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Original article

Body composition measures and cardiovascular risk in high-risk ethnic groups

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SUMMARY

Background & aims: Cardiovascular disease (CVD) is highly prevalent in Suriname, a middle-income country with predominantly people of African and Asian ancestry. We examined whether the more comprehensive body composition measures determined by bioelectrical impedance analysis (BIA) are superior to the more traditional BMI and waist measures in relation to cardiovascular risk.

Methods: Data from the cross-sectional Healthy Life in Suriname (HELISUR) study were used to calculate BMI, waist-hip ratio, waist-to-height ratio, and waist circumference. BIA was used to estimate fat percentage, fat-free mass index, and fat-to-fat-free mass ratio. High cardiovascular risk was defined as 1) a 10-year Framingham coronary heart disease risk score ≥10% in African-Surinamese and ≥12% in Asian-Surinamese, and 2) an increased arterial stiffness (pulse wave velocity >10 m/s). Using logistic regression analysis, we pre-selected the strongest correlate (i.e. lowest *p*-value below 0.05) of all body composition items for both outcomes of cardiovascular risk separately, and subsequently, used forward logistic regression modelling to determine whether other measures added value to the initial model with the strongest correlate (−2 log-likelihood (−2LL) of initial model minus −2LL of new model, χ-square statistic >3.841, 1 df). Analyses were adjusted for sex, age and ethnicity.

Results: We examined 691 participants (65% women; 48% African-Surinamese) with a mean age of 42 (SD 14) years. Waist circumference was the strongest correlate for high 10-year CVD risk in the total group, in men and African-Surinamese. In Asian-Surinamese, fat-free mass index was the strongest correlate of high 10-year CVD risk. Increased arterial stiffness was most strongly related with waist-to-height ratio in the total group and in African-Surinamese, and with BMI in men. None of the measures were significantly associated in women (for both outcomes) and Asian-Surinamese (for increased arterial stiffness). Forward selection showed that only BMI added value next to waist-to-height ratio in the total group in relation to increased arterial stiffness.

Conclusions: Waist measures, in particular waist circumference and waist-to-height ratio, and BMI should be used in African and Asian-Surinamese to identify who is at increased cardiovascular risk. Overall, we found little advantage in using BIA measures rather than simple anthropometric measures.

1. Introduction

Obesity is an important independent risk factor for cardiovascular events, promoting atherogenesis [1–3]. Although obesity is often defined using the body mass index (BMI), a growing base of evidence suggests that waist measures, such as waist circumference and waist-hip ratio, are better predictors of cardiovascular disease (CVD) [4,5]. Furthermore, body composition is known to

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vary between different ethnic groups [6,7]. At the same level of BMI, Asian populations have more total body fat and more abdominal fat, whereas Afro-Americans showed higher fat-free mass and less body fat compared to Caucasians [6,7]. High fat-free mass, a reflection of high muscle mass, has been linked to a lower risk for CVD, which might be mediated by physical activity [8]. Moreover, a low fat-free mass together with a high fat mass (i.e. sarcopenic obesity) is proposed as a more sensitive predictor of cardiovascular risk, carrying the cumulative risk derived from each of the two individual body composition phenotypes [9]. The use of body composition measures such as fat mass, fat-free mass or fat-to-fat-free mass ratio might therefore improve CVD risk prediction, particularly in multi-ethnic populations.

The burden of CVD in low- and middle-income countries (LMIC) has increased greatly [10–12]. In Suriname, a middle-income country in South America with an African and Asian ancestry population, CVD is the number one cause of mortality [13–15]. Drastic measures should be taken to prevent further increases in CVD morbidity and mortality. Therefore, it is vital to accurately identify people at risk for CVD. A recent study in Suriname showed that in most ethnic groups waist circumference had more discriminatory power than BMI in the relation with hypertension, diabetes, and an adverse cardiometabolic risk profile [16]. However, it remains unclear if more complex body composition measures determined by bioelectrical impedance analysis (BIA), such as fat percentage, fat-free mass index, and fat-to-fat-free mass ratio, could be useful in CVD risk assessment. Therefore, we examined whether BIA measures (fat percentage, fat-free mass index, fat-to-fat-free mass ratio) are superior to the simple anthropometric measures (BMI, waist circumference, waist-hip ratio, waist-to-height ratio) in the association with CVD risk in people of African and Asian ancestry.

2. Methods

2.1. Study population

The study population consisted of participants of the Healthy Life in Suriname (HELISUR) study, a population-based observational study, as previously described [17]. The HELISUR study was conducted according to the principles of the Declaration of Helsinki (59th WMA General Assembly, Seoul, October 2008) and in accordance with the Medical Research Involving Human Subjects Act. Ethical clearance was obtained from the Ethics Committee of the Ministry of Health in Suriname in 2012 (Approval nr. VG021-2012).

In brief, we randomly selected a representative multi-ethnic sample of 1800 non-institutionalized men and women aged 18–70 years living in the capital Paramaribo [17]. Eligible subjects were interviewed at home and subsequently invited for an examination at the local hospital [17]. A total of 1157 subjects participated in both the interview and the physical examination.

2.2. Data collection

2.2.1. Questionnaire

Information on demographic factors, tobacco smoking, use of medication, and CVD history were collected by means of a questionnaire. Ancestry was self-defined.

2.2.2. Physical examination

Participants were examined in the morning in a fasting state. Height and weight were measured in duplicate to the nearest 0.1 cm and 0.1 kg, respectively, with participants wearing no shoes and only light underwear. Waist circumference was obtained with a measuring tape, measured midway between the lower rib and the spina iliaca anterior to the nearest 0.1 cm. In more obese subjects for whom bone palpation was difficult, the level of the umbilicus was utilized to measure waist circumference. Hip circumference was measured at the level of the trochanter major to the nearest 0.1 cm. Repeat measurements were obtained for waist and hip circumferences, and a third measurement was made if the difference between the first two readings was more than 1.0 cm.

Body composition was assessed using bioelectrical impedance analysis (BIA) (Bodyscout, Fresenius Kabi, 's Hertogenbosch, the Netherlands). BIA measures the electrical impedance of the body by introducing a small alternating electrical current (5–800 μA, 5 kHz–1 MHz) into the body. Adhesive electrodes were placed using the four-electrode method, as described by Lukaski et al. [18] Impedance was measured on the left side of the participant in supine position. The measurement provides a rapid, non-invasive, and relatively reliable estimation of fat mass and fat-free mass with minimal intra- and inter-observer variability and <1% error on repeated measurements [18–20].

Aortic pulse wave velocity was estimated non-invasively in duplicate in the supine position by analysis of the oscillometric pressure curves registered on the right upper arm, using the validated Arteriograph device (TensioMed, Budapest, Hungary) [21]. Blood pressure was measured twice in the sitting position with an automated oscillometric device (WatchBP Office; Microlife AG, Widnau, Switzerland) and an appropriately adjusted cuff size on the left upper arm supported at heart level. Fasting blood samples were drawn to measure glucose and lipid spectrum.

2.3. Definitions

Participants were mainly Asian (self-identified South Asian and Indonesian ancestry); or African-Surinamese (self-identified Creoles and Maroons), hitherto referred to as African and Asian [15]. Persons of other ancestry (Native Surinamese, and persons of Chinese, European, and other ancestry) were excluded for the current analysis.

BMI was computed as weight divided by height squared. To capture abdominal obesity, we used waist-hip ratio (waist divided by hip), waist-to-height ratio (waist divided by height) and waist circumference. BIA measures included fat percentage (fat mass divided by weight x100%), and fat-free mass index (fat-free mass divided by height squared), as a surrogate measure of muscle mass. Furthermore, we used fat-to-fat-free mass ratio (fat mass divided by fat-free mass) as a measure of sarcopenic obesity [9].

To define high CVD risk, we used the Framingham Risk Score equation to calculate the 10-year coronary heart disease (CHD) risk [22]. Subsequently, we used the lowered ethnic-specific thresholds as proposed by Cappuccio and colleagues [23] of ≥12% in Asians and ≥10% in Africans to estimate the 10-year risk for combined CVD (i.e. CHD plus stroke). Additionally, we included pulse wave velocity (PWV), which is known as a predictor of CVD events, and defined increased arterial stiffness as a PWV >10 m/s [24].

2.4. Statistical analysis

We assessed differences in CVD risk and body composition between African and Asian men and women using the chi-square test and Student *t*-test. Subsequently, continuous data on different measures of body composition were transferred into categories based on international standards: BMI (African: <18.5, 18.5–25.0, 25.0–30.0, >30.0; Asian: <18.5, 18.5–23.0, 23.0–27.5, >27.5), waist-hip ratio (men: ≥0.90; African women: ≥0.85; Asian women: ≥0.80), waist-to-height ratio (<0.50 or ≥0.50), waist circumference (African men: >94 cm; Asian men: >90 cm; women: >80 cm), fat percentage (men: ≤18, 18–25, >25; women: ≤25, 25–35, >35), fat-

free mass index (men: <16.7; women: <14.6), and fat-to-fat-free mass ratio (quartiles: <0.38, 0.38–0.58, 0.58–0.81, >0.81). Five models using logistic regression analysis were generated; for the total study population, for men, women, Asian and African. Categorized body composition measures were entered as independent variables and CVD risk as the dependent variable. First, using logistic regression analysis, we assessed the strongest correlate of CVD risk in pre-screening using the lowest p-value below $p < 0.05$ (i.e. highest Wald statistic). Subsequently, using forward multivariable logistic regression modelling, we added the remaining body composition measures that were significantly associated with CVD risk in pre-screening one by one to the model with the strongest correlate. Due to multicollinearity issues, only one of the three waist measures was included in the multivariable model. To assess whether a body composition measure added value, we used the model chi-square statistic, which is equal to −2LL of the new model minus the value of the −2LL of the initial model. This value has a chi-square distribution, indicating that a significant better model should have a model chi-square statistic of >3.841 at the $p = 0.05$ level with 1 degree of freedom (df) (for 2 df >5.991; for 3 df >7.815, at the $p = 0.05$ level) [25,26]. All analyses were adjusted for sex, age, and ethnicity. Statistical analysis of the data was carried out using the SPSS version 20.0 (SPSS Inc., Chicago, IL, USA) software for Windows.

3. Results

3.1. Subjects

Body composition was assessed in 733 participants. Of these, we excluded participants with a prior CVD event (n = 42). Thus, we analysed data of 691 participants (65% women; 48% African) with a mean age of 42.2 (SD 13.5) years (Table 1). High 10-year CVD risk was seen in 19.7% of the participants, with higher proportions in men than in women for both ethnic groups. Pulse wave velocity was measured in a sub-sample of 517 participants (56% women; 50% African). The overall prevalence of increased arterial stiffness was 14.5% and higher in women than in men for both ethnic groups.

3.2. Ethnic differences in body composition

As depicted in Table 2, the majority of the population was overweight (33.6%) or obese (40.1%), with 71.6% up to 78.4% being abdominally obese depending on the specific measure used (waist-hip ratio, waist-to-height ratio or waist circumference). Abdominal obesity was less prevalent in African men (28.8% up to 50.5%; $p < 0.01$). Compared to African men, Asian men had higher waist-hip ratio/waist-to-height ratio/waist circumference, fat percentage, and fat-to-fat-free mass ratio, and lower fat-free mass index (all $p < 0.01$), although BMI levels were similar ($p = 0.73$). Despite higher BMI levels in African women, Asian women had higher waist-hip ratio, lower fat-free mass index (all $p < 0.01$) but equal levels of fat percentage and fat-to-fat-free-mass ratio (both $p > 0.05$).

3.3. Body composition measures and cardiovascular risk

Table 3A shows the pre-screening of body composition measures in the association with a high 10-year CVD risk, adjusted for sex, age, and ethnicity. Adjusted odds ratios (ORs) showed that overall participants with high waist measures had more often a high 10-year CVD risk. In line with this, the lowest p-value (i.e. strongest correlate) was seen for waist circumference in the total population, in men and in Africans. In Asians, fat-free mass index was the strongest correlate of a high 10-year CVD risk. In women, none of the body composition measures was significantly associated with the outcome. Forward logistic regression modelling showed that neither BMI, waist circumference, fat percentage nor fat-to-fat-free mass ratio added value over the strongest correlate (i.e. waist circumference in the total group, men and African; fat-free mass index in Asian) in the association with high 10-year CVD risk ($p > 0.05$ for all multivariable models; Table 4A).

Table 3B shows the pre-screening of body composition measures in association with an increased arterial stiffness. Adjusted ORs showed that overall participants with higher categories of BMI, waist-to-height ratio, waist circumference, fat percentage and fat-to-fat-free mass ratio were more likely to have increased arterial stiffness. In the pre-screening, increased arterial stiffness was most strongly associated with waist-to-height ratio in the total group and in the Africans, and with BMI in men. In women and Africans, none of the body composition measures were associated with increased arterial stiffness in the pre-screening. In forward logistic regression modelling, adding BMI to waist-to-height ratio increased the value of the model in the total group (χ-square statistic with 3 df = 8.935, $p = 0.03$; critical value of the χ-square statistic with 3 df = 7.815, at the $p = 0.05$ level; Tabel 4B).

4. Discussion

The main finding of this study is that cardiovascular risk in people of African and Asian ancestry overall is most strongly associated with waist measures, in particular waist circumference

Table 1
Characteristics of the total study population and by sex and ancestry.

	Total (n = 691)	African		Asian	
		Men (n = 111)	Women (n = 219)	Men (n = 132)	Women (n = 229)
Framingham characteristics					
Age, years*	42.2 ± 13.5	40.7 ± 14.8	41.2 ± 13.3	43.0 ± 13.3	43.4 ± 13.1
Tobacco smoking, %	17.8	38.7	7.3§	34.1	8.3§
Systolic blood pressure, mmHg*	128.6 ± 20.0	131.3 ± 19.0	128.9 ± 22.1	127.9 ± 17.2	127.3 ± 20.0
Cholesterol, mmol/L*	4.7 ± 1.1	4.1 ± 1.0	4.5 ± 1.0§	4.9 ± 0.9‖	5.1 ± 1.1‖
HDL, mmol/L*	1.2 ± 0.3	1.2 ± 0.3	1.3 ± 0.3§	1.1 ± 0.2‖	1.2 ± 0.3§‖
Diabetes mellitus, %	14.7	3.6	8.2	20.6‖	22.8‖
CVD risk					
Framingham CHD risk score†	4.0 (1.0–10.0)	4.0 (2.0–10.0)	1.0 (1.0–7.0)§	7.0 (3.0–13.0)‖	3.0 (1.0–10.0)§‖
High 10-year CVD risk, %	19.7	27.0	17.4§	25.8	14.8§‖
Pulse wave velocity*‡	8.3 ± 2.3	7.5 ± 1.8	8.6 ± 2.4§	7.8 ± 1.9	9.0 ± 2.7§
Increased arterial stiffness, %‡	14.5	9.9	15.5§	10.6	17.9§

*Mean with standard deviation. †Median with interquartile range. ‡Based on a different sample size: n = 518. §Significantly different from men with the same ancestry ($p < 0.05$). ‖Significantly different from Africans of the same sex ($p < 0.05$). High 10-year CVD risk was defined as a 10-year risk of CHD ≥12% in Asians and ≥10% in Africans. Increased arterial stiffness was defined as a pulse wave velocity >10 m/s. HDL, high-density lipoprotein; CVD, cardiovascular disease; CHD, coronary heart disease.

Table 2
Body composition measures of the total study population and by sex and ethnicity.

	Total (n = 691)	African		Asian	
		Men (n = 111)	Women (n = 219)	Men (n = 132)	Women (n = 229)
BMI	27.9 ± 6.2	25.2 ± 5.1	30.4 ± 6.7*	25.5 ± 5.0	28.1 ± 5.6*†
Underweight, %	4.1	4.5	2.7	7.6	3.1
Normal weight, %	22.3	49.5	19.6*	28.0†	15.3*†
Overweight, %	33.6	28.8	24.7	44.7†	37.6†
Obesity, %	40.1	17.1	53.0*	25.8	47.2§
WHR	0.92 ± 0.10	0.90 ± 0.08	0.90 ± 0.10	0.96 ± 0.08†	0.93 ± 0.11*†
High WHR, %	71.6	47.7	63.5*	75.0†	89.1*†
WHtR	0.58 ± 0.10	0.50 ± 0.08	0.61 ± 0.11*	0.55 ± 0.08†	0.61 ± 0.10*
High WHtR, %	78.4	50.5	84.9*	72.0†	89.5*
WC	95.0 ± 15.5	88.1 ± 14.3	98.8 ± 16.7*	93.2 ± 13.8†	95.8 ± 14.8
High WC, %	71.8	28.8	84.9*	59.1†	87.3*
BF%	35.5 ± 11.7	21.6 ± 9.2	40.9 ± 8.7*	27.5 ± 9.2†	41.5 ± 7.6*
Low BF%, %	11.1	37.8	3.7*	16.7†	2.2§
Elevated BF%, %	20.7	27.9	21.5	18.9	17.5
High BF%, %	68.2	34.2	74.9*	64.4†	80.3*
FFMI	17.5 ± 2.6	19.4 ± 2.5	17.5 ± 2.5*	18.1 ± 2.1†	16.1 ± 2.3*†
Low FFMI, %	17.1	9.0	11.0	19.7†	25.3†
FM/FFM	0.60 ± 0.29	0.29 ± 0.16	0.73 ± 0.25*	0.40 ± 0.19†	0.74 ± 0.23*
FM/FFM Q1, %	24.7	73.0	5.9*	50.0†	4.8*
FM/FFM Q2, %	25.8	22.5	25.6	35.6†	21.8*
FM/FFM Q3, %	25.0	3.6	30.1*	11.4†	38.4*
FM/FFM Q4, %	24.5	0.9	38.4*	3.0	34.9*

Values are mean with standard deviation, except if stated otherwise. *Significantly different from men with the same ancestry ($p < 0.05$). †Significantly different from Africans of the same sex ($p < 0.05$). Underweight, normal weight, overweight, and obesity respectively, body mass index (BMI) < 18.5, 18.5–25.0, 25.0–30.0, >30.0 in Africans, <18.5, 18.5–23.0, 23.0–27.5, >27.5 in Asians; high waist-hip ratio (WHR), men ≥0.90, African women ≥0.85, Asian women ≥0.80; high waist-to-height ratio (WHtR), ≥0.50; high waist circumference (WC), African men >94 cm, Asian men >90 cm, women >80 cm; low, elevated, and high body fat percentage (BF%) respectively, men ≤18, 18–25, >25, women ≤25, 25–35, >35; low fat-free mass index (FFMI), men <16.7, women <14.6; fat-to-fat-free mass ratio (FM/FFM) quartiles (Q), Q1 <0.38, Q2 0.38–0.58, Q3 0.58–0.81, Q4 >0.81.

and waist-to-height ratio, independently of sex, age and ethnicity. BMI seemed to have additional value in the total group and in men in the association with increased arterial stiffness. Overall, we found little advantage in using BIA measures rather than simple anthropometric measures.

It is growingly accepted that waist measures are important determinants of obesity-related diseases; possibly more so than general obesity measures such as BMI [3,4,27,28]. Correspondingly, we showed in an African and Asian population that overall BMI was inferior to waist measures in the association with CVD risk. One reason why waist measures best predict cardiovascular risk is the high correspondence of waist measures with the amount of visceral adiposity tissue. This is in turn strongly associated with a range of metabolic disturbances, such as impaired glucose tolerance and dyslipidemia [29]. Nevertheless, BMI was of additional value in the total group and in men using increased arterial stiffness as outcome for cardiovascular risk and, therefore, should not be ruled out.

Our data implicate that more comprehensive BIA measures seem of little additional value to waist measures in cardiovascular risk prediction in people of African and Asian ancestry. This is in line with previous large-scale studies demonstrating that once waist-hip ratio is taken into account, fat percentage measured by BIA did not add to the prediction of cardiometabolic abnormalities [30], increased arterial stiffness [31], cardiovascular disease [32], or mortality [32]. However, measuring the amount of visceral adipose tissue directly appeared to be a good predictor of CVD risk, and even improved risk prediction over BMI [31,33]. This finding supports the hypothesis that the distribution rather than the overall amount of adipose tissue is important in CVD risk prediction.

Fat-free mass index showed benefits in Asian-Surinamese in the association with 10-year CVD risk. In contrast to studies finding no association [8] or a negative association [34], we found a positive association, indicating that persons with high fat-free mass index had more often a high CVD risk. Further exploration of the data showed that persons with high fat-free mass index also had higher waist-hip ratio, waist-to-height ratio or waist circumference. Second, persons with high fat-free mass index had higher systolic blood pressure levels, which is a determinant of the Framingham Risk Score equation [22]. More research should elucidate if the use of fat-free mass index and fat-to-fat-free mass ratio aside waist measures improves the prediction of cardiovascular risk, especially as these measures require more resources and time compared to simple anthropometric measurements.

The present study also demonstrated ethnic differences in body composition suggesting that at similar BMI level Asians generally have more fat mass than Africans. This is in line with the international literature and supports the adoption of lower BMI and waist circumference thresholds for Asian populations compared to other ethnic populations [6,16].

