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Waist:height ratio: a superior index in estimating cardiovascular risks in Turkish adults

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Abstract

Objective: To determine the best anthropometric measurement among waist: height ratio (WHtR), BMI, waist:hip ratio (WHR) and waist circumference (WC) associated with high CHD risk in adults and to define the optimal cut-off point for WHtR.
Design: Population-based cross-sectional study.
Setting: Balcova, Izmir, Turkey.
Subjects: Individuals (*n* 10 878) who participated in the baseline survey of the Heart of Balcova Project. For each participant, 10-year coronary event risk (Framingham risk score) was calculated using data on age, sex, smoking status, blood pressure, serum lipids and diabetes status. Participants who had risk higher than 10 % were defined as 'medium or high risk'.
Results: Among the participants, 67·7 % were female, 38·2 % were obese, 24·5 % had high blood pressure, 9·2 % had diabetes, 1·5 % had undiagnosed diabetes (≥126 mg/dl), 22·0 % had high total cholesterol and 45·9 % had low HDL-cholesterol. According to Framingham risk score, 32·7 % of them had a risk score higher than 10 %. Those who had medium or high risk had significantly higher mean BMI, WHtR, WHR and WC compared with those at low risk. According to receiver-operating characteristic curves, WHtR was the best and BMI was the worst indicator of CHD risk for both sexes. For both men and women, 0·55 was the optimal cut-off point for WHtR for CHD risk.
Conclusions: BMI should not be used alone for evaluating obesity when estimating cardiometabolic risks. WHtR was found to be a successful measurement for determining cardiovascular risks. A cut-off point of '0·5' can be used for categorizing WHtR in order to target people at high CHD risk for preventive actions.

Keywords
CHD
Risk
Waist:height ratio
Anthropometric measurement

Obesity, particularly abdominal obesity, is associated with metabolic abnormalities such as insulin resistance, impaired glucose tolerance and elevated serum lipids, as well as hypertension, diabetes, CVD and mortality[1,2]. BMI has been used for determining obesity for many years, but within the last two decades measurements of abdominal obesity such as waist circumference (WC), waist:hip ratio (WHR) and waist:height ratio (WHtR) have become more important in defining associations between obesity and cardiometabolic risks[2,3].

Defined by Adolphe Quetelet in the 19th century, BMI is the most frequently used obesity index, but today we know that it has many disadvantages. First of all, it provides information about total body fat and does not provide clues regarding fat mass or fat distribution. Moreover, even though it uses only weight and height, a calculator is needed for its calculation. Finally, the WHO has defined cut-off points for BMI in adults, but these cut-off points are not applicable for children and the elderly[4–6].

In the late 1940s, the French physician Jean Vague stated that fat distribution in the body is more important than total body fat and defined gynoid and android type fatness, with latter being more hazardous for cardiometabolic risks. However, the importance of fat distribution in association with CVD began to be discussed in the 1980s[2,7]. In the 1990s, it was hypothesized that WC alone would be enough to estimate cardiometabolic risks. Even though measuring WC is very practical, easy and cheap, it has unfavourable aspects such as being affected by race and not taking height into account[8]. Moreover, in a study conducted in Japan, it was found that short people having moderate WC had a higher cardiometabolic risk than taller people[9].

WHtR (WC divided by height) is a relatively new abdominal obesity index. Ashwell and co-workers were the first to suggest using WHtR in the mid-1990s[10,11]. On the basis of a study conducted among UK department store employees, Ashwell *et al.* stated that adjusting WC

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by height would improve the definition of metabolic syndrome[12]. A meta-analysis published in 2011 showed that WHtR was superior to BMI and WC in detecting cardiometabolic risks in both sexes[3]. In a large Taiwanese sample, WHtR was found to be a simple and effective index of cardiometabolic risk[13]. Since it also considers height, WHtR is not affected by body shape or race. According to different studies conducted recently, a cut-off point of 0·5 is suggested for both men and women in different age and ethnic groups. This cut-off point also has the advantage of being easy to remember[2,14–17].

The objective of the present study was to investigate the best anthropometric measurement associated with high CHD risk among BMI, WC, WHR and WHtR, and to define the optimal cut-off point for WHtR.

Materials and methods

Background

The Heart of Balcova (BAK) Project was initiated in 2007 in Balcova, an urban settlement of Izmir, Turkey, with the collaboration of Balcova Municipality and Dokuz Eylul University Faculty of Medicine. The objective of the BAK Project was to improve the cardiovascular health of the population through population- and individual-level primary prevention initiatives, including reducing smoking and promoting healthy diet and physical activity. A baseline population survey was conducted between 2007 and 2009 to determine the cardiovascular risk status of the residents aged 30 years and over. Ethical approval was granted by the Ethics Committee of Dokuz Eylul University and written informed consent was obtained from each participant. Details of the BAK Project are published elsewhere[18,19].

Participants

The current cross-sectional study includes 10 878 individuals who participated in the baseline survey of the BAK Project who were not pregnant, had no missing data and who were eligible for estimating Framingham risk score.

Variables

Coronary event risk within 10 years was calculated using a Framingham risk score that included data on age, sex, smoking status, blood pressure, serum lipids and diabetes status[20–22]. Those who had risk lower than 10 % were designated 'low' risk, whereas those who fell between 10 % and 19 % were 'medium risk', and those with a risk higher than 20 % were classified as 'high risk'. In the statistical analysis, medium risk and high risk groups were combined as 'medium or high risk'. A questionnaire on sociodemographic variables, smoking status and health history was completed. Blood samples were collected after one night of fasting into Vacutainer tubes by trained nurses. All blood samples were taken to the Dokuz Eylul University Central Laboratory and an Abbott Architect c16000 auto-analyser was used with its original kits for analyses of blood glucose and serum lipids. Standard blood pressure measurements were taken by skilled physicians and nurses using a validated mercury sphygmomanometer from patients at rest (5–10 min) in the sitting position, with the values averaged over two measurements. Weight, height, WC and hip circumference (HC) were measured and BMI, WC, WHR and WHtR were calculated to obtain anthropometric measurements. Weight was measured using a scale, with the participant wearing light clothes and without shoes; height was measured with a standard height scale mounted on the wall. Participants stood still, without shoes, in the Frankfort plane position. BMI was calculated as weight (kilograms) divided by the square of height (metres). WC and HC were measured with a non-elastic standard measuring tape, with the participant wearing light clothes, standing still, in an upright position and with arms open sidewards. WC was measured at the midpoint between the distal border of the lowest rib and the superior border of the iliac crest. HC was measured at the widest point of the hips. WHtR was calculated by dividing WC circumference by height and WHR was calculated by dividing WC by HC. Cut-off points were defined as follows: BMI $\geq$30 kg/m^2[2,23]; WC $\geq$102 cm (men), $\geq$88 cm (women)[24–26]; WHR $\geq$0·90 (men), $\geq$0·85 (women)[27]; and WHtR $\geq$0·5[2,8,14].

Statistical methods

Continuous variables were calculated as means with their standard errors and categorical variables were calculated as percentages. Men and women were compared for anthropometric measurements and metabolic characteristics such as blood glucose and serum lipids using Student's *t* test. The χ^2 test was used to compare men and women for categorized anthropometric measurements and metabolic risks. Receiver-operating characteristic (ROC) curves for anthropometric measurements were drawn for medium or high coronary event risk and the measurement with the largest area under the curve (AUC) was accepted to be the best indicator. An AUC of 1·0 indicates perfect discrimination between the absence and presence of the condition tested, whereas an AUC of 0·5 indicates no discriminative capability. To determine the optimal cut-off point for WHtR in men and women, the Youden index (J) was used, where J = sensitivity + specificity − 1. The WHtR value which had the highest J value was defined as the optimal cut-off point[15]. Logistic regression models were used to determine independent associations of anthropometric indices with medium or high Framingham risk scores. Crude and age-, sex- and BMI-adjusted odds ratios were calculated. Interaction between BMI categories and WHtR was also evaluated using logistic regression and the Breslow–Day test. Data were analysed using the SPSS statistical software package version 15·0. Significance was defined as $P < 0·05$.

Results

In total, 10 878 participants were assessed. Within the sample, 67·7 % were female, 82·9 % were married, 44·7 % had primary and 35·9 % had higher education. Mean age was 51·23 (SE 0·19) years for men and 49·59 (SE 0·13) years for women. According to their health history, 24·5 % had high blood pressure, 9·2 % had diabetes and 31·5 % were current smokers, with men being significantly more likely to smoke than women (38·7 % in men, 28·7 % in women, $P < 0·001$). When metabolic risks were assessed, 7·5 % had impaired fasting blood glucose (110–125 mg/dl), 1·5 % had undiagnosed diabetes (≥126 mg/dl), 22·0 % had high total cholesterol, 19·8 % had high LDL-cholesterol and 45·9 % had low HDL-cholesterol. Using BMI as a measure, 39·3 % of the participants were overweight and 38·2 % were obese. When the Framingham risk score was evaluated, one tenth (9·4 %) of the participants had high risk (risk ≥20 %) and 23·2 % had medium risk (risk 10–19 %).

