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Accuracy of Anthropometric Indicators of Obesity to Predict Cardiovascular Risk

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Context: Obesity is associated with various cardiovascular risk factors. The body mass index (BMI) is the standard measure of overweight and obesity. However, more recently, waist to hip ratio (WHR) or waist circumference (WC) as more sensitive measures for visceral obesity have been proposed to be more indicative of cardiovascular risk.

Objective: This study was performed to test the predictive value of anthropometric parameters for the presence of several cardiovascular risk conditions.

Design: The DETECT (Diabetes Cardiovascular Risk-Evaluation: Targets and Essential Data for Commitment of Treatment) study is a cross-sectional, clinical-epidemiological study.

Participants: We studied 5377 unselected subjects (2016 men, 3361 women) without arteriosclerotic disease, aged 20–79 yr, from the DETECT laboratory sample.

Setting: This study was conducted by primary care physicians.

Intervention: We measured anthropometric parameters and assessed cardiovascular risk by clinical examination, patient history, and a standardized laboratory program.

Main Outcome Measures: We assessed the associations of BMI, WC, hip circumference, WHR, and waist to height ratio (WHtR) to cardiovascular risk by calculating the area under the receiver-operating characteristic curve and adjusted odds ratios for metabolic syndrome, dyslipidemia, and type 2 diabetes.

Results: The area under the receiver-operating characteristic curve for WHtR was significantly higher than for all other anthropometric parameters with respect to all risk conditions in women and to dyslipidemia and type 2 diabetes in men. The odds ratios for the presence of risk conditions with 1 SD increase of each anthropometric parameter were highest for WHtR or WC.

Conclusions: There are some indications that WHtR or WC may predict prevalent cardiovascular risk better than BMI or WHR, even though the differences are small. ***(J Clin Endocrinol Metab* 92: 589–594, 2007)**

OBESITY IS A major risk factor for the development of chronic diseases and mortality (1–3). The risk of cardiovascular events rises with increasing body mass index (BMI) (4). The World Health Organization recommends measurement of the BMI as a universal criterion of overweight (≥25) and obesity (≥30); measures of abdominal fat distribution such as waist circumference (WC) or waist to hip ratio (WHR) are also encouraged (5). Prospective epidemiological studies have shown increased abdominal fat accumulation to be an independent risk factor for type 2 diabetes mellitus and cardiovascular risk conditions, such as coronary artery disease (CAD), stroke, and hypertension (6–8). Visceral fat accumulation is associated with increased secretion of free fatty acids, hyperinsulinemia, insulin resistance, hypertension, and dyslipidemia (reviewed in Refs. 9 and 10). The WHR as a measure of abdominal fat accumulation has been a better predictor of cardiovascular risk than BMI (6–8, 11). Other authors (12, 13) have promoted the WC, and two different cutoffs for WC have been proposed based on data derived from population-based studies (94 or 102 cm for men, and 80 or 88 cm for women, respectively). The National Cholesterol Education Program (NCEP) has adopted the upper levels, and the use of the term metabolic syndrome has been suggested to identify the common cluster of metabolic abnormalities, defined as three or more of five criteria: 1) abdominal obesity (WC, >102 cm in men and >88 cm in women); 2) hypertriglyceridemia [≥1.69 mmol/liter (≥150 mg/dl)]; 3) low high-density lipoprotein (HDL) [<1.04 mmol/liter (<40 mg/dl) in men and <1.29 mmol/liter (<50 mg/dl) in women]; 4) hypertension (≥130/85 mm Hg); and 5) elevated

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Abbreviations: AUC, Area under the ROC curve; BMI, body mass index; BP, blood pressure; CAD, coronary artery disease; HC, hip circumference; HDL, high-density lipoprotein; OR, odds ratio; ROC, receiver-operating characteristic; WC, waist circumference; WHR, waist to hip ratio; WHtR, waist to height ratio.

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fasting glucose [≥6.1 mmol/liter (≥110 mg/dl)] (14). It has been shown that the hazard ratios for future coronary heart disease or diabetes mellitus increase with the presence of each additional factor of the metabolic syndrome (15). More recently, the International Diabetes Foundation has suggested a redefinition of the metabolic syndrome using adapted WCs for different ethnic groups (16). Based on this new definition, in the United States, a higher prevalence of the metabolic syndrome than previously estimated was found (17). The WC has also correlated well with area of visceral fat mass assessed with magnetic resonance imaging (18).

However, the WC has been criticized for not taking into account differences in body height, and the ratio of WC to height [waist to height ratio (WHtR)] has been proposed as a better predictor of cardiovascular risk (19, 20), mortality (21), and intraabdominal fat (22). In a population-based study from Hong Kong, this ratio has been most strongly associated with cardiovascular risk when using receiver-operating characteristic (ROC) analysis and a cutoff of 0.5 has been suggested for an Asian population (23). We have recently shown in a large cohort of primary care patients from the Diabetes Cardiovascular Risk-Evaluation: Targets and Essential Data for Commitment of Treatment (DETECT) study that the WHtR predicts point prevalence of CAD, type 2 diabetes, and dyslipidemia, as assessed by physicians' records, better than other measures of obesity. However, BMI best predicted hypertension (20).

In this study we aimed to compare the association of the anthropometric measures WHR, hip circumference (HC), WC, BMI, and WHtR with the presence of the metabolic syndrome, hypertension, and type 2 diabetes in a large primary care sample with a standardized laboratory assessment and physical examination.

Patients and Methods

Design

DETECT is a cross-sectional study of 55,518 unselected consecutive patients (59% women; over 17 yr) in 3,188 primary care offices in Germany, including a prospective substudy in a random subset of 7,519 patients, characterized additionally by an extensive standardized laboratory program (24). For participation in the standardized laboratory program, 1000 randomly selected doctors were asked to participate. Of these, 149 doctors dropped out, leaving 851 doctors participating in the laboratory program. By comparing the final participating doctors to a prestudy questionnaire, they were found to be nationally representative in terms of regional distribution, age, years of experience, specialty orientation, and patient load per day (24).

Patients

The local ethics committee approved the study, and all patients gave written informed consent. During a specified half day, all patients attending the primary care practice were asked to participate in the study. We did not record ethnicity, but, being representative of the German population, the patients were mainly of Caucasian ethnicity. To define clearly cardiovascular risk conditions, we only included patients from the subset with the standardized laboratory program in this study. Patients with known CAD, peripheral artery occlusion, carotid stenosis, or stroke, age 20 or less or more than 79 yr, and with a lack of complete anthropometrical data were excluded. Thus, 5377 patients (2016 men, 3361 women) were finally analyzed in this study. For the definition of the metabolic syndrome, we additionally excluded patients with type 2 diabetes or intake of medications used to lower triglycerides (nicotinic acid derivates, fibrates), leaving 4585 patients (1636 men, 2949 women) for this analysis.

Instruments and measures

The primary care physicians recorded all diagnoses. Physician's diagnoses were classified as definite, possible, or not present, and current medication was recorded. In case of diabetes, type 1 or type 2 was indicated. Laboratory values obtained in the central laboratory in Graz were used for risk assessment. Doctors were advised to measure weight, height, blood pressure (BP), and waist and HCs according to written, standardized instructions given in a manual. Indirect cuff sphygmomanometry measured systolic and diastolic BP after several minutes of rest in a sitting position. The use of an appropriate cuff size was advised. WC was measured with a tape measure midway between the lowest rib and pelvis; HC was measured at the widest circumference of the hip. The following anthropometric parameters were calculated: BMI (weight in kg divided by the square of height in meters); WC (in cm); HC (in cm); WHR: WC divided by HC; and WHtR (WC divided by measured height in cm).

Lipids and lipoproteins

Blood samples were collected and shipped to the central laboratory at the Medical University of Graz, Austria, within 24 h. Clinical chemical parameters, as well as cholesterol and triglycerides were determined on a Roche Modular automatic analyzer (Roche Diagnostics Scandinavia, Bromma, Sweden). Lipoproteins (HDL, low-density lipoprotein, and very low-density lipoprotein) were determined electrophoretically on the HELENA SAS-3/SAS-4 system (Helena BioSciences Europe, Tyne & Wear, UK). Hemoglobin A1c was determined chromatographically on a ADAMS HA 8160 analyzing system (Menarini, Firenze, Italy). For all parameters, reagents and secondary standards were used as recommended by the manufacturers. Interassay coefficients of variation of these methods are provided in (24).

We analyzed the associations of the anthropometric measures with metabolic syndrome, dyslipidemia, and type 2 diabetes. The variables were defined as follows for the purpose of this study:

Metabolic syndrome. Presence of at least two of the following conditions: serum triglycerides 150 mg/dl or greater, HDL less than 40 mg/dl in men and less than 50 mg/dl in women, measured BP 130/85 mm Hg or greater, and fasting blood glucose 110 mg/dl or greater.

Dyslipidemia. Low-density lipoprotein cholesterol levels above the target values defined by the NCEP risk categories I–III or if there was a clinical history of dyslipidemia (physician's diagnosis or being on lipid-lowering medication). Risk category I: zero or one NCEP risk factor; risk category II: two or more NCEP risk factors, or 10-yr risk 20% or less; and risk category III: 10-yr risk greater than 20% or a diagnosis of coronary heart disease, or previous stroke or symptomatic carotid stenosis or peripheral arterial disease. NCEP risk factors were: cigarette smoking, hypertension (BP ≥ 140/90 mm Hg or on antihypertensive medication), low HDL cholesterol (<40 mg/dl), family history of premature CAD (CAD in male first-degree relative <55 yr; CAD in female first-degree relative <65 yr), age (men ≥ 45 yr; women ≥ 55 yr) (14).

Type 2 diabetes. Definite physician's diagnosis of type 2 diabetes or oral antidiabetic intake or insulin therapy, exclusion of patients with diagnosis of type 1 diabetes.

Patients' history, laboratory examination, or physical examination was used to assess confounding conditions. Specifically, the conditions were defined as follows: smoking status, patients' history of previous or current smoking; physical activity, patients' history of physical activity more than 2 h/wk; and hypertension, measured BP 140/90 mm Hg or less.

Statistical analyses

Patients were analyzed separately by sex, for all age groups, and three age groups (20–44, 45–65, 66–79 yr). Additionally we analyzed the high-risk age groups as defined by the NCEP (14) with the ages of 35–65 and 45–75 yr in men and women, respectively. Sensitivity and specificity were examined by ROC analysis, and the areas under the ROC curves

TABLE 1. Prevalence of cardiovascular risk conditions in the studied sample

	No.	Metabolic syndrome (n = 924) (%)	Dyslipidemia (n = 2893) (%)	Type 2 diabetes (n = 714) (%)
Total	5377	20.2	53.8	13.3
18–44 yr	1368	11.1	25.6	2.3
45–65 yr	2667	21.3	57.4	12.4
66+ yr	1342	29.9	75.0	26.2
Female	3361	16.8	48.6	11.2
18–44 yr	919	6.7	18.8	2.0
45–65 yr	1597	17.7	52.0	9.5
66+ yr	845	29.0	74.7	24.4
Male	2016	26.3	62.5	16.8
18–44 yr	449	20.3	40.3	2.9
45–65 yr	1070	27.2	65.6	16.8
66+ yr	497	31.7	75.7	29.4

(AUCs) were calculated for each anthropometrical parameter and risk condition. Individual cutoffs were defined as that point on the curve where the sum of sensitivity and specificity was highest. Differences between AUCs were tested with a nonparametrical test (25). Additionally, we calculated adjusted odds ratios (ORs) by applying logistic regression models of the different conditions in case of an increase of one SD of the respective anthropometric parameter. Statistical inference is based on 95% confidence intervals (CIs) and 5% P values, respectively. These estimates were calculated by the Huber-White-Sandwich Matrix (26) to account for the clustered structure (clusters: primary care settings) of the sample. All statistical analyses were conducted with the software package STATA 9.2 (Stata Corp., College Station, TX).

Results

Table 1 summarizes the prevalences of metabolic syndrome, dyslipidemia, and type 2 diabetes. The prevalences were weighted for regional distribution of the total sample. The prevalence of the three risk conditions was higher in men than in women, and the prevalences increased with age groups in both genders.

The AUCs of the ROC analyses are shown in Table 2. The AUC is a measure of the degree of separation between affected and nonaffected subjects by a specific test. An AUC of one indicates perfect separation between affected and nonaffected subjects, and an AUC of 0.5 indicates no discriminative value of the test used. Regarding dyslipidemia and type 2 diabetes, the AUCs for the WHtR were significantly higher than for the other anthropometric parameters in both sexes. Additionally, the AUC for WHtR was significantly higher regarding metabolic syndrome only in women. In the high-risk age groups (men 35–65 yr, women 45–75 yr), there were significant differences for dyslipidemia in both sexes. Separate analyses of the age groups 20–44, 45–65, and 66–79 yr revealed no further significant differences (data not shown). Table 3 displays the calculated cutoff levels, and respective sensitivities and specificities.

Figure 1 shows the ORs for the different risk conditions for a one SD increase of the respective anthropometric parameters after adjustment for: 1) age; 2) age, smoking status, physical activity, family history of type 2 diabetes, dyslipidemia, and hypertension; and 3) all factors and BMI (for WHtR)/WHtR (for all other anthropometric parameters). In men, the ORs were highest for WHtR, followed by WC and BMI for all conditions. Women had the highest ORs for WC, followed by WHtR and BMI. In both sexes, WHR had the lowest ORs for all conditions.

Discussion

Here we present data of a large study examining the association of several anthropometric parameters with three distinct cardiovascular risk conditions in a primary care population. We used metabolic syndrome, dyslipidemia, and type 2 diabetes because these risk factors are associated with obesity and are independent risk factors for cardiovascular events. Additionally, cardiovascular risk accumulates with increasing numbers of factors that constitute the metabolic syndrome (15).

In the ROC analysis, WHtR proved to predict most conditions significantly better than all other anthropometric parameters. When calculating ORs that allow to adjust for further influencing factors, WHtR was still a slightly better predictor in men, whereas in women, WC was slightly superior. Other authors (12, 13) have proposed WC as a general

TABLE 2. Associations of anthropometric variables and metabolic syndrome, dyslipidemia, and type 2 diabetes (n = 5377)

	WHR		HC		WC		BMI		WHtR	
	AUC	95% CI	AUC	95% CI	AUC	95% CI	AUC	95% CI	AUC	95% CI
Female										
Metabolic syndrome	0.62	0.60–0.64	0.69	0.67–0.71	0.72	0.70–0.74	0.72	0.70–0.73	0.73[a]	0.71–0.74
Dyslipidemia	0.62	0.60–0.64	0.65	0.63–0.67	0.68	0.66–0.70	0.67	0.66–0.69	0.70[a]	0.68–0.72
Type 2 diabetes	0.65	0.62–0.68	0.71	0.68–0.74	0.75	0.72–0.77	0.74	0.72–0.77	0.76[a]	0.74–0.79
Female age group 45–75 yr										
Metabolic syndrome	0.61	0.58–0.63	0.66	0.64–0.69	0.69	0.67–0.71	0.68	0.66–0.71	0.69	0.67–0.71
Dyslipidemia	0.60	0.57–0.62	0.61	0.59–0.64	0.64	0.61–0.66	0.63	0.61–0.65	0.65[a]	0.63–0.67
Type 2 diabetes	0.63	0.60–0.66	0.69	0.65–0.72	0.72	0.69–0.74	0.72	0.69–0.75	0.73	0.70–0.76
Male										
Metabolic syndrome	0.59	0.56–0.61	0.64	0.62–0.67	0.67	0.64–0.69	0.66	0.64–0.69	0.67	0.65–0.70
Dyslipidemia	0.58	0.55–0.60	0.60	0.58–0.63	0.63	0.60–0.65	0.62	0.59–0.64	0.65[a]	0.62–0.67
Type 2 diabetes	0.61	0.58–0.64	0.67	0.64–0.70	0.69	0.66–0.72	0.69	0.66–0.72	0.72[a]	0.69–0.74
Male age group 35–65 yr										
Metabolic syndrome	0.60	0.57–0.63	0.64	0.61–0.67	0.68	0.65–0.71	0.68	0.65–0.71	0.69	0.66–0.72
Dyslipidemia	0.57	0.54–0.60	0.62	0.59–0.65	0.63	0.60–0.66	0.62	0.59–0.65	0.64[a]	0.61–0.67
Type 2 diabetes	0.62	0.57–0.66	0.69	0.65–0.73	0.71	0.67–0.75	0.71	0.67–0.75	0.72	0.68–0.76

AUC estimated by ROC analyses.

[a] AUC is significantly larger than the next smaller AUC; significance was calculated only for the difference between parameters with the highest and second highest AUC.

measure of abdominal obesity. Possibly, the fact that WHtR takes differences in body height into account contributes to the higher AUC of the WHtR with respect to the WC in the ROC analyses. It has been shown that WHtR is a better predictor of mortality and cardiovascular risk factors than WC (19–21).

The WHR has also been proposed as a good predictor of cardiovascular events (6–8, 11). We found it to be most weakly associated with all risk conditions. This is possibly due to the fact that we have examined a high-risk population with a high prevalence of morbidity and obesity. Here, the concomitant increase in HC might have rendered the WHR less useful.

The HC was also positively associated with most single and combined cardiovascular risk conditions. Surprisingly, in an Australian study, a lower prevalence of newly diagnosed diabetes and dyslipidemia was found in subjects with higher HCs (27). In a recent case-control study by Yusuf *et al.* (11), higher HCs were also protective against myocardial infarction. The reason for these different results is unclear. Differences in study design (case-control *vs.* cross-sectional), subject populations (general population or highly selected hospitalized patients *vs.* primary care patients), statistical methods (such as adjustment for waist and other factors), definitions of conditions (newly diagnosed risk conditions *vs.* all patients with risk conditions), and methods of measurement of HC (at the great trochanters *vs.* at the largest HC) possibly played a role. Moreover, in the study by Yusuf *et al.* (11), patients from other hospital wards were included as controls. The presence of other diseases among the controls might have possibly led to potential bias (20).

Our results of a positive, albeit less strong, association of HC with cardiovascular risk suggest that not only visceral fat is involved in the cardiovascular risk of obesity. Although it is not clear whether this association is a consequence of direct detrimental effects of sc fat or, rather, an indirect effect due to the fact that HC is also an indicator of overall fatness, including visceral fat. This positive association might also explain why the WHR had the weakest association with cardiovascular risk. If both waist and HC are positively associated with risk factors, it can be expected that the ratio of both has a weaker association. Although in some studies the WHR has been strongly associated with cardiovascular risk factors (6–8, 11), it has also been criticized for masking accumulation of abdominal fat, if the HC is also increased (28).

It has to be kept in mind that this is a cross-sectional study. Therefore, these findings should be interpreted against that background. Our data only show the association with present risk factor conditions but do not directly predict the future risk of cardiovascular events. Moreover, a survivor bias cannot be ruled out. It is possible that older persons with highest risk have died who could not be studied here. On the other hand, the association with risk factors clearly points to an increased risk of future events. However, to elucidate which anthropometric parameter is the predictor of future cardiovascular events, prospective studies are necessary. A further limitation of our study is the fact that treating physicians only received written instructions on the anthropometric measurements. A more detailed training would have possibly reduced potential measurement errors. On the other hand, this study was designed to reflect an everyday routine in primary care. The fact that we have found clear results shows that these anthropometric parameters can be used in a daily routine and that they have a predictive value if applied in daily routine.

The WHtR has already been suggested as a common measure of central obesity for an Asian population; here, a cutoff level of 0.5 for both sexes has been recommended (23, 29, 30). This cutoff level has also been suggested for use in European subjects (31). Our study suggests the use of a higher cutoff (range 0.54–0.59). These studies differ from our study in several aspects. First, the sample number investigated there was smaller than our sample size. Second, these cutoff values have been established for an Asian population, and it has been shown that cardiovascular risks are present at a lower BMI in Asians than Caucasians (32), therefore, the WHtR cutoffs for Caucasians are likely to differ as well. And, third, these studies have been conducted in the general population, whereas our study was carried out in a primary care setting. Thus, our sample is more representative of the high-risk

