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Association Of Anthropometric Indices With Cardiovascular Risk Factors And Cardiovascular Diseases: A Methodological Secondary Analysis Based On The Türkiye Nutrition And Health Survey

Nilufer Merve Celik
Ministry of Health
Hakan Tüzün
hakantuzun@gazi.edu.tr
Gazi University

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Abstract

Background

Anthropometric indices are widely used to assess cardiometabolic risk; however, their discriminatory performance may vary across populations. Using nationally representative data from Türkiye, this study aimed to compare the ability of body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), and neck circumference (NC) to discriminate cardiovascular disease (CVD) and its risk factors—diabetes, hypertension, and dyslipidemia—and identify optimal cut-off values.

Methods

This secondary analysis used data from the 2017 Turkish Nutrition and Health Survey, and analyses accounted for the complex sampling design with survey weights. Discriminatory performance was evaluated using receiver operating characteristic (ROC) analysis, optimal cut-off values were determined using the Youden index, and areas under the curve (AUC) were compared using the bootstrap method (B = 2000). Survey-weighted logistic regression models incorporating quartiles of anthropometric indices were constructed for CVD.

Results

In women, WHtR showed the highest AUC values for diabetes, hypertension, and CVD (AUC range: 0.719–0.799), and differed significantly from the other indices ($p < 0.05$). In men, WHR had the highest AUC for hypertension and CVD (0.748 and 0.708, respectively), but was not significantly different from WHtR. The identified cut-off values were generally consistent with internationally recommended cut-offs; however, the application of the recommended gender-independent cut-offs (BMI ≥ 30; WHtR ≥ 0.6) reduced sensitivity to 30.9–58.0% among men. In regression analyses, individuals in the highest quartile (Q4) of anthropometric indices had higher odds of CVD. In women, odds were higher for WHtR (OR: 2.41; 95% CI: 1.24–4.68), WC (OR: 2.38; 95% CI: 1.32–4.30), and NC (OR: 2.03; 95% CI: 1.18–3.50), whereas in men odds were higher for WC (OR: 2.83; 95% CI: 1.69–4.73), BMI (OR: 2.66; 95% CI: 1.62–4.34), WHR (OR: 2.39; 95% CI: 1.44–3.99), and WHtR (OR: 2.30; 95% CI: 1.37–3.85).

Conclusions

In Türkiye, WHtR in women and WHtR and WHR in men showed the best discriminatory performance for CVD and its risk factors. Although internationally recommended cut-off values appear applicable, our findings support sex-specific cut-offs. Although strong associations between anthropometric indices and CVD and its risk factors were observed, cohort studies are needed to clarify causal relationships.

Introduction

Obesity is defined as excessive fat accumulation in the body to an extent that impairs health (1). More than 1 billion people worldwide live with obesity, and at least 2.8 million people die each year from causes related to overweight or obesity (1, 2). Obesity is associated with numerous noncommunicable diseases (NCDs), such as cardiovascular disease (CVD), diabetes mellitus (DM), and cancer (3). Although progress has been made in addressing risk factors for NCDs, which account for eight of the top 10 causes of death globally and half of disability-adjusted life years (DALYs) lost to premature mortality, DALYs attributable to high body mass index (BMI) increased by 11% between 2010 and 2023 (4). This trend indicates that obesity represents an increasingly important public health burden.

The risk of cardiovascular and metabolic diseases is significantly increased in obese individuals; even in the presence of normal carbohydrate metabolism, dyslipidemia (DL), hypertension (HT), and vascular inflammation can develop through insulin resistance and increased adipokines (5, 6). It has been demonstrated that being overweight increases the risk of incident HT in both sexes (7), and the prevalence of DL increases with increasing BMI (8). Strong evidence from prospective cohort studies indicates that obesity plays a role across the spectrum of CVD, not only through these risk factors but also as an independent risk factor (9, 10).

The cardiovascular and metabolic risk levels of obese individuals vary depending on body fat distribution. Abdominal obesity carries a higher risk for DM and CVD compared with peripheral or gluteofemoral obesity (11–13). Anthropometric indices, which are simple, safe, and inexpensive methods for assessing obesity and its degree, may serve as useful identifiers of cardiovascular and metabolic risk (14). Although BMI is widely used in clinical practice, it is a crude measure with limitations because it cannot distinguish between fat and muscle mass and does not adequately reflect abdominal fat (15, 16). Furthermore, BMI may not accurately reflect obesity in older adults and athletes (14, 16, 17). The World Health Organization (WHO) has emphasized the importance of abdominal fat mass and the need to use complementary indices in addition to BMI (16). Waist circumference (WC) is strongly correlated with the amount of intra-abdominal fat (18). The WHO has stated that the waist-to-hip ratio (WHR) can be used to assess abdominal obesity (19). However, WHR has several limitations, including the need for precise anatomical positioning and potential challenges related to measurement procedures and participant acceptability when assessing waist and hip circumferences. Studies have also shown that relatively new anthropometric indices, such as the waist-to-height ratio (WHtR) and neck circumference (NC), may serve as useful indicators of CVD and its risk factors (20, 21). Nevertheless, it remains unclear which anthropometric index provides the best discriminatory performance.

In Türkiye, NCDs account for approximately two-thirds of all deaths (22). The risk of premature mortality (ages 30–70) due to NCDs is 15%, with ischemic heart disease and stroke ranking among the leading causes of years of life lost (YLL) (22, 23). Furthermore, Türkiye has the highest prevalence of overweight or obesity (66.8%) and obesity (32.1%) in the European region (24). The prevalence of obesity in Türkiye

is above the OECD average, indicating that obesity is a problem requiring attention not only at the regional but also at the global level (23).

Obesity in Türkiye exhibits a unique profile compared with many other countries in terms of its distribution according to sex, education level, and sociodemographic variables (24). It has been reported that the discriminatory performance of anthropometric indices in relation to CVD and its risk factors, as well as their optimal cut-off values, may vary across ethnic groups, potentially challenging the validity of universal thresholds (16, 25). However, most studies examining the risk of CVD associated with obesity are based on data from the United States or European countries, and data for Türkiye are limited and largely derived from studies lacking national representativeness (26, 27). Consequently, an important gap remains in the literature regarding the evaluation of the relationship between anthropometric indices and CVD and its risk factors using nationally representative data. In Türkiye, determining anthropometric indices that can be easily self-measured by individuals and have high discriminatory ability for chronic diseases, along with their corresponding cut-off values, may enable the identification of risk groups and the development of early preventive interventions. Establishing Türkiye-specific cut-off values may facilitate clearer identification of intervention targets and contribute to achieving the objectives of national action plans for NCDs.

The dataset of the nationally representative Türkiye Nutrition and Health Survey 2017 (TNHS-2017) was used in this study. This study aimed to evaluate the discriminatory performance of the anthropometric indices BMI, WC, WHR, WHtR, and NC for CVD and for the cardiovascular risk factors DM, HT, and DL; to determine appropriate cut-off values for these indices; and to examine the association between these anthropometric indices and CVD.

Methods

Study Population

This study is a secondary data analysis based on data from the TNHS-2017, which was conducted by the Ministry of Health. The TNHS-2017 is the most recent national nutrition and health survey designed to represent the population of Türkiye. The study was based on a complex multistage sampling design incorporating sample weights, strata, and clusters. Accordingly, TNHS-2017 was conducted using a stratified three-stage cluster sampling design based on the Address-Based Population Registration System. In the first stage, settlements were defined as clusters containing approximately 100 addresses, and these clusters were selected using probability proportional to size sampling. In the second stage, addresses were selected from each selected cluster using systematic sampling. In the third stage, the selected addresses were matched with the Ministry of Health Family Medicine Information System database, and one person aged 15 years or older was randomly selected from each address among eligible individuals by the Turkish Statistical Institute. In the sample size calculation, a total non-response rate of 0.40 was assumed based on household and individual loss rates observed in household survey studies conducted by the Turkish Statistical Institute. Because loss rates were considered in the sample

size calculation, substitution was not used for households or individuals in the study. All calculations were made considering rare variables (28).

Figure 1. Flow diagram of participants included in the study from the TNHS dataset

In the study, the initial sample consisted of 13,020 participants. Participants who did not meet the inclusion criteria and those with missing data were excluded. No imputation was performed (complete-case analysis), and the final analytical sample consisted of 9,814 adult participants (Fig. 1). Because the definitions of the dependent variables were based on references specific to adults, the analyses were restricted to individuals aged 18 years and older.

Variables

All data in this study were obtained from the TNHS-2017 dataset.

Dependent Variables

The dependent variables in this study were CVD and cardiovascular risk factors. Diabetes mellitus, hypertension, and dyslipidemia were examined as cardiovascular risk factors. For biochemical measurements, blood samples were collected from participants after at least 8 hours of fasting (28).

Diabetes mellitus was defined in this study as representing type 2 diabetes, based on the presence of a previous physician diagnosis of diabetes, fasting plasma glucose ≥ 126 mg/dL, or HbA1c ≥ 6.5%, and the absence of type 1 diabetes (3).

Hypertension was assessed based on self-report, as blood pressure measurement data were not available in the study. Individuals who reported a previous physician diagnosis of hypertension or the use of antihypertensive medication were classified as having hypertension.

Dyslipidemia was defined as participants who reported receiving treatment for dyslipidemia, as well as those not receiving treatment but having laboratory results indicating total cholesterol (TCHO) ≥ 200 mg/dL and/or low-density lipoprotein cholesterol (LDL-C) ≥ 130 mg/dL and/or triglycerides (TG) ≥ 150 mg/dL and/or high-density lipoprotein cholesterol (HDL-C) < 40 mg/dL for men and < 50 mg/dL for women (29).

Cardiovascular disease was defined as participants who reported a previous physician diagnosis of ischemic heart disease, hypertensive heart disease, or stroke. In line with the study objectives, individuals with inflammatory or rheumatic heart diseases, whose direct association with the risk factors examined in this study has not been clearly established, were excluded from this group. Participants with a diagnosis of hypertension only were not included in the CVD group to avoid classification overlap and were evaluated within the HT group.

All dependent variables in the study were defined as binary variables (yes/no).

Independent Variables

The independent variables in this study were anthropometric indices and other independent variables.

The anthropometric indices included BMI, WC, NC, WHR, and WHtR. Anthropometric indices were calculated using the following formulas: BMI = body weight (kg) / height² (m^2), WHR = waist circumference (cm) / hip circumference (cm), and WHtR = waist circumference (cm) / height (cm).

In the TNHS-2017, body weight was measured using a digital scale and height using a stadiometer, whereas anthropometric circumference measurements were obtained using a non-elastic flexible measuring tape. In accordance with WHO recommendations, WC was measured at the midpoint between the lowest rib and the iliac crest, and hip circumference at the widest point in the lateral view. NC was measured with the participant positioned in the Frankfort horizontal plane, with the neck exposed, just below the thyroid cartilage at the level of the neck base.

BMI was categorized according to the WHO classification as < 18.5, 18.5–24.9, 25.0–29.9, 30.0–39.9, and ≥ 40.0 kg/m^2 (19). In this study, the sensitivity and specificity of internationally recommended cut-off values for anthropometric indices were also evaluated. Accordingly, for BMI, cut-off values of ≥ 25 kg/m^2 (overweight) and ≥ 30 kg/m^2 (obesity) were used; for WC, ≥ 80 cm (risk) and ≥ 88 cm (high risk) for women and ≥ 94 cm (risk) and ≥ 102 cm (high risk) for men, in line with WHO recommendations (16). For WHR, cut-off values of ≥ 0.85 for women and ≥ 0.90 for men were applied according to WHO criteria (16). For WHtR, cut-off values of ≥ 0.5 (risk) and ≥ 0.6 (take action) were evaluated based on the recommendations of Ashwell et al. (30). For NC, the cut-off values for overweight and obesity were considered as ≥ 34 cm and ≥ 36.5 cm for women, and ≥ 37 cm and ≥ 39.5 cm for men, respectively, based on the studies of Ben-Noun et al. (31).

Other independent variables included age (years), perceived income adequacy, place of residence (province/district center or village), smoking status, and years of education. Smoking status (never vs ever) and perceived income adequacy, which was assessed using a Likert-type question in the TNHS, were dichotomized for the analyses (those who could make ends meet easily or without much difficulty vs. those who made ends meet with some or great difficulty). Data on these variables were obtained through self-report using the standardized TNHS-2017 questionnaire.

Statistical Analysis

All statistical analyses were performed using R software (version 4.5.1; R Foundation for Statistical Computing, Vienna, Austria). Within the framework of the complex sampling design, sample weights (AW), strata, and primary sampling units (PSU) were specified, and all analyses were conducted using design-based weighted methods in the survey package. All analyses were stratified by sex. For

comparisons between groups according to sex, appropriate statistical tests considering the survey design were used for continuous and categorical variables.

Descriptive statistics were presented as weighted percentages (%) for categorical variables and as weighted means with standard errors (SE) for continuous variables. The discriminatory performance of anthropometric indices in identifying cardiovascular risk factors and cardiovascular diseases was evaluated using receiver operating characteristic (ROC) analyses. The 95% confidence intervals (CI) for the area under the curve (AUC) and the statistical evaluation of AUC differences ($\Delta AUC = AUC_{reference} - AUC_{comparator}$) were obtained using PSU-level bootstrap resampling (B = 2000). Positive values indicate a difference in favor of the reference index. Two-sided p-values for ΔAUC were calculated based on the bootstrap distribution.

For this study, optimal cut-off values were determined by maximizing the Youden index (J = sensitivity + specificity − 1) (32). Sensitivity and specificity values for the WHO and internationally recommended cut-off values were also calculated using the study data.

The associations between anthropometric indices and the presence of cardiovascular disease were examined using survey-weighted logistic regression analyses accounting for the complex sampling design. Separate logistic regression models were constructed for each sex. Anthropometric indices were included in the models as weighted quartiles. The core model included age, perceived income adequacy, place of residence, smoking status, and years of education. The extended model additionally included diabetes mellitus, hypertension, and dyslipidemia.

Pearson's correlation analysis was performed to assess the correlations among anthropometric indices. To avoid multicollinearity, separate logistic regression models were constructed for anthropometric indices that showed high and statistically significant correlations with each other.

Statistical significance was set at $p < 0.05$.

Results

A total of 9,814 participants were included in the study, comprising 5,353 women and 4,461 men. Statistically significant differences were observed between sexes in the anthropometric indices evaluated. Additionally, glucose, TCHO, TG, and HDL-C levels differed significantly by sex. The prevalence of HT and the distribution of BMI categories also varied significantly between sexes ($p < 0.001$) (Table 1).

Table 1
Anthropometric indices, cardiovascular risk factors and cardiovascular diseases by sex*

Age (years)	**women (n = 5353)**	**men (n = 4461)**	***p***
	Mean (SE)	**Mean (SE)**	
	43.24 (0.32)	**41.81 (0.31)**	**0.001**
Height (cm)	157.3 (0.13)	171.9 (0.15)	**< 0.001**
Weight (kg)	71.6 (0.33)	80.7 (0.30)	**< 0.001**
BMI (kg/m^2)	29.07 (0.15)	27.29 (0.10)	**< 0.001**
WC (cm)	91.44 (0.33)	95.53 (0.27)	**< 0.001**
HIP (cm)	107.2 (0.27)	103.7 (0.17)	**< 0.001**
WHR	0.85 (0.002)	0.92 (0.002)	**< 0.001**
WHtR	0.58 (0.002)	0.56 (0.002)	**< 0.001**
NC (cm)	34.8 (0.067)	39.14 (0.070)	**< 0.001**
Glucose (mg/dL)	96.6 (0.52)	98.3 (0.68)	**0.037**
HbA1c (%)	5.60 (0.02)	5.64 (0.02)	0.170
TCHO (mg/dL)	188.4 (0.77)	183.2 (0.80)	**< 0.001**
TG (mg/dL)	122.2 (1.29)	146.6 (1.71)	**< 0.001**
LDL-C (mg/dL)	112.8 (0.64)	112.2 (0.69)	0.540
HDL-C (mg/dL)	52.3 (0.24)	43.4 (0.19)	**< 0.001**
Diabetes (%)	12.5	12.2	0.065
Hypertension (%)	16.9	9.8	**< 0.001**
Dyslipidemia (%)	72.9	71.0	0.122
CVD (%)	8.1	6.2	**0.013**
BMI Category (%)			
< 18.5	2.5	1.6	**< 0.001**
18.5–24.9 kg/m^2	28.3	31.2	
25.0–29.9 kg/m^2	28.2	41.4	
30.0- 39.9 kg/m^2	34.3	24.7	
> 40.0	6.7	1.1	

BMI, body mass index; WC, waist circumference; HIP, hip circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; NC, neck circumference; TG, triglycerides; TCHO, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; HbA1c, glycated hemoglobin; CVD, cardiovascular disease.

*Values are survey-weighted.

Table 2 presents the AUC values for anthropometric indices predicting cardiovascular risk factors and CVD by sex. In women, WHtR exhibited the highest AUC values across all cardiovascular risk factors and CVD, followed by WC and BMI. In men, WHtR had the highest AUC for DM, with only a slight difference compared with WHR. For hypertension and CVD in men, WHR had the highest AUC values, followed by WHtR, whereas for DL, WC demonstrated the highest AUC, followed by WHtR. NC, yielded the lowest AUC values in both sexes (Table 2). The corresponding ROC curves are shown in Fig. 2.

Table 2
Area under the ROC curve (AUC) for anthropometric indices for cardiovascular risk factors and cardiovascular diseases by sex*

	Diabetes AUC (95% CI)	Hypertension AUC (95% CI)	Dyslipidemia AUC (95% CI)	CVD AUC (95% CI)
Women				
BMI	0.752 (0.730–0.773)	0.735 (0.715–0.755)	0.691 (0.670–0.712)	0.669 (0.622–0.717)
WC	0.774 (0.751–0.793)	0.773 (0.753–0.792)	0.693 (0.673–0.713)	0.706 (0.662–0.749)
WHtR	0.788(0.766–0.807)	0.799 (0.780–0.817)	0.698 (0.677–0.719)	0.719 (0.677–0.760)
WHR	0.740 (0.719–0.761)	0.745 (0.727–0.763)	0.667 (0.646–0.688)	0.665 (0.637–0.693)
NC	0.700 (0.676–0.724)	0.679 (0.658–0.700)	0.635 (0.613–0.657)	0.623 (0.584–0.663)
Men				
BMI	0.704 (0.679–0.728)	0.674 (0.647–0.699)	0.697 (0.676–0.719)	0.647 (0.613–0.681)
WC	0.724 (0.700–0.746)	0.708 (0.684–0.732)	0.703 (0.681–0.724)	0.683 (0.649–0.717)
WHtR	0.752 (0.730–0.773)	0.736 (0.712–0.760)	0.701 (0.678–0.723)	0.705 (0.671–0.738)
WHR	0.751 (0.729–0.774)	0.748 (0.724–0.771)	0.684 (0.662–0.707)	0.708 (0.676–0.741)
NC	0.667 (0.640–0.693)	0.639 (0.610–0.669)	0.648 (0.625–0.670)	0.588 (0.553–0.624)

CVD, cardiovascular disease; BMI, body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio; NC, neck circumference.

*AUCs and 95% CIs were estimated using survey-weighted ROC analyses.

Figure 2. ROC curves of anthropometric indices for cardiovascular diseases and cardiovascular risk factors by sex

ΔAUC represents the difference between the reference and comparator anthropometric indices; positive values indicate a higher AUC for the reference index, while negative values indicate a higher AUC for the comparator index. In pairwise comparisons, using WHtR as the reference index in women revealed statistically significant differences between WHtR and other anthropometric indices for diabetes,

hypertension, and CVD ($p < 0.05$). In men, with WHR as the reference index, significant differences were observed between WHR and other indices—except WHtR—for cardiovascular risk factors other than dyslipidemia and for CVD ($p < 0.05$). No statistically significant difference was found between WHR and WHtR for outcomes other than dyslipidemia. For dyslipidemia in men, ΔAUC values were negative for all anthropometric indices except NC, because these indices had higher AUC values than WHR (Table 3).

Table 3
Sex-specific pairwise comparisons of AUCs among anthropometric indices for cardiovascular risk factors and cardiovascular diseases

Comparison	Diabetes ΔAUC (95% CI)	Hypertension ΔAUC (95% CI)	Dyslipidemia ΔAUC (95% CI)	CVD ΔAUC (95% CI)
Women				
WHtR & BMI	0.040* (0.030; 0.051)	0.066* (0.056; 0.076)	0.008 (-0.001; 0.017)	0.050* (0.036; 0.065)
WHtR & WC	0.015* (0.010; 0.020)	0.025* (0.020; 0.029)	0.005* (0.001; 0.010)	0.016* (0.009; 0.023)
WHtR& WHR	0.047* (0.032; 0.063)	0.052* (0.039; 0.065)	0.032* (0.013; 0.050)	0.028* (0.009; 0.047)
WHtR & NC	0.089* (0.072; 0.105)	0.113* (0.097; 0.128)	0.058* (0.043; 0.073)	0.083* (0.061; 0.105)
Men				
WHR & BMI	0.047* (0.026; 0.069)	0.065* (0.043; 0.087)	-0.018* (-0.033; -0.002)	0.062* (0.036; 0.087)
WHR & WC	0.027* (0.012; 0.042)	0.034* (0.018; 0.049)	-0.024* (-0.035; -0.013)	0.029* (0.010; 0.049)
WHR & WHtR	-0.003 (-0.018; 0.012)	-0.001 (-0.015; 0.014)	-0.015* (-0.026; -0.005)	0.002 (-0.016; 0.020)
WHR & NC	0.086* (0.062; 0.109)	0.102* (0.077; 0.128)	0.015 (-0.004; 0.034)	0.106* (0.075; 0.138)

CVD, cardiovascular disease ; CI, confidence interval.;ΔAUC, difference in area under the curve

WHtR was used as the reference anthropometric index in women, whereas WHR was used in men.

* $p < 0.05$

Table 4 summarizes sensitivity and specificity values for anthropometric indices in women and men regarding cardiovascular risk factors and CVD, based on both study-derived cut-off values and those recommended by the World Health Organization and existing literature.

Table 4
Sensitivity, and specificity of anthropometric indices for cardiovascular risk factors and cardiovascular diseases according to different cut-off values

		WOMEN			MEN		
		Cut-off	**sensitivity (%)**	**specificity (%)**	**Cut-off**	**sensitivity (%)**	**specificity (%)**
Diabetes							
BMI	Present study	28.4	83.6	54.7	26.5	79.8	49.3
	WHO overweight	25	96.2	34.7	25	88.0	35.8
	WHO obesity	30	72.1	63.4	30	49.0	77.5
WC	Present study	91.6	84.6	56.1	97.3	72.4	60.4
	WHO risk	80	98.4	28.8	94	83.0	47.8
	WHO high-risk	88	91.1	47.0	102	58.2	71.9
WHtR	Present study	0.61	79.7	63.2	0.56	81.2	56.3
	Risk	0.50	98.8	28.3	0.50	96.0	27.8
	Take action	0.60	80.1	62.6	0.60	58.0	75.8
WHR	Present study	0.84	82.8	52.8	0.94	73.9	65.0
	WHO high-risk	0.85	80.1	54.7	0.90	88.1	44.3
NC	Present study	35.0	75.0	54.7	39.3	69.1	57.2
	overweight	34.0	85.3	42.0	37.0	89.5	24.3
	obesity	36.5	53.2	74.2	39.5	68.4	57.7
Hypertension							
BMI	Present study	28.6	79.5	57.2	26.5	78.3	48.3

BMI, body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio; NC, neck circumference; CVD, cardiovascular disease.

Units: BMI, kg/m²; WC and NC, cm; WHR and WHtR, unitless.

		WOMEN			MEN		
		Cut-off	sensitivity (%)	specificity (%)	Cut-off	sensitivity (%)	specificity (%)
Diabetes							
	WHO overweight	25	93.0	35.6	25	87.6	35.1
	WHO obesity	30	70.0	64.9	30	45.8	76.4
WC	Present study	91.4	84.1	58.2	98.3	68.3	63.0
	WHO risk	80	97.1	30.0	94	82.4	46.9
	WHO high-risk	88	89.5	48.7	102	58.0	71.1
WHtR	Present study	0.59	82.7	64.0	0.56	80.8	54.8
	Risk	0.50	97.7	29.5	0.50	95.8	27.1
	Take action	0.60	81.4	65.2	0.60	55.4	74.6
WHR	Present study	0.87	72.7	64.2	0.94	72.6	66.1
	WHO high-risk	0.85	79.5	56.4	0.90	87.7	43.4
NC	Present study	35.1	63.7	63.3	39.2	65.6	55.7
	overweight	34	81.2	42.6	37	88.6	23.8
	obesity	36.5	49.4	74.9	39.5	63.5	56.5
Dyslipidemia							
BMI	Present study	27.1	66.9	63.6	25.5	72.1	57.2
	WHO overweight	25	76.4	50.2	25	75.3	52.9
	WHO obesity	30	48.0	77.7	30	30.9	86.9

BMI, body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio; NC, neck circumference; CVD, cardiovascular disease.