Results from this study should be understood with a few limitations in mind. First, the cross-sectional nature of our study implies that causal associations cannot be established. Second, the Framingham risk score was based on an all-white cohort. We used the recommended ethnic-specific cut-off values for African and Asian populations [23]; however, this was not validated for the Surinamese population in specific. Although some information bias might exist, this algorithm provides an initial heuristic for exploring risk patterns in Suriname. More importantly, we found similar results with pulse wave velocity, which is a more direct physical measure of damage of the vascular system [35]. Nevertheless, prospective studies are needed to relate body composition measures with hard cardiovascular outcomes. Finally, we used bioelectrical spectroscopy to estimate fat percentage and fat-free mass index. It estimates fat-free mass based on values of total body water. Therefore, in obese subjects who have a relatively high amount of total body water, fat-free mass might be overestimated and consequently fat mass might be underestimated [18]. Nevertheless, compared to single and multi-frequency bio-impedance

Table 3
Results of the pre-screening of candidate correlates of A) high cardiovascular disease risk and B) increased arterial stiffness, adjusted for sex, age, and ethnicity.

A) High 10-year CVD risk

Measure	Total (n = 691)			Men (n = 243)[a]			Women (n = 448)[a]			African (n = 330)[b]			Asian (n = 361)[b]		
	Wald	df	*p*	Wald	df	*p*	Wald	df	*p*	Wald	df	*p*	Wald	df	*p*
BMI	6.936	3	0.07	3.650	3	0.30	1.229	3	0.75	**8.023**	**3**	**0.05**	0.226	3	0.97
WHR	**7.043**	**1**	**<0.01**	**6.204**	**1**	**0.01**	1.281	1	0.26	3.216	1	0.07	3.445	1	0.06
WHtR	**6.069**	**1**	**0.01**	**4.752**	**1**	**0.03**	0.856	1	0.36	3.409	1	0.07	3.399	1	0.07
WC	**12.162**	**1**	**<0.01**	**9.097**	**1**	**<0.01**	1.782	1	0.18	**9.331**	**1**	**<0.01**	**4.139**	**1**	**0.04**
BF%	**7.735**	**2**	**0.02**	5.652	2	0.06	0.363	2	0.83	**6.500**	**2**	**0.04**	4.137	2	0.13
FFMI	2.856	1	0.09	1.408	1	0.24	1.386	1	0.24	0.008	1	0.93	**4.426**	**1**	**0.04**
FM/FFM	5.033	3	0.17	5.965	3	0.11	3.404	3	0.33	**10.445**	**3**	**0.02**	0.631	3	0.89

Categories	Adjusted OR (95%CI)		Adjusted OR (95%CI)		Adjusted OR (95%CI)		Adjusted OR (95%CI)		Adjusted OR (95%CI)	
Normal weight	Reference		Reference		Reference		Reference		Reference	
Underweight	0.13	(0.01–2.18)	0.29	(0.01–7.20)	–	–	0.27	(0.00–32.98)	–	–
Overweight	1.68	(0.74–3.85)	2.05	(0.73–5.80)	1.10	(0.28–4.25)	**5.64**	**(1.25–25.46)**	0.91	(0.32–2.59)
Obesity	2.25	(0.99–5.14)	2.46	(0.76–7.96)	1.61	(0.46–5.61)	**7.24**	**(1.67–31.35)**	1.09	(0.37–3.20)
Low WHR	Reference		Reference		Reference		Reference		Reference	
High WHR	**3.33**	**(1.37–8.08)**	**4.54**	**(1.38–14.95)**	2.07	(0.59–7.26)	3.50	(0.73–16.80)	8.04	(0.89–72.69)
Low WHtR	Reference		Reference		Reference		Reference		Reference	
High WHtR	**3.38**	**(1.28–8.90)**	**3.29**	**(1.13–9.58)**	3.07	(0.29–33.15)	4.16	(0.92–18.92)	4.66	(0.91–23.94)
Low WC	Reference		Reference		Reference		Reference		Reference	
High WC	**4.43**	**(1.92–10.22)**	**4.39**	**(1.68–11.48)**	4.66	(0.49–44.56)	**11.55**	**(2.40–55.50)**	**3.05**	**(1.04–8.94)**
Low/normal BF%	Reference		Reference		Reference		Reference		Reference	
Elevated BF%	**4.69**	**(1.31–16.88)**	2.86	(0.73–11.25)	–	–	4.40	(0.54–35.85)	**7.02**	**(1.07–45.95)**
High BF%	**5.36**	**(1.64–17.49)**	**4.63**	**(1.30–16.54)**	–	–	**12.72**	**(1.57–102.9)**	4.86	(0.85–27.86)
High FFMI	Reference		Reference		Reference		Reference		Reference	
Low FFMI	0.48	(0.20–1.13)	0.47	(0.14–1.63)	0.49	(0.15–1.60)	1.07	(0.26–4.39)	**0.31**	**(0.10–0.92)**
FM/FFM Q1	Reference		Reference		Reference		Reference		Reference	
FM/FFM Q2	**2.47**	**(1.10–5.54)**	1.83	(0.74–4.54)	8.77	(0.78–98.25)	**12.94**	**(2.51–66.71)**	1.15	(0.44–3.01)
FM/FFM Q3	1.92	(0.75–4.92)	1.55	(0.39–6.20)	5.26	(0.51–54.71)	5.97	(0.88–40.61)	1.19	(0.40–3.55)
FM/FFM Q4	2.32	(0.85–6.28)	**33.23**	**(1.54–714.95)**	5.60	(0.55–56.93)	**11.45**	**(1.71–76.56)**	0.83	(0.23–2.92)

B) Increased arterial stiffness

Measure	Total (n = 517)			Men (n = 226)[a]			Women (n = 291)[a]			African (n = 257)[b]			Asian (n = 261)[b]		
	Wald	df	*p*	Wald	df	*p*	Wald	df	*p*	Wald	df	*p*	Wald	df	*p*
BMI	**11.330**	**3**	**0.01**	**15.167**	**3**	**<0.01**	2.592	3	0.46	**8.716**	**3**	**0.03**	4.412	3	0.22
WHR	1.051	1	0.31	1.799	1	0.18	0.056	1	0.81	1.309	1	0.25	0.010	1	0.92
WHtR	**6.016**	**1**	**0.01**	2.776	1	0.10	3.457	1	0.06	**5.982**	**1**	**0.01**	0.516	1	0.47
WC	**5.155**	**1**	**0.02**	2.970	1	0.09	2.604	1	0.11	**5.513**	**1**	**0.02**	1.111	1	0.29
BF%	4.523	2	0.10	2.658	2	0.27	0.010	2	0.99	5.892	2	0.05	3.271	2	0.20
FFMI	0.214	1	0.64	0.014	1	0.91	0.238	1	0.63	0.930	1	0.34	0.003	1	0.96
FM/FFM	**7.843**	**3**	**0.05**	6.660	3	0.08	3.680	3	0.30	**9.270**	**3**	**0.03**	2.422	3	0.49

Categories	Adjusted OR (95%CI)		Adjusted OR (95%CI)		Adjusted OR (95%CI)		Adjusted OR (95%CI)		Adjusted OR (95%CI)	
Normal weight	Reference		Reference		Reference		Reference		Reference	
Underweight	1.45	(0.23–9.19)	19.92	(1.65–239.97)	–	–	–	–	2.95	(0.34–25.68)
Overweight	1.28	(0.56–2.93)	2.51	(0.54–11.55)	0.81	(0.28–2.32)	2.01	(0.56–7.22)	0.94	(0.30–2.90)
Obesity	**2.94**	**(1.33–6.49)**	**14.99**	**(3.12–72.01)**	1.42	(0.54–3.75)	**5.21**	**(1.57–17.23)**	1.96	(0.64–6.00)
Low WHR	Reference		Reference		Reference		Reference		Reference	
High WHR	1.49	(0.70–3.17)	2.54	(0.65–9.88)	1.12	(0.44–2.84)	1.70	(0.69–4.21)	1.07	(0.28–4.09)
Low WHtR	Reference		Reference		Reference		Reference		Reference	
High WHtR	**3.93**	**(1.32–11.72)**	3.15	(0.82–12.13)	7.27	(0.90–58.84)	**13.70**	**(1.68–111.62)**	1.64	(0.43–6.31)
Low WC	Reference		Reference		Reference		Reference		Reference	
High WC	**2.53**	**(1.14–5.64)**	2.42	(0.89–6.62)	3.58	(0.76–16.86)	**4.32**	**(1.27–14.68)**	1.80	(0.60–5.40)
Low/normal BF%	Reference		Reference		Reference		Reference		Reference	
Elevated BF%	**5.13**	**(1.04–25.31)**	3.56	(0.63–20.27)	–	–	3.70	(0.37–37.06)	6.33	(0.64–62.32)
High BF%	**5.24**	**(1.13–24.17)**	3.74	(0.75–18.65)	–	–	**9.12**	**(1.04–79.86)**	3.75	(0.41–34.21)
High FFMI	Reference		Reference		Reference		Reference		Reference	
Low FFMI	0.83	(0.37–1.85)	0.92	(0.23–3.68)	0.78	(0.29–2.11)	0.46	(0.09–2.24)	1.03	(0.39–2.68)
FM/FFM Q1	Reference		Reference		Reference		Reference		Reference	
FM/FFM Q2	2.30	(0.98–5.42)	2.02	(0.72–5.72)	2.50	(0.44–14.24)	**7.91**	**(1.75–35.74)**	1.11	(0.38–3.29)
FM/FFM Q3	**2.85**	**(1.10–7.34)**	**1.35**	**(1.35–21.59)**	2.41	(0.44–13.20)	**2.06**	**(2.06–64.64)**	1.32	(0.40–4.34)
FM/FFM Q4	**4.11**	**(1.53–11.04)**	0.36	(0.36–170.62)	3.88	(0.72–21.04)	**2.40**	**(2.40–81.40)**	2.32	(0.64–8.35)

Significant associations are in **bold**. Values are odds ratios (OR) with 95% confidence intervals (CI), adjusted for sex, age, and ethnicity.
BMI, body mass index; WHR, waist-hip ratio; WHtR, waist-to-height ratio; WC, waist circumference; BF%, body fat percentage; FFMI, fat-free mass index; FM/FFM, fat-to-fat-free mass ratio; Q, quartiles.
[a] Adjusted for age and ethnicity.
[b] Adjusted for age and sex.

Table 4
Forward logistic regression modelling to assess the strongest associated body composition measures with A) high cardiovascular disease risk and B) Increased arterial stiffness.

	Strongest correlate	Other significantly associated measures	Initial−2LL[a]	New model−2LL[b]	Model $\chi 2$ statistic	df	*p*
A) High 10-year CVD risk							
Total (n = 691)	**WC**	+BF	359.125	356.562	2.563	2	0.28
Men (n = 243)	**WC**	–	–	–	–		–
Women (n = 448)	–	–	–	–	–		–
African (n = 330)	**WC**	+FM/FFM	127.031	121.924	5.107	3	0.16
		+BF%	127.031	125.461	1.570	2	0.46
		+BMI	127.031	126.767	1.264	3	0.74
Asian (n = 361)	**FFMI**	+WC	219.744	216.421	3.323	1	0.07
B) Increased arterial stiffness							
Total (n = 518)	**WHtR**	**+BMI**	378.297	369.362	8.935	3	**0.03**
		+FM/FFM	378.297	374.871	3.427	3	0.33
Men (n = 226)	**BMI**	–	–	–	–	–	–
Women (n = 291)	–	–	–	–	–	–	–
African (n = 257)	**WHtR**	+FM/FFM	167.572	163.832	3.740	3	0.29
		+BMI	167.572	162.595	4.978	3	0.17
Asian (n = 261)	–	–	–	–	–	–	–

BMI, body mass index; WHtR, waist-to-height ratio; WC, waist circumference; BF%, body fat percentage; FFMI, fat-free mass index; FM/FFM, fat-to-fat-free mass ratio.
[a] Initial −2 log-likelihood (−2LL) model included sex, age, ethnicity and the body composition measure that was most strongly related to the outcome in the pre-screening (for men/women: not adjusted for sex; for African/Asian: not adjusted for ethnicity).
[b] New −2LL model included the initial model plus a statistically significantly associated body composition measure. If the model $\chi 2$ statistic >3.84 with 1 degree of freedom (df) (i.e. $p < 0.05$), the new model added value over and above the initial model. The body composition measure or set of measures that were most strongly correlated with the outcome of interest are depicted in **bold**.

analysis, bioelectrical spectroscopy relies less on assumptions that may be violated in disease states and is highly correlated with DEXA [19,36].

In conclusion, CVD is the main cause of death in Suriname, and accurate identification of adults who are at high risk for obesity-related diseases is urgently needed. We found that overall waist measures are overall the strongest correlates of a high cardiovascular risk in this population of African and Asian ancestry. Furthermore, BMI should not be ruled out, but the more complex BIA measures seemed of no clinically relevant additional value in the association with CVD risk. The use of waist measures and BMI can be well applied in resource-limited settings, where the health care infrastructure is less developed.

Conflicts of interest

None.

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