

Discriminatory Ability of Adiposity Phenotypes in Identifying Cardiometabolic Disorders in Indigenous and Non-indigenous African Populations

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Abstract

Background: Whether any of the anthropometric indices are associated with cardiometabolic outcomes in indigenous Fulani African populations is not known. This study assesses anthropometric indices in predicting cardiometabolic outcomes in indigenous and non-indigenous populations.

Methods: A population-based cross-sectional study recruited 1921 participants from the settled Fulani, nomadic pastoral Fulani and the general population. Body weight (BW), height, waist circumference (WC), and hip circumference (HC) were measured and body mass index (BMI), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), Conicity Index (Cindex), body adiposity index (BAI), body roundness index (BRI) and body shape index (ABSI) were determined. The associations of anthropometric indices with cardiometabolic disorders were assessed by multivariable adjusted logistic regression and the area under the receiver-operating characteristic curve compared the predictive abilities.

Results: In women, BW and BMI showed good performance in identifying dysglycaemia in Fulbe and general population. In men, WC, HC and BRI, and WC and BRI had good performance in all groups to predict hypertension and dysglycaemia/hypertension respectively. All the anthropometric indices showed good performance to identify MetS.

Conclusion: With transition from nomadic to settled life indigenous Fulani are at greater risk for MetS. Adiposity indices for identification of cardiometabolic disorders vary by ethnicity and sex. WC, WHtR and BRI are better anthropometric indices to identify MetS in indigenous Fulani population.

Keywords: Indigenous Fulani populations, Anthropometric indices, Cardiometabolic disorders

Introduction

Obesity and underweight might be symptomatic of an underlying health condition and malnutrition [1]. Globally the prevalence of obesity ($\text{BMI} \geq 30 \text{ kg/m}^2$) increased from 3.2% to 10.8% in adult men and from 6.4% to 14.9% in adult women and underweight ($\text{BMI} < 18.5 \text{ kg/m}^2$) reduced from 13.8% to

8.8% [2]. This data does not include indigenous populations from Africa that have been shown to have high prevalence of underweight and low prevalence of obesity [3,4]. Typically, weight and body mass index (BMI) have been used in clinical settings, though classifying risk based on body weight (BW) and BMI is insufficient due to large variability. Cardiometabolic risk prediction is useful in the identification of sub-phenotypes

of metabolically unhealthy normal weight from metabolically healthy obesity using abdominal obesity indices. Increasing evidence have provided independent and additional information for inclusion of waist circumference (WC) in routine clinical practice [5]. The BMI, waist circumference (WC), and waist-to-hip ratio (WHR) has been shown not to improve cardiovascular risk prediction even with the inclusion of systolic blood pressure, history of diabetes and lipid levels in studies in developed countries [6]. Anthropometric indices such as the hip circumference (HC), waist-to-height ratio (WHtR), conicity index (Cindex) and body adiposity index (BAI) are preferred for their simplicity and as such convenient to determine the cardiometabolic risk related to body adiposity. The BAI calculates the percentage of the body fat for adults of different ethnicities without using the BW [7]. They do not require technical equipment and are used in resource limited settings. There is controversy over which anthropometric measurements best define obesity and underweight and which best describes the risk gradient of cardiometabolic disturbance by sex and for each ethnic group.

Without population specification the use of these recommendations and cut off points is inapplicable. Epidemiologic studies suggest that these anthropometric measurements and criteria warrant a re-evaluation and appropriate ethnic specific modification proposed to suit diverse populations [8-11]. These inconsistent findings warrant exploration of other anthropometric approaches that pose no risk to patients, and it remains unclear which sex-specific and ethnicity-specific anthropometric measurement has a superior discriminative power and should be adopted. Population specific cut-off points have been recommended but no assessment has been proposed for indigenous populations of Africa who generally lack health data. Previously we have shown that statistically significant differences exist between Mbororo and Fulbe for height, weight, WC, HC, BMI, BAI and between the general population and Fulbe for weight, WC, WHR, WHtR, BMI, Cindex, and fasting capillary glucose and the general population and Mbororo for weight, WC, HC, WHR, WHtR, BMI, Cindex, BAI and fasting capillary glucose and age and sex standardised prevalence of the cardiometabolic risk factors [3]. There is a paucity of studies comparing anthropometric indices in different populations and by sex with the other common obesity markers.

Accordingly, this cross-sectional study aimed to identify the best anthropometric indicators for cardiometabolic disorders in the indigenous Fulani divided into settled Fulani known as Fulbe and nomadic pastoral Fulani known as Mbororo both sharing a common ancestry and language (Fulfulde), and the mixed non-indigenous population of the Bantu described as the general population. We compared the ability of the body weight, WC, HC, BMI, WHR, WHtR, Cindex, BAI, body roundness index (BRI), and body shape index (ABSI) in discerning higher risk of dysglycaemia, hypertension (HBP), dysglycaemia/hypertension and metabolic syndrome (MetS).

Study Design and Methods

A cross-sectional study was conducted in five sites (Madjou II, Guiwa-Yangamou, Mazidou, Sabga and Gom-Mana) inhabited mostly by Fulani in the East and Adamawa regions of Cameroon. The detailed description of the study design and procedures has been described elsewhere [3,4]. In summary, a multi-stage sampling procedure was used to recruit participants and a modified World Health Organisation (WHO) STEPwise approach questionnaire for the surveillance of NCDs was used to collect data. Data was collected on ethnic descent, behavioural risk factors included physical activity, diet and alcohol, tobacco consumption, health and medical history and family history of diabetes, hypertension, and obesity. The body weight, height, waist and hip circumference were measured using standard procedures and BMI, WHR, WHtR, Cindex, BAI, BRI, and ABSI were determined.

Determination of anthropometric values

BMI was calculated as weight/height² (kg/m²) from weight and height [12]. Central obesity was determined from the WHR and WHtR [13-15]. The Cindex was calculated from waist circumference (m) $\div$ 0.019 $\times \sqrt{[\text{Weight (Kg)}/\text{Height (m)}]}$ [16,17]. The BAI [18] was obtained from $\text{BAI} = ((\text{hip circumference in cm}) / ((\text{height in meters})^{1.5}) - 18)$. The BRI combines height and WC to predict the percentage of regional and total fat was estimated from $\text{BRI} = 364.2 - 365.5 \times \sqrt{1 - ((\text{WC}/(2\pi))^{2}/(0.5 \times \text{Height})^{2})}$ [19] and body shape index reflecting body shape by incorporating WC, weight and height was obtained from $\text{ABSI} = \text{WC}/(\text{BMI}^{2/3}) \times (\text{Height}^{1/2})$ [20].

Blood pressure and fasting capillary glucose measurement

Blood pressure was measured on the right arm with uncrossed legs using arm blood pressure fully automated calibrated Omron M3 machine. Mean blood pressure of two closest measures was calculated. Fasting capillary glucose was measured with HemoCue Hb 201 DM Analyser (Angelholm, Sweden) [21] for participants who had no caloric intake for at least eight hours through an overnight fast.

Definition of Cardiometabolic Disorders

IFG and Diabetes or dysglycaemia

International Diabetes Federation (IDF) and WHO diagnostic and classification criteria were used for two similar results with discordant results excluded for this analysis. Participants with fasting capillary glucose of 6.1–6.9 mmol/L (110 mg/dl–125 mg/dl) were classified as impaired fasting glucose (IFG), ≥ 7 mmol/L (126 mg/dl) as diabetes and/or on anti-diabetic medication [22]. Dysglycaemia was defined as IFG and diabetes or IFG and taking diabetes medication.

Hypertension: Blood pressure for participants with mean Systolic Blood Pressure (SBP) ≥ 130 mmHg or mean Diastolic

Blood Pressure (DBP) ≥ 85 mmHg or the two and/or self-reported current treatment of hypertension and/or taking anti-hypertensive medication were considered as hypertensive. Normal SBP was <130 mmHg and DBP <80 mmHg.

Dysglycaemia/hypertension

Dysglycaemia as defined above and SBP ≥ 130 mmHg or mean DBP ≥ 85 mmHg or the two and/or self-reported current treatment of hypertension and/or taking anti-hypertensive medication were considered as hypertensive and classified as dysglycaemia/hypertension.

Metabolic syndrome (MetS)

Metabolic syndrome was defined as elevated WC ≥ 102 cm in men and ≥ 88 cm in women, elevated blood pressure ≥ 130 mmHg of SBP or ≥ 85 mmHg of DBP or on antihypertensive drug treatment in a patient with a history of hypertension and elevated fasting capillary glucose of 6.1 mmol/L (110 mg/dl) or on drug treatment for elevated glucose [23].

Data management and statistical analysis

Data was captured with Epi Data 3.0 and analysed using STATA 18.5 MP (StataCorp. College Station, TX: StataCorp LP). The Shapiro-Wilks test was used to assess the normal distribution of data. The socio-demographic, lifestyle factors, anthropometric measurements and metabolic disorder are described in the 3 population groups as frequencies and percentages for categorical data and median and 25th to 75th percentile for skewed continuous data as well as the mean for all normally distributed continuous variables as means and standard deviation. Spearman correlation coefficients (rho) were determined for each pair of the anthropometric measures and classified as very strong if rho was 0.8–1.0, strong if 0.6–0.8, moderate for 0.4–0.5, weak for >0.0 –0.4 and no relationship if zero. Z-scores was calculated for each of the anthropometric values for the whole sample. The use of Z-scores permitted the comparison of the risk magnitude per 1 standard deviation (SD) change in the anthropometry, as well as sex-stratification using Fisher's Yates transformation [24]. The predictive ability of the anthropometric measurements for the cardiometabolic disorders were compared by the area under the curve (AUC) receiver-operating characteristic (ROC) curve and the 95% confidence interval (CIs) using the trapezoidal rule [25]. The AUC of <0.60 reflects no discrimination, 0.60–0.69: moderate, 0.70–0.79: acceptable and 0.80–0.89: excellent and ≥ 0.90 : outstanding [26,27]. Multiple logistic regression was used to evaluate the association between cardiometabolic disorder risk, and each standard deviation (SD) increase of the anthropometric measure adjusted for age group, marital status, physical activity, smoking and drinking status, fruit and vegetable consumption, salt and sugar intake and site and the multivariable adjusted odds ratios (MAORs) and 95% CI was reported. A p-value of <0.05 was considered statistically significant.

Ethical approval

The study protocol was approved by National Ethics Committee of Cameroon, authorization No: 236/CNE/SE/2012. Informed consent was obtained from each participant by signing or thumb printing before inclusion in the study. Participants' privacy and confidentiality during interview was guaranteed and data was anonymized and kept confidential. Statistical analysis was carried out on codified anonymous dataset. Each participant after counselling received confidential results of the anthropometric measures, blood pressure and fasting capillary glucose (FCG).

Results

Descriptive results

Data was analysed for 1921 participants aged 32 (24–45) years, women 1284 (66.8%) aged 30 (23–41) and men 637 (33.2%) aged 38 (27–50) years. The prevalence of BW was significantly higher in the general population when compared to the Fulbe and Mbororo groups for men and women. The Mbororo women had the lowest BW [49 (43–56) kg, 53 (45–63) kg, 56 (50–65) kg, $p=0.001$] and BMI [(18.4 (16.7–20.8) kg/m^2 , 19.7 (17.3–22.9) kg/m^2 , 21.1 (19.3–24.0) kg/m^2 , $p=0.001$] when compared to the Fulbe and general population groups (Table 1).

Correlation between the anthropometric values by sex and group (Table 2)

The BW was strongly correlated with the WC, HC, BMI WHtR, BAI, and BRI and weakly correlated with the Cindex and ABSI, $p<0.05$ in female and male of the Fulbe group except with the BAI in female that was moderate while the BW was strongly correlated with the WC, HC, and BMI in the female and the BMI of the male in the Mbororo and BW was strongly correlated with the WC, HC, and BMI of the female and males in the general population. The BW was not correlated with the WHR and Cindex of the female and male in the general population but weakly corrected in the female of the Mbororo population and weakly correlated with the male of the Mbororo but not with the Cindex. WC was strongly correlated with the HC, BMI, WHR, WHtR, Cindex, and BRI in both the female and male and moderately correlated with ABSI in the female but not with ABSI of the Fulbe group while the WC was strongly correlated with the HC, BMI, WHR, WHtR, Cindex, and BRI in the female of Mbororo and general population and with the WHR, WHtR, Cindex, and BRI in the male of the Mbororo group and with the HC, BMI, WHtR, Cindex, and BRI of the male in general population group while the BAI and ABSI were moderately correlated with the WC in the Mbororo and the general population of both sexes. The HC was strongly correlated with BMI, WHtR, BAI, and BRI, weakly correlated with Cindex and not correlated with WHR or ABSI in the female and male of the Fulbe group. The BMI was strongly correlated with the WHtR, BAI, and BRI and weakly correlated with the WHR, and Cindex and not with the ABSI in the female and male of the

Table 1: Description of the 1921 participants.						
Sex, n (%)	Female, 1284 (66.8)			Male, 637 (33.2)		
Ethnicity, n (%)	Fulbe, 280 (21.8)	Mbororo, 632 (49.2)	General population, 372 (29.0)	Fulbe, 139 (21.8)	Mbororo, 286 (44.9)	General population, 212 (33.3)
Age in years, median (25 th – 75 th)	30 (23 - 40)	30 (24 - 40)	30 (23 - 43)	37 (24 - 51)	38 (28 - 52)	35.5 (26 - 50)
Age group, years, n (%)						
20 – 39	197 (70.4)	445 (70.4)	255 (68.6)	77 (55.4)	151 (52.8)	121 (57.1)
40 – 59	67 (23.9)	145 (22.9)	84 (22.6)	38 (27.3)	98 (34.3)	64 (30.2)
≥ 60	16 (5.7)	42 (6.7)	33 (8.9)	24 (17.3)	37 (12.9)	27 (12.7)
Smoker, n (%)	5 (1.8)	15 (2.4)	25 (6.7)	27 (19.4)	49 (17.1)	68 (32.1)
Ever drank alcohol, n (%)	11 (3.9)	21 (3.3)	205 (55.1)	24 (17.3)	32 (11.2)	132 (62.3)
Fruit consumption						
High (5 – 7days/week)	70 (25.0)	101 (16.0)	78 (21.0)	34 (24.5)	45 (15.7)	49 (23.1)
Moderate (3 – 4 days/week)	64 (22.9)	149 (23.6)	84 (22.6)	39 (28.1)	77 (26.9)	54 (25.5)
Low (0 – 2 days/week)	146 (52.1)	382 (60.4)	210 (56.5)	66 (47.5)	164 (57.3)	109 (51.4)
Vegetable consumption						
High (5 – 7days/week)	178 (63.6)	320 (50.6)	162 (43.6)	82 (59.0)	150 (52.4)	82 (38.7)
Moderate (3 – 4 days/week)	77 (27.5)	210 (33.2)	133 (35.7)	41 (29.5)	91 (31.8)	80 (37.7)
Low (0 – 2 days/week)	25 (8.9)	102 (16.1)	77 (20.7)	16 (11.5)	45 (15.7)	50 (23.6)
Always add salt to food	54 (19.3)	112 (17.7)	87 (23.4)	23 (16.6)	50 (17.5)	34 (16.0)
Always add sugar to tea/coffee	51 (18.2)	94 (14.9)	94 (25.3)	31 (22.3)	58 (20.3)	56 (26.4)
10 mins Physical activity at work, n (%)						
Vigorous	101 (36.1)	235 (37.2)	166 (44.6)	63 (45.3)	148 (51.8)	135 (63.7)
Moderate	79 (28.2)	205 (32.4)	130 (35.0)	34 (24.5)	66 (23.1)	39 (18.4)
Low	100 (35.7)	192 (30.4)	76 (20.4)	42 (30.2)	72 (25.2)	38 (17.9)
Anthropometry, median (25th – 75th)						
Body Weight (BW)	50.0 (43.0 – 59.5)	46.0 (41.0 – 53.0)	54.0 (49.0 – 62.0)	57.0 (52.0 – 68.0)	54.0 (48.0 – 61.0)	60.0 (54.0 – 67.0)
Waist circumference (WC)	74.0 (66.5 – 84.0)	72.0 (66.0 – 80.0)	78.0 (72.0 – 85.5)	76.0 (70.0 – 83.0)	75.0 (70.0 – 81.0)	76.0 (72.0 – 84.0)
Hip circumference (HC)	90.0 (84.0 – 98.0)	87.0 (83.0 – 93.0)	92.0 (86.0 – 98.0)	90.0 (86.0 – 97.0)	88.0 (83.0 – 92.0)	89.0 (85.0 – 96.0)

Body mass index (BMI)	19.3 (16.9–23.0)	18.3 (16.5–20.6)	21.1 (19.4 – 24.5)	20.1 (18.0 – 22.9)	18.8 (17 – 21.1)	21.2 (19.1 – 23.4)
Waist-Hip-Ratio (WHR)	0.82 (0.76–0.89)	0.82 (0.78–0.88)	0.85 (0.80 – 0.91)	0.85 (0.80 – 0.90)	0.86 (0.81 – 0.91)	0.86 (0.82 – 0.90)
Waist-Height-Ratio (WHtR)	0.46 (0.42–0.53)	0.45 (0.42–0.50)	0.49 (0.46 – 0.54)	0.44 (0.41 – 0.49)	0.45 (0.42 – 0.48)	0.45 (0.42 – 0.49)
Conicity Index (Cindex)	1.21 (1.14–1.31)	1.22 (1.15–1.30)	1.22 (1.16 – 1.30)	1.21 (1.14 – 1.28)	1.22 (1.15 – 1.29)	1.18 (1.12 – 1.25)
Body adiposity Index (BAI)	26.9 (23.8 – 30.8)	25.6 (23.3 – 28.3)	27.5 (25.5 – 31.1)	23.0 (19.9 – 25.3)	21.7 (19.9 – 24.6)	22.6 (20.7 – 25.6)
Body roundness index (BRI)	2.70 (1.97–3.95)	2.48 (1.93–3.36)	3.19 (2.58–4.08)	2.36 (1.84–3.25)	2.40 (1.94–3.02)	2.54 (2.03 – 3.28)
Body shape index (ABSI)	0.81 (0.76 – 0.85)	0.82 (0.77 – 0.86)	0.79 (0.76 – 0.85)	0.79 (0.75 – 0.85)	0.81 (0.77 – 0.87)	0.77 (0.73 – 0.82)
Metabolic disorder, n (%)						
Dysglycaemia or IFG/Diabetes	42 (15.0)	96 (15.2)	58 (15.6)	23 (16.6)	42 (14.7)	37 (17.5)
Hypertension	117 (41.8)	254 (40.2)	152 (40.9)	81 (58.3)	152 (53.2)	107 (50.5)
Dysglycaemia/Hypertension	133 (47.5)	312 (49.4)	183 (49.2)	91 (65.5)	170 (59.4)	126 (59.4)
Metabolic Syndrome (MetS)	127 (45.4)	220 (34.8)	196 (52.7)	36 (25.9)	60 (21.0)	57 (26.9)

Fulbe group. The WHR was strongly correlated with the WHtR, Cindex, BRI, and ABSI and not with the BAI in both the male and female of the Fulbe group. The WHtR was strongly correlated with Cindex, BAI, and BRI in the female and male but weakly correlated with the ABSI female and moderately in male. The Cindex was strongly correlated with BRI and ABSI and weakly correlated with the BAI in both female and male. The BAI was strongly correlated with BRI in both the female and male but weakly correlated with the ABSI in the female and not with the male in the Fulbe population while the ABSI was weakly correlated with the BRI in female and moderately correlated with the BRI in the male population of the Fulbe.

Comparison of obesity phenotypes

The BW of women and men differed significantly for the Fulbe, Mbororo, and general population (all, $p<0.001$). The WC and BMI of women and men was similar for the Fulbe ($p>0.05$), and general population ($p>0.05$) but was lower for the Mbororo women compared to the men (WC: 72.0 vs. 75.0, $p=0.001$ and BMI: 18.3 vs. 18.8, $p=0.028$). There was no difference in the HC of women and men for the Fulbe ($p=0.987$), and Mbororo ($p=0.641$) but women of the general population had as higher HC compared to the men (92.0 vs. 89.0, $p=0.002$). Women had lower WHR than men of the Fulbe (0.82 vs. 0.85, $p=0.001$) and Mbororo (0.82 vs. 0.86, $p<0.001$) but similar in the general population ($p=0.233$).

Comparison of the prevalence of cardiometabolic disorder (Figure 1)

The prevalence of dysglycaemia was similar for women and men in Fulbe (15.0% vs. 16.6%, $p=0.681$), Mbororo (15.2% vs. 14.7%, $p=0.843$) and general population (15.6% vs. 17.5%, $p=0.558$). Women had significantly lower prevalence of hypertension than men, Fulbe (41.8% vs. 58.3%, $p=0.001$), Mbororo (40.2% vs. 53.2%, $p<0.001$), and the general population (40.9% vs. 50.5%, $p=0.025$). The prevalence of dysglycaemia/hypertension was significantly lower in women than men, Fulbe (47.5% vs. 65.5%, $p=0.001$), Mbororo (49.4% vs. 59.4%, $p=0.005$) and general population (49.2% vs. 59.4%, $p=0.017$). Women had significantly higher prevalence of MetS than men, Fulbe (45.4% vs. 25.9%, $p<0.001$), Mbororo (34.8% vs. 21.0%, $p<0.001$), and the general population (52.7% vs. 26.9%, $p<0.001$).

There was no significant difference in the prevalence of dysglycaemia for the three groups for women ($p=0.976$) and men ($p=0.694$); the prevalence of hypertension for women ($p=0.901$) and for men ($p=0.356$) as well as for dysglycaemia/hypertension for women ($p=0.866$) and men ($p=0.437$). There were significant differences in the prevalence of MetS in the three groups for women (Fulbe: 45.4%, Mbororo; 34.8% & general population; 52.7%, $p<0.001$) and not for men (Fulbe; 25.9%, Mbororo; 21.0% & general population; 26.9%, $p=0.263$).

Table 2. Correlation between the anthropometric measures.

		Male (n=139)									
		BW	WC	HC	BMI	WHR	WHtR	Cindex	BAI	BRI	ABSI
Female (n=280)	Fulbe										
	BW	----	0.751*	0.807*	0.898*	0.327*	0.613*	0.219*	0.508*	0.614*	-0.044
	WC	0.748*	-----	0.741*	0.744*	0.716*	0.941*	0.755*	0.595*	0.942*	0.523*
	HC	0.854*	0.730*	-----	0.774*	0.162	0.656*	0.363*	0.799*	0.660*	0.126
	BMI	0.917*	0.713*	0.812*	-----	0.380*	0.740*	0.213*	0.722*	0.740*	-0.085
	WHR	0.272*	0.705*	0.103	0.260*	----	0.743*	0.789*	0.154	0.743*	0.674*
	WHtR	0.653*	0.952*	0.677*	0.736*	0.689*	----	0.754*	0.705*	0.998*	0.520*
	Cindex	0.157*	0.723*	0.235*	0.115*	0.837*	0.698*	----	0.321*	0.758*	0.940*
	BAI	0.622*	0.601*	0.825*	0.796*	0.072	0.713*	0.179*	-----	0.705*	0.092
	BRI	0.651*	0.953*	0.676*	0.732*	0.690*	0.999*	0.702*	0.711*	----	0.524*
	ABSI	-0.176*	0.423*	-0.073	-0.244*	0.711*	0.390*	0.917*	-0.125*	0.394*	----
		Male (n=286)									
	Mbororo	BW	WC	HC	BMI	WHR	WHtR	Cindex	BAI	BRI	ABSI
Female (n=632)	BW	----	0.602*	0.543*	0.879*	0.254*	0.414*	-0.088	0.133*	0.423*	-0.300*
	WC	0.657*	----	0.530*	0.550*	0.698*	0.891*	0.666*	0.288*	0.912*	0.478*
	HC	0.750*	0.674*	----	0.474*	-0.145*	0.406*	0.212*	0.672*	0.429*	0.077
	BMI	0.888*	0.641*	0.687*	----	0.231*	0.533*	-0.146*	0.402*	0.547*	-0.384*
	WHR	0.265*	0.755*	0.091*	0.294*	----	0.665*	0.621*	-0.193*	0.684*	0.534*
	WHtR	0.525*	0.943*	0.591*	0.653*	0.754*	----	0.676*	0.471*	0.977*	0.446*
	Cindex	0.085*	0.754*	0.289*	0.067	0.779*	0.735*	----	0.128*	0.657*	0.936*
	BAI	0.424*	0.527*	0.752*	0.657*	0.084*	0.658*	0.243*	----	0.490*	0.008
	BRI	0.526*	0.944*	0.593*	0.652*	0.755*	0.998*	0.736*	0.659*	----	0.469*
	ABSI	-0.197*	0.504*	0.054	-0.244*	0.649*	0.485*	0.935*	0.022*	0.487*	----
		Male (n=212)									
	General population	BW	WC	HC	BMI	WHR	WHtR	Cindex	BAI	BRI	ABSI
Female (n=372)	BW	----	0.573*	0.698*	0.887*	0.007	0.405*	-0.082	0.391*	0.404*	-0.332*
	WC	0.637*	----	0.669*	0.559*	0.536*	0.930*	0.691*	0.524*	0.931*	0.462*
	HC	0.794*	0.663*	-----	0.652*	-0.165*	0.573*	0.218*	0.742*	0.573*	0.003
	BMI	0.899*	0.663*	0.717*	-----	0.038	0.533*	-0.099	0.614*	0.534*	-0.374*
	WHR	0.063	0.617*	-0.095*	0.108*	-----	0.559*	0.696*	-0.064	0.562*	0.632*
	WHtR	0.487*	0.938*	0.554*	0.608*	0.651*	----	0.706*	0.652*	0.998*	0.485*
	Cindex	-0.072	0.656*	0.128*	-0.077	0.761*	0.675*	----	0.232*	0.707*	0.950*
	BAI	0.493*	0.549*	0.775*	0.679*	-0.045	0.653*	0.157*	-----	0.653*	0.034
	BRI	0.486*	0.939*	0.554*	0.607*	0.652*	0.998*	0.677*	0.652*	----	0.486*
	ABSI	-0.368*	0.369*	-0.133*	-0.397*	0.648*	0.391*	0.927*	-0.094	0.393*	----
*: Statistically significant with p<0.05											

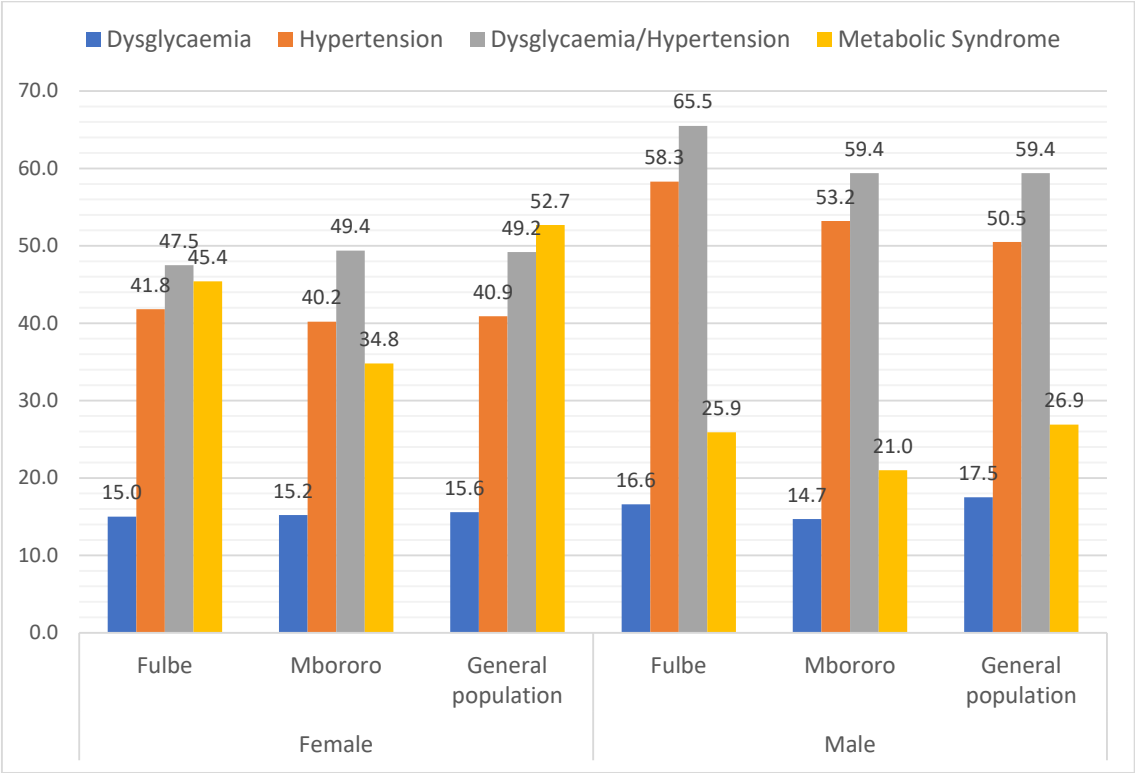


Figure 1. Prevalence of cardiometabolic disorder by group and sex.

Predictors of dysglycaemia

The area under the ROC curve showed no discrimination for ABSI and moderate discrimination for the WC, HC, WHR, Cindex, BAI, and BRI in women and for HC and BAI in men of the Fulbe group while acceptable discrimination was observed for BW, BMI, and WHtR in women and BW, WC, BMI, WHR, WHtR, Cindex, BRI, and ABSI in men. For the Mbororo group, all the anthropometric measures had moderate discrimination except ABSI that had no discrimination in women while in men; the BW, WC, HC, BMI, WHtR, Cindex, BRI, and ABSI showed moderate discrimination except for WHR which had acceptable and BAI that had no discrimination. All the anthropometric measures showed moderate discrimination in women and men except BAI and ABSI in women and BW and BMI in men that showed no discrimination for the general population (Table 3). The area under the curve ROC analysis consistently showed moderate AUC values and highest MAORs for BW and BMI, all of which were statistically significant as the best predictor in identifying dysglycaemia in women of the Fulbe group and general populations and none for men. The WC, HC, WHR, WHtR, Cindex, BAI, BRI, and ABSI were the worse predictors of dysglycaemia in both women and men of the Fulbe, Mbororo, and general population (Tables 3 and 4).

Predictors of hypertension

From the area under the ROC curve, the BW, WC, and HC showed moderate discrimination in women while BW, BMI, WHtR, and Cindex showed moderate discrimination and WC, HC, BAI, and BRI showed acceptable discrimination in men of the Fulbe group in identifying hypertension. ROC analysis showed moderate discrimination for BW, WC, HC, BMI, WHtR, BAI, and BRI had moderate discrimination for women while BW, WC, HC, BMI, WHR, WHtR, Cindex, BRI, and ABSI in men of the Mbororo group. For the general population, all the anthropometric measures showed moderate discrimination in women and men except for ABSI in men (Table 3). ROC curves consistently showed moderate AUC values and highest MAORs for BW, HC, BMI, and BAI in women and in men WC, HC and BRI in the Mbororo group. For the general population, the ROC analysis consistently showed best predicting capacity with BW, WC, HC, WHtR, Cindex, BAI and BRI in women and with BW, WC, HC, BMI, WHtR, BAI and BRI in men. However, none of the anthropometric measures identified hypertension in the women but BW, WC, HC, BMI, WHR, BAI and BRI consistently showed best predicting capacity with ROC analysis and MAORs in men of the Fulbe group. The ABSI was the worse predictor of hypertension in both women and men for all three groups (Tables 3 and 4).

Table 3. The area under the ROC curve (95% CI) of each anthropometric measurement for the dysglycaemia, Hypertension, dysglycaemia/hypertension and MetS.								
	Female, (n=1 284)				Male, (n=637)			
Metabolic disturbance	Fulbe	Mbororo	General population	P-value	Fulbe	Mbororo	General population	P-value
1 –Dysglycaemia	(n=280)	(n=632)	(n=372)		(n=139)	(n=286)	(n=212)	
Body Weight (BW)	0.61 (0.51–0.71)	0.54 (0.48 – 0.71)	0.52 (0.43 – 0.60)	0.241	0.61 (0.49 – 0.73)	0.57 (0.46 – 0.67)	0.47 (0.37 – 0.59)	0.241
Waist circumference (WC)	0.58 (0.47–0.68)	0.53 (0.47 – 0.49)	0.54 (0.46 – 0.62)	0.787	0.66 (0.54 – 0.78)	0.59 (0.50–0.69)	0.55 (0.44 – 0.65)	0.388
Hip circumference (HC)	0.59 (0.48–0.69)	0.54 (0.48 – 0.61)	0.44 (0.35 – 0.53)	0.087	0.57 (0.45 – 0.69)	0.54 (0.43 – 0.64)	0.51 (0.41 – 0.60)	0.685
Body mass index (BMI)	0.60 (0.50–0.70)	0.56 (0.49 – 0.62)	0.55 (0.46 – 0.63)	0.723	0.61 (0.49–0.74)	0.53 (0.42 – 0.63)	0.48 (0.37 – 0.58)	0.270
Waist-Hip-Ratio (WHR)	0.55 (0.45 – 0.64)	0.52 (0.46 – 0.58)	0.59 (0.51 – 0.67)	0.401	0.65 (0.53–0.77)	0.60 (0.52–0.68)	0.56 (0.45 – 0.66)	0.563
Waist-Height-Ratio (WHtR)	0.65 (0.53–0.77)	0.53 (0.47 – 0.59)	0.56 (0.48 – 0.64)	0.845	0.64 (0.51–0.77)	0.57 (0.48 – 0.66)	0.56 (0.45 – 0.67)	0.648
Conicity Index (Cindex)	0.52 (0.43 – 0.61)	0.52 (0.45 – 0.58)	0.52 (0.43 – 0.61)	0.997	0.64 (0.53–0.76)	0.55 (0.47 – 0.64)	0.58 (0.47 – 0.69)	0.467
Body adiposity Index (BAI)	0.55 (.46 – 0.65)	0.56 (0.49–0.62)	0.47 (0.38 – 0.56)	0.277	0.55 (0.41–0.69)	0.49 (0.39 – 0.59)	0.52 (0.42 – 0.62)	0.813
Body roundness index (BRI)	0.56 (0.47 – 0.66)	0.53 (0.47 – 0.59)	0.56 (0.48 – 0.64)	0.837	0.64 (0.51–0.77)	0.57 (0.48–0.66)	0.56 (0.46 – 0.67)	0.603
Body shape index (ABSI)	0.46 (0.37 – 0.56)	0.49 (0.43 – 0.56)	0.49 (0.40 – 0.58)	0.874	0.62 (0.51–0.73)	0.54 (0.45 – 0.63)	0.58 (0.47 – 0.70)	0.537
2 – Hypertension	(n=280)	(n=632)	(n=372)		(n=139)	(n=286)	(n=212)	
Body Weight (BW)	0.56 (0.49 – 0.62)	0.57 (0.53–0.62)	0.57 (0.51 – 0.63)	0.904	0.63 (0.54–0.73)	0.59 (0.53 – 0.66)	0.61 (0.53 – 0.68)	0.795
Waist circumference (WC)	0.55 (0.48 – 0.62)	0.56 (0.52 – 0.61)	0.63 (0.57 – 0.69)	0.100	0.66 (0.57–0.75)	0.61 (0.54–0.67)	0.61 (0.53 – 0.68)	0.606
Hip circumference (HC)	0.57 (0.50–0.63)	0.58 (0.53–0.62)	0.61 (0.55 – 0.67)	0.546	0.69 (0.60–0.78)	0.57 (0.50–0.63)	0.61 (0.53 – 0.68)	0.088
Body mass index (BMI)	0.54 (0.47 – 0.61)	0.57 (0.52–0.61)	0.56 (0.50 – 0.62)	0.817	0.63 (0.53–0.72)	0.57 (0.51 – 0.64)	0.61 (0.53 – 0.68)	0.632
Waist-Hip-Ratio (WHR)	0.53 (0.46 – 0.59)	0.52 (0.48 – 0.57)	0.56 (0.50 – 0.62)	0.650	0.52 (0.42 – 0.61)	0.57 (0.50–0.63)	0.55 (0.47 – 0.62)	0.708
Waist-Height-Ratio (WHtR)	0.54 (0.47 – 0.61)	0.56 (0.51 – 0.60)	0.62 (0.56 – 0.68)	0.124	0.64 (0.55–0.73)	0.59 (0.52– 0.65)	0.61 (0.54 – 0.69)	0.647
Conicity Index (Cindex)	0.54 (0.47 – 0.61)	0.53 (0.49 – 0.58)	0.60 (0.55 – 0.66)	0.140	0.59 (0.49 – 0.68)	0.56 (0.50 – 0.63)	0.54 (0.46 – 0.62)	0.784
Body adiposity Index (BAI)	0.54 (0.47 – 0.61)	0.55 (0.51 – 0.59)	0.60 (0.54 – 0.66)	0.350	0.67 (0.58–0.76)	0.52 (0.46 – 0.59)	0.62 (0.55 – 0.69)	0.026
Body roundness index (BRI)	0.54 (0.47 – 0.61)	0.56 (0.51 – 0.60)	0.62 (0.56 – 0.68)	0.147	0.65 (0.56–0.74)	0.59 (0.53 – 0.66)	0.61 (0.54 – 0.69)	0.647
Body shape index (ABSI)	0.52 (0.45 – 0.59)	0.50 (0.46 – 0.55)	0.56 (0.50 – 0.62)	0.273	0.53 (0.44 – 0.63)	0.55 (0.48 – 0.62)	0.51 (0.42 – 0.58)	0.712

3-Dysglycaemia/ hypertension	(n=280)	(n=632)	(n=372)		(n=139)	(n=286)	(n=212)	
Body Weight (BW)	0.53 (0.46 – 0.60)	0.57 (0.53–0.62)	0.57 (0.52 – 0.63)	0.571	0.66 (0.56–0.76)	0.59 (0.53 – 0.66)	0.57 (0.49 – 0.65)	0.356
Waist circumference (WC)	0.53 (0.46 – 0.59)	0.57 (0.52–0.61)	0.62 (0.56 – 0.67)	0.131	0.70 (0.61–0.79)	0.61 (0.55–0.68)	0.61 (0.53 – 0.68)	0.240
Hip circumference (HC)	0.53 (0.47 – 0.60)	0.59 (0.54–0.63)	0.58 (0.52 – 0.63)	0.440	0.70 (0.61–0.79)	0.56 (0.50 – 0.63)	0.60 (0.52 – 0.67)	0.058
Body mass index (BMI)	0.52 (0.45 – 0.58)	0.57 (0.53–0.61)	0.58 (0.52 – 0.64)	0.325	0.66 (0.57–0.76)	0.56 (0.50 – 0.63)	0.57 (0.49 – 0.65)	0.227
Waist-Hip-Ratio (WHR)	0.54 (0.47–0.60)	0.52 (0.48 – 0.57)	0.57 (0.51 – 0.63)	0.397	0.55 (0.45 – 0.65)	0.58 (0.52 – 0.65)	0.56 (0.48 – 0.63)	0.813
Waist-Height-Ratio (WHtR)	0.52 (0.45 – 0.59)	0.56 (0.51 – 0.60)	0.62 (0.56 – 0.67)	0.080	0.68 (0.58–0.77)	0.59 (0.52 – 0.66)	0.62 (0.54 – 0.69)	0.338
Conicity Index (Cindex)	0.54 (0.47–0.61)	0.54 (0.49 – 0.58)	0.58 (0.52 – 0.63)	0.574	0.60 (0.50 – 0.70)	0.57 (0.50 – 0.64)	0.58 (0.50 – 0.66)	0.874
Body adiposity Index (BAI)	0.51 (0.44 – 0.58)	0.57 (0.52–0.61)	0.57 (0.52 – 0.63)	0.310	0.69 (0.60–0.78)	0.51 (0.44 – 0.58)	0.62 (0.55 – 0.69)	0.005
Body roundness index (BRI)	0.52 (0.45 – 0.59)	0.56 (0.51 – 0.60)	0.61 (0.56 – 0.67)	0.104	0.69 (0.59–0.78)	0.60 (0.53–0.66)	0.62 (0.54 – 0.69)	0.318
Body shape index (ABSI)	0.53 (0.47 – 0.60)	0.51 (0.46 – 0.55)	0.53 (0.47 – 0.59)	0.762	0.54 (0.43 – 0.64)	0.56 (0.49 – 0.63)	0.55 (0.47 – 0.63)	0.949
4 – MetS	(n=280)	(n=632)	(n=372)		(n=139)	(n=286)	(n=212)	
Body Weight (BW)	0.83 (0.78–0.87)	0.73 (0.68–0.77)	0.78 (0.74 – 0.83)	0.014	0.78 (0.68–0.87)	0.60 (0.52–0.69)	0.63 (0.54 – 0.73)	0.020
Waist circumference (WC)	0.92 (0.88–0.95)	0.87 (0.83–0.91)	0.93 (0.89 – 0.96)	0.045	0.79 (0.70–0.89)	0.63 (0.55–0.72)	0.67 (0.58 – 0.76)	0.035
Hip circumference (HC)	0.82 (0.77–0.87)	0.75 (0.71–0.79)	0.78 (0.73 – 0.83)	0.100	0.77 (0.67–0.88)	0.61 (0.52–0.69)	0.65 (0.56 – 0.74)	0.047
Body mass index (BMI)	0.82 (0.77–0.87)	0.74 (0.70–0.79)	0.79 (0.74 – 0.83)	0.098	0.74 (0.64–0.84)	0.57 (0.48 – 0.67)	0.65 (0.56 – 0.74)	0.055
Waist-Hip-Ratio (WHR)	0.80 (0.75–0.85)	0.77 (0.73–0.81)	0.76 (0.71 – 0.81)	0.585	0.71 (0.61–0.81)	0.59 (0.51 – 0.66)	0.59 (0.50 – 0.67)	0.106
Waist-Height-Ratio (WHtR)	0.91 (0.87–0.95)	0.86 (0.83–0.90)	0.91 (0.87 – 0.94)	0.152	0.75 (0.64–0.85)	0.62 (0.53–0.70)	0.68 (0.59 – 0.77)	0.153
Conicity Index (Cindex)	0.80 (0.75–0.85)	0.78 (0.74–0.82)	0.76 (0.71 – 0.80)	0.441	0.74 (0.65–0.84)	0.60 (0.52–0.68)	0.62 (0.53 – 0.70)	0.056
Body adiposity Index (BAI)	0.78 (0.73–0.84)	0.73 (0.69–0.78)	0.73 (0.68 – 0.78)	0.301	0.68 (0.5–0.79)	0.56 (0.47 – 0.65)	0.65 (0.56 – 0.74)	0.199
Body roundness index (BRI)	0.91 (0.87–0.95)	0.86 (0.83–0.90)	0.91 (0.87 – 0.94)	0.147	0.75 (0.65–0.86)	0.62 (0.53–0.70)	0.69 (0.60 – 0.77)	0.144
Body shape index (ABSI)	0.67 (0.61–0.73)	0.68 (0.63–0.72)	0.63 (0.57 – 0.68)	0.379	0.67 (0.57–0.77)	0.57 (0.49 – 0.65)	0.55 (0.47 – 0.64)	0.155
p-value: testing the null hypothesis H_0 : AUC (Fulbe)=AUC (Mbororo)=AUC (General population), Bold : indicates the highest value of the AUC by sex.								

Table 4: Multivariable Adjusted Odds Ratio (95% CI) for the presence of dysglycaemia, Hypertension, dysglycaemia/hypertension and MetS from multivariate logistic regression.

	Female			Male		
	Fulbe	Mbororo	General population	Fulbe	Mbororo	General population
1-Dysglycaemia	(n=275)	(n=632)	(n=372)	(n=139)	(n=286)	(n=212) 205
BW	1.55 (1.15 – 2.09)^{aa}	1.26 (0.95 – 1.66) ^b	1.40 (1.04 – 1.87)^{aa}	1.17 (0.75 – 1.82) ^b	1.36 (0.89 – 2.09) ^b	0.86 (0.55 – 1.34) ^b
WC	1.28 (0.94 – 1.74) ^b	1.09 (0.87 – 1.37) ^b	1.16 (0.84 – 1.61) ^b	1.37 (0.86 – 2.18) ^b	1.46 (0.93 – 2.29) ^b	1.14 (0.74 – 1.77) ^b
HC	1.32 (0.99 – 1.75) ^b	1.23 (0.95 – 1.60) ^b	1.01 (0.74 – 1.36) ^b	1.20 (0.73 – 1.97) ^b	1.31 (0.83 – 2.06) ^b	1.05 (0.71 – 1.53) ^b
BMI	1.41 (1.06 – 1.88)^{aa}	1.21 (0.96 – 1.52) ^b	1.44 (1.09 – 1.89)^{aa}	1.23 (0.75 – 2.01) ^b	1.28 (0.82 – 1.99) ^b	0.88 (0.54 – 1.43) ^b
WHR	0.99 (0.69 – 1.41) ^b	0.95 (0.75 – 1.19) ^b	1.30 (0.93 – 1.81) ^b	1.58 (0.79 – 3.14) ^b	1.16 (0.81 – 1.66) ^b	1.07 (0.71 – 1.62) ^b
WHtR	1.18 (0.86 – 1.62) ^b	1.09 (0.87 – 1.35) ^b	1.19 (0.86 – 1.64) ^b	1.40 (0.84 – 2.32) ^b	1.33 (0.85 – 2.10) ^b	1.22 (0.77 – 1.92) ^b
Cindex	0.93 (0.68 – 1.28) ^b	0.96 (0.76 – 1.20) ^b	0.82 (0.58 – 1.15) ^b	1.54 (0.77 – 3.07) ^b	1.19 (0.83 – 1.71) ^b	1.31 (0.87 – 1.98) ^b
BAI	1.13 (0.83 – 1.55) ^b	1.19 (0.93 – 1.51) ^b	1.04 (0.76 – 1.42) ^b	1.29 (0.70 – 2.36) ^b	1.13 (0.68 – 1.89) ^b	1.11 (0.69 – 1.78) ^b
BRI	1.22 (0.88 – 1.67) ^b	1.07 (0.87 – 1.32) ^b	1.16 (0.86 – 1.58) ^b	1.37 (0.84 – 2.22) ^b	1.38 (0.85 – 2.23) ^b	1.23 (0.76 – 1.98) ^b
ABSI	0.85 (0.61 – 1.17) ^b	0.89 (0.71 – 1.13) ^b	0.74 (0.52 – 1.05) ^b	1.36 (0.63 – 2.92) ^b	1.21 (0.82 – 1.78) ^b	1.33 (0.87 – 2.03) ^b
2 - Hypertension	(n=275)	(n=632)	(n=372)	(n=139)	(n=286)	(n=212)
BW	1.19 (0.92 – 1.53) ^b	1.33 (1.06 – 1.66)^{aa}	1.28 (1.01 – 1.62)^{aa}	2.01 (1.26 – 3.22)^{aa}	1.33 (0.95 – 1.86) ^b	1.44 (1.03 – 2.02)^{aa}
WC	1.13 (0.89 – 1.44) ^b	1.14 (0.95 – 1.36) ^b	1.54 (1.19 – 1.99)^{ac}	1.88 (1.18 – 2.99)^{aa}	1.49 (1.07 – 2.08)^{aa}	1.45 (1.02 – 2.06)^{aa}
HC	1.18 (0.94 – 1.48) ^b	1.35 (1.10 – 1.65)^{ac}	1.39 (1.10 – 1.77)^{ac}	2.69 (1.59 – 4.56)^{ad}	1.40 (1.01 – 1.94)^{aa}	1.37 (1.01 – 1.86)^{aa}
BMI	1.09 (0.86 – 1.39) ^b	1.28 (1.05 – 1.54)^{aa}	1.22 (0.97 – 1.51) ^b	2.16 (1.27 – 3.67)^{aa}	1.33 (0.93 – 1.91) ^b	1.79 (1.22 – 2.65)^{aa}
WHR	0.92 (0.69 – 1.22) ^b	0.93 (0.78 – 1.10) ^b	1.19 (0.91 – 1.57) ^b	0.81 (0.48 – 1.35) ^b	1.18 (0.91 – 1.53) ^b	1.06 (0.78 – 1.45) ^b
WHtR	1.07 (0.83 – 1.37) ^b	1.14 (0.96 – 1.35) ^b	1.47 (1.14 – 1.89)^{aa}	1.84 (1.12 – 3.02)^{aa}	1.34 (0.94 – 1.89) ^b	1.59 (1.11 – 2.31)^{aa}
Cindex	1.03 (0.80 – 1.33) ^b	0.98 (0.82 – 1.16) ^b	1.46 (1.12 – 1.91)^{aa}	1.25 (0.73 – 2.17) ^b	1.07 (0.81 – 1.41) ^b	1.06 (0.79 – 1.43) ^b
BAI	1.05 (0.82 – 1.34) ^b	1.29 (1.07 – 1.57)^{aa}	1.31 (1.02 – 1.67)^{aa}	2.76 (1.50 – 5.07)^{ac}	1.33 (0.92 – 1.94) ^b	1.94 (1.29 – 2.89)^{ac}
BRI	1.09 (0.84 – 1.41) ^b	1.11 (0.94 – 1.31) ^b	1.44 (1.13 – 1.83)^{aa}	1.94 (1.14 – 3.31)^{aa}	1.54 (1.06 – 2.25)^{aa}	1.65 (1.11 – 2.45)^{aa}
ABSI	0.99 (0.76 – 1.29) ^b	0.91 (0.76 – 1.08) ^b	1.31 (1.00 – 1.72) ^b	0.88 (0.49 – 1.59) ^b	1.13 (0.86 – 1.47) ^b	0.94 (0.69 – 1.28) ^b

3-Dysglycaemia/hypertension	(n=275)	(n=632)	(n=372)	(n=139)	(n=286)	(n=212)
BW	1.18 (0.92 – 1.53) ^b	1.33 (1.06 – 1.65)^{aa}	1.28 (1.01 – 1.62)^{aa}	2.01 (1.26 – 3.22)^{aa}	1.32 (0.94 – 1.86) ^b	1.27 (0.91 – 1.77) ^b
WC	1.13 (0.89 – 1.44) ^b	1.14 (0.95 – 1.36) ^b	1.54 (1.19 – 1.99)^{ac}	1.88 (1.18 – 2.99)^{aa}	1.50 (1.07 – 2.09)^{aa}	1.45 (1.02 – 2.06)^{aa}
HC	1.18 (0.94 – 1.48) ^b	1.35 (1.10 – 1.65)^{ac}	1.40 (1.10 – 1.77)^{aa}	2.70 (1.59 – 4.56)^{ad}	1.40 (1.01 – 1.94)^{aa}	1.33 (0.97 – 1.81) ^b
BMI	1.10 (0.86 – 1.39) ^b	1.28 (1.05 – 1.54)^{aa}	1.36 (1.09 – 1.71)^{aa}	2.16 (1.27 – 3.67)^{aa}	1.33 (0.93 – 1.91) ^b	1.80 (1.22 – 2.65)^{aa}
WHR	0.92 (0.69 – 1.22) ^b	0.93 (0.78 – 1.10) ^b	1.19 (0.91 – 1.57) ^b	0.81 (0.49 – 1.35) ^b	1.18 (0.91 – 1.53) ^b	1.06 (0.78 – 1.45) ^b
WHtR	1.07 (0.83 – 1.37) ^b	1.14 (0.96 – 1.35) ^b	1.47 (1.14 – 1.89)^{aa}	1.84 (1.12 – 3.02)^{aa}	1.34 (0.94 – 1.89) ^b	1.59 (1.11 – 2.30)^{aa}
Cindex	1.03 (0.80 – 1.33) ^b	0.98 (0.82 – 1.16) ^b	1.19 (0.92 – 1.53) ^b	1.26 (0.73 – 2.17) ^b	1.07 (0.81 – 1.41) ^b	1.06 (0.79 – 1.43) ^b
BAI	1.05 (0.82 – 1.34) ^b	1.30 (1.08 – 1.57)^{aa}	1.24 (0.98 – 1.58) ^b	2.83 (1.56 – 5.16)^{aa}	1.33 (0.92 – 1.94) ^b	1.94 (1.30 – 2.89)^{ac}
BRI	1.09 (0.84 – 1.41) ^b	1.11 (0.94 – 1.31) ^b	1.44 (1.13 – 1.83)^{aa}	1.94 (1.14 – 3.31)^{aa}	1.54 (1.06 – 2.25)^{aa}	1.65 (1.11 – 2.45)^{aa}
ABSI	0.99 (0.76 – 1.29) ^b	0.91 (0.77 – 1.08) ^b	1.31 (1.00 – 1.72) ^b	0.88 (0.49 – 1.59) ^b	1.13 (0.86 – 1.48) ^b	0.94 (0.69 – 1.28) ^b
4 - MetS	(n=280)	(n=632)	(n=372)	(n=139)	(n=286)	(n=212)
BW	5.56 (3.48 – 8.89)^{ad}	3.93 (2.94– 5.27)^{ad}	5.76 (3.76 – 8.84)^{ad}	3.64 (1.91 – 6.94)^{ad}	1.68 (1.14 – 2.49)^{aa}	1.99 (1.33 – 2.98)^{ac}
WC	19.56 (9.41– 40.66)^{ad}	11.44 (7.72– 16.95)^{ad}	77.13 (29.78– 199.75)^{ad}	4.24 (2.11– 8.51)^{ad}	1.98 (1.30– 3.01)^{aa}	2.44 (1.54 – 3.88)^{ad}
HC	4.20 (2.80 – 6.29)^{ad}	4.19 (3.15 – 5.57)^{ad}	4.33 (2.98 – 6.29)^{ad}	3.67 (1.86 – 7.25)^{ad}	2.01 (1.32 – 3.06)^{ac}	2.08 (1.37 – 3.15)^{ad}
BMI	4.43 (2.95 – 6.65)^{ad}	3.82 (2.88 – 5.07)^{ad}	5.20 (3.48 – 7.77)^{ad}	2.82 (1.49 – 5.32)^{ac}	1.63 (1.08 – 2.44)^{aa}	2.23 (1.43 – 3.48)^{ad}
WHR	4.12 (2.73 – 6.22)^{ad}	3.42 (2.62 – 4.45)^{ad}	4.29 (2.88 – 6.41)^{ad}	2.52 (1.27 – 5.00)^{ad}	1.11 (0.82 – 1.52) ^b	1.22 (0.85 – 1.76) ^b
WHtR	12.93 (7.04– 23.72)^{ad}	9.79 (6.74– 14.21)^{ad}	31.01 (14.82– 64.85)^{ad}	3.11 (1.64 – 5.89)^{ad}	1.70 (1.13 – 2.54)^{aa}	2.45 (1.53 – 3.93)^{ad}
Cindex	4.10 (2.74 – 6.13)^{ad}	3.84 (2.96 – 4.99)^{ad}	3.63 (2.53 – 5.22)^{ad}	3.43 (1.63 – 7.20)^{ac}	1.23 (0.90 – 1.69) ^b	1.41 (0.97 – 2.04) ^b
BAI	2.84 (2.02 – 3.99)^{ad}	3.36 (2.58 – 4.38)^{ad}	3.08 (2.20 – 4.32)^{ad}	2.15 (1.14 – 4.04)^{aa}	1.78 (1.13 – 2.81)^{aa}	2.25 (1.42 – 3.58)^{ac}
BRI	17.03 (8.67– 33.46)^{ad}	12.26 (8.11– 18.53)^{ad}	36.55 (16.74 – 79.81)^{ad}	3.51 (1.74 – 7.07)^{ad}	1.93 (1.24 – 2.99)^{aa}	2.71 (1.64 – 4.47)^{ad}
ABSI	1.94 (1.43 – 2.64)^{ad}	2.26 (1.82 – 2.80)^{ad}	1.78 (1.33 – 2.37)^{ad}	2.05 (0.97 – 4.35) ^b	1.20 (0.86 – 1.66) ^b	1.16 (0.81 – 1.66) ^b
The bold denotes statistical significance: ^{aa} p<0.05, ^{ac} p<0.01, ^{ad} p<0.001 & the normal denotes not statistically significant: ^b p>0.05						
Adjusted for age group, marital status, physical activity, smoking and drinking status, fruit and vegetable consumption, salt and sugar intake and site.						

Predictors of dysglycaemia/hypertension

For the Fulbe group, the area under the ROC curve did not show any discrimination characteristics as well as MAORs for all the anthropometric measures in women as well as WHR in men but showed moderate discrimination for BW, BMI, WHtR, Cindex, BAI, and BRI in men. The ROC analysis showed moderate discrimination for the anthropometric measures in women as well as in men except for WC and BRI that showed acceptable discrimination for men of the Mbororo group. In the general population group the ROC analysis had moderate discrimination for BW, HC, BMI, WHR, Cindex, BAI, and ABSI in women and BW, BMI, WHR, Cindex, and ABSI in men. Acceptable discrimination for WC, WHtR, and BRI in women and WC, HC, WHtR, BAI, and BRI in men (**Table 3**). The BW, HC, BMI, BAI in women and WC, HC, and BRI consistently had best predictor in men of the Mbororo group while BW, WC, HC, BMI, WHtR, BAI, and BRI were consistently best predictors in only men of the Fulbe group. While BW, WC, HC, BMI, WHtR, and BRI were consistently the best predictors in women, the WC, BMI, WHtR, BAI and BRI were consistently the best predictors in men of the general population. The WHR and ABSI were consistently the worse predictors of dysglycaemia/hypertension in both women and men of the Fulbe, Mbororo, and general population (**Tables 3 and 4**).

Predictors of metabolic syndrome (MetS)

The area under the ROC curve showed moderate discrimination for ABSI, acceptable discrimination for BAI, excellent discrimination for BW, HC, BMI, WHR, and Cindex and outstanding discrimination for WC, WHtR, and BRI in the women and moderate discrimination for ABSI and BAI, acceptable discrimination for BW, WC, HC, BMI, WHR, WHtR, Cindex, and BRI in men of the Fulbe group. For the Mbororo, ROC analysis had moderate discrimination for ABSI, moderate for BW, HC, BMI, WHR, Cindex and BAI and excellent discrimination for WC, WHtR and BRI in women while in men, moderate discrimination was for BMI, WHR, BAI and ABSI, acceptable in BW, WC, HC, WHtR, Cindex, and BRI. For the general population, the ABSI showed moderate discriminatory, acceptable discrimination for BW, HC, BMI, WHR, Cindex, and BAI and excellent discrimination for WC, WHtR and BRI in women while in men the WHR and ABSI showed moderate discrimination, the BW, WC, HC, BMI, WHtR, Cindex, BAI, and BRI had acceptable discrimination, and no excellent discrimination was showed for MetS in men (**Table 3**).

All the anthropometric measures consistently showed good performance in predicting MetS in women and men except ABSI in the men of the Fulbe, Mbororo and general population group and WHR and Cindex in the Mbororo and general population (**Tables 3 and 4**).

Anthropometric z-scores were associated with higher risk for MetS in Fulbe than Mbororo and the general population

for every 1 standard deviation increase in anthropometric measure. When stratified by sex the statistically significant anthropometric z-scores were associated with higher risk for MetS in women than men for every 1 S.D increase in anthropometric measure in the Fulbe, Mbororo, and the general population while WHtR, BAI and BRI were associated with higher risk for hypertension in men than women of the general population group (**Table 4**).

Discussion

The key findings of the study were that all the anthropometric measures had good performance in predicting MetS risk in women while BW, WC, HC, BMI, and WHtR, BAI and BRI showed best performance in predicting MetS for the men in all the groups. The strength of association between anthropometric measures and MetS risk was greater in settled Fulani (Fulbe) than nomadic pastoral Fulani (Mbororo) and the general population and the risk was higher in women compared to men in all the groups. These findings suggest that with transition from nomadic to settled life indigenous Mbororo will be at a greater risk of MetS and the women at a greater than the men. The BW, HC, and BMI had best performance in women of the Mbororo and general population and not Fulbe while WC and BRI showed best performance in all the three groups of men in predicting dysglycaemia/hypertension. The BW, HC, and BAI had best performance in women of the Mbororo and general population and not Fulbe while in men, the WC, HC, and BRI showed best performance in predicting hypertension. Only the BW and BMI had best performance in women of Fulbe and general population in predicting dysglycaemia. The worse performance in predicting dysglycaemia, hypertension and dysglycaemia/hypertension was from WHR and ABSI in both men and women of all the groups. WC and BRI are better predictors of hypertension and dysglycaemia/hypertension in men in all the groups but not in women of all the groups.

The BW, WC, HC, BMI, WHtR, BAI, and BRI were the better predictors of MetS in both men and women in the Fulbe, Mbororo, and the general population. This is in line with the results of a study in Chinese men and women which identified anthropometric measures of abdominal obesity, especially WHtR in identifying MetS, dysglycaemia and dyslipidemia and BMI for identifying people with hypertension and hyperuricemia in men [28] whereas our study suggested BMI for identifying women of the Mbororo group and men of the Fulbe and the general population at risk of hypertension. Using ROC analysis, WC and WHtR in our study for men and women of the Fulbe, Mbororo, and general population and BMI in women of all the three groups and in men of the Fulbe predicted MetS. This was similar to a Chinese study that identified WC, BMI, and WHtR to predict ≥ 3 metabolic risk factors in men and WC and BMI to predict ≥ 3 metabolic risk factors in women [29]. Similar findings have been reported in a study of 202 Southern-Indians using area under the ROC curve analysis and adjusted odds ratios for age, sex, BMI,

history of smoking and alcohol intake showed that BRI was superior in identifying MetS as well as Cindex if only area under the ROC curve analysis was considered with variations after stratification by sex [30]. Similar findings were reported in a European study that analysed data of 12,328 participants, where using AUC analysis the BMI and WC in men and WHtR and WC in women was shown to have a better discriminatory power in identifying MetS except ABSI [31].

Our findings showed that WHtR was the best predictor for hypertension in women and men of the general population and women of the Fulbe group. Similar findings to our study were reported in the study of indigenous population of Orang Asli villages in the Krau Wildlife Reserve, Pahang, Peninsular Malaysia where WHtR was the best predictor for hypertension [32]. Contrary to the Orang Asli indigenous populations we showed in that BW, HC, and BAI in women of the Mbororo indigenous group and WC, HC, and BRI in men of the Fulbe and Mbororo indigenous populations were equally good predictors of hypertension. This study showed similar findings to a study in Brazil for WC and WHtR as best predictors for hypertension in women of the general population [33]. On the contrary our study also showed that WC, BMI, and WHtR were also good predictors of hypertension in the men of the Fulbe and the general population.

Using area under the ROC curve analysis WC and WHtR were the best predictors of IFG (>110 mg/dL) in a study of 12,294 adults attending annual physical exams provided by EHE International in United States [34]. This is in line with our ROC curve results of dysglycaemia for women and men of the Fulbe group in our study. On further analysis of MAORs, neither WC nor WHtR was associated with the dysglycaemia in our study.

Results of area under the ROC curve showed that measures of central adiposity such as WC, WHtR, and BRI (measure of central adiposity) were consistently better predictors of MetS in both sexes than BMI (measure of overall adiposity) suggesting that complications of obesity are more closely related to body fat distribution rather than absolute degree of adiposity per se. This is consistent with other finding in a Singaporean study of Chinese, Malay, and Indian adults suggesting that measures of central adiposity are associated CVD risk factors than BMI [35]. Further analysis using MAORs investigating the effect of central adiposity on the overall adiposity showed that for each SD increase of WC, WHtR, and BRI had significant ORs for MetS suggesting that measures of central adiposity increase the odds of cardiometabolic risk independent of BMI in women and men of all the groups and for hypertension and dysglycaemia/hypertension of women in the general population and men of Fulbe, Mbororo, and general population. We showed that WC, WHtR, and BRI perform better in predicting MetS in both women and men of all the groups. BAI estimates percentage adiposity directly and similar to the Singaporean study, our study showed that it may be a good predictor of cardiometabolic disorders but not better than BMI [35].

A study of the Inuit populations in Nunavik (Northern Quebec, Canada) using AUC analysis reported an acceptable capacity of BW, BMI, WC, and WHtR to predict hypertension in women and men similar to our study that showed a moderate acceptance in men of the Fulbe and Mbororo indigenous populations and women of the Mbororo indigenous populations [36]. The difference may be explained by the differences in socio-economic status, nutrition and epidemiologic transition and genetics between the indigenous Fulani populations of Africa and the Inuit populations in Canada.

Some studies have suggested WHtR [37,38], some prefer WC [39,40] and WHR [41], others all of them [42] some a combination [43,44] and another concluded that whether singly or in combination discriminating by sex [45], while some suggest no improvement in the prediction of cardiovascular disease risk [6]. For the diverse African populations, the various optimal WC cut off for the identification of cardiometabolic risk by sex have been proposed from ≥ 78 cm to ≥ 80 cm for men and ≥ 82 cm to ≥ 85 cm for women and 96.8 cm for both dysglycaemia and type 2 diabetes for men [46] and 91.8 cm for incident dysglycaemia and 95.8 cm for type 2 diabetes for women [47] and ≥ 81.2 cm for men and ≥ 81.0 cm for women [48]. WC often signify visceral adiposity is as important as the BMI if not more informative in individuals with elevated WC is associated with increased cardiometabolic risk in adults. Independent of sex and age, WC is associated with health outcomes within all BMI categories with the strength of the association between WC and morbidity and/or mortality after adjusting for BMI. When WC and BMI are used as continuous variables in risk prediction models, WC remains as a positive predictor of risk of death, but BMI is not or negatively related to the risk of death [49]. To overcome the limitations of the traditional obesity markers, ABSI combining the weight, height and WC and BRI using height and WC to estimate the percentage of regional and total fat have been developed [50-53]. Studies have shown that ABSI and BRI are associated with abdominal adipose tissue and cardiometabolic risk, onset of type 2 diabetes, premature mortality hazards than BMI and WC [28,29,54-55] and that BRI is even a better predictor of cardiometabolic risk in Southern-Indian adults and Eastern-China adults [30,56]. BRI and WHR have been shown to be a better predictor of CVD risk factors as well as WHtR and WC in assessing hypertension [57]. A meta-analysis reported that BRI and ABSI have a discriminatory power for hypertension with BRI significantly a better predictor of hypertension than ABSI [58].

Similar to a prospective cohort of White European in a UK Biobank study using 11 anthropometric markers, most of the markers were associated with type 2 diabetes differing in the strength of the associations and WHtR showing the strongest association [59]. A meta-analysis of 38 cross-sectional and 2 cohort studies reported slight differences in the AUC of anthropometric indices with indices of abdominal obesity especially WHR better at predicting CVD in adults aged 18 years and above [60]. Using WHO-STEPs survey data

anthropometric indices predicting CVD risk varied across countries, with ABSI, BAI, BRI, WHtR, and hip index showing better predictions in South Asians while ABSI, BRI, CI, WHtR, and WHR displayed enhanced predictions in Southeast Asians [61].

Upon stratification by sex, we observed variation in the correlation of the anthropometric measures, area under the ROC curve, MAORs and the strength of the association of anthropometric measures and MetS. Similar to our findings, Evans *et al.* reported that WC and WHtR performed well in identifying MetS in women [62]. The differences in BW, WC, and HC and the general body fat distribution in women and men may explain the relative performance of the anthropometric measures. Further, the BW, WC, WC, and height are direct measures used to calculate the BMI, WHR, WHtR, Cindex, BAI, BRI, and ABSI. While Cindex is similar to the WHR in being a health indicator, the Cindex formula adjusts for WC for height and BW not requiring HC for body fat distribution [63]. The use of HC in the BAI formula allowed for sex differences in adiposity to be considered when compared to BMI calculation that uses BW and height. BAI had good predictive power in the women of our study and Southern-Indian women and a lower predictive power in men [30]. This may be explained by the lower adiposity in men as compared to women. Sex hormones, sex-specific molecular mechanisms, and gender have been shown to influence pathophysiologic mechanisms through glucose and lipid metabolisms and function leading to cardiometabolic disorders affecting men and women differently [64]. Transition from nomadic to settled life by the indigenous Fulani and non-indigenous populations leads to the adoption of western diets and sedentary behaviours linked to metabolic disorders by the disrupted metabolism of xenobiotics that become toxic to tissues such as the pancreas, heart, kidney, brain and liver. Urbanisation, nutritional and environmental epigenetics may provide an explanation for the spike in the general chronic disease epidemic associated with insulin resistance such as cardiometabolic diseases, non-alcoholic fatty liver disease and neurodegenerative diseases due to the repression of the anti-aging gene Sirtuin 1 with increased risk for MetS [65,66]. The complex interplay between adiposity and cardiometabolic disorders maybe linked to Sirtuin 1 inactivation. The phenotypic differences between men and women in cardiometabolic disorders and the underlying risk factors, determinants and mechanistic processes needs to be elucidated.

Strengths and limitations of the study

Strengths of the study included a response rate of more than 90% for this quantitative population-based study. The study focused on an indigenous population as well as non-indigenous populations. Risks factors are analysed for participants of indigenous Fulani populations from the settled Fulani (Fulbe) and the nomadic pastoral Fulani (Mbororo) and compared with the general population. The study involved risk factor analysis centred on individuals as a preponderant

scale in probing epidemiological questions and adequately explaining who is at risk. The area under the ROC curve and multivariable adjusted logistic regression were used to assess the discriminatory capabilities. We standardised the estimates by the use of Z-scores which permitted us to compare the risk magnitude per 1 standard deviation (SD) change. Standardised WHO questionnaires and international guidelines were used for the definition of diabetes, hypertension, classes of overweight and obesity. The study provides baseline data on risk factors of indigenous populations. Trained enumerators conversant with the widely spoken local Fulfulde language administered the questionnaires. Anthropometric measurements such as body weight, height, WC and HC and calculations such as BMI are less likely to have measurement errors [67]. However, evidence suggests measurements in body weight, WC, and HC are prone to higher proportions of errors in obese populations [68] which was less likely in this study as the obesity levels were low. This is a cross-sectional study and limited to examining multiple scale causal mechanisms. Findings should be interpreted with caution and therefore does not allow for causal deductions. Potential bias includes selection bias which may lead to overestimation or underestimation of the true association and introduction of measurement errors which may affect the generalizability of the results. Accurate prediction of disease risk is difficult in specific population subtypes due to complexity of fundamental causes of diseases such as social, environmental drivers and genetic factors and interactions with environments and life course trajectories [69,70]. Some indices may perform better in some populations due to societal and cultural influence on body composition such as body image, traditional cuisine and food availability, social eating practices, physical activity levels, socioeconomic status and acculturation [71].

Conclusions

Anthropometric indices are important risk assessing tools for cardiometabolic disorders. The findings show variation in the discriminatory capabilities of anthropometric measures by ethnicity and sex and the importance of using other indicators apart from the BMI which has the advantage of being simple, easy and cost-effective in resource limited settings. The BW, WC, HC, WHtR, BAI, and BRI in addition to BMI are better in assessing MetS in indigenous as well as non-indigenous African populations. When stratified by sex, WC, and BRI is a better alternative for detecting risk from hypertension and dysglycaemia/hypertension in men of the indigenous Fulbe and Mbororo populations as well as in the women and men of the general population while the BW and BMI may be appropriate to predict dysglycaemia in women of the Fulbe and general populations. WHR, Cindex, and ABSI were the worse anthropometric measures in predicting dysglycaemia, hypertension and dysglycaemia/hypertension in women and men of all groups while ABSI was the worse in detecting MetS in the men all the groups. This study suggests that with transition from nomadic to settled life, indigenous Fulani are at greater risk for MetS than the general populations with women

at greater risk for MetS than men. Routine screening of MetS in indigenous populations may use WC, WHtR and BRI. This work is important for the understanding of the pathophysiology of cardiometabolic disorders in African populations, as well as to guide future intervention studies and for public health messaging. With rising overweight and obesity rates, further research such as longitudinal studies to assess the impact of lifestyle changes and genetic studies are needed to develop specific and culturally sensitive interventions in indigenous Fulani as well as non-indigenous populations to understand the complex interplay between adiposity and cardiometabolic disorders.

Competing Interest

The authors have no competing interest to declare.

Authors' Contributions

JCM and CNK reviewed the article. CNK designed the analytic strategy, analysed the data and wrote the first and subsequent drafts. All authors contributed to the design, data collection and subsequent drafts which were read, reviewed and approved.

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Data Availability

Clement Nyuyki Kufe had full access to all the data of the quantitative study, wrote and submitted the article for publication. The data is available upon reasonable time request from Dr Clement Nyuyki Kufe.

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