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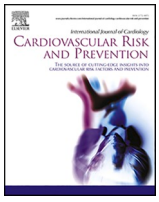

Prevalence and correlates of metabolic syndrome among adults in freetown, Sierra Leone: A comparative analysis of NCEP ATP III, IDF and harmonized ATP III criteria

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ABSTRACT

Background: Metabolic syndrome (MetS) is a global health concern, especially for low and middle-income countries with limited resources and information. The study's objective was to assess the prevalence of MetS in Freetown, Sierra Leone, using the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III), International Diabetes Federation (IDF) and Harmonize ATP III. Additionally, we aimed to establish the concordance between these three different criteria used.

Methods: This community-based health screening survey was conducted from October 2019 to October 2022. A multistage stratified random design was used to select adults aged 20 years and above. Mean, interquartile range (IQR), and logistic regression were used for statistical analysis. The kappa coefficient statistics resolved the agreement between these defined criteria.

Results: The prevalence for NCEP ATP III, Harmonize ATP III and IDF criteria was 11.8 % (95 % CI: 9.0–15.15), 14.3 % (95 % CI: 11.3–18.0), and 8.5 % (95 % CI: 6.2–11.2), respectively for the 2394 selected adults. The kappa coefficient (κ) agreement between the MetS is: Harmonized ATP III and IDF criteria = [(208 (60.8 %); (κ = 0.62)]; Harmonized ATP III and NCEP ATP III = [(201 (58.7 %); (κ = 0.71)]; while IDF and NCEP ATP III was [(132 (38.6 %); (κ = 0.52)]. In the multivariable regression analysis, waist circumference correlated with all three MetS criteria: ATP III [AOR = 0.85; C.I 95 %: (0.40–1.78), p = 0.032], Harmonized ATP III [AOR = 1.14; C. I 95 %: (0.62–2.11), p = 0.024], IDF [AOR = 1.06; C.I 95 % (0.52–2.16), p = 0.018]

Conclusion: We reported a high prevalence of MetS in Freetown, Sierra Leone and identified waist circumference as a major risk factor for MetS. This underscores the crucial role of health education and effective management of MetS in Sierra Leone.

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1. Introduction

Metabolic syndrome (MetS) is a group of closely related risk factors associated with an increased risk of cardiovascular diseases and type 2 diabetes [1–3]. Studies have shown that people with MetS are three times more likely to suffer a stroke or heart attack than those without MetS [4,5]. The risk factors associated with MetS include elevated blood pressure, high triglycerides, low high-density lipoprotein cholesterol (HDL-C), high fasting glucose, and central obesity [6]. Early detection and appropriate treatment of MetS are crucial to preventing serious health conditions, as they are essential for optimal health outcomes. Therefore, it is important to prioritize these measures to prevent potential health risks [7]. Leading public health experts and professional organizations have validated different diagnostic criteria for MetS [8–13]. Each criterion has recommended cut-off values that are distinct and essential for diagnosing MetS. To combine the various criteria of these organizations, Alberti et al. proposed the Harmonized National Cholesterol Education Program (NCEP) Adult Treatment Panel (ATP) III criteria [14]. Nevertheless, the accuracy of MetS criteria in predicting cardiovascular diseases is still controversial. Koutsovasilis et al. suggested that the International Diabetes Federation (IDF) criterion better predicts acute coronary syndrome in NCEP ATP III than Harmonized ATP III, but in a similar study, Nilsson did not find evidence supporting IDF's superiority [15,16]. Further research is therefore needed to understand this issue.

In several Sub-Saharan African (SSA) countries, the prevalence of non-communicable diseases (NCDs) has increased because of the shift from communicable diseases. This change can be attributed to increased urbanization and changing lifestyles in many low- and middle-income countries [17]. Hence, it can be inferred that metabolic syndrome is common, given the high prevalence of cardiovascular diseases and diabetes in SSA [1]. However, there is a lack of information on MetS in the SSA region, as most research on MetS is conducted in North America, Europe, and Asia [18,19]. Notwithstanding, most data on MetS in SSA emanate from small clinical studies, with a limited number of documented reports on epidemiological studies [20].

The lack of epidemiological data on MetS in Sierra Leone must be addressed urgently to determine the appropriate interventions required to mitigate its effects on the population. Our study aimed to determine the prevalence of MetS among adult Sierra Leoneans by using three different definitions: the ATP III, IDF, and Harmonized ATP III Criteria. Furthermore, we sought to evaluate the level of agreement between the three diagnostic criteria for metabolic syndrome.

2. Methods

2.1. Study area, study design, and sampling technique

This population-based cross-sectional survey was conducted between October 2019 and October 2021 among adult residents of Western Area Urban in Freetown, Sierra Leone. Freetown is a cosmopolitan city and the primary commercial centre of Sierra Leone, with a population of approximately 1.5 million individuals [21]. This community health screening and awareness survey for non-communicable diseases was funded by Ecobank Sierra Leone Limited. The study was designed to provide a representative sample of Sierra Leone's adult population in an urban settlement. A stratified random sampling technique was used to recruit adults aged 20 years and above, from eight electoral constituencies in Western Area Urban-Freetown [21,22]. The sample size was calculated based on the clinical estimated prevalence of 22 % for hypertension in Sierra Leone using the Leslie Kish formula [23,24]. The WHO stepwise approach guided the data collection process for this study. Medical students, doctors, and nurses received training on conducting the campaign and collecting data.

Table 1
Diagnostic criteria and cutoff points of metabolic syndrome according to various organizations.

Parameter/criteria	Harmonized criteria −2009	IDF-2005	NCEP ATP III-2001
Prerequisites for diagnosing MetS	Any three of the following	Abdominal obesity along with any other two	Any three of the following
Waist Circumference (cm)			
Men	≥90 cm	≥90 cm	≥102 cm
Woman	≥80 cm	≥80 cm	≥88 cm
HDL-C			
Men <40	<1.03 mmol/L	<1.03 mmol/L	<1.03 mmol/L
Woman <50	<1.30 mmol/L	<1.30 mmol/L	<1.30 mmol/L
Blood pressure (mmHg)	130/85 mmHg	130/85 mmHg	130/85 mmHg
Fasting Triglyceride	5.6 mmoL/l ≥1.70 mmol/L (150 mg/dL)	5.6 mmoL/l ≥1.70 mmol/L (150 mg/dL)	6.1 mmoL/l ≥1.70 mmol/L (150 mg/dL)

2.2. Socio-demographic, behavioural and clinical characteristics, and anthropometric and blood pressure measurements

Socio-demographic information such as age, sex, gender, educational level, religion, marital status, smoking status, and alcohol consumption was collected. We also collected information on the medical history (including a family history of hypertension and diabetes mellitus), fruit and vegetable consumption, and physical activity. Blood pressure was measured using an OMRON M3 sphygmomanometer with an appropriate cuff size while the participant was seated. After resting for 3–5 min, two readings were taken, and the average was considered. Body weight, height, and waist circumference were also measured with light clothing and no shoes.

2.3. Inclusion and exclusion criteria

The individuals included in the study were adults aged 20 years or older who had lived in the city for a minimum of twelve months. Pregnant and lactating mothers, participants with mental illness/dementia and persons unwilling to grant consent were excluded from the study.

2.4. Clinical biochemistry measurements

Blood samples were collected from participants after an overnight fast of 8–10 h. The Beckman Coulter AU480 Chemistry System analyzed glucose, total cholesterol, triglycerides, high-density lipoprotein, and low-density lipoprotein.

2.5. Definition of metabolic syndrome

We used the Harmonized criteria-2009, IDF-2005, and NCEP-ATP III-2001 criteria to determine the prevalence of MetS as reported in Table 1.

2.6. Ethical approval and registration

The Sierra Leone Ethics and Scientific Review Committee approved the research protocol, questionnaire, and consent form. The study protocol was registered with the Research Registry and assigned the unique identification number researchregistry8201 [https://www.researchregistry.com/browse-the-registry#home/. The credibility and reliability of our methods and findings strictly adhered to the guidelines outlined in the STROBE statement [25].

2.7. Statistical analyses

IBM SPSS Statistical 2.6 and STATA 17 software were used to analyze

Table 2
Demographic, anthropometric and biochemical variables of study population.

Characteristics	Total (2394)	Male (1250)	Female (1144)	p-value
	Median (IQR)	Median (IQR)	Median (IQR)	
Age	41.6 (34–49)	39 (33–48)	42 (34–49)	**0.043**
Weight	70.4 (61.8–85.4)	69.9 (61.6–85.1)	70.5 (61.7–85.0)	0.634
Height	1.73 (1.70–1.77)	1.74 (1.70–1.77)	1.73 (1.70–1.77)	**0.012**
BMI	23.7 (21.1–27.8)	23.6 (20.9–27.6)	23.8 (20.9–27.7)	0.107
WC	89.0 (78.7–92.7)	92.6 (89.8–96.7)	78.8 (75.9–82.7)	**<0.001**
SBP	126 (107–148)	127 (106–146)	125 (106–147)	0.178
DBP	85 (77–94)	86 (78–94)	85 (75–94)	0.126
Triglyceride	1.53 (1.45–1.63)	1.53 (1.45–1.62)	1.54 (1.45–1.65)	0.447
Total Cholesterol	4.79 (4.67–5.00)	4.65 (4.67–4.89)	4.91 (4.66–5.90)	**<0.001**
Low HDL-C	1.34 (1.26–1.41)	1.34 (1.26–1.41)	1.34 (1.25–1.41)	0.532
LDL-C	2.97 (2.56–3.20)	2.99 (2.54–3.21)	2.95 (2.51–3.17)	0.118
FBS	4.70 (4.10–5.40)	4.80 (4.10–5.40)	4.70 (4.10–5.40)	0.249
HBA1C	5.10 (4.60–5.60)	5.10 (4.60–5.60)	5.10 (4.8–5.6)	0.481

the dataset of this study. All baseline characteristics of metabolic syndrome were examined. Median and IQR were used as necessary. Univariate and multivariable logistic regression was conducted to explore the relationship between demographic characteristics and cardiovascular risk factors. We included several independent variables such as age, BMI, waist circumference, fruit and vegetable intake, blood pressure, alcohol consumption, smoking status, diabetes mellitus, total cholesterol, HDL-C, LDL-C, triglycerides, and physical activity levels. A two-tailed p-value of ≤ 0.05 was considered statistically significant. The Kappa statistic was used to evaluate the level of agreement among three criteria. NCEP ATP III, Harmonized ATP III, and IDF criteria were used to calculate the prevalence of each component of MetS.

3. Results

3.1. Basic characteristics of the study

Of the 2394 participants recruited for this study, 1250 (52.2 %) were male. The median age of the participants was 41.6 years [IQR:34–49] years. Age, height, waist circumference, and total cholesterol levels showed statistical differences, as shown in Table 2.

3.2. Prevalence of metabolic syndrome

The MetS prevalence rates for NCEP ATP III, Harmonized ATP III criteria and IDF criteria were 11.8 % [95 % CI: (9.0–15.2)], 14.3 % [95 % CI: (11.3–18.0)], and 8.5 % [95 % CI: (6.2–11.2)], respectively (Table 3). Using the NCEP ATP III, Harmonized ATP III, and IDF criteria, the prevalence of MetS for men was 6.3 % (95 % CI: 4.6–8.9), 7.6 % (95 % CI: 5.5–10.2), and 4.6 % (95 % CI: 3.2–7.9), respectively. For women, the prevalence rates were 5.3 % (95 % CI: 3.9–21.1), 6.8 % (95 % CI: 4.7–9.4), and 3.8 % (95 % CI: 2.4–5.8), respectively. The highest prevalence of MetS for men according to NCEP ATP III [2.4 % (95 % CI: 1.9–3.1)], Harmonized ATP III [2.9 % (95 % CI: 2.3–3.1)], and IDF criteria [1.8 % (95 % CI: 1.4–2.4)] were documented in the age group 30–39 years. Unlike women, the highest prevalence for NCEP ATP III [1.5 % (95 % CI: 1.1–2.1)], Harmonized ATP III [1.8 % (95 % CI: 1.3–2.4)], and IDF criteria [1.0 % (95 % CI: 0.7–1.5) were recorded in a much older age group 40–49 years. The prevalence of Metabolic Syndrome among diabetic and hypertensive individuals is also represented in Table 3.

3.3. Agreement among NCEP ATP III, harmonized ATP III, and IDF criteria

The distribution for most MetS criteria by sex and age group is similar, except for waist circumference criteria (Fig. 1). The Venn diagram showed that only 8.6 % of all the MetS participants had all three defined MetS criteria. (Fig. 2). Agreement between Harmonized ATP III and IDF criteria was 60.8 % (208) with kappa statistics of 0.62, while the agreement between Harmonized ATP III and NCEP ATP III was 58.7 % (201) with kappa statistics of 0.71. The agreement of MetS by IDF and NCEP ATP III was 38.6 % (132), with a kappa statistic of 0.52. The agreement level varied among the criteria used to assess cardiovascular risk factors. The highest agreement was found between Harmonized ATP III and NCEP ATP III, with a kappa statistic of 0.71. However, the lowest agreement was observed between NCEP ATP III and IDF criteria, with a kappa statistic of 0.52 (Table 4).

Table 3
Prevalence of metabolic syndrome among study population.

Characteristics	ATP III			Harmonized ATP III			IDF		
	Men (n = 153)	Women (n = 129)	Total (N = 282)	Men (n = 180)	Women (n = 162)	Total (N = 342)	Men (n = 111)	Women (n = 90)	Total (N = 201)
	% (95%CI)	% (95%CI)	% (95%CI)	% (95%CI)	% (95%CI)	% (95%CI)	% (95%CI)	% (95%CI)	% (95%CI)
Overall (year)	6.3 (4.6–8.9)	5.3 (3.9–7.9)	11.8 (9.0–15.1)	7.6 (5.5–10.2)	6.8 (4.7–9.4)	14.3 (11.3–18.0)	4.6 (3.2–6.7)	3.8 (2.4–5.8)	8.5 (6.2–11.2)
Age group (year)									
20–29	1.4 (1.0–2.0)	0.8 (0.5–1.3)	2.3 (1.7–2.9)	1.2 (0.8–1.7)	1.2 (0.8–1.7)	2.4 (1.8–3.1)	0.7 (0.4–1.1)	0.8 (0.5–1.2)	1.5 (1.0–2.0)
30–39	2.4 (1.9–3.1)	1.4 (1.0–2.0)	3.8 (3.1–4.7)	2.9 (2.3–3.6)	1.6 (1.1–2.1)	4.5 (3.7–5.4)	1.8 (1.4–2.4)	0.7 (0.4–1.1)	2.5 (2.0–3.2)
40–49	1.4 (1.0–2.0)	1.5 (1.1–2.1)	3.0 (2.3–3.7)	2.0 (1.5–2.6)	1.8 (1.3–2.4)	3.8 (3.1–4.6)	1.3 (0.9–1.8)	1.0 (0.7–1.5)	2.3 (1.7–2.9)
50–59	0.8 (0.5–1.2)	1.0 (0.7–1.5)	1.8 (1.3–2.4)	0.8 (0.5–1.2)	1.5 (1.1–2.1)	2.3 (1.8–3.0)	0.5 (0.3–0.8)	0.9 (0.6–1.3)	1.4 (1.0–1.9)
>60	0.3 (0.2–0.6)	0.6 (0.3–1.0)	0.9 (0.6–1.4)	0.7 (0.4–1.1)	0.7 (0.4–1.1)	1.3 (0.9–1.9)	0.3 (0.2–0.6)	0.4 (0.2–0.7)	0.8 (0.5–1.2)
Diabetes Mellitus									
YES	5.9 (5.0–6.9)	4.9 (4.1–5.9)	10.8 (9.6–12.1)	6.8 (5.9–7.9)	6.2 (5.3–7.2)	13.0 (11.7–14.4)	4.2 (3.5–5.1)	3.4 (2.7–4.2)	7.6 (6.6–8.6)
NO	0.5 (0.3–0.9)	0.5 (0.2–0.8)	1.0 (0.7–1.5)	0.7 (0.4–1.1)	0.6 (0.3–1.0)	1.3 (0.9–1.8)	0.4 (0.2–0.7)	0.4 (0.2–0.7)	0.8 (0.5–1.2)
Hypertension									
YES	4.0 (3.2–4.8)	3.1 (2.5–3.9)	7.1 (6.1–8.2)	4.2 (3.5–5.1)	3.9 (3.2–4.8)	8.1 (7.1–9.3)	2.5 (1.9–3.2)	2.3 (1.7–2.9)	4.8 (4.0–5.7)
NO	2.4 (1.9–3.1)	2.3 (1.7–2.9)	4.7 (3.9–5.6)	3.3 (2.6–4.1)	2.8 (2.2–3.6)	6.1 (5.2–7.2)	2.1 (1.6–2.8)	1.5 (1.1–2.1)	3.6 (2.9–4.4)

CI: 95 % confidence interval.

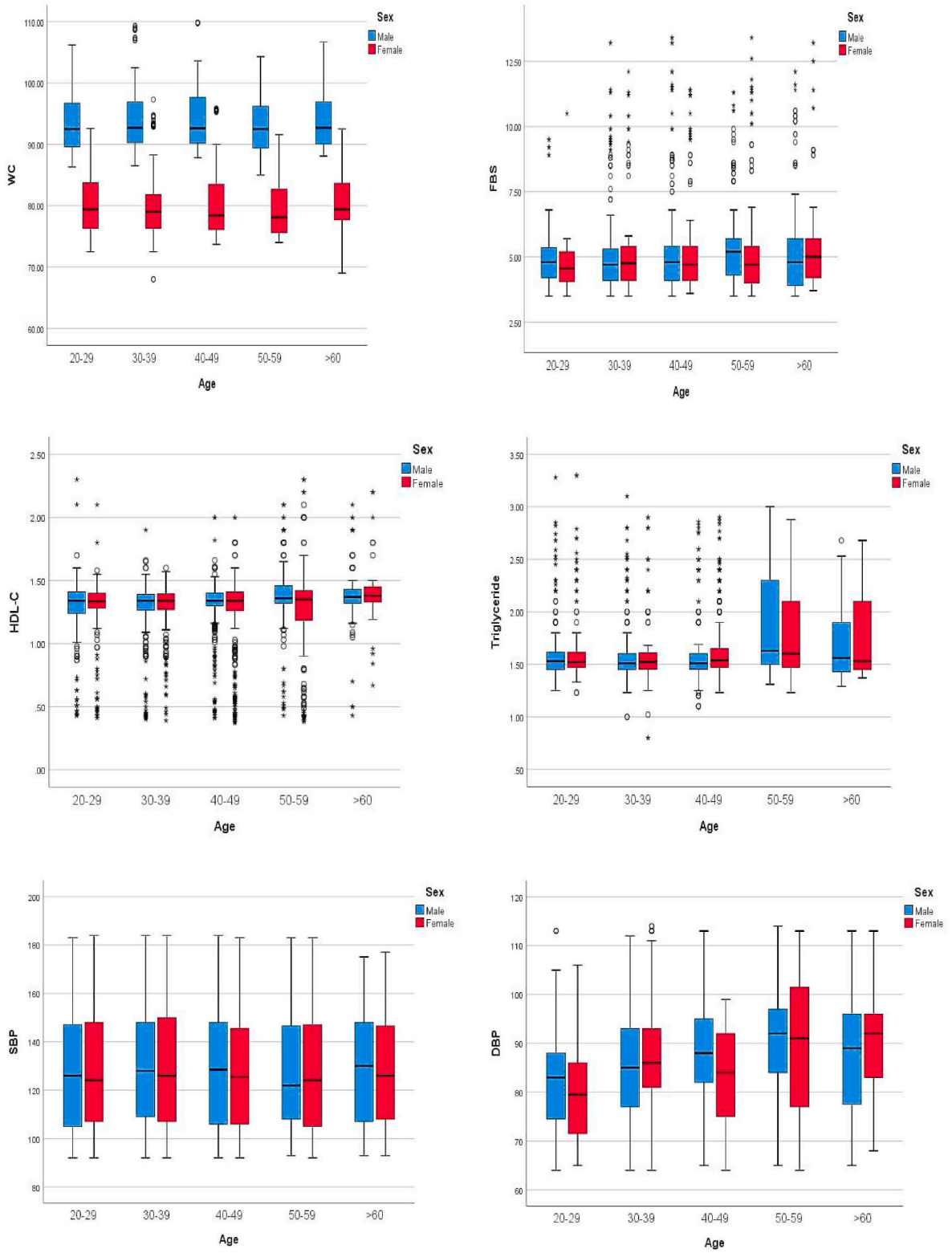

Fig. 1. Boxplot showing comparative analysis of the different risk factors of MetS by age and sex.
Male (blue) and Female (red). Horizontal black lines denote median values; boxes extend from the 25th to the 75th percentile of each group's distribution of values; vertical extending lines denote adjacent values (i.e., the most extreme values within 1.5 interquartile range of the 25th and 75th percentile of each group); dots denote observations outside the range of adjacent values. WC: Waist Circumference, FBS: Fasting Blood Sugar, HDL-C: High- Density Lipoprotein-C, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure. All data age-standardized to the WHO 2000–2025 standard population. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

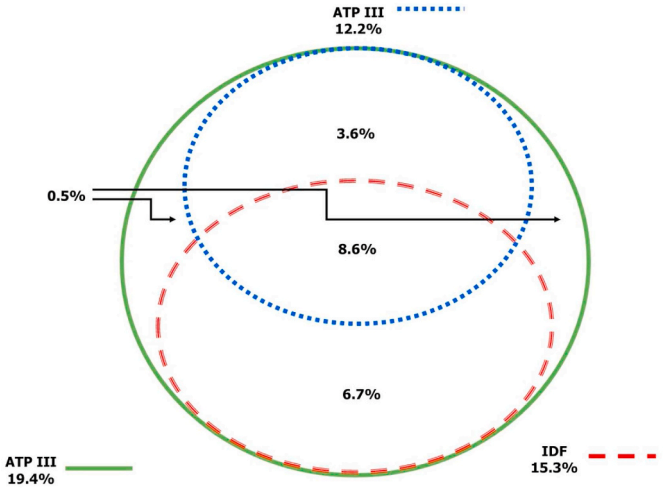

Fig. 2. Overall crude prevalence of MetS according to ATP III, IDF and Harmonized ATP III criteria.

Table 4
Agreement among the different criteria in diagnosis of metabolic syndrome.

Harmonized criteria					
		MetS +	MetS-	Total	Kappa (95 % CI)
IDF	MetS+	208	74	282	0.62 (0.59–0.64)
	MetS-	134	1978	2112	
	Total	342	2051	2394	
Harmonized criteria					
ATP III	Met +	201	0	201	0.71 (0.69–0.73)
	Met -	141	2052	2193	
	Total	342	2052	2394	
NCEP ATP III					
IDF	Met +	132	0	132	0.52 (0.50–0.54)
	Met -	210	2052	2262	
	Total	342	2052	2394	

3.4. Logistic regression model among NCEP ATP III, harmonized ATP III, and IDF criteria

We included several independent variables such as age, BMI, waist circumference, fruit and vegetable intake, blood pressure, alcohol consumption, smoking status, diabetes mellitus, total cholesterol, HDL-C, LDL-C, triglycerides, and physical activity levels in the stepwise logistic regression model to analyze the various MetS criteria (Table 4) (see Table 5).

WC as a risk factor correlated with all the MetS criteria: NCEP ATP III, Harmonized ATP III, and IDF. In the NCEP ATP III model, the crude odds ratio was 1.07 with a 95 % confidence interval of (0.76–1.5) and a p-value of 0.04. After adjusting for relevant factors, the adjusted odds ratio was 0.85 [95 % CI (0.40–1.78)], with a p = 0.036. Similarly, the Harmonized ATP III model's crude odds ratio was 1.05 [95 % CI (0.79–1.39)] and a p-value of 0.045. The adjusted odds ratio was 1.14 [95 % CI (0.62–2.11)] and a p-value of 0.02. In the IDF criteria, the crude odds ratio was 1.20 [95 % CI (0.86–1.65)] and a p-value of 0.026, while the adjusted odds ratio was 1.06 [95 % CI (0.52–2.16)] and a p-value of 0.018.

Stage 1 Hypertension is associated with both NCEP ATP III and IDF. For NCEP ATP III, the Crude OR is 0.55 [95 % C.I (0.35–0.86)] with a p-value of 0.01, while the adjusted OR is 0.58 [95 % C.I (0.36–0.93)] and a p-value of 0.04. The crude odds ratio in the IDF is 0.6, with a [95 % C.I (0.37–1.01)] and a p-value of 0.44. However, after adjustments, the odds ratio is 0.54 [95 % C.I (0.32–0.91)] and a p-value of 0.02. Smoking is a risk factor that was found to be associated with NCEP ATP III and IDF. The data showed that for NCEP ATP III, the crude odds ratio is 1.04 [95 % C.I (0.54–2.03)] and a p-value of 0.01, while the adjusted odds ratio was 1.03 [95 % C.I (0.52–2.03)] and a p-value of 0.01. For IDF, the crude odds ratio was 0.63 [95 % C.I (0.39–1.03)] and a p-value of 0.04, while the adjusted odds ratio is 0.60 [95 % C.I (0.37–0.10)] and a p-value of 0.05.

Several variables, including age, fruit and alcohol consumption, diabetes mellitus, total cholesterol, HDL–C, LDL–C, triglyceride levels, and daily physical activities, did not demonstrate an independent association with MetS when other covariates were considered.

4. Discussion

This community-based health screening survey for NCD has provided additional data on MetS in SSA. It is the first survey to document the prevalence of MetS in Sierra Leone based on three different criteria (NCEP ATP III, Harmonized ATP III, and IDF) and the second-largest dataset on MetS in the West African subregion, following Nwamko et al. [26]. Our study, unlike the design of Nwamko et al. was conducted as a community health screening survey to accurately represent the true magnitude of metabolic syndrome. In contrast, Nwamko et al. conducted their study in a general outpatient department within a hospital setting. The findings of our study are, therefore, based on a broader and more diverse range of participants captured in a real-world setting, as opposed to a more controlled hospital environment. The current study found that the prevalence of MetS varied according to the diagnostic criteria used.

In recent years, metabolic syndrome has become a common disorder worldwide, with different African regions experiencing varying prevalence rates [20]. Factors such as urbanization, industrialization, an ageing population, sampling methods, lifestyle choices, genetic variations and criteria used to define MetS are believed to contribute to this trend [17]. The prevalence rate for each MetS criterion in our study population was 11.8 % for NCEP ATP III, 14.3 % for Harmonized ATP III criteria and 8.5 % for IDF criteria. Using the NCEP ATP III criterion, the prevalence of MetS is lower than studies reported in Khartoum, Sudan (19.8 %), Assin Fosu, Ghana (37.1 %), Ogbomoso, Nigeria (33.0 %), Ilara-Akaka, Nigeria (21.1 %), Dakar, Senegal (15.7 %), and Cape Town, South Africa (55.4 %), but relatively higher than reported studies from Brazzaville, Congo (8.7 %), Abuja, Nigeria (8.8 %) and Mizan-Aman, Ethiopia (9.6 %) [27–35].

However, our study found that the prevalence of Harmonized ATP III was comparable to the reported 15.1 % from China but lower than the rates of 23.6 % in Nigeria and 40.7 % in Ethiopia [36–38]. Using IDF, the prevalence of MetS was similar to the reported rates in Cotonou, Benin (7.4 %) and Bondo District, Kenya (8.5 %), but lower than rates found in Ghana, South Africa, and Nigeria [39–43]. Recent data from a systematic review and meta-analysis on the prevalence of MetS in SSA according to the different diagnostic criteria are consistent with some of our findings [20]. The inconsistencies in our research findings when compared with other studies are multifactorial and this could be attributed to variations in respondents' characteristics, diverse criteria for MetS, differences in sample sizes and sampling techniques. The variation in these factors can impact the study's outcome, making it difficult to draw definitive conclusions. Therefore, it is essential to ensure that research studies are designed carefully to minimize the potential for inconsistencies in MetS findings. Our study demonstrated that metabolic syndrome is a major public health challenge in Sierra Leone. Like other African countries, Metabolic syndrome is becoming more common and should be given sufficient attention.

According to our study, males had a greater risk of developing MetS than females. Using all the three defined criteria, the prevalence of MetS is higher in men than women, and this is comparable to studies reported in Abuja, Nigeria; Brazzaville, Congo; Nairobi, Kenya; South-west province, Ethiopia; [44–47]. Nevertheless, preventing and effectively managing cardiovascular diseases related to Metabolic Syndrome (MetS) should be of utmost importance regardless of gender. Making this

Table 5
Logistic regression analysis of independent variables for metabolic syndrome.

Variables	ATP III				Harmonized ATP III				IDF			
	Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis	
	COR (95 % CI)	p-value	AOR (95% CI)	p-value	COR (95 % CI)	p-value	AOR (95% CI)	p-value	COR (95 % CI)	p-value	AOR (95% CI)	p-value
Age, by group												
20–29	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
30-39	0.88 (0.49–1.60)	0.671	0.89 (0.46–1.72)	0.733	0.79 (0.49–1.26)	0.326	0.79 (0.47–1.33)	0.382	1.14 (0.67–1.92)	0.631	1.35 (0.75–2.44)	0.313
40–49	0.98 (0.57–1.703)	0.952	0.92 (0.51–1.67)	0.784	0.97 (0.63–1.48)	0.871	0.89 (0.56–1.44)	0.653	1.25 (0.76–2.04)	0.383	1.38 (0.80–2.39)	0.254
50–59	0.89 (0.51–0.55)	0.673	0.79 (0.43–1.45)	0.454	0.83 (0.53–1.28)	0.392	0.75 (0.47–1.21)	0.235	0.96 (0.58–1.59)	0.874	1.17 (0.66–2.06)	0.884
>60	1.06 (0.58–1.93)	0.865	0.97 (0.53–1.81)	0.936	0.98 (0.61–1.58)	0.941	0.93 (0.57–1.52)	0.777	1.14 (0.66–1.96)	0.661	1.169 (0.66 2.06)	0.591
BMI												
Underweight	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Normal	0.81 (0.23–2.84)	0.741	0.77 (0.22–2.8)	0.693	0.64 (0.24–1.73)	0.383	0.62 (0.22–1.71)	0.353	1.02 (0.37–2.81)	0.975	0.86 (0.30–2.45)	0.782
Overweight	0.86 (0.54–1.38)	0.542	0.84 (0.52–1.36)	0.473	0.65 (0.46–1.93)	**0.024**	0.65 (0.45–0.95)	**0.012**	0.91 (0.61–1.37)	0.666	0.93 (0.60–1.44)	0.767
Obese	0.80 (0.48–1.31)	0.413	0.76 (0.44–1.32)	0.325	0.72 (0.49–1.06)	0.095	0.67 (0.44–1.03)	0.075	0.82 (0.51–1.29)	0.383	0.79 (0.48–1.30)	0.355
WC												
Normal	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Abnormal	1.07 (0.76–1.53)	**0.042**	0.85 (0.40–1.78)	**0.032**	1.05 (0.79–1.39)	**0.043**	1.14 (0.62–2.11)	**0.024**	1.20 (0.86–1.65)	**0.026**	1.06 (0.52–2.16)	**0.018**
Blood pressure												
Normal	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Pre-HTN	0.69 (0.41–1.14)	0.152	0.67 (0.39–1.15)	0.153	0.64 (0.4–0.96)	0.031	0.64 (0.42–0.98)	0.043	0.78 (0.50–1.21)	0.272	0.64 (0.40–1.03)	0.074
HTN stage 1	0.66 (0.37–1.16)	0.153	0.67 (0.37–1.22)	0.192	0.55 (0.35–0.86)	**0.010**	0.58 (0.36–0.93)	**0.020**	0.61 (0.37–1.01)	**0.042**	0.54 (0.32–0.91)	**0.023**
HTN stage 2	0.97 (0.59–1.64)	0.928	0.95 (0.56, 1.64)	0.860	0.87 (0.57–1.31)	0.502	0.86 (0.56–1.31)	0.482	0.87 (0.55–1.38)	0.565	0.79 (0.49–1.27)	0.327
Fruits/Vegetables												
<3 serving	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
>3 serving	1.22 (0.71–2.11)	0.476	1.32 (0.75–2.32)	0.343	1.06 (0.70–1.59)	0.793	1.07 (0.70–1.63)	0.762	1.17 (0.74–1.85)	0.514	1.24 (0.77–2.00)	0.378
Alcohol												
Never	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Current previous	1.09 (0.67–1.79)	0.723	0.99 (0.59–1.66)	0.981	0.96 (0.66–1.39)	0.813	0.91 (0.62, 1.34)	0.631	1.05 (0.69–1.60)	0.812	0.97 (0.63, 1.50)	0.905
Previous	1.09 (0.64–1.85)	0.763	0.90 (0.51–1.59)	0.713	0.94 (0.63–1.42)	0.771	0.79 (0.50–1.23)	0.293	1.05 (0.67–1.65)	0.845	0.86 (0.52–1.12)	0.549

Variables	ATP III				Harmonized ATP III				IDF			
	Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis	
	COR (95 % CI)	p-value	AOR (95%CI)	p-value	COR (95 % CI)	p-value	AOR (95%CI)	p-value	COR (95 % CI)	p-value	AOR (95%CI)	p-value
Smoking												
Never	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Current	1.04 (0.54–2.03)	**0.017**	1.03 (0.52–2.03)	**0.013**	0.98 (0.59–1.64)	0.943	0.97 (0.57–1.64)	0.921	0.63 (0.39–1.03)	**0.032**	0.60 (0.37–0.10)	**0.021**
Ex smoker	0.99 (0.44–2.27)	0.994	1.05 (0.45–2.44)	0.920	0.88 (0.46–1.69)	0.701	0.97 (0.50–1.89)	0.923	0.61 (0.32–1.16)	0.132	0.57 (0.29–1.12)	0.133
Diabetes												
Normal	Ref		Ref.		Ref.		Ref.		Ref.		Ref.	
pre-diabetes	0.85 (0.52–1.40)	0.532	0.86 (0.52–1.44)	0.511	0.92 (0.61–1.39)	0.697	0.96 (0.63–1.46)	0.847	0.96 (0.61–1.50)	0.855	0.93 (0.59–1.48)	0.774
Diabetes	1.019 (0.46–2.28)	0.963	1.065 (0.47–2.42)	0.886	1.19 (0.63–2.26)	0.595	1.24 (0.64–2.36)	0.524	1.34 (0.68–2.65)	0.403	1.37 (0.68–2.74)	0.382
Total Cholesterol												
Normal	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
High	1.17 (0.70–1.96)	0.594	1.22 (0.60–2.42)	0.584	1.04 (0.70–1.54)	0.844	0.93 (0.54–1.61)	0.803	1.54 (0.95–2.51)	0.083	1.31 (0.69–2.51)	0.421
LDL-C												
Normal	Ref		Ref.		Ref.		Ref.		Ref		Ref.	
High	1.08 (0.70, 1.67)	0.738	1.17 (0.54–1.72)	0.682	0.95 (0.68–1.33)	0.771	0.83 (0.47–1.49)	0.556	1.01 (0.70–1.46)	0.952	0.84 (0.42–.65)	0.613
HDL-C												
Normal	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	

(*continued on next page*)

Table 5 (*continued*)

Variables	ATP III				Harmonized ATP III				IDF			
	Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis	
	COR (95 % CI)	p-value	AOR (95%CI)	p-value	COR (95 % CI)	p-value	AOR (95%CI)	p-value	COR (95 % CI)	p-value	AOR (95%CI)	p-value
High	1.07 (0.67–1.70)	0.774	0.96 (0.54)	0.903	1.07 (0.74–1.55)	0.736	0.99 (0.63–1.59)	0.997	1.83 (1.12–2.96)	0.023	1.84 (1.04–3.25)	0.042
Triglyceride												
Normal	Ref		Ref.		Ref.		Ref.		Ref.		Ref.	
High	1.12 (0.78–1.61)	0.532	1.22 (0.74–2.01)	0.462	1.10 (0.83–1.46)	0.506	1.20 (0.80–1.78)	0.385	1.23 (0.90–1.68)	0.202	0.93 (0.60–1.46)	0.761
Daily physical activity												
Low	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Moderate	0.92 (0.62–1.37)	0.686	0.86 (0.57–1.30)	0.492	1.00 (0.73–1.37)	0.105	0.93 (0.68–1.29)	0.684	0.92 (0.65–1.29)	0.625	0.83 (0.58–1.18)	0.293
Vigorous	1.17 (0.80–1.72)	0.437	1.12 (0.76–1.65)	0.581	1.06 (0.78–1.44)	0.714	1.03 (0.75–1.40)	0.889	1.04 (0.74–1.45)	0.817	0.99 (0.70–1.39)	0.943

a top priority in any healthcare strategy is crucial for optimizing patient outcomes.

We investigated the prevalence of MetS by age group and found that the highest prevalence was observed in the third decade for both males and females for all three defined criteria. The high prevalence rate of MetS in the third decade is due to the youthful cohort of our study, as almost half of our population is under 40 years. Ageing as an independent cardiovascular risk is associated with the evolution of insulin resistance and accumulation of visceral adipose tissue, which is important in the pathogenesis of MetS [48,49]. Our analysis to identify the prevalence of MetS amongst diabetic individuals indicated a lower prevalence than studies reported from Africa [50,51]. Whereas most African research on MetS and diabetics are often hospital-based studies, our findings reflect a community-based screening in metabolic syndrome, which may account for the lower prevalence. Since hypertension is a significant component of MetS and a widely recognized risk factor for cardiovascular disease, we evaluated the prevalence of MetS among individuals with hypertension. Consistent with other research conducted in Africa, our findings suggest that hypertension contributes to the exacerbation of MetS [52–54].