Health status of the participants is presented in Table 1. Men had significantly higher prevalences of hypertension, elevated fasting blood glucose, high LDL-cholesterol, high TAG and obesity according to WHR and WHtR compared with women (Table 1). Women, on the other hand, significantly more frequently had low HDL-cholesterol. In addition, women had significantly elevated WC and BMI compared with men ($P < 0·001$ for all, except $P = 0·03$ for LDL-cholesterol).

Among men, 21·2 % had high cardiovascular risk and 31·9 % had medium risk, whereas in women these rates were 3·8 % and 19·1 %, respectively. There were significantly more men than women in the medium or high risk group ($P < 0·001$). The association of anthropometric measurements with cardiovascular risk is presented in Table 2. As shown in Table 2, both in men and women,

Table 1 Health status of the participants according to gender: Turkish men and women participating in the baseline survey of the Heart of Balcova Project, 2007–2009

	Total (*n* 10 878)		Men (*n* 3510)		Women (*n* 7368)		
Health status	*n*	%	*n*	%	*n*	%	*P*
Smoking	3428	31·5	1357	38·7	2071	28·1	<0·001
Fasting blood glucose*							
Normal & IGT (<126 mg/dl)†	9713	98·3	3112	97·4	6601	98·8	<0·001
Probable DM (≥126 mg/dl)	164	1·7	84	2·6	80	1·2	
Hypertension (≥140 and/or 90 mmHg)	2037	18·7	884	30·9	1153	21·5	<0·001
Hypercholesterolaemia (≥200 mg/dl)	6350	58·4	2027	57·7	4323	58·7	0·37
Elevated LDL-C (≥130 mg/dl)	5541	50·9	1842	52·5	3699	50·2	0·03
Decreased HDL-C (men ≤40 mg/dl; women ≤50 mg/dl)	4989	45·9	1500	42·8	3489	47·4	<0·001
Elevated TAG (≥150 mg/dl)	3701	34·0	1582	45·1	2119	28·8	<0·001
Obesity according to different indices							
BMI							
Non-obese (<30 kg/m^2)‡	6721	61·8	2479	70·7	4242	57·6	<0·001
Obese (≥30 kg/m^2)	4157	38·2	1031	29·4	3126	42·4	
WC (men ≥102 cm; women ≥88 cm)	3881	35·7	772	22·0	3109	42·2	<0·001
WHR (men ≥0·90; women ≥0·85)	4074	39·4	2153	65·3	1921	27·3	<0·001
WHtR (≥0·50)	7914	75·4	2837	83·5	5077	71·5	<0·001

IGT, impaired glucose tolerance; DM, diabetes mellitus; LDL-C, LDL-cholesterol; HDL-C, HDL-cholesterol; WC, waist circumference; WHR, waist:hip ratio; WHtR, waist:height ratio.
*Pre-diagnosed diabetics were excluded.
†IGT: 284 men had 110–125 mg/dl, 537 women had 110–125 mg/dl.
‡Among non-obese individuals, 1705 men were overweight and 2546 women were overweight.

Table 2 Association of anthropometric measurements with CHD risk* according to gender: Turkish men and women (*n* 10 878) participating in the baseline survey of the Heart of Balcova Project, 2007–2009

	Men (*n* 3510)					Women (*n* 7368)				
	Low CHD risk (*n* 1645)		Medium or high CHD risk (*n* 1865)			Low CHD risk (*n* 5679)		Medium or high CHD risk (*n* 1689)		
Index	Mean	SE	Mean	SE	*P*	Mean	SE	Mean	SE	*P*
BMI (kg/m^2)	27·45	0·10	28·53	0·10	<0·001	28·53	0·07	32·61	0·14	<0·001
WC (cm)	91·68	0·25	95·26	0·24	<0·001	82·96	0·16	93·74	0·27	<0·001
WHR	0·90	0·02	0·93	0·01	<0·001	0·79	0·01	0·85	0·02	<0·001
WHtR	0·53	0·01	0·57	0·01	<0·001	0·53	0·01	0·61	0·02	<0·001

WC, waist circumference; WHR, waist:hip ratio; WHtR, waist:height ratio.
*Framingham risk score.