TABLE 3. Cutoff values, sensitivity (Sens), and specificity (Spez) for the association of anthropometric parameters and metabolic syndrome, dyslipidemia, and type 2 diabetes (n = 5377)

	WHR			HC			WC			BMI			WHtR		
	Cutoff	Sens	Spez	Cutoff	Sens	Spez	Cutoff	Sens	Spez	Cutoff	Sens	Spez	Cutoff	Sens	Spez
Female															
Metabolic syndrome	≥0.85	0.60	0.59	≥104	0.64	0.66	≥89	0.66	0.67	≥25.8	0.66	0.66	≥0.54	0.70	0.65
Dyslipidemia	≥0.85	0.60	0.58	≥104	0.61	0.62	≥89	0.63	0.63	≥25.9	0.63	0.63	≥0.55	0.63	0.67
Type 2 diabetes	≥0.87	0.58	0.63	≥108	0.66	0.66	≥94	0.68	0.67	≥27.8	0.68	0.68	≥0.58	0.70	0.68
Female age group 45–75 yr															
Metabolic syndrome	≥0.85	0.61	0.55	≥105	0.63	0.63	≥90	0.66	0.63	≥26.3	0.64	0.64	≥0.56	0.63	0.67
Dyslipidemia	≥0.86	0.54	0.59	≥105	0.59	0.58	≥91	0.58	0.62	≥26.4	0.59	0.59	≥0.56	0.60	0.62
Type 2 diabetes	≥0.87	0.58	0.61	≥109	0.64	0.64	≥96	0.65	0.67	≥28.3	0.67	0.67	≥0.59	0.67	0.67
Male															
Metabolic syndrome	≥0.95	0.60	0.54	≥104	0.60	0.59	≥99	0.62	0.64	≥26.5	0.62	0.62	≥0.56	0.63	0.62
Dyslipidemia	≥0.96	0.54	0.59	≥105	0.56	0.59	≥100	0.58	0.58	≥26.8	0.59	0.58	≥0.57	0.59	0.62
Type 2 diabetes	≥0.97	0.58	0.60	≥107	0.62	0.63	≥103	0.65	0.64	≥28.0	0.64	0.64	≥0.59	0.65	0.67
Male age group 35–65 yr															
Metabolic syndrome	≥0.95	0.61	0.56	≥104	0.59	0.62	≥98	0.64	0.63	≥26.6	0.63	0.64	≥0.55	0.66	0.60
Dyslipidemia	≥0.96	0.54	0.60	≥104	0.59	0.55	≥99	0.60	0.58	≥26.9	0.58	0.59	≥0.56	0.60	0.60
Type 2 diabetes	≥0.97	0.62	0.61	≥107	0.64	0.65	≥103	0.66	0.66	≥28.2	0.65	0.66	≥0.58	0.68	0.64

The cutoff was estimated by the Youden-Index with equal weighted sensitivity and specificity in ROC analyses.