The threshold for WC among Black Africans is still controversial as there is no robust research related to a validated cut-off. However, most African studies use thresholds of 102 cm for men and 88 cm for women to define abdominal obesity among African indigenes [19,54]. Due to urbanization and lifestyle changes, many African countries are experiencing increased abdominal obesity. In our studies, the waist circumference distribution by sex and group was significantly different when adjusted for age, with men having a higher WC distribution. The high cut-off for men may explain the disparity in WC distribution by sex and age group in our study, which is consistent with other African studies [5,13,17,30]. The IDF and Harmonized ATP III criteria use lower cut-off values than the NCEP ATP III criteria and may lead to the inclusion of individuals with lower levels of these risk factors. The mandatory use of a low cut-off of WC (male >90 cm, females >80 cm) and any other risk factors for IDF definition may account for the low prevalence of MetS in our study. Therefore, some individuals with MetS may not be identified using the IDF criteria. On the other hand, the Harmonized ATP III definition is non-discriminatory and requires a minimum of any three risk factors for its diagnosis. As a result, the probability of having more individuals being diagnosed with MeS is high. This may be the reason for the high prevalence of MetS in the Harmonized ATP III definition in our study.

Our study showed that Harmonized ATP III and IDF criteria gave better agreement, while the agreement between NCEP ATP III and IDF was good. However, the agreement between Harmonized ATP III and NCEP ATP III criteria was the best. The significant overlap among the MetS criteria in our study is not unexpected, as other studies have also reported similar findings in Nigeria, Brazil, India and Mongolia [26,55–57]. Even though MetS has been extensively researched in the last decade, public awareness is limited in most LMIC and industrial countries. Our study, therefore, showed that MetS is a public health issue in Sierra Leone, requiring much-needed public awareness.

Our study's regression analysis of demographics, anthropometrics, lifestyle, biochemical factors, and MetS is consistent with previous African literature [17,27,32,46]. WC was the only variable that correlated with all three MetS criteria when both unadjusted and adjusted ratios were used. The relationship between WC and obesity health-related risks can be attributed to factors such as low physical activity and high-energy diets. This relationship underscores the existence of many abnormalities in people with metabolic syndrome. Current smoking was found to be associated with both the unadjusted and adjusted ratio in the ATP III and IDF criteria, which was unlikely in the NCEP ATP III criterion. There is a clear correlation between smoking and MetS, which is supported by increased circulating hormones like cortisol, catecholamines, vasopressin and growth hormones [58]. As a causal factor in the development of MetS, it is therefore imperative that individuals should understand the associated risk of smoking and take steps to quit or avoid smoking. When unadjusted and adjusted ratios were analyzed, there was a correlation between stage 1 hypertension and the MetS criteria for Harmonized ATP III and IDF criteria. Since hypertension is a major cause of metabolic syndrome, it predisposes individuals to the risk of developing cardiovascular diseases [51]. Hence, blood pressure control is imperative in preventing cardiovascular morbidity and mortality.

4.1. Limitations and strengths of the study

When interpreting our study, it is important to consider the following limitations. Firstly, our study's cross-sectional design would not allow us to determine direct causality inference. Therefore, additional research is required to verify the association between the risk factors and their impact on the outcome. Secondly, the MetS criteria used for this study were not specific for the African population, as the validated cut-off points were designed for the European, American, and Asian populations [59,60]. Thirdly, the WHO tool was utilized to measure WC and was subsequently used to evaluate the prevalence of all three defined MetS criteria for this study. The WHO-recommended site for the measurement of WC is at the midpoint between the lowest rib and the superior border of the iliac crest, whereas ATP III and Harmonized ATP III measurement of WC is directly above the superior border of the iliac crest [61]. As a result, the prevalence rates reported in this review may not accurately reflect the true prevalence rate in SSA. Finally, our study recruited primarily young people, which might affect the accuracy of our findings.

Despite these limitations, the study was powered to generate statistically significant results that reflect the adult population in Sierra Leone. Our study is the first to report the prevalence of MetS among

adults in Freetown, Sierra Leone, using the ATP III, IDF, and Harmonized ATP III criteria.

5. Conclusions

The findings of this community-based survey suggested that MetS is a significant public health burden in Sierra Leone, with a strong correlation to an increased risk of cardiovascular disease. To decrease the high prevalence of MetS in Sierra Leone, it is imperative to develop effective controlled strategies that necessitate tackling obesity, reducing sedentary behaviour, and improving physical activities.

Declaration of competing interest

All authors declare no competing interests.

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CRediT authorship contribution statement

James Baligeh Walter Russell: Conceptualization, Funding acquisition, Investigation, Methodology, Supervision, Validation, Writing - original draft, Writing - review & editing. **Theresa Ruba Koroma:** Data curation, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **Santigie Sesay:** Conceptualization, Methodology, Supervision, Writing - original draft. **Sallieu K. Samura:** Data curation, Formal analysis, Software. **Sulaiman Lakoh:** Writing - original draft, Writing - review & editing. **Ansumana Bockarie:** Writing - original draft, Writing - review & editing. **Onomeh Abiri Abiri:** Conceptualization, Writing - original draft, Writing - review & editing. **Victor Conteh:** Methodology, Project administration, Supervision, Writing - original draft. **Sorie Conteh:** Writing - original draft, Writing - review & editing. **Mohamed Smith:** Methodology, Project administration, Supervision, Writing - original draft. **Othman Z. Mahdi:** Writing - original draft, Writing - review & editing. **Durodami R. Lisk:** Writing - original draft, Writing - review & editing.

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