Després JP, Bouchard C. The prediction of abdominal visceral fat level from body composition and anthropometry: ROC analysis. Int J Obes Relat Metab Disord 1999; 23(8): 801-9.

34. Taylor RW, Keil D, Gold EJ, Williams SM, Goulding A. Body mass index, waist girth, and waist-to-hip ratio as indexes of total and regional adiposity in women: evaluation using receiver operating characteristic curves. Am J Clin Nutr 1998; 67(1): 44-9.

35. Willett WC, Dietz WH, Colditz GA. Guidelines for healthy weight. N Engl J Med 1999; 341(6): 427-34.

36. WHO/IASO/IOTF. The Asia-Pacific perspective: redefining obesity and its treatment. Sydney: Health Communications; 2000.

37. Weng X, Liu Y, Ma J, Wang W, Yang G, Caballero B. Use of body mass index to identify obesity-related metabolic disorders in the Chinese population. Eur J Clin Nutr 2006; 60: 931-7.

38. Narksawat K, Podang J, Punyarathabundu P, Podhipak A. Waist circumference, body mass index and health risk factors among middle aged Thais. Asia Pac J Public Health 2007; 19: 10-5.

39. Lin WY, Lee LT, Chen CY, Lo H, Hsia HH, Liu IL, et al. Optimal cut-off values for obesity: using simple anthropometric indices to predict cardiovascular risk factors in Taiwan. Int J Obes Relat Metab Disord 2002; 26: 1232-8.

40. Bouguerra R, Alberti H, Smida H, Salem LB, Rayana CB, El Atti J, et al. Waist circumference cut-off points for identification of abdominal obesity among the Tunisian adult population. Diabetes Obes Metab 2007; 9(6): 859-68.

41. Lee SY, Park HS, Kim DJ, Han JH, Kim SM, Cho GJ, et al. Appropriate waist circumference cutoff points for central obesity in Korean adults. Diabetes Res Clin Pract 2007; 75: 72-80.

42. Mansour AA, Al-Hassan AA, Al-Jazairi MI. Cut-off values for waist circumference in rural Iraqi adults for the diagnosis of metabolic syndrome. Rural Remote Health 2007; 7: 765.

43. Delavari A, Forouzanfar MH, Alikhani S, Sharifian A, Kelishadi R. The first nationwide study of the prevalence of the metabolic syndrome and optimal cut-off points of waist circumference in the Middle East: the national survey of risk factors for non-communicable diseases of Iran. Diabetes Care 2009.

44. Sarrafzadegan N, Kelishadi R, Baghaei A, Hussein Sadri G, Malekafzali H, Mohammadifard N, et al. Metabolic syndrome: an emerging public health problem in Iranian women: Isfahan healthy heart program. Int J Cardiol 2008; 131: 90-96.

45. Kelishadi R, Alikhani S, Delavari A, Alaedini F, Safaie A, Hojatzadeh E. Obesity and associated lifestyle behaviours in Iran: findings from the First national

non-communicable disease risk factor surveillance survey. Public Health Nutr 2008; 11: 246-51.

46. Daryani A, Berglund L, Andersson A, Kocturk T, Becker W, Vessby B. Risk factors for coronary heart disease among immigrant women from Iran and Turkey, compared to women of Swedish ethnicity. Ethn Dis 2005; 15: 213-20.

47. Pollard TM, Unwin N, Fischbacher C, Chamley JK. Differences in body composition and cardiovascular and Type 2 diabetes risk factors between migrant and British-born British Pakistani women. Am J Hum Biol 2008; 20(5): 545-9.