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Detection of cardio-metabolic risk by BMI and waist circumference among a population of Guatemalan adults

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Abstract

Background: BMI and waist circumference (WC) are used to screen for cardio-metabolic risk; however it is unclear how well these indices perform in populations subject to childhood stunting.

Objectives: To evaluate BMI and WC as indicators of cardio-metabolic risk and to determine optimal cut-off points among 1325 Guatemalan adults (44 % stunted: ≤150 cm women; ≤162 cm men).

Methods: Cardio-metabolic risk factors were systolic/diastolic blood pressure ≥130/≥85 mmHg, glucose ≥5·5 mmol/l, TAG ≥1·7 mmol/l, ratio of total cholesterol to HDL-cholesterol ≥5·0, and the presence of two or more and three or more of the preceding risk factors. Receiver operating characteristic (ROC) curve analysis was used.

Results: Areas under the ROC curve were in the range of 0·59–0·77 for BMI and 0·59–0·78 for WC among men and 0·66–0·72 and 0·64–0·72 among women, respectively. Optimal cut-off points for BMI were 24·7–26·1 kg/m^2 among men (24·5–26·1 kg/m^2 stunted; 24·8–26·3 kg/m^2 non-stunted) and 26·5–27·6 kg/m^2 among women (26·3–27·8 kg/m^2 stunted; 26·6–27·9 kg/m^2 non-stunted). Optimal cut-off points for WC were 87·3–91·1 cm among men (85·3–89·4 cm stunted; 88·5–93·3 cm non-stunted) and 91·3–95·3 cm among women (90·9–94·4 cm stunted; 91·8–95·6 cm non-stunted).

Conclusion: Optimal cut-off points for BMI were slightly higher among women than men with no meaningful differences by stature. Optimal cut-off points for WC were several centimetres lower for stunted compared with non-stunted men, and both were substantially lower than the current recommendations among Western populations. Cut-off points derived from Western populations may not be appropriate for developing countries with a high prevalence of stunting.

Keywords
BMI
Waist circumference
Cardio-metabolic risk factors
Receiver operating characteristic curve
Cut-off point

It is now widely acknowledged that excess adipose tissue has adverse effects on the cardio-metabolic profile. Overweight and obesity are associated with hypertension, insulin resistance, diabetes, dyslipidaemia, and CVD mortality[1,2]. The prevalence of overweight and obesity is increasing rapidly in less-developed countries, contributing to global epidemics of diabetes and CVD[3–5].

Various measures are used to screen for overweight and obesity. The BMI is easy to obtain, and globally recognised standards (≥25 kg/m^2 overweight; ≥30 kg/m^2 obese) allow for group comparisons[6]. However, BMI is an indicator of total adiposity at best and may not capture central obesity, which is associated with cardio-metabolic risk independently of overall obesity[7–9]. Waist circumference (WC) values of >102 cm among men and >88 cm among women have been recommended as indicators of abdominal obesity and are used clinically in the USA[10]; these were developed to correspond to a BMI of 30 kg/m^2 in a large, predominantly white, British population[11].

The associations among BMI and WC and cardio-metabolic risk factors may differ by racial/ethnic group[12,13]. The commonly used cut-off points for BMI have been shown to be inappropriate for some Asian populations, leading to the adoption of new classifications for Asians (≥23 kg/m^2 overweight; ≥25 kg/m^2

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obese)[14]. Similarly, ethnic-specific WC cut-off points have been suggested: >94 cm among men and >80 cm among women of European descent, and >90 cm among men and >80 cm among women of Asian descent[15]. To date, there are insufficient data for recommendations of specific cut-off points for Latin American populations.

An underlying explanation for some of the discrepancies in the associations of body composition and cardio-metabolic risk among racial/ethnic groups may be differences in attained height. Mean height in developing countries is typically lower than in developed countries, reflecting poor nutritional status in early life[16]. In Mexico, body fat (expressed as a percentage of total weight) is higher among short-stature (≤150 cm women, ≤160 cm men) than tall-stature subjects with the same BMI[17], and the prevalence of obesity-related co-morbidities is higher among short-stature compared with normal-stature subjects, across all BMI levels[18]. In Brazil, short stature (≤150 cm women, ≤162 cm men) is associated with obesity and hypertension among women, but not among men[19,20]. An unfavourable early-life nutritional environment is also thought to be reflected not simply in height, but in relative skeletal dimensions. Shorter legs, and thus a higher ratio of sitting height to height (SH:H), have been associated with increased adiposity, CVD risk and CVD mortality[21–23].

Our objectives in the present work were: (i) to evaluate the ability of easily obtained anthropometric indices to detect CVD risk among a sample of stunted and non-stunted Guatemalan men and women; and (ii) determine optimal cut-off points for BMI and WC in this population and whether they differ by sex and stature.

Methods

Our sample included men and women (and their spouses) surveyed in 2002–2004 as part of a follow-up study of men and women who were born in one of four Guatemalan villages and participated in the Institute of Nutrition of Central America and Panama (INCAP) Longitudinal Study (1969–1977)[24]. Details of the follow-up have been published elsewhere[25]; 1891 original subjects and spouses provided anthropometric data, of whom 1343 also provided complete cardio-metabolic data. We excluded pregnant respondents (*n* 17) for a final sample of 1326. Data collection was approved by the human subjects review boards at INCAP and Emory University; informed consent was obtained from all participants.

Anthropometry

Height, sitting height, weight and WC measures were obtained in duplicate by trained field researchers; if the measures differed by greater than 0·5 kg for body weight, 1·0 cm for height or 1·5 cm for WC, a third measure was taken and the closest two were used. We categorised participants as overweight (BMI ≥ 25 kg/m^2) or obese (BMI ≥ 30 kg/m^2), and as having central obesity if WC was >102 cm (men) or >88 cm (women)[6]. Percentage body fat was calculated using predictive equations that were developed from this population[26]. We defined stunting as height ≤150 cm for women and ≤162 cm for men; these correspond to values at least 2 SD below the median of the 2000 US reference population[27].

Plasma lipids and glucose

All participants fasted for at least 8 h; finger-prick blood samples were analysed with an enzymatic peroxidase dry chemistry method (Cholestech LDX System, Hayward, CA, USA) to determine lipid and glucose concentrations. These measures have previously been compared with venous blood collected at the time of the finger prick and analysed at Emory University's Lipid Research Laboratory[28]. Linear correlations were >0·9, but concordance was only moderately sufficient (0·69) for HDL-cholesterol (HDL-C). We classified participants as having elevated glucose when plasma glucose levels were ≥5·5 mmol/l (≥100 mg/dl)[29]. An adverse lipid profile was defined as ratio of total cholesterol (TC) to HDL-C ≥5·0 and TAG≥1·7 mmol/l (≥150 mg/dl)[30].

Blood pressure

Measurements were taken at least 3 min apart with a digital sphygmomanometer (model UA-767; A&D Medical, Milpitas, CA, USA) on the left arm resting on a table at heart level. Three cuff sizes were available and selected for use based on arm circumference. If blood pressure measurements differed by more than 10 mmHg, a fourth was taken; otherwise the second and third measures were recorded. We classified participants as having elevated blood pressure if systolic blood pressure (SBP) ≥130 mmHg and/or diastolic blood pressure (DBP) ≥85 mmHg[31].

Statistical analysis

We conducted analyses stratified by sex and stature, and determined group differences by ANOVA for continuous variables or by the χ^2 test for dichotomous variables. Sensitivity was defined as the percentage of participants with a cardio-metabolic risk factor that was correctly identified at a specified anthropometric cut-off point; specificity was defined as the percentage of participants without the cardio-metabolic risk factor correctly identified at the same cut-off point. Positive predictive value was defined as the percentage of participants with an anthropometric value at or above the cut-off point who had the cardio-metabolic risk factor; negative predictive value was defined as the percentage of participants with an anthropometric value below the cut-off point who

did not have the risk factor. We plotted sensitivity *v.* (1 − specificity) over the entire range of cut-off values of BMI and WC to obtain receiver operating characteristic (ROC) curves. The area under the curve (AUC) is a measure of the diagnostic power of the test, with 1·0 indicating a perfect test while 0·5 represents chance[32]. Optimal cut-off points for BMI and WC were derived by simultaneously maximising sensitivity and specificity, correctly identifying the highest number of subjects with and without the risk factor[33,34]. All analyses were conducted using the Statistical Analysis Systems statistical software package version 9·1 (SAS Institute, Cary, NC, USA).

Results

The population as a whole was short compared with US norms (mean *Z* score −1·7 (SD 0·8)). Demographic and anthropometric data and CVD risk factors are summarised in Table 1. Among both men and women, compared with non-stunted participants, stunted participants had higher SH:H and lower height, weight, WC, percentage body fat and SBP. Among men only, TAG was lower among stunted compared with non-stunted participants.

AUC was in the range of 0·59–0·77 for BMI and 0·59–0·78 for WC among men and 0·66–0·72 and 0·64–0·72, respectively, among women (Table 2). AUC tended to be higher for adverse lipid and composite risk factors and lower for elevated glucose among men compared with women, for both BMI and WC. In comparing stunted *v.* non-stunted groups, other than elevated blood pressure among men and elevated TAG among women, AUC tended to be either similar between the groups or higher among non-stunted participants.

Table 3 shows the sensitivity, specificity, positive predictive value and negative predictive value of the empirically determined optimal cut-off points determined for BMI, as well as for the standard cut-off points for overweight and obesity. For the various risk factors, optimal cut-off values ranged from 24·7 to 26·1 kg/m^2 among men and from 26·5 to 27·6 kg/m^2 among women. Further stratifying by stature, optimal cut-off points were 24·5–26·1 kg/m^2 among stunted men and 24·8–26·3 kg/m^2 among non-stunted men, and 26·3–27·8 kg/m^2 and 26·6–27·9 kg/m^2 among women, respectively. Overall, the optimal cut-off points for BMI tended to be higher among women than men, and similar among stunted and non-stunted groups.

Table 4 provides the same data for the empirically determined optimal cut-off points determined for WC, as well as for the standard cut-off points for abdominal obesity. Optimal cut-off points for WC were in the range 87·3–91·1 cm among men and 91·3–95·3 cm among women. Stratified by stature, optimal cut-off points were in the range of 85·3–89·4 cm among stunted men, 88·5–93·3 cm among non-stunted men, 90·9–94·4 cm among stunted women and 91·8–95·6 cm among non-stunted women. The optimal cut-off points were consistently lower, by several centimetres, among stunted compared with non-stunted men; a similar but weaker relationship was found among women. Sensitivity was much lower among men (8–24 % stunted; 13–18 % non-stunted) than women (70–88 % stunted; 74–91 % non-stunted) for the standard cut-off points.

Additionally, we calculated the AUC for SH:H as a predictor of each of the CVD risk factors (data not shown). SH:H had no better predictive ability than chance (AUC ~ 0·5) for identifying any of the cardio-metabolic risk factors, other than an adverse TC:HDL-C ratio among men (AUC = 0·62, 95 % CI 0·55, 0·65).

Discussion

In Guatemala childhood stunting remains common while the country is simultaneously experiencing significant increases in obesity and obesity-related chronic diseases[5,35,36]. Therefore, it is critical to establish simple screening tools and cut-off points to identify CVD risk which are appropriate for this relatively short population. Using the globally recognised cut-off point for overweight (BMI ≥ 25 kg/m^2) 57–77 % of men and 72–87 % of women at increased risk for CVD were correctly identified, while for obesity (BMI ≥ 30 kg/m^2) only 15–22 % of men and 32–51 % of women were correctly identified. Sensitivity for the currently used WC value of 88 cm among women was high, but sensitivity for the WC cut-off point of 102 cm among men was very low (13–18 % non-stunted; 8–24 % stunted), and would result in failure to identify CVD risk in a substantial portion of this group.

Empirically derived optimal BMI cut-off points were slightly higher among women than men. We did not find differences in optimal BMI cut-off points when stratifying by stature. These findings are consistent with a recent study which reported that the association between percentage body fat and BMI was similar among stunted and non-stunted Brazilian children[37]. However, we did find differences in WC cut-off points between stunted and non-stunted men; the optimal cut-off points were 3·0–7·0 cm higher among non-stunted men across all risk categories. Furthermore, the optimal cut-off points for both stunted and non-stunted men were substantially lower than the widely used cut-off point of 102 cm. Of interest, we identified optimal WC cut-off points that were higher for women than for men. Some of the difference in cut-off points may be due to the method of determination; the common cut-off points of 102 cm and 88 cm among men and women, respectively, were developed to correspond to a BMI of 30 kg/m^2, whereas our cut-off points were developed in relation to specific cardio-metabolic risk factors. Although higher than our empirically derived optimal cut-off points (likely in some part

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Table 1 Characteristics of the sample of Guatemalan adults by sex and stature