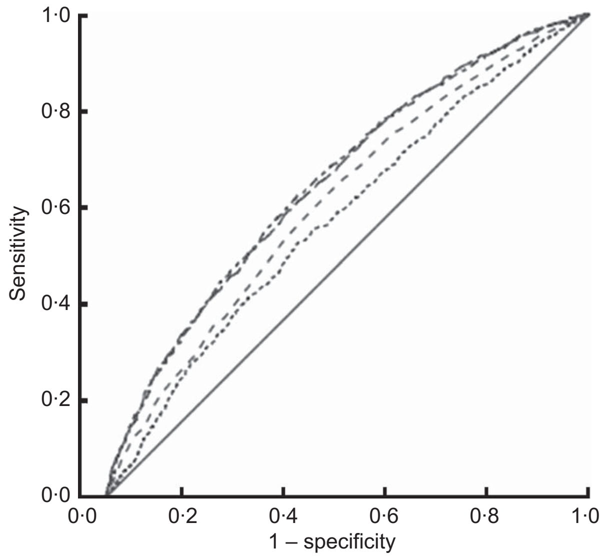

Fig. 1 Receiver-operating characteristic curves of anthropometric measurements (-----, BMI; —–—–—, waist circumference; ———, waist:hip ratio; –---–, waist:height ratio) for the prediction of CHD risk (as expressed by medium or high Framingham risk score) among Turkish men (*n* 3510) participating in the baseline survey of the Heart of Balcova Project, 2007–2009. ——— is the reference line; diagonal segments are produced by ties

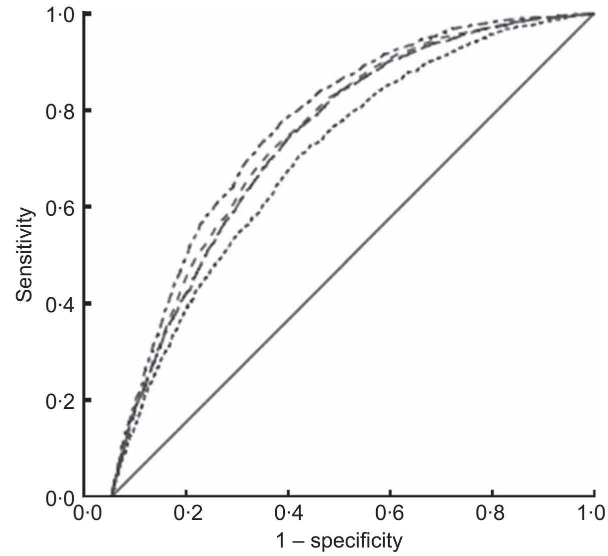

Fig. 2 Receiver-operating characteristic curves of anthropometric measurements (-----, BMI; —–—–—, waist circumference; ———, waist:hip ratio; –---–, waist:height ratio) for the prediction of CHD risk (as expressed by medium or high Framingham risk score) among Turkish women (*n* 7368) participating in the baseline survey of the Heart of Balcova Project, 2007–2009. ——— is the reference line; diagonal segments are produced by ties

those in the medium or high risk group had significantly higher mean anthropometric measurements.

Figures 1 and 2 illustrate the most accurate anthropometric measurement for estimating CHD risk in men and women, respectively, and Table 3 illustrates the AUC of the anthropometric measurements. According to Table 3 and Fig. 1, WHtR was found to be the best indicator for estimating CHD risk in men, followed by WHR, whereas BMI was found to be the worst indicator. In Fig. 2, WHtR found to be the best indicator for women, followed by WC, and similarly BMI was found to be worst indicator for estimating CHD risk. Predictive values of all indices were higher for women, with AUC varying between 71 % and 78 %.

Using ROC curves and the Youden index, the optimal cut-off points for WHtR in men and women were determined. For both men and women 0·55 was found to be the optimal cut-off point for WHtR in estimating CHD risk.

In logistic regression models (Table 4), WHtR above 0·55 was significantly associated with having medium or high CHD risk (OR = 4·17; 95 % CI 3·81, 4·57). After adjusting for age and sex, the odds were decreased (OR = 2·24; 95 % CI 2·09, 2·63). Adding BMI to the model had little effect and WHtR remained independently associated with medium or high CHD risk (OR = 1·73; 95 % CI 1·48, 2·02). A similar pattern was seen for high WHR (OR = 1·91; 95 % CI 1·69, 2·15) and for high WC (OR = 1·77; 95 % CI 1·53, 2·05) in the age-, sex- and BMI-adjusted model.

Table 3 AUC values for anthropometric measurements in estimating CHD risk* according to gender: Turkish men and women (*n* 10 878) participating in the baseline survey of the Heart of Balcova Project, 2007–2009

	Men		Women	
	AUC	*P*	AUC	*P*
BMI	0·579	<0·001	0·709	<0·001
WC	0·613	<0·001	0·754	<0·001
WHR	0·654	<0·001	0·746	<0·001
WHtR	0·656	<0·001	0·775	<0·001

AUC, area under the receiver-operating characteristic curve; WC, waist circumference; WHR, waist:hip ratio; WHtR, waist:height ratio.
*Medium or high Framingham risk score.

The interaction between BMI and WHtR was evaluated and is presented in Table 5 as the odds ratios of high WHtR in estimating CHD risk stratified for BMI category. High WHtR was significantly associated with medium or high CHD risk in each category of BMI. No interaction was detected between BMI and WHtR (Table 5).

Discussion

In the present study, half of the participants had elevated serum total cholesterol and LDL-cholesterol and reduced HDL-cholesterol, and one-third of the participants had elevated serum TAG. According to BMI, WC and WHR, one-third of the sample was obese. Moreover, according

Table 4 Association between CHD risk* and abdominal obesity indices: Turkish men and women (*n* 10 878) participating in the baseline survey of the Heart of Balcova Project, 2007–2009

	Crude		Adjusted for age and sex		Adjusted for age, sex and BMI	
	OR	95 % CI	OR	95 % CI	OR	95 % CI
WHtR ≥0·55 *v.* <0·55	4·17	3·81, 4·57	2·34	2·09, 2·63	1·73	1·48, 2·02
WHR ≥0·90 *v.* <0·90 (men); ≥0·85 *v.* <0·85 (women)	4·84	4·43, 5·29	2·25	2·00, 2·52	1·91	1·69, 2·15
WC ≥102 *v.* <102 cm (men); ≥88 *v.* <88 cm (women)	2·23	2·06, 2·43	2·33	2·08, 2·62	1·77	1·53, 2·05

WHtR, waist:height ratio; WHR, waist:hip ratio; WC, waist circumference.
*Medium or high Framingham risk score.

Table 5 Odds ratios and 95 % confidence intervals of high WHtR for predicting CHD risk* stratified by BMI category: Turkish men and women (*n* 10 878) participating in the baseline survey of the Heart of Balcova Project, 2007–2009

BMI category	OR*	95 % CI
Normal	4·808	3·001, 7·704
Overweight	4·132	3·582, 4·766
Obese	5·972	4·432, 8·046

WHtR, waist:height ratio.
No interaction was detected between BMI and WHtR: Breslow-Day test, $P = 0{\cdot}082$.
*Medium or high Framingham risk score.

to the Framingham risk score, one-third (32·7 %) of the participants had a risk of higher than 10 % for developing a coronary event in the next 10 years. Participants who had medium or high CHD risk had higher mean anthropometric measurements. Based on the ROC curves, WHtR was found to be the best indicator for estimating medium or high CHD risk, whereas BMI was found to be the worst indicator in both men and women. WHtR, WHR and WC each had an independent association with CHD risk even after adjusting for age, sex and BMI. There was no interaction between WHtR and BMI.

Obesity

Obesity is increasing worldwide, not in only developed countries but also in developing countries. The prevalence of obesity in Europe ranges between 10 and 25 % in men and between 10 and 30 % in women, and in the past decade it has increased by 10–40 %(23). Turkey has the same pattern, with obesity even slightly higher in women, according to the National Ministry of Health. Prevalence of obesity in Turkey was found to be 21·7 % in men and 41·3 % in women in adults (aged ≥30 years)(28). In the current study, the prevalence of obesity defined by BMI was 29·4 % in men and 42·4 % in women.

In a study conducted in six different regions of Turkey which included participants aged 20 years and older, obesity prevalence was 21·8 % in men and 36·9 % in women(29). Similarly, in another study which included those over 20 years of age living in the Black Sea region, obesity prevalence was 16·5 % for men and 29·4 % for women(30). In our study, obesity prevalence was slightly higher than the average for Turkey, which may be due the older sample or differences in lifestyle due to urbanization.

Waist:height ratio and cardiometabolic risk

In our study, WHtR was found to be the best indicator for estimating medium or high CHD risk, whereas BMI was found to be the worst indicator in both sexes. For WHtR, the AUC was 66 % for men and 78 % for women. There are many studies evaluating the predictive power of anthropometric indices for cardiovascular deaths, CVD, hypertension, cardiometabolic risks, diabetes and dyslipidaemia(3,13,31–35). Systemic reviews and meta-analyses have shown that WHtR is superior in estimating cardiometabolic risks. Ashwell *et al.* conducted a meta-analysis in 2011 and concluded that WHtR was more successful in estimating cardiometabolic risks compared with BMI and WC(3). In a systematic review, Browning *et al.* showed that WHtR had the highest AUC for diabetes, insulin resistance, hypertension, CVD and dyslipidemia in both men and women(8). In another meta-analysis conducted by Lee *et al.* similar results were found, with WHtR being superior in estimating hypertension, type II diabetes and dyslipidaemia, whereas BMI was found to be the worst indicator(36).

WHtR has positive aspects including providing similar results for both men and women, not being affected by race or ethnicity, taking height into account, and being easy to calculate(13,14). There are some studies which have evaluated the utility of WHtR in estimating metabolic risks in different age and racial groups. In Germany, in two cohort studies, DETECT and SHIP, all-cause mortality, cardiovascular mortality and a composite index of stroke and/or myocardial infarction were evaluated using ROC curves and WHtR was found to be the best indicator and BMI the worst, indicating that BMI should not be used alone for estimating risks(33). In Japan, 6141 men and 2137 women participated in a study where hypertension, elevated blood glucose, elevated TAG and reduced HDL-cholesterol were evaluated as coronary risk factors. Those who had two or more risk factors were grouped as high risk. According to the ROC curves drawn, WHtR was found to be the best indicator for estimating high risk, with the AUC being 68 % in men and 75 % in women[37]. In a study conducted in Turkey, it was found that WHtR was the best indicator for predicting most of the cardiometabolic risk factors[38]. These results also support our findings, pointing to WHtR as the superior indicator.

Although there are many studies about the superiority of WHtR over other indices, the optimal cut-off point for WHtR is debatable. In the current study, 0·55 was found to be the optimal cut-off point for both men and women. WHtR remained statistically significantly associated with CHD risk even after adjusting for age, sex and BMI. In another study conducted in Turkey, Can *et al.* recommended the optimal cut-off point for Turkish adults as 0·59 for men and women[15]. There are some studies conducted in different populations which recommend 0·5 as the optimal cut-off point. In two different studies conducted on Chinese adults, 0·5 was found to be the optimal cut-off point for both men and women[39,40], with the same conclusions drawn in a study conducted in Iran[41]. A review by Browning *et al.* assessing findings across fourteen countries also recommended 0·5 as an optimal boundary[8]. On the other hand, a study on hospital workers in Mexico found the optimal cut-off point as 0·52 for men and 0·53 for women[42]. In Japan, the influence of height on metabolic syndrome was evaluated and it was found that the optimal cut-off point for men was 0·52, whereas for women it was 0·53[43].

Strengths and limitations of the study

The present study was conducted in an urban area of Izmir, the third largest city of Turkey. The population of this area comprises mainly relatively well-educated white collar workers or retired people, with a regular income. Obesity prevalence might be higher than expected due to the sedentary lifestyle of these urban residents. The cross-sectional design of the study prevents us from determining a cause-and-effect relationship between anthropometric indices and CHD risk. However, similar analyses can be repeated in the future in the follow-up of the Balcova cohort. On the other hand, obtaining data from a large community-based sample and implementing standardized measurement protocols might be considered as the strengths of the study.

Conclusions

One-third of participants were obese when evaluated using BMI, WC and WHR and one-third were in the medium or high risk group according to their Framingham risk score. According to WHtR, three-quarters of the participants were defined as obese. In both men and women, WHtR was found to be the best predictor of medium or high CHD risk, whereas BMI was found to be the least predictive. The optimal cut-off value for WHtR was 0·55 for both men and women, which can be rewritten as the slogan as ‘your waist circumference must not exceed half of your height’ for the public[2].

Malnutrition, sedentary lifestyle and smoking are the common risk factors for many non-communicable diseases. Intervention studies must be conducted in order to decrease these risk factors at both the community and individual level. In the evaluation of obesity for cardiometabolic risks, BMI should not be used alone and an abdominal obesity index must be added. The use of WHtR is recommended, since it is easy to calculate, non-invasive, cheap and practical. Longitudinal studies should be conducted in order to determine the cause-and-effect relationship between anthropometric indices and cardiometabolic risks.

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