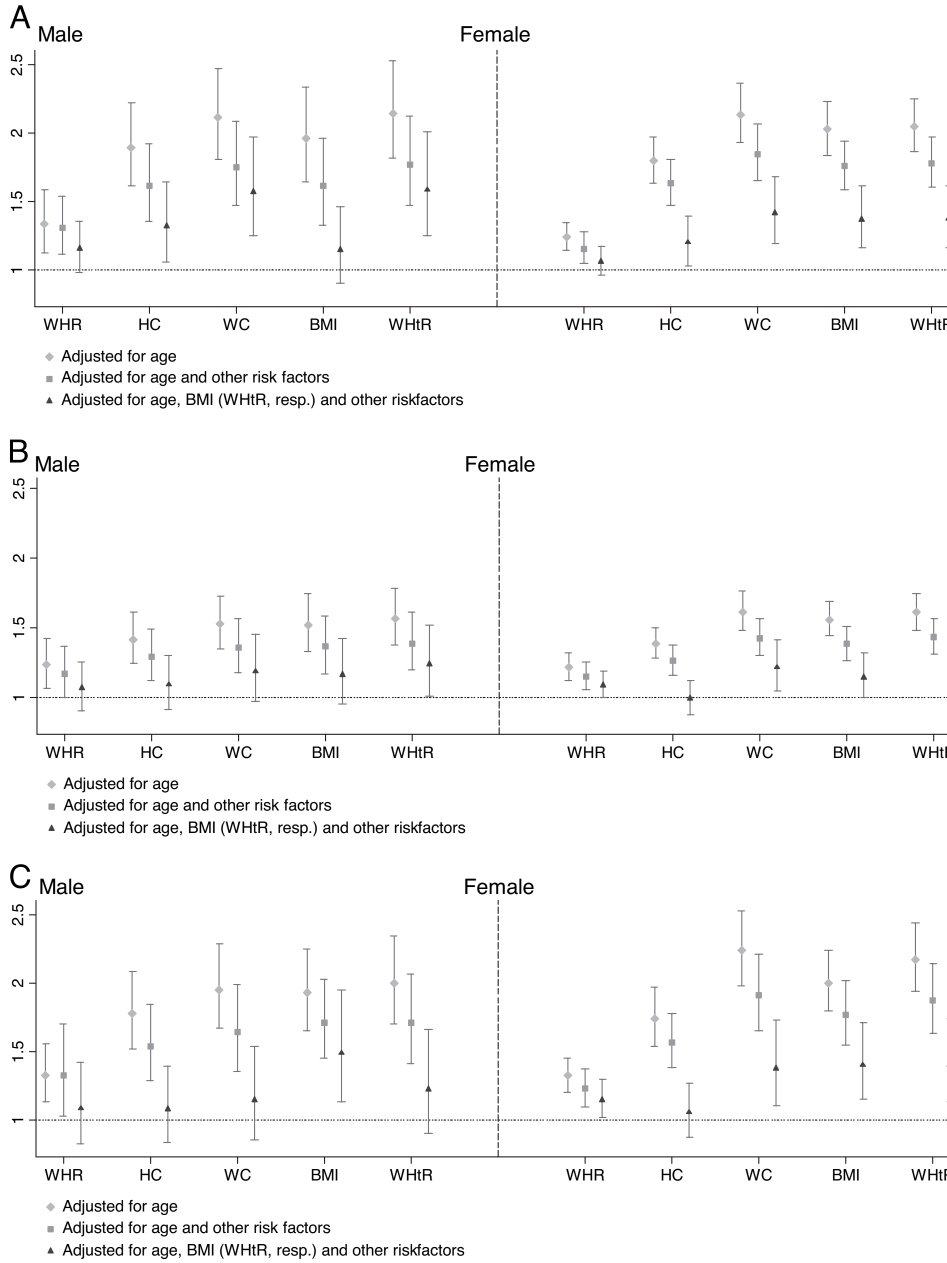

FIG. 1. ORs for metabolic syndrome (A), dyslipidemia (B), and type 2 diabetes (C) for one SD increase in anthropometric parameter (*vertical bars*, 95% CIs; other risk factors: smoking status, physical activity, family history type 2 diabetes, dyslipidemia, and hypertension. *Triangles* were additionally adjusted for BMI, except BMI; here, we adjusted additionally for WHtR. One SD female: WHR, 0.11; HC, 13.96 cm; WC, 14.72 cm; BMI, 5.35; WTR, 0.09; one SD male: WHR, 0.09; HC, 10.78 cm; WC, 12.77 cm; BMI, 4.27; and WTR, 0.08.

population seen in general practice where the question of weight management often arises. Recently, a large-scale international study (33) has addressed the issue of ethnic differences in abdominal obesity.

Together, our data indicate that the WHtR and, to a lesser extent, the WC appear to be better indicators of cardiovascular risk than the BMI. The WHtR is a parameter that is simple to assess. It has advantages over BMI because it is easier to calculate and understand for lay persons (no square term is used in the formula), and less clothes need to be removed for measurement. Moreover, measures including WC are more sensitive to diet and training than the BMI because increase of muscle mass might lead to little change of BMI but clear changes in WC and WHtR. The WHR is not only more complicated to assess, but it also has been shown to be a far weaker predictor of cardiovascular risk factors. Our study favors the use of an anthropometric parameter of abdominal obesity over BMI, though, further prospective studies are needed for a definite conclusion on the best predictor of future cardiovascular events.

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