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Prevalence and Diagnostic Concordance of Metabolic Syndrome amongst University Students in Navrongo Upper East Region of Ghana: A Cross-Sectional study

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Abstract

Background: Metabolic syndrome (MetS) is a cluster of cardiometabolic abnormalities that significantly predisposes individuals to cardiovascular disease and type 2 diabetes mellitus. Although MetS has traditionally been associated with older adults, emerging evidence indicates an increasing burden amongst young adults, particularly university students. However, data on the prevalence and comparative diagnostic performance of MetS criteria amongst university populations in Ghana remain limited.

Methods: A cross-sectional study was conducted amongst 219 undergraduate students aged 18-36 years at the University of Technology and Applied Sciences (UTAS), Navrongo, Ghana. Anthropometric measurements, blood pressure, and fasting blood samples were collected following standard protocols. MetS was defined using four criteria, namely World Health Organization (WHO), National Cholesterol Education Programmed Adult Treatment Panel III (NCEP ATP III), International Diabetes Federation (IDF), and Harmonized (H_MS) definitions. Logistic regression analysis was applied to identify risk factors associated with MetS. Receiver operating characteristic (ROC) curve and Cohen's kappa statistics were used to evaluate diagnostic performance and agreement between criteria.

Results: The prevalence of MetS varied across diagnostic criteria, with the highest prevalence observed using IDF (10.1%), followed by H_MS (8.2%), NCEP ATP III (7.3%), and WHO (5.5%). Females exhibited higher prevalence of MetS under IDF, NCEP ATP III, and H_MS criteria, while males showed slightly higher prevalence under WHO criteria. Low high-density lipoprotein cholesterol (HDL-C) was the most prevalent component (76.3%), followed by elevated fasting blood glucose (25.6-29.2%) and elevated blood pressure (18.7%). Logistic regression analysis identified fasting blood glucose as the strongest predictor of MetS across all definitions ($p<0.001$). ROC analysis showed that the H_MS definition demonstrated the highest discriminatory ability

relative to the WHO definition (AUC=0.677), followed by NCEP ATP III (AUC=0.638), while IDF exhibited poor performance (AUC=0.491). Kappa agreement analysis established fair concordance between WHO and NCEP ATP III (k=0.238, p<0.001) and between WHO and H_MS (k=0.286, p<0.001), but poor agreement between WHO and IDF (k=-0.013, p=1.00).

Conclusion: Although the overall prevalence of MetS amongst UTAS students was relatively low, a substantial proportion exhibited one or more metabolic abnormalities, indicating early cardiