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Associations between anthropometric measurements and cardiometabolic risk factors in White European and South Asian adults in the UK

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Abstract

Objective: To investigate the association of four anthropometric measurements with cardiometabolic risk factors in a UK bi-ethnic sample in the UK of South Asians (SA) and white Europeans (WE).

Patients: Baseline data from adults of WE and SA origin participating in the ADDITION-Leicester study between August 2004 to December 2007.

Methods: Overall, 6,268 WE and SA adults had measures of body mass index (BMI), waist circumference (WC), waist:hip ratio (WHR) and waist:height ratio (WHtR) assessed between August 2004 and December 2007. Hypertension, dyslipidaemia and dysglycaemia were established from venous blood samples using standard definitions. Crude and adjusted (covariates used were age, sex, ethnicity, smoking and alcohol consumption) odds ratios were calculated using multivariate logistic regression. Receiver operating characteristic curves (ROC) and the area under the curve (AUC) were used to calculate optimal cut points overall and for both ethnic groups.

Results: Increases in all anthropometric measurements resulted in higher odds of each of the risk factors in both the crude and adjusted models (P<.001). Adjusted odds of dyslipidaemia, hypertension and dysglygaemia ranged from 1.30 – 1.35, 1.36 – 1.52 and 1.62 – 1.75 (all P<.001), respectively, for WE. Adjusted odds of dyslipidaemia, hypertension and dysglygaemia ranged from 1.50 – 1.65 *(P*<.01), 1.40 – 1.60 *(P*<.01) and 1.96 – 2.11 *(P*<.001), respectively, for SA.

AUROCs for all of the anthropometric measurements had low accuracy (P<.70) for the whole cohort and when stratified by ethnicity and sex.

Conclusion: There is insufficient evidence to recommend replacing BMI with another anthropometric measurement for the ethnically diverse population in the UK.

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Abbreviations

AUC = area under the curve

BMI = body mass index

CI = confidence interval

OR = odds ratio

ROC = receiver operating characteristic curve

SA = South Asian

WC = waist circumference

WE = White European

WHR = waist to hip ratio

WHtR = waist to height ratio

Introduction

Obesity is a recognised, modifiable risk factor for cardiovascular disease,[1] type 2 diabetes,[2, 3] dyslipidaemia,[4] hypertension[5] and stroke.[6] As obesity is often a precursor to these chronic conditions it is important to have an assessment of adiposity that can identify those at elevated risk. Adiposity based risk status can be assessed in a variety of ways including body mass index (BMI), waist circumference (WC), waist:hip ratio (WHR) and waist:height ratio (WHtR). Evidence for the best measure at detecting those with increased cardiometabolic risk remains equivocal. Available evidence is further complicated by ethnic differences in the relationships between measures of adiposity and individual cardiometabolic risk factors and a paucity of information on some populations such as those of South Asians origin (countries in the Indian sub-continent). In order to add to the body of literature regarding the use of anthropometric measurements to identify risk we investigated four common anthropometric measurements to predict precursors to chronic disease in a bi-ethnic population from the UK.

Methods

Study population

Data have been taken from the population-based screening phase (baseline) of the ADDITION-Leicester study,[7] that formed part of ADDITION-Europe. Overall 6,749 South Asian (SA) and white European (WE) adults,,who were not known to have diabetes, were recruited through 20 general practices across Leicestershire, UK between August 2004 to December 2007. Potential participants were identified through the practice list and invited to as assessment visit that took place at a hospital site or a mobile screening unit located within their community. The age inclusion criteria was 40 – 75 years for WE and, in acknowledgement of type 2 diabetes developing in younger people of minority background, 25 – 75 years for SA. Those with complete data on all anthropometric measurements and risk factors (n = 6268) are included herein. Those on antihypertensive (n = 1425) and lipid lowering (n = 712) treatment were excluded from analyses of hypertension and dyslipidaemia, respectively. Ethical approval was obtained from the University Hospitals of Leicester (UHL09320) and Leicestershire Primary Care Research Alliance (64/2004) local research ethics committees. Written informed consent was obtained from all participants.

Anthropometric measurements

Anthropometric measurements were performed by trained staff following standard operating procedures. Height was measured to the nearest 0.1 cm using a rigid stadiometer. Weight was measured in light indoor clothing to the nearest 0.1 kg using a Tanita scale (Tanita, Europe). WC was measured to the nearest 0.1 cm at the mid-point between the lower costal margin and the level of the anterior superior iliac crest. Hip circumference was measured to the nearest 0.1cm at the greatest protrusion of the gluteal muscles. BMI was calculated as weight (kg) divided by height^2 (m). WHR and WHtR were calculated as WC (cm) divided by hip circumference (cm) and height (cm), respectively.

Cardiometabolic risk factors

Arterial blood pressure was measured three times with the participant seated, using a standardised digital sphygmomanometer (Omron M7, Omron Healthcare, Milton Keynes, UK) with the average of the second and third readings used in the analysis. Participants undertook a 75g oral glucose tolerance test that included fasting and 2-hour venous blood samples. All blood samples were processed in the same pathology laboratory of the University Hospitals of Leicester NHS Trust, UK. Glucose was processed using an Abbott

Aeroset clinical chemistry analyser, which employs the hexokinase enzymatic method. HbA1c was analysed by a DCCT aligned Biorad Variant HPLC II system.

Covariates

Participants self-reported their ethnicity, current smoking status, alcohol consumption and occupation via questionnaire. Excess alcohol consumption was defined as more than 21 units per week in males and more than 14 units per week in females. Current and ex-smokers were designated as 'ever smokers'.

Definition of outcomes

The criteria proposed by the Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults were used in defining cardiometabolic risk factors.[8] Hypertension was defined as systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥90 mmHg. Raised total cholesterol was defined as levels ≥5.2 mmol/l, raised low density lipoprotein cholesterol as ≥3.36mmol/l, low high density lipoprotein cholesterol as <1.03 mmol/l, and raised triglycerides as ≥1.7 mmol/l. Dyslipidaemia was defined as abnormal levels of one or more lipid measurements. Type 2 diabetes was diagnosed using World Health Organisation 1999 criteria[9] of fasting blood glucose ≥7.0 mmol/l or an oral glucose tolerance test 2-hour value ≥11.1 mmol/l. Impaired glucose tolerance (IGT) (fasting plasma glucose < 7.0 mmol/l and an oral glucose tolerance test 2-hour value ≥7.8 mmol/l but <11.1 mmol/l) and impaired fasting glucose (fasting plasma glucose ≥6.1 mmol/l but <7.0 mmol/l) were treated as pre-diabetes (n = 865) and were combined with type 2 diabetes (n = 197) and designated as dysglycaemia for the purposes of analyses.

Statistical Analysis

Continuous data are presented as mean (standard deviation) and categorical data as frequency (percentage). Differences between WE and SA were assessed using t-tests for continuous data and chi-squared test for categorical data. Standardised odds ratios (OR) with 95% confidence intervals (95% CI) for cardiometabolic risk factors in relation to BMI, WC, WHR and WHtR were calculated using univariate and multivariate logistic regression. The interaction between each anthropometric measure and ethnicity was assessed using Wald's test. Although these were not significant data are still presented stratified by ethnicity. For each model, age, gender, ethnicity, smoking status (smokers vs. ever smokers) and excess alcohol intake were included as *a priori* confounders in the multivariate analysis. ORs were standardised by using transformed observations ([observation-mean]/SD) in the models. Crude and age-adjusted receiver operating characteristic (ROC) curves were plotted and the area under the curve (AUC) calculated for BMI, WC, WHR and WHtR, first for the cohort as a whole and then stratified by ethnicity and sex. The optimal cut point for each measure of adiposity in detecting cardiometabolic risk factors was chosen as the point on the curve with the highest Youden Index (sensitivity + specificity -1). The age-adjusted AUCs generated for each anthropometric measure were formally compared within each risk factor using the method suggested by DeLong et al.[10] A *P*-value of less than .05 was considered statistically significant. All data were analysed using Stata IC version 14.

Results

Participant characteristics

Demographic data of the 6,268 participants included in the analyses herein are shown in Table 1. WEs in this sample had significantly higher BMI and WC ($P<.001$) compared to

SAs but there were no differences in WHR or WHtR. There were more than double the percentage of those that ever smoked in the WE group compared with the SA group (WE 51% vs. % SA 17%, P<.001). A similar difference in proportions was seen in those with excess alcohol consumption (WE 13% vs. SA 6%, P<.001). Dyslipidaemia was the most commonly seen risk factor, being present in 80% of the total population, 82% of WEs and 74% of SAs (P<.001). There were significantly more hypertensive WEs than SAs (47% vs. 35%, P<.001). There were significantly fewer participants with dysglycaemia amongst WEs than SAs (16 % vs. 20%, P<.001).

Association of anthropometric measurements with cardiometabolic risk factors

The associations between each anthropometric measurement and cardiometabolic risk factors stratified by ethnicity are shown in Table 2. Increases in all anthropometric measurements resulted in higher odds of each of the risk factors in both the crude and adjusted models (P<.001) except for WHR and dyslipidaemia in SA adults (P=.08). Odds of dyslipidaemia, hypertension and dysglygaemia ranged from 1.30 – 1.35, 1.36 – 1.52 and 1.62 – 1.75, respectively, for WE and 1.29 – 1.65, 1.40 – 1.60 and 1.96 – 2.11 respectively for SA. Due to overlapping confidence intervals, the odds were not significantly different between anthropometric measurements.

Cut points for anthropometric measurements

The AUROC curves (95% CI) and optimum cut-points for predicting dyslipidaemia, hypertension and dysglycaemia for each of the anthropometric measurements are presented in Table 3. Although significantly different, the AUROCs for all of the anthropometric measurements had low accuracy[11] for detecting each cardiometabolic risk factor in both the crude and age-adjusted analyses. For dyslipidaemia, the optimum cut-points were 24 kg/m^2 (sensitivity = 80, specificity = 34, AUROC = 0.582) for BMI, 85 cm (sensitivity = 75, specificity = 41, AUROC = 0.599) for WC, 0.86 (sensitivity = 64, specificity = 52, AUROC = 0.598) for WHR and 0.51 (sensitivity = 78, specificity = 37, AUROC = 0.588) for WHtR. For hypertension, the optimum cut-points were 25 kg/m^2 (sensitivity = 74, specificity = 42, AUROC = 0.599) for BMI, 92 cm (sensitivity = 59, specificity = 59, AUROC = 0.613) for WC, 0.92 (sensitivity = 43, specificity = 72, AUROC = 0.597) for WHR and 0.54 (sensitivity = 0.65, specificity = 0.52, AUROC = 0.607) for WHtR. For dysglycaemia, the optimum cut-points were 27 kg/m^2 (sensitivity = 67, specificity = 53, AUROC = 0.633) for BMI, 91 cm (sensitivity = 74, specificity = 47, AUROC = 0.640) for WC, 0.91 (sensitivity = 55, specificity = 62, AUROC = 0.606) for WHR and 0.54 (sensitivity = 81, specificity = 43, AUROC = 0.666) for WHtR. The age-adjusted values presented in Table 3 were slightly higher but the AUROCs still being considered low accuracy at <0.70.

Table 4 shows the results of ROC analyses stratified by ethnicity. Similar to the analysis of the cohort as a whole, the AUCs were all low for the crude and age-adjusted analyses. The optimal BMI cut point for predicting dyslipidemia was higher in WEs (24 kg/m^2) than SAs (23 kg/m^2), was the same (25 kg/m^2) for hypertension and slightly higher in WEs (28 kg/m^2) than SAs (27 kg/m^2) for dysglycaemia. The optimal WC cut for dyslipidaemia was higher in South Asians (89 cm) than WEs (84 cm) but for dysglycaemia was lower in SAs (91 cm) than WEs (97 cm). For further clinical applicability Table S1 presents the results stratified by both ethnicity and sex. Again, all AUROCs were low between anthropometric measurements and between groups.

We also investigated the performance (i.e. the sensitivity and specificity) of commonly used BMI and WC cut-points on the cohort as a whole. For BMI of 30 kg/m^2 the performance was 29 and 76, 31 and 78, 43 and 74 for dyslipidaemia, hypertension and dysglycaemia, respectively. For WC of 102 cm the performance was 26 and 82, 29 and 82 and 39 and 76 for dyslipidaemia, hypertension and dysglycaemia, respectively**.**

Discussion

Using data from a large bi-ethnic cohort, we found that a number of common anthropometric measurements had similarly low, although statistically significant different, associations with cardiometabolic risk factors. As obesity continues to be a global problem, measurements that are acceptable to patients and healthcare professionals alike are needed to identify people in the population who are most risk of developing cardiometabolic morbidity and mortality in order to signpost for appropriate testing or intervention.[12] The results herein would suggest that each of these measurements have similarly low utility in identifying those who may benefit from further confirmatory tests or general lifestyle based prevention strategies.

In the sample as a whole our analysis has shown that all four measures of adiposity (BMI, WC, WHR and WHtR) had a low capacity to predict individual cardiometabolic risk factors and, similar to a study investigating the ability of these measures in predicting type 2 diabetes, [14] no clear pattern emerged for any measure that was superior. Although the AUCs reported in table 3 were statistically different, they are all lower than those reported on in previous cross-sectional,[13] meta-analysis[15] and bi-racial analysis from the US.[16] However, the differences in populations (none of the included studies were UK based or had South Asian cohort) and definitions of the risk factors may account for these differences.

Studies have reported on ethnic differences in the performance of common anthropometric measurements.[17, 18]As the AUROCs were low we did not formally test for differences in the performance of the measurements by ethnic group. However, we did find ethnic differences in the optimal cut-point for dyslipidaemia (84 cm vs. 89 cm), hypertension (92 cm vs. 90 cm) and dysglycemia (97 cm vs. 91 cm). The optimal cut points that reduce the level of false positives would suggest that lower cut points for South Asians would be supported. National and international guidelines do support the use of ethnic specific cut-points.[19, 20] as reviews have pointed out the large disparity in optimal cut-points between and within ethic groups.[21]

Meta-analytical strategies suggest that a measure of central obesity, such as WC or WHtR, is superior to BMI for identifying hypertension, type 2 diabetes and dyslipidemia.[15, 21, 22] However, papers have cautioned that the discriminatory capability differences between BMI and individual measures of central obesity were clinically non-significant.[21] As none of the studies included in these reviews included a large cohort of South Asian adults the results herein add to the body of evidence comparing the utility of common anthropometric measurements in those of South Asian background. As obesity is a heterogeneous condition referring to excess adipose tissue deposited both subcutaneously and viscerally[23, 24] it is both the excess total fat and its distribution which are important to assess. It is unlikely therefore that any single measure of adiposity will be adequate to correctly identify all those at risk in a given population. Even in those with a normal BMI there is value in further exploration using WC,[25] dual-energy X-ray absorptiometry[26] or % body fat from air displacement plethysmography.[27, 28] Although suggested by guidelines,[29, 30] the practicality of even adding a simple WC or % body fat measurement to a BMI measurement in routine clinical care may be difficult given the constraints on healthcare professional time and the limitations to bioelectrical impedance outputs.[31] Although WC is often more correlated with body fat than BMI, WC is just as correlated with total body fat as with abdominal fat.[16]

To our knowledge, this is one of the largest studies to date to compare the utility of common anthropometric measures in predicting cardiometabolic risk within two different ethnic groups in the UK. However, we used data from the screening phase of ADDITION-Leicester, thus only making use of cross-sectional data with no account of longitudinal risks or the inclusion of a hard clinical end point. Data on the inter- and intra- technician reliability of the anthropometric measurements was not collected, however, variability would be minimised as the technicians were trained and followed the same standardised operating protocol which is more that would happen if that measure were collected in routine clinical practice. Previous analyses reported that BMI, WC and WHR had similar correlates with 10-year risk of fatal cardiovascular disease[32] while both BMI and WC were associated with increased all-cause, cardiovascular disease and cancer mortality risk[33] indicating that these measures have similar value from a longitudinal point of view for diabetes.[22, 34] Although the site used herein (mid-point between the iliac crest and the lowest floating rib) is recommend by the World Health Organization[30] as a WC measurement site, the iliac crest is often used, and recommended for use,[31] in US contexts. Although the absolute value of the measurement can differ between sites, the mid-point site has been equally well correlated with cardiometabolic risk factors compared with the iliac crest site.[35] The SAs enrolled in this study were members of a migrant population and the duration of time spent in the UK was not assessed. Due to potential heterogeneity in lifestyle and dietary factors, these results cannot be generalised across all SA populations. Further research is needed to confirm whether anthropometric measurements such as WHR or WHtR adds any additional information to composite risk scores which already include either BMI or WC or both. Particularly in the SA population, more work is needed to assess the utility of these anthropometric measurements in a longitudinal fashion. Our data would suggest that there is little to be gained by simply replacing BMI or WC with another measure.

Conclusion

Obesity and its associated conditions remain of public health concern and it is important that public health interventions are appropriately targeted. Weight based anthropometric calculations have been used to indicate disease risk historically[1] and currently there is a large number of anthropometric measurements for healthcare professionals, policy makers and researchers to choose from. Although statistically there was a difference in the performance of the indicators of adiposity for each risk factor no clean pattern was seen in the performance as all were similarly low. The variety of anthropometric measurements can be utilised pragmatically as a screening tool to identify adults who may be at risk of chronic disease and who may benefit from further tests/confirmatory tests. Similar to previous reviews[21] there is insufficient evidence to recommend one anthropometric measurement over another. However, due to its historical use and the amassed epidemiological evidence BMI would seem to be the most suitable measurement to be done alone or in conjunction with an indicator of central adiposity. However, healthcare professionals should always be mindful of patient preference, equipment available and the skill of their team.

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Table 1. Baseline characteristics

	Total sample (N = 6,268)	White Europeans (N = 4,604)	South Asians (N = 1,664)	P-value (WE vs SA)
Males number **(%)**	2979 (47.5)	2162 (47.0)	817 (49.1)	.134
Age (years)	56.1 (10.7)	58.5 (9.5)	49.2 (11.1)	<.001
Body mass index (kg/m^2)	28.0 (5.0)	28.3 (4.9)	27.3 (5.0)	<.001
Waist circumference (cm)	93 (13)	94 (13)	92 (12)	<.001
Waist to hip ratio	0.89 (0.08)	0.89 (0.08)	0.89 (0.08)	.775
Waist to height ratio	0.56 (0.07)	0.56 (0.08)	0.57 (0.07)	.136
Ever smoker (%)	2597 (42)	2313 (51)	284 (17)	<.001
Excess alcohol consumption (%)	569 (12)	525 (13)	44 (6)	<.001

Dyslipidaemia[†] (%)	4450 (80)	3327 (82)	1123 (74)	<.001
Hypertension[†] (%)	2065 (43)	1589 (47)	476 (35)	<.001
Dysglycaemia (%)	1065 (17)	735 (16)	330 (20)	<.001

Note: continuous variables are presented as means with SD in parenthesis and categorical variables are presented as %. WE – White Europeans, SA - South Asians. [†]Analysis of dyslipidaemia and hypertension exclude those on lipid-lowering and antihypertensive treatment, respectively.

Table 2 – Crude and adjusted standardised odds Ratio (95% CI) for cardiometabolic risk factors in relation to anthropometric measures in the whole cohort, stratified by ethnicity.

	Crude OR (95% CI)*	**Adjusted OR (95% CI)**	***P* value for adjusted OR**
Dyslipidaemia			
White Europeans			
BMI	1.38 (1.26 – 1.51)	1.30 (1.18 – 1.44)	<.001
WC	1.41 (1.30 – 1.54)	1.32 (1.20 – 1.46)	<.001
WHR	1.36 (1.25 – 1.47)	1.35 (1.20 – 1.53)	<.001
WHtR	1.48 (1.36 – 1.62)	1.32 (1.20 – 1.45)	<.001
South Asians			
BMI	1.18 (1.05 – 1.33)	1.65 (1.29 – 2.11)	<.001
WC	1.41 (0.24 – 1.61)	1.50 (1.17 – 1.93)	.002
WHR	1.57 (1.38 – 1.78)	1.29 (0.97 – 1.72)	.08
WHtR	1.20 (1.07 – 1.36)	1.52 (1.19 – 1.96)	.001
Hypertension			
White Europeans			
BMI	1.41 (1.31 – 1.52)	1.52 (1.40 – 1.66)	<.001
WC	1.47 (1.36 – 1.57)	1.45 (1.33 – 1.58)	<.001
WHR	1.43 (1.33 – 1.53)	1.36 (1.23 – 1.51)	<.001
WHtR	1.51 (1.41 – 1.63)	1.47 (1.35 – 1.61)	<.001
South Asians			
BMI	1.44 (1.28 – 1.62)	1.60 (1.29 – 1.98)	<.001
WC	1.63 (1.43 – 1.85)	1.60 (1.28 – 2.01)	<.001
WHR	1.49 (1.32 – 1.69)	1.40 (1.06 – 1.85)	.02
WHtR	1.54 (1.37 – 1.74)	1.49 (1.20 – 1.86)	<.001
Dysglycaemia			
White Europeans			
BMI	1.58 (1.46 – 1.70)	1.62 (1.48 – 1.77)	<.001
WC	1.66 (1.54 – 1.80)	1.75 (1.59 – 1.93)	<.001
WHR	1.46 (1.34 – 1.58)	1.73 (1.54 – 1.94)	<.001
WHtR	1.78 (1.64 – 1.93)	1.75 (1.60 – 1.92)	<.001
South Asians			
BMI	1.56 (1.39 – 1.75)	1.96 (1.56 – 2.47)	<.001
WC	1.79 (1.56 – 2.04)	2.11 (1.64 – 2.73)	<.001
WHR	1.51 (1.33 – 1.72)	2.06 (1.49 – 2.85)	<.001
WHtR	1.78 (1.57 – 2.02)	2.03 (1.59 – 2.59)	<.001

OR = Odds Ratio, CI = confidence interval, BMI = body mass index, WC= waist circumference, WHR = waist to hip ratio, WHtR = waist to height ratio. Each measure has been transformed.
Adjusted model is adjusted for age, sex, ethnicity, smoking status and excess alcohol consumption.
*all models significant at $P<.01$

Table 3. Crude and adjusted AUC and optimal cut points for anthropometric measurements in relation to cardiometabolic risk factors for the whole cohort

		Crude AUC (95% CI)	Crude optimal cut point	Sens (%)	Spec (%)	Adjusted AUC (95% CI)*	Adjusted optimal cut point*	Sens (%)*	Spec (%)*	*P*
Dyslipidaemia										
	BMI	0.582 (0.562 – 0.601)	24	80	34	0.621 (0.602 – 0.640)	22	72	47	.006
	WC	0.599 (0.580 – 0.618)	85	75	41	0.630 (0.611 – 0.650)	93	78	44	
	WHR	0.598 (0.579 – 0.617)	0.86	64	52	0.632 (0.613 – 0.652)	0.78	73	50	
	WHtR	0.588 (0.569 – 0.608)	0.51	78	37	0.620 (0.601 – 0.640)	0.50	81	38	
Hypertension										
	BMI	0.599 (0.583 – 0.615)	25	74	42	0.680 (0.665 – 0.695)	30	72	48	<.001
	WC	0.613 (0.597 – 0.629)	92	59	59	0.684 (0.669 – 0.699)	106	73	49	
	WHR	0.597 (0.580 – 0.613)	0.92	43	72	0.677 (0.662 – 0.692)	0.89	67	55	
	WHtR	0.607 (0.591 – 0.623)	0.54	65	52	0.679 (0.664 – 0.694)	0.54	77	42	
Dysglycaemia										
	BMI	0.633 (0.615 – 0.651)	27	67	53	0.663 (0.645 – 0.680)	23	73	47	<.001
	WC	0.640 (0.622 – 0.658)	91	74	47	0.664 (0.647 – 0.682)	81	76	46	
	WHR	0.606 (0.587 – 0.624)	0.91	55	62	0.642 (0.624 – 0.660)	0.88	73	51	
	WHtR	0.666 (0.649 – 0.684)	0.54	81	43	0.682 (0.665 – 0.699)	0.52	79	40	

AUC = area under the receiver-operating characteristics curve, CI =confidence interval, sens = sensitivity, spec= specificity, BMI = body mass index, WC = waist circumference, WHR = waist to hip ratio, WHtR = waist to height ratio, * = Adjusted model is adjusted for age, *P* value derived by comparing AUC across all four anthropometric measures.

Table 4. Crude and adjusted AUC and optimal cut points for measures of adiposity in relation to cardiometabolic risk factors, by ethnicity

	Crude AUC (95%CI)	Crude optimal cut point	Sens (%)	Spec (%)	Adjusted AUC (95% CI)*	Adjusted optimal cut point*	Sens (%)*	Spec (%)*	*P*
Dyslipidaemia									
White Europeans									
BMI	0.590 (0.567 – 0.614)	24 (79.7)	82	32	0.631 (0.607 – 0.656)	24	70	50	<.001
WC	0.596 (0.572 – 0.620)	84 (74.2)	77	39	0.633 (0.608 – 0.657)	92	73	50	
WHR	0.587 (0.563 – 0.610)	0.84 (70.3)	73	42	0.626 (0.601 – 0.651)	0.95	69	53	
WHtR	0.609 (0.585 – 0.633)	0.51 (74.6)	78	41	0.635 (0.611 – 0.659)	0.56	67	52	
South Asians									
BMI	0.553 (0.519 – 0.587)	23 (82.4)	85	26	0.555 (0.520 – 0.590)	18	73	48	<.001
WC	0.594 (0.560 – 0.627)	89 (53.9)	58	59	0.594 (0.560 – 0.628)	91	73	47	
WHR	0.627 (0.594 – 0.660)	0.86 (61.4)	67	55	0.628 (0.595 – 0.661)	0.85	75	44	
WHtR	0.555 (0.521 – 0.590)	0.49 (86.0)	89	22	0.555 (0.520 – 0.590)	0.49	72	47	
Hypertension									
White Europeans									
BMI	0.594 (0.575 – 0.613)	25 (66.8)	75	41	0.668 (0.650 – 0.686)	27	75	45	.01
WC	0.603 (0.584 – 0.622)	92 (51.5)	60	56	0.671 (0.653 – 0.687)	73	74	48	
WHR	0.597 (0.578 – 0.616)	0.92 (35.2)	43	72	0.666 (0.648 – 0.683)	0.93	67	55	
WHtR	0.608 (0.589 – 0.627)	0.54 (52.2)	61	55	0.668 (0.650 – 0.686)	0.51	78	41	
South Asians									
BMI	0.601 (0.570 – 0.632)	25 (61.8)	72	44	0.680 (0.650 – 0.708)	20	71	48	<.001
WC	0.631 (0.601 – 0.662)	90 (48.8)	63	59	0.687 (0.658 – 0.716)	91	72	30	
WHR	0.602 (0.571 – 0.634)	0.93 (29.0)	40	77	0.673 (0.644 – 0.703)	0.79	76	46	
WHtR	0.618 (0.587 – 0.648)	0.54 (58.5)	71	49	0.677 (0.647 – 0.706)	0.58	78	41	
Dysglycaemia									
White Europeans									
BMI	0.641 (0.619 – 0.662)	28 (43.9)	62	59	0.688 (0.667 – 0.708)	22	73	47	<.001
WC	0.643 (0.621 – 0.664)	97 (40.9)	58	62	0.686 (0.665 – 0.706)	109	77	44	
WHR	0.602 (0.580 – 0.624)	0.91 (40.9)	53	61	0.660 (0.640 – 0.681)	0.78	69	53	
WHtR	0.666 (0.645 – 0.687)	0.58 (40.2)	61	64	0.696 (0.676 – 0.716)	0.49	70	50	
South Asians									
BMI	0.632 (0.600 – 0.663)	27 (62.3)	61	61	0.679 (0.648 – 0.709)	26	70	51	<.001
WC	0.655 (0.625 – 0.686)	91 (49.8)	70	55	0.683 (0.652 – 0.713)	92	76	46	
WHR	0.616 (0.582 – 0.649)	0.91 (39.5)	57	65	0.648 (0.615 – 0.681)	0.73	73	50	
WHtR	0.667 (0.638 – 0.697)	0.54 (61.8)	85	44	0.687 (0.657 – 0.717)	0.56	73	50	

AUC = area under the receiver-operating characteristics curve, CI =confidence interval, sens = sensitivity, spec= specificity, BMI = body mass index, WC = waist circumference, WHR = waist to hip ratio, WHtR = waist to height ratio, * = Adjusted model is adjusted for age, *P* value derived by comparing AUC across all four anthropometric measures.