Units: BMI, kg/m²; WC and NC, cm; WHR and WHtR, unitless.

		WOMEN			MEN		
		Cut-off	sensitivity (%)	specificity (%)	Cut-off	sensitivity (%)	specificity (%)
Diabetes							
WC	Present study	83.3	74.9	54.3	90.3	74.3	57.6
	WHO risk	80	81.8	44.9	94	64.5	64.8
	WHO high-risk	88	65.5	63.0	102	38.2	84.0
WHtR	Present study	0.55	68.4	61.9	0.53	74.0	58.4
	Risk	0.50	82.4	44.5	0.50	83.4	45.1
	Take action	0.60	50.0	77.0	0.60	33.9	85.1
WHR	Present study	0.81	75.0	49.7	0.89	69.9	59.4
	WHO high-risk	0.85	55.8	67.0	0.90	68.0	60.7
NC	Present study	33.9	67.2	53.6	38.2	66.4	58.2
	overweight	34	67.1	53.7	37	81.7	32.9
	obesity	36.5	33.4	82	39.5	51.8	70.2
CVD							
BMI	Present study	29.8	68.4	60.2	26.6	75.5	47.7
	WHO overweight	25	86.2	32.3	25	83.7	34.0
	WHO obesity	30	66.9	61.2	30	44.1	75.5
WC	Present study	94.5	72.1	60.3	99.0	65.9	62.3
	WHO risk	80	91.8	26.9	94	78.3	45.5

BMI, body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio; NC, neck circumference; CVD, cardiovascular disease.

Units: BMI, kg/m²; WC and NC, cm; WHR and WHtR, unitless.

		WOMEN			MEN		
		Cut-off	sensitivity (%)	specificity (%)	Cut-off	sensitivity (%)	specificity (%)
Diabetes							
	WHO high-risk	88	82.1	44.4	102	54.8	69.8
WHtR	Present study	0.60	74.8	60.1	0.57	70.0	62.2
	Risk	0.50	92.7	26.5	0.50	92.5	26.0
	Take action	0.60	74.8	60.1	0.60	55.4	73.4
WHR	Present study	0.88	61.4	65.8	0.93	73.4	58.1
	WHO high-risk	0.85	73.1	52.4	0.90	85.7	42.1
NC	Present study	34.5	69.8	50.2	39.5	60.3	55.6
	overweight	34	77.7	40.0	37	85.2	23.1
	obesity	36.5	44.6	72.1	39.5	60.3	55.6

BMI, body mass index; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio; NC, neck circumference; CVD, cardiovascular disease.

Units: BMI, kg/m²; WC and NC, cm; WHR and WHtR, unitless.

Pearson's correlation analysis demonstrated statistically significant correlations among all anthropometric indices examined ($p < 0.001$). Considering these correlations, separate logistic regression models were constructed for each index to assess associations with cardiovascular disease (Table 5). In women, core models showed that CVD risk was higher in the highest quartile (Q4) of WC, WHtR, and NC than in the lowest quartile (Q1). Specifically, for WC and WHtR, the risk of CVD in Q4 was approximately 2.4 times higher than in Q1 (WC: odds ratio [OR] = 2.38, 95% confidence interval [CI]: 1.32–4.30; WHtR: OR = 2.41, 95% CI: 1.24–4.68). However, these associations were not statistically significant in the extended models. In men, core models indicated that BMI and WC in the upper two quartiles (Q3 and Q4) were associated with elevated CVD risk compared with Q1. In extended models, the increased risk remained statistically significant only for Q4 compared with Q1 (BMI: OR = 2.02, 95% CI: 1.19–3.44; WC: OR = 2.09, 95% CI: 1.22–3.59). For WHR, the increased risk observed in Q4 in the core model also remained statistically significant in the extended model (OR = 1.82, 95% CI: 1.06–3.10).

Table 5
Logistic regression analysis of cardiovascular disease risk according to weighted quartiles of anthropometric indices

Anthropometric	Quartile	Model 1 (core)		Model 2 (extended)	
		OR	95% CI	OR	95% CI
Women					
BMI	Q1(Ref)	1		1	
	Q2	0.79	0.49–1.26	0.75	0.47–1.20
	Q3	1.38	0.90–2.11	1.21	0.78–1.89
	Q4	1.60	0.90–2.83	1.32	0.69–2.54
WC	Q1 (Ref)	1		1	
	Q2	0.94	0.57–1.55	0.88	0.53–1.46
	Q3	1.41	0.90–2.18	1.25	0.79–1.98
	Q4	2.38*	1.32–4.30	1.96	1.00-3.84
WHR	Q1 (Ref)	1		1	
	Q2	1.01	0.65–1.55	0.95	0.61–1.48
	Q3	1.58	0.86–2.91	1.42	0.75–2.70
	Q4	1.33	0.88-2.00	1.13	0.74–1.73
WHtR	Q1 (Ref)	1		1	
	Q2	0.90	0.54–1.51	0.87	0.51–1.47
	Q3	1.61	0.99–2.62	1.45	0.87–2.41
	Q4	2.41*	1.24–4.68	2.00	0.95–4.22
NC	Q1 (Ref)	1		1	
	Q2	1.36	0.91–2.02	1.27	0.85–1.88
	Q3	1.47*	1.01–2.15	1.34	0.91–1.97
	Q4	2.03*	1.18–3.50	1.71	0.91–3.20
Men					
BMI	Q1 (Ref)	1		1	
	Q2	1.40	0.84–2.35	1.30	0.76–2.23

Anthropometric	Quartile	Model 1 (core)		Model 2 (extended)	
		OR	95% CI	OR	95% CI
Women					
	Q3	1.89*	1.15–3.13	1.60	0.93–2.72
	Q4	2.66*	1.62–4.34	2.02*	1.19–3.44
WC	Q1 (Ref)	1		1	
	Q2	1.47	0.85–2.55	1.31	0.75–2.30
	Q3	1.76*	1.03–2.98	1.43	0.83–2.46
	Q4	2.83*	1.69–4.73	2.09*	1.22–3.59
WHR	Q1 (Ref)	1		1	
	Q2	1.13	0.62–2.05	1.08	0.59–1.98
	Q3	1.63	0.95–2.80	1.41	0.81–2.43
	Q4	2.39*	1.44–3.99	1.82*	1.06–3.10
WHtR	Q1 (Ref)	1		1	
	Q2	1.05	0.59–1.85	0.94	0.52–1.69
	Q3	1.55	0.91–2.66	1.27	0.72–2.21
	Q4	2.30*	1.37–3.85	1.70	0.98–2.94
NC	Q1 (Ref)	1		1	
	Q2	0.69	0.45–1.07	0.67	0.43–1.06
	Q3	1.15	0.78–1.69	0.99	0.65–1.49
	Q4	1.33	0.92–1.92	1.03	0.70–1.54

OR, odds ratio; CI, confidence interval; BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; NC, neck circumference.

Model 1 (Core): Adjusted for age, income status, place of residence, tobacco use and years of education. Model 2 (Extended): Additionally adjusted for diabetes, hypertension and dyslipidemia.

Units: BMI, kg/m²; WC and NC, cm; WHR and WHtR, unitless.

* $p < 0.05$

Discussion

NCDs account for the vast majority of deaths worldwide and in Türkiye, with CVD representing the leading cause of mortality (4, 23). In Türkiye, CVD accounts for 36% of all deaths, with ischemic heart disease ranking first among disease-specific causes in terms of both YLL and DALYs (4). In Türkiye, the prevalences of the CVD risk factors examined in this study are 11.0% for diabetes mellitus (DM), 18.3% for HT, and 11.7% for high cholesterol. These findings highlight that not only CVD but also these risk factors constitute significant public health concerns in Türkiye (23). Using nationally representative data from the TNHS-2017, this study evaluated the discriminatory performance of anthropometric indices for cardiovascular risk factors and diseases, assessed appropriate cut-off values for these indices, and examined their associations with CVD.

Among the anthropometric indices evaluated, WHtR demonstrated the best discriminatory performance in women for CVD and its risk factors, with statistically significant differences compared to other indices for DM, HT, and CVD. In men, WHR showed higher discriminatory performance than BMI, WC, and NC for DM, HT, and CVD; however, no statistically significant difference was found between WHR and WHtR. A meta-analysis predominantly including participants from Asian countries reported WHtR as a superior discriminatory index compared to BMI, WC, and WHR for HT, DM, and DL in both sexes (25). Two local studies in Türkiye also reported WHtR's superiority in discriminating cardiovascular risk factors (26, 33). Nonetheless, the literature indicates that different anthropometric indices may perform better depending on sex and outcome measures. For DM, higher discriminatory performance has been reported for WHR in both sexes in Iraq (34), WC in Iranian women and adults in Cameroon (35, 36), and WC and WHtR in both sexes in Kenya (37). For HT, BMI and WHtR in both sexes in China (14, 38), WC in young American men and WHtR and body roundness index (BRI) in women (39), and WC and WHtR in adults aged 39–72 years in Korea (40) have shown better performance. For DL, BMI and WC in men and WC in women in China (14), and WC in both sexes in Canada (41) demonstrated higher discriminatory ability. For CVD, WHR in Iranian women (35) and BRI and WHtR in Japanese men (42) showed superior performance. While our findings support previous studies reporting the superiority of WHtR, they also emphasize that WHR's discriminatory performance in men should not be overlooked. Therefore, in Türkiye, WHtR in women and both WHtR and WHR in men appear to be the most practical and feasible anthropometric indices with the best discriminatory performance for assessing CVD and its risk factors. The variation in the best-performing anthropometric indices across countries suggests that their discriminatory ability should be evaluated within country-specific contexts.

Some of the cut-off values identified in this study were found to partially correspond with reference values reported in the literature. In men, BMI cut-off values ranged from 25.5 to 26.6 kg/m², close to the WHO-recommended overweight threshold of 25 kg/m² (16). For WHtR, cut-off values for DM, HT, and CVD in women aligned with the "take action" threshold recommended in the literature (30). WHR cut-off values in both sexes were largely consistent with "high-risk" thresholds reported in the literature (0.85 for women and 0.90 for men) (16). NC cut-off values in men were close to the obesity threshold (39.5 cm) reported in the literature across outcomes and matched this cut-off for CVD (31). These findings suggest

that the recommended reference cut-off values may provide clinically appropriate risk classification for the Turkish population. Importantly, the cut-off values identified fell between the lower and higher risk thresholds within the two-level classification approach proposed by WHO and the literature (BMI: overweight and obesity; WC: risk and high risk; WHtR: risk and “take action”; NC: overweight and obesity). Overall, compared with reference thresholds indicating lower risk, the cut-offs identified showed lower sensitivity but higher specificity. An exception was WC for DL in men, where the cut-off value (90.3 cm) was lower than the WHO “risk” threshold (94 cm) (16), resulting in higher sensitivity and acceptable specificity. Given that screening programs prioritize minimizing missed cases and that diagnoses of DM, HT, DL, and CVD can be confirmed using standard criteria, interpreting these findings from a sensitivity-oriented screening perspective may be appropriate (43, 44). Thus, screening based on lower risk thresholds within the two-level classification framework may enhance early detection opportunities in Türkiye. On the other hand, cardiometabolic risk has been shown to emerge at lower levels of BMI and central obesity in some Asian populations; therefore, the WHO has proposed alternative cut-off values below those recommended for White populations for these groups (19, 45). Although Türkiye is geographically located between Asia and Europe, the findings of our study do not support proposing alternative cut-off values below the lower-risk thresholds defined by the WHO for White populations.

WHO and Ashwell propose sex-independent cut-off values for BMI and WHtR (≥ 25 kg/m² and ≥ 30 kg/m² for BMI; ≥0.5 and ≥ 0.6 for WHtR) (16, 30). However, consistent with some literature (46, 47), this study found marked differences in sensitivity and specificity between women and men at the same cut-off levels. For example, when a BMI cut-off value of 30 kg/m² (obesity) was used for CVD, sensitivity was 67% in women but decreased to 44% in men. Similarly, when a WHtR cut-off value of 0.6 (take action) was used, sensitivity was 75% in women and 55% in men.Overall, these cut-off values provide higher sensitivity in women but lower sensitivity in men. These findings indicate that sex-specific sensitivity profiles should be considered when applying current cut-off values.

Separate regression models were constructed for each sex to evaluate the association between anthropometric indices and CVD. In women, core models showed that being in the highest quartile of WC, WHtR, or NC was associated with an approximately 2–2.5-fold increase in CVD risk. In men, core models indicated approximately 2.5–2.8-fold increases in CVD risk in the highest quartiles of anthropometric indices other than NC, with the most pronounced increase observed for WC. Previous studies similarly report a two- to three-fold increase in CVD risk in higher categories of anthropometric indices (48–50). In this context, the magnitude of risk observed in the highest quartiles of anthropometric indices supports the role of central obesity as a strong and clinically meaningful indicator of CVD. In men, in the extended models, which included DM, HT, and DL in addition to the core variables, the previously significant associations observed for BMI and WC in the third quartile were no longer statistically significant, while the associations in the highest quartiles were attenuated but remained statistically significant for WHR, BMI, and WC. In women, the anthropometric indices that were significant in the highest quartiles in the core models (WC, WHtR, and NC), lost statistical significance in the extended models. A meta-analysis confirmed obesity as an important cardiovascular risk factor but reported limited additional predictive value of simple anthropometric indices when lipid profile, blood

pressure, and glycemic status were included (51). Our findings indicate that the association between central obesity and CVD risk, particularly in women, may largely be influenced by metabolic factors such as DM, HT, and DL.

Strengths and Limitations

Analyses were conducted using weighted methods that accounted for the complex sampling design of TNHS-2017, with the aim of improving the generalizability of the findings to the adult population of Türkiye. Sex-specific analyses were conducted, reflecting differences in anthropometric indices between women and men. The discriminatory performance of anthropometric indices was statistically compared, and sensitivity and specificity values were calculated both for WHO- or literature-recommended cut-offs and those identified in this study, enabling comparative evaluation. The WHO expert report on waist circumference and waist-to-hip ratio emphasizes that cut-off values should primarily be determined according to their associations with health outcomes, particularly cardiometabolic risk factors such as diabetes, rather than solely reflecting abdominal fat distribution (16). Consistent with this recommendation, cut-off values in this study were determined based on health outcomes. This represents one of the main strengths of the study.

The cross-sectional design limits evaluation of temporal relationships or causality, constituting the main limitation. DM was defined based on the presence of at least one of the following criteria: a previous diagnosis of diabetes, fasting plasma glucose ≥ 126 mg/dL, or HbA1c ≥ 6.5%. This single measurement approach, common in epidemiological studies (52–54), may have included false positives, as diagnosis typically requires repeat testing. HT assessment relied on self-reported data, potentially leading to underreporting and misclassification of false negatives. Finally, defining CVD based on high-mortality cardiovascular diseases may have introduced survival (Neyman) bias, which could have resulted in an underestimation of the true risk estimates.

Conclusion

This study provides a comprehensive epidemiological framework for the Türkiye population regarding the relationship between anthropometric indices and cardiovascular disease and its risk factors. WHtR in women and WHtR and WHR in men showed the highest discriminatory performance for cardiovascular diseases and their risk factors. The use of WHtR and WHR, which are simple and cost-free measurements easily applied in primary care, may enhance early detection and prevention strategies.

The WHO-recommended cut-off values for White populations may generally be considered applicable as reference values for the Turkish population. However, although WHO and the literature recommend sex-independent cut-offs, acceptable sensitivity was observed in women at the BMI “obesity” and WHtR “take action” thresholds, whereas sensitivity in men remained between 30.9% and 58.0%. These findings support the use of sex-specific cut-off values.

An increased risk of CVD was observed in higher anthropometric quartiles; however, these associations were attenuated when cardiometabolic risk factors were included, suggesting that anthropometric measures should be considered alongside existing metabolic risk profiles rather than in isolation in cardiovascular risk assessment.

Although strong associations between anthropometric indices and cardiovascular diseases and their risk factors were identified, cohort studies are needed to clarify the causal nature of these relationships.

Abbreviations

AUC Area under the curve

BMI Body mass index

CI Confidence interval

CVD Cardiovascular disease

DALY Disability-adjusted life year

DL Dyslipidemia

DM Diabetes mellitus

HDL-C High-density lipoprotein cholesterol

HT Hypertension

LDL-C Low-density lipoprotein cholesterol

NC Neck circumference

NCD Noncommunicable disease

OECD Organisation for Economic Co-operation and Development

PSU Primary sampling unit

ROC Receiver operating characteristic

SE Standard error

TG Triglycerides

TCHO Total cholesterol

TNHS-2017 Türkiye Nutrition and Health Survey 2017

WC Waist circumference

WHR Waist-to-hip ratio

WHtR Waist-to-height ratio

WHO World Health Organization

YLL Years of life lost

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval for this secondary data analysis was obtained from the Gazi University Ethics Committee (no. 2024/673; Ankara, Türkiye). Permission to use the TNHS-2017 data was granted by the Ministry of Health of the Republic of Türkiye. Within the TNHS-2017, written informed consent was obtained from all participants during the data collection phase. The dataset used in this study was anonymized and contained no personally identifiable information.

Consent for publication

Not applicable. This manuscript does not contain any individual data in any form.

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Author Contribution

Nilüfer Merve CELİK (NMC): Conceptualization, methodology, data collection, statistical analysis, and writing – original draft.Hakan TÜZÜN (HT): Conceptualization, methodology, review, and editing.All authors read and approved the final manuscript.

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Data Availability

The dataset analyzed during the current study was obtained from the Türkiye Nutrition and Health Survey 2017 (TNHS-2017) with permission from the Ministry of Health of the Republic of Türkiye. The data are not publicly available due to data-protection policies.

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55. Large, Tables.

Figures

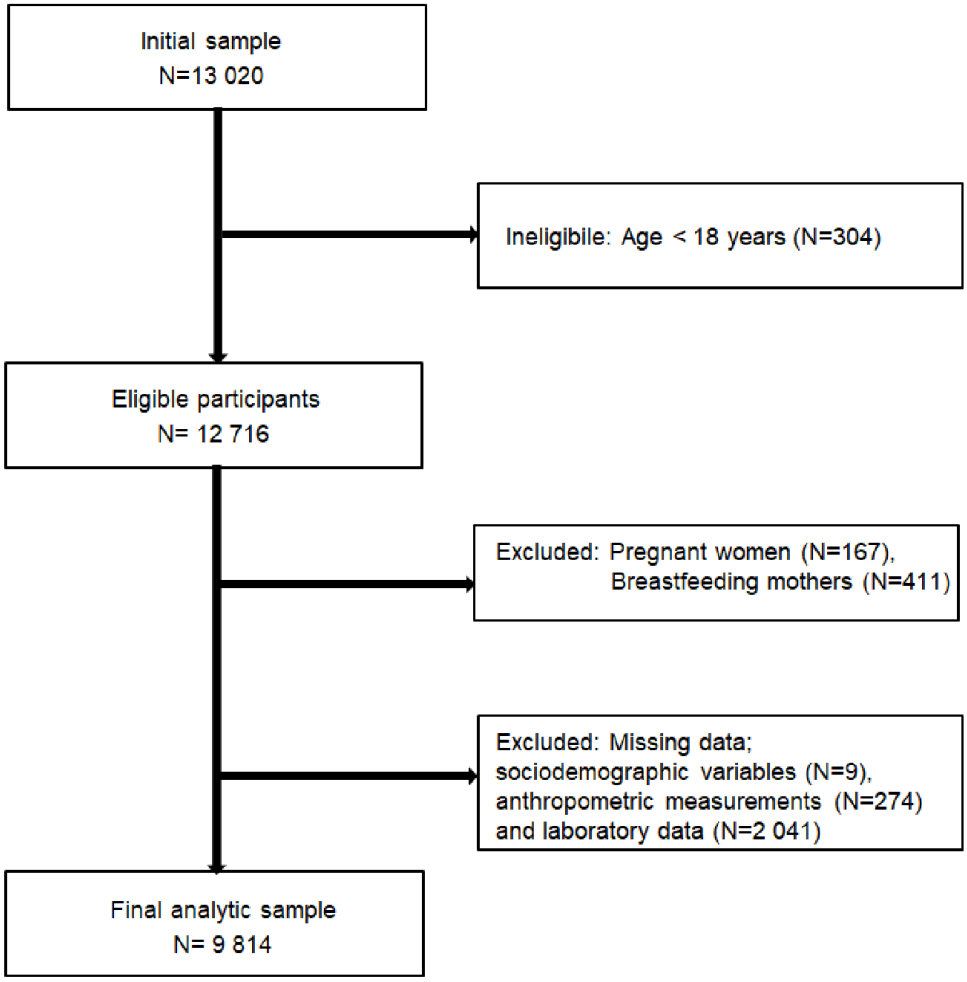


Figure 1

Flow diagram of participants included in the study from the TNHS dataset

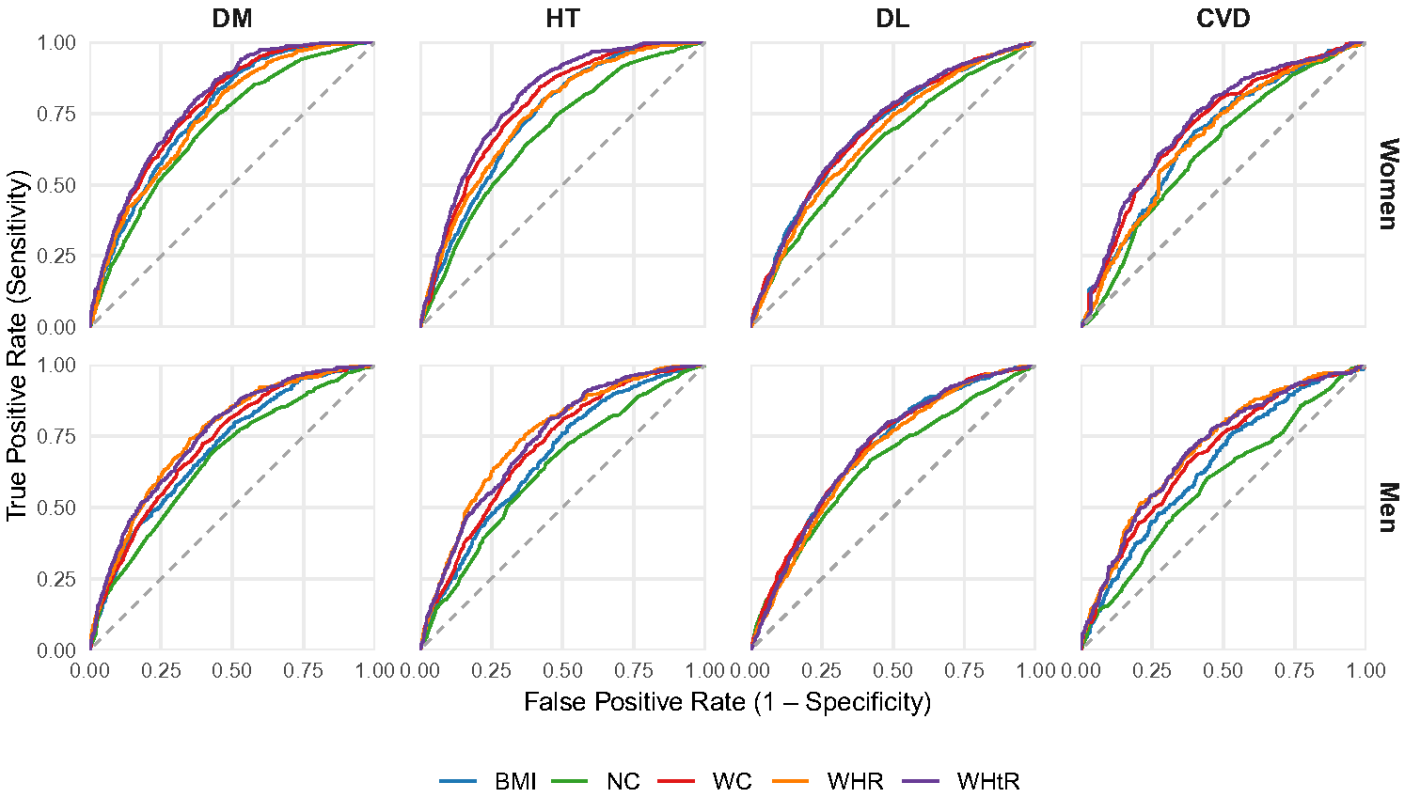


Figure 2

ROC curves of anthropometric indices for cardiovascular diseases and cardiovascular risk factors by sex