	Total					Men					Women				
	Men (*n* 536)		Women (*n* 790)			Stunted (*n* 232)		Non-stunted (*n* 304)			Stunted (*n* 356)		Non-stunted (*n* 434)		
	Mean	SD	Mean	SD	*P*	Mean	SD	Mean	SD	*P*	Mean	SD	Mean	SD	*P*
Age (years)	34·2	6·3	32·1	5·3	<0·01	34·3	6·3	34·1	6·3	0·7	32·1	5·3	32·1	5·3	0·8
Height (cm)	163·1	5·9	150·6	5·4	<0·01	157·8	3·4	167·1	3·7	<0·01	145·9	3·2	154·4	3·4	<0·01
Height-for-age *Z* score*	−1·35	0·6	−1·96	0·8	<0·01	−1·86	0·3	−0·96	0·4	<0·01	−2·68	0·5	−1·37	0·5	<0·01
SH:H (×100)	53·1	1·2	53·9	1·3	<0·01	53·4	1·1	52·8	1·1	<0·01	54·3	1·3	53·6	1·3	<0·01
Weight (kg)	67·1	11·1	60·6	11·8	<0·01	62·4	9·8	70·7	10·6	<0·01	57·0	10·7	63·4	11·9	<0·01
BMI (kg/m^2)	25·2	3·7	26·7	4·8	<0·01	25·0	3·7	25·3	3·7	0·4	26·7	4·8	26·6	4·7	0·6
≥25 kg/m^2 (%)	47·4		60·8		<0·01	44·0		50·0		0·2	59·9		61·8		0·6
≥30 kg/m^2 (%)	11·2		23·2		<0·01	10·8		11·5		0·8	25·0		21·7		0·3
WC (cm)	88·4	9·8	91·8	11·7	<0·01	86·2	9·1	90·2	9·9	<0·01	90·9	11·3	92·6	12·0	0·03
>102 cm (men), >88 cm (women) (%)	9·0		60·9		<0·01	6·9		10·5		0·1	59·3		62·2		0·4
Body fat (%)	21·8	7·1	34·7	7·2	<0·01	20·7	6·8	22·5	7·3	<0·01	34·1	6·8	35·2	7·4	0·03
SBP (mmHg)	117·2	12·7	111·1	14·0	<0·01	115·9	12·8	118·1	12·8	0·04	109·9	14·4	112·0	13·7	0·04
DBP (mmHg)	72·3	9·2	71·6	10·1	0·2	71·5	9·3	73·0	9·1	0·06	70·4	10·2	72·6	9·9	<0·01
SBP/DBP ≥130/≥85 mmHg (%)	19·0		12·0		<0·01	14·7		22·4		0·02	10·7		13·1		0·3
Glucose (mmol/l)	5·2	0·8	5·2	1·6	0·3	5·2	0·6	5·2	0·9	0·9	5·1	1·1	5·3	1·9	0·1
≥5·5 mmol/l (%)	19·4		19·6		<0·01	20·7		18·4		0·3	17·1		21·7		0·1
TC:HDL-C	5·0	1·6	4·3	1·3	<0·01	4·9	1·7	5·1	1·6	0·3	4·4	1·3	4·4	1·3	0·9
Ratio ≥5·0 (%)	45·3		27·9		<0·01	42·7		47·4		0·3	28·4		27·4		0·8
TAG (mmol/l)	2·0	1·0	1·9	1·0	<0·01	1·9	1·0	2·1	1·1	0·02	1·9	1·0	1·8	1·0	0·5
≥1·7 mmol/l (%)	53·2		48·4		0·09	49·6		57·6		0·07	48·4		48·3		0·9
≥2 risk factors (%)	45·9		33·2		<0·01	41·8		49·0		0·1	32·9		33·4		0·9
≥3 risk factors (%)	19·0		12·0		<0·01	15·1		22·0		0·04	13·6		10·1		0·1

SH:H, ratio of sitting height to height; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, HDL-cholesterol.
*Compared with US population, 2000.

Table 2 Area under the receiver operating characteristic curve (and 95 % CI) for BMI and waist circumference (WC) in relation to CVD risk factors among Guatemalan adults, by sex and stature

	Men											
	Total (*n* 536)				Stunted (*n* 232)				Non-stunted (*n* 304)			
	BMI		WC		BMI		WC		BMI		WC	
	AUC	95 % CI	AUC	95 % CI	AUC	95 % CI	AUC	95 % CI	AUC	95 % CI	AUC	95 % CI
SBP/DBP ≥130/≥85 mmHg	0·69	0·63, 0·74	0·73	0·68, 0·78	0·73	0·63, 0·82	0·78	0·69, 0·86	0·66	0·59, 0·73	0·68	0·61, 0·75
Glucose ≥5·5 mmol/l	0·59	0·53, 0·65	0·59	0·52, 0·65	0·52	0·43, 0·61	0·50	0·41, 0·60	0·66	0·58, 0·74	0·67	0·59, 0·74
TC:HDL-C ≥5·0	0·74	0·70, 0·78	0·74	0·69, 0·78	0·74	0·68, 0·81	0·72	0·66, 0·79	0·73	0·68, 0·79	0·74	0·68, 0·80
TAG ≥1·7 mmol/l	0·74	0·70, 0·78	0·74	0·70, 0·79	0·74	0·67, 0·80	0·73	0·67, 0·80	0·75	0·69, 0·80	0·75	0·69, 0·80
≥2 risk factors	0·77	0·73, 0·81	0·78	0·74, 0·82	0·75	0·68, 0·81	0·75	0·68, 0·81	0·78	0·73, 0·83	0·79	0·74, 0·84
≥3 risk factors	0·73	0·68, 0·78	0·75	0·70, 0·80	0·72	0·63, 0·81	0·73	0·65, 0·82	0·73	0·67, 0·80	0·75	0·69, 0·81
	Women											
	Total (*n* 790)				Stunted (*n* 356)				Non-stunted (*n* 434)			
	BMI		WC		BMI		WC		BMI		WC	
	AUC	95 % CI	AUC	95 % CI	AUC	95 % CI	AUC	95 % CI	AUC	95 % CI	AUC	95 % CI
SBP/DBP ≥130/≥85 mmHg	0·72	0·67, 0·78	0·72	0·67, 0·77	0·69	0·60, 0·78	0·71	0·62, 0·79	0·75	0·68, 0·81	0·73	0·66, 0·79
Glucose ≥5·5 mmol/l	0·68	0·63, 0·72	0·66	0·61, 0·70	0·66	0·59, 0·73	0·65	0·57, 0·72	0·69	0·63, 0·75	0·66	0·61, 0·72
TC:HDL-C ≥5·0	0·66	0·62, 0·70	0·64	0·59, 0·68	0·63	0·56, 0·69	0·61	0·54, 0·67	0·68	0·63, 0·74	0·66	0·61, 0·72
TAG ≥1·7 mmol/l	0·67	0·64, 0·71	0·67	0·63, 0·70	0·68	0·63, 0·74	0·69	0·63, 0·74	0·66	0·61, 0·72	0·65	0·59, 0·70
≥2 risk factors	0·72	0·68, 0·75	0·69	0·65. 0·73	0·71	0·65, 0·77	0·69	0·64, 0·75	0·72	0·67, 0·77	0·69	0·64, 0·74
≥3 risk factors	0·70	0·65, 0·76	0·69	0·64, 0·74	0·68	0·59, 0·77	0·68	0·59, 0·76	0·72	0·65, 0·79	0·69	0·63, 0·76

AUC, area under the curve; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, HDL-cholesterol.

Table 3 Diagnostic accuracy of optimal and commonly used cut-off values of BMI to identify subjects with cardio-metabolic CVD risk factors, by sex and stature

	Men														
	Total (*n* 536)					Stunted (*n* 232)					Non-stunted (*n* 304)				
	Cut-off point (kg/m^2)	Sens (%)	Spec (%)	PPV (%)	NPV (%)	Cut-off point (kg/m^2)	Sens (%)	Spec (%)	PPV (%)	NPV (%)	Cut-off point (kg/m^2)	Sens (%)	Spec (%)	PPV (%)	NPV (%)
SBP/DBP ≥130/ ≥85 mmHg	25·9*	65·7	67·7	32·4	89·4	26·1*	67·6	71·2	28·4	92·7	25·9*	64·7	66·9	35·8	86·7
	25	67·7	57·4	27·2	88·3	25	70·6	60·6	23·5	92·3	25	66·2	54·7	29·6	84·9
	30	21·6	91·2	36·7	83·2	30	29·4	92·4	40·0	88·4	30	17·7	90·3	34·3	79·2
Glucose ≥5·5 mmol/l	25·2*	56·7	59·0	25·0	85·0	24·5*	52·1	51·1	21·7	80·3	25·8*	64·3	63·3	28·4	88·7
	25	56·7	54·9	23·2	84·0	25	43·8	56·0	20·6	79·2	25	67·9	54·0	25·0	88·2
	30	16·4	90·1	28·3	81·7	30	12·5	89·7	24·0	79·7	30	19·6	90·3	31·4	83·3
TC:HDL-C ≥5·0	24·9*	69·1	69·6	65·4	73·1	24·7*	68·7	70·7	62·4	74·8	25·1*	69·4	69·4	67·4	70·6
	25	67·9	69·6	65·0	72·3	25	64·7	71·4	62·8	73·1	25	70·1	68·1	66·5	71·7
	30	16·1	92·8	65·0	57·1	30	20·2	96·2	80·0	61·8	30	13·2	90·0	54·3	53·5
TAG ≥1·7 mmol/l	24·7*	69·3	69·9	73·1	65·9	24·5*	67·0	67·5	67·0	67·5	24·8*	70·9	71·3	76·9	63·9
	25	65·9	74·4	75·2	64·9	25	62·6	74·4	70·6	66·9	25	68·0	74·4	78·3	63·2
	30	15·2	93·5	73·3	48·3	30	6·5	94·9	76·0	53·6	30	14·3	92·3	71·4	44·2
≥2 risk factors	24·9*	70·7	71·4	67·7	74·2	24·7*	68·0	69·6	60·6	74·8	25·1*	71·8	72·9	72·2	71·9
	25	69·9	71·7	67·7	73·8	25	66·0	71·9	62·8	74·6	25	72·5	57·8	34·2	90·1
	30	17·9	94·5	73·3	57·6	30	20·6	96·3	80·0	62·8	30	16·1	92·9	68·6	53·5
≥3 risk factors	26·1*	70·6	70·7	36·0	91·1	25·8*	68·6	68·0	26·7	91·8	26·3*	73·1	72·6	42·9	90·1
	25	76·5	59·5	30·7	91·5	25	74·3	61·4	25·5	93·1	25	77·6	57·8	34·2	90·1
	30	20·6	91·0	35·0	83·0	30	22·9	91·4	32·0	87·0	30	19·4	90·7	37·1	79·9
	Women														
	Total (*n* 790)					Stunted (*n* 356)					Non-stunted (*n* 434)				
	Cut-off point (kg/m^2)	Sens (%)	Spec (%)	PPV (%)	NPV (%)	Cut-off point (kg/m^2)	Sens (%)	Spec (%)	PPV (%)	NPV (%)	Cut-off point (kg/m^2)	Sens (%)	Spec (%)	PPV (%)	NPV (%)
SBP/DBP ≥130/ ≥85 mmHg	27·6*	63·2	63·9	19·3	92·7	27·8*	63·2	63·5	16·7	93·4	27·6*	64·9	64·7	21·6	92·1
	25	87·4	42·9	17·3	96·1	25	81·6	40·6	14·1	94·9	25	91·2	44·8	20·0	97·1
	30	50·5	80·5	26·2	92·3	30	52·6	78·3	22·5	93·3	30	49·1	82·5	29·8	91·5
Glucose ≥5·5 mmol/l	27·3*	62·6	63·0	29·2	87·3	27·0*	60·7	59·7	23·7	88·0	27·4*	64·9	65·3	53·5	86·9
	25	80·7	44·1	26·0	90·3	25	78·7	41·7	21·8	90·4	25	81·0	46·2	29·6	90·2
	30	40·7	81·1	34·4	84·8	30	44·3	79·0	30·3	87·3	30	38·3	82·9	38·3	82·9
TC:HDL-C ≥5·0	27·0*	63·2	61·9	39·0	81·3	26·8*	59·4	60·0	37·0	78·9	27·3*	65·5	66·3	42·4	83·6
	25	75·9	45·1	34·8	82·9	25	73·3	42·8	33·6	80·2	25	78·2	47·0	35·8	85·1
	30	36·8	82·1	44·3	77·1	30	39·6	80·8	44·9	77·2	30	34·5	83·2	43·6	77·1
TAG ≥1·7 mmol/l	26·5*	60·9	61·1	60·0	62·1	26·3*	63·0	62·8	61·6	64·3	26·6*	59·6	59·3	58·2	59·7
	25	71·5	49·5	57·5	64·5	25	73·4	49·2	57·7	66·2	25	70·0	49·8	57·3	63·2
	30	32·4	85·6	68·3	57·0	30	37·0	86·3	71·9	59·2	30	28·6	85·1	64·9	55·3
≥2 risk factors	26·9*	65·8	65·3	48·6	79·8	26·9*	65·8	65·3	47·8	79·2	27·2*	66·2	67·1	50·0	79·3
	25	80·5	49·1	44·0	83·6	25	78·6	46·4	41·8	81·6	25	82·1	51·2	45·8	85·1
	30	40·5	85·4	57·9	74·3	30	45·3	84·9	59·6	76·0	30	36·7	85·8	56·4	72·9
≥3 risk factors	27·4*	64·2	61·4	18·5	92·6	27·4*	58·3	60·6	14·3	92·8	27·9*	66·1	67·2	24·1	92·3
	25	84·2	42·5	16·7	95·2	25	86·1	40·9	14·1	96·3	25	83·1	43·7	18·9	94·3
	30	48·4	80·3	25·1	91·9	30	50·0	77·8	20·2	93·3	30	47·5	82·4	29·8	90·9

Sens, sensitivity; Spec, specificity; PPV, positive predictive value; NPV, negative predictive value; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, HDL-cholesterol.
*Empirically determined optimal cut-off point for BMI (kg/m^2), defined as the value where (Sens+Spec) is maximised.

Table 4 Diagnostic accuracy of optimal and commonly used cut-off values of waist circumference (WC) to identify subjects with cardio-metabolic CVD risk factors, by sex and stature

	Men														
	Total (*n* 536)					Stunted (*n* 232)					Non-stunted (*n* 304)				
	Cut-off point (cm)	Sens (%)	Spec (%)	PPV (%)	NPV (%)	Cut-off point (cm)	Sens (%)	Spec (%)	PPV (%)	NPV (%)	Cut-off point (cm)	Sens (%)	Spec (%)	PPV (%)	NPV (%)
SBP/DBP ≥130/≥85 mmHg	90·7*	66·7	67·5	32·5	89·6	89·4*	70·6	70·2	28·9	93·3	92·5*	63·2	66·5	35·3	86·3
	102	19·6	93·6	41·7	83·2	102	23·5	96·0	50·0	88·0	102	17·7	91·5	37·5	79·4
Glucose ≥5·5 mmol/l	89·1*	56·7	58·1	24·6	84·8	85·3*	52·1	50·5	20·9	79·5	92·3*	60·7	64·1	27·1	87·4
	102	12·5	54·9	27·1	81·4	102	8·3	93·5	25·0	79·6	102	16·1	54·0	28·1	82·7
TC:HDL-C ≥5·0	88·3*	68·7	69·3	65·0	72·8	85·7*	65·7	66·2	58·7	71·5	90·2*	69·4	70·0	68·3	71·7
	102	12·8	94·2	64·6	56·6	102	13·1	97·7	81·3	60·2	102	12·5	91·3	56·3	53·7
TAG ≥1·7 mmol/l	87·3*	69·7	70·7	73·7	66·4	85·5*	68·7	69·2	69·6	69·2	88·5*	73·1	72·9	78·3	65·7
	102	11·7	94·3	70·8	56·6	102	9·6	95·7	68·8	5·9	102	13·1	93·0	71·9	44·1
≥2 risk factors	88·3*	72·0	72·4	68·9	75·3	86·0*	70·0	70·0	62·6	76.0	89·5*	71·8	71·6	70·.7	72·1
	102	13·8	95·2	70·8	56·6	102	11·3	96·3	68·8	60·2	102	15·4	94·2	71·9	53·7
≥3 risk factors	91·1*	69·6	70·3	35·5	90·8	89·1*	71·4	69·0	28·2	92·5	93·3*	73·1	73·4	43·6	90·2
	102	17·7	93·1	37·5	82·8	102	20·0	95·4	43·8	87·0	102	16·4	91·1	34·4	79·4
	Women														
	Total (*n* 790)					Stunted (*n* 356)					Non-stunted (*n* 434)				
	Cut-off point (cm)	Sens (%)	Spec (%)	PPV (%)	NPV (%)	Cut-off point (cm)	Sens (%)	Spec (%)	PPV (%)	NPV (%)	Cut-off point (cm)	Sens (%)	Spec (%)	PPV (%)	NPV (%)
SBP/DBP ≥130/≥85 mmHg	95·3*	65·3	66·6	21·1	93·4	94·4*	65·8	67·9	19·4	94·0	95·6*	66·7	65·5	21·8	94·0
	88	88·4	42·9	17·5	96·4	88	84·2	43·7	15·2	95·9	88	91·2	42·2	19·3	95·9
Glucose ≥5·5 mmol/l	93·1*	60·0	61·3	27·4	86·3	93·6*	57·4	65·4	25·0	87·7	93·3*	60·6	59·7	29·4	87·7
	88	79·4	44·1	25·6	89·6	88	73·8	43·7	21·3	89·0	88	83·0	46·2	28·9	89·0
TC:HDL-C ≥5·0	92·6*	59·1	60·2	36·4	79.2	91·8*	59·4	58·4	36·0	78·1	93·3*	62·2	61·9	38·1	78·1
	88	74·6	44·4	34·1	81·9	88	70·3	45·1	33·7	79·3	88	78·2	43·8	34·4	79·3
TAG ≥1·7 mmol/l	91·3*	60·6	60·9	59·7	61·8	90·9*	62·4	62·3	60·8	63·3	91·8*	59·2	58·8	58·1	63·3
	88	73·1	50·7	58·6	66.3	88	72·3	53·0	59·2	66·9	88	73·7	48·9	58·2	66·9
≥2 risk factors	92·6*	63·7	64·0	46·8	78.1	92·1*	63·2	63·2	45·3	77·4	93.1*	64·1	64·0	47·2	77·4
	88	79·4	48·3	43·2	82·5	88	76·1	49·0	42·2	80·7	88	82·1	47·8	44·1	80·7
≥3 risk factors	93·9*	61·1	62·2	18·1	92·1	93·6*	61·1	64·1	15·4	93·2	94·8*	61.0	60·8	19·7	93·2
	88	86·3	42·6	17·1	95·8	88	88·1	41·9	19·3	95·7	88	83·3	43·4	14·2	95·9

Sens, sensitivity; Spec, specificity; PPV, positive predictive value; NPV, negative predictive value; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, HDL-cholesterol.
*Empirically determined optimal cut-off point for WC (cm), defined as the value where (Sens+Spec) is maximised.

due to different definitions of hypertension and the prediction of diabetes rather than impaired fasting glucose), the Mexican National Health Survey also identified optimal WC cut-off points that were slightly higher for women than men (94–99 cm and 93–98 cm, respectively)[38]. A study of hospital workers in Mexico described optimal cut-off points for WC as 90 cm among men and 85 cm among women[39]. These results together confirm the need to develop new guidelines for identifying abdominal obesity in Latin American populations, particularly among men.

Stunting and SH:H have been associated with excess adiposity and cardio-metabolic risk in previous studies, but findings have been inconsistent among different populations and by sex[18,19]. The mechanisms by which short stature or short leg length is associated with CVD risk are unclear, although some evidence suggests that the growth hormone–insulin-like growth factor axis underlies the observed associations[40]. Disparities in associations may be due to genetic, nutritional, environmental or socio-economic effects. In the present analysis we did not find any evidence of increased obesity or consequent risk among those who were stunted *v.* non-stunted. Furthermore, we did not find SH:H to be predictor of CVD risk.

It is still unclear as to whether ethnic differences in adolescent growth and ultimate attained height are due primarily to genetic or dietary and environmental factors[41]. As such, there are no globally recognised values for classifying adult stunting. Among women, multiple studies have categorised values for short stature or stunting based on obstetric risk, providing threshold values ranging from 145 cm to 155 cm[42,43]. We used thresholds that were based on comparison with the US population and described those with height ≤ -2 SD of the median as stunted and those with height > -2 SD as non-stunted, as is done among children, but recognise that even those denoted as non-stunted remain shorter than US norms; only 11 % of our sample had a height > -1 SD. This high prevalence of short stature is consistent with recent analysis of Demographic and Health Surveys; among forty-three countries Guatemala had by far the largest percentage (35 %) of women with height less than 145 cm[44]. Our study may not be generalisable to populations where childhood stunting is uncommon; however, as the CVD epidemic progresses the majority of the disease burden is occurring in developing countries where stunting is still a problem, and the identification of appropriate anthropometric indices for identifying risk will have a significant public health impact.

The present results indicate the need to establish optimal cut-off points for WC in diverse populations experiencing the nutrition transition. The common cut-off point for WC failed to identify the majority of men at risk for CVD. Of the commonly used cut-off points for BMI and WC, BMI $\geq 25\ kg/m^2$ adequately identified increased risk among stunted and non-stunted men and women. Further research is also needed to clarify the associations between short stature and CVD risk. Such findings will be critical for the development of public health strategies for the prevention of chronic disease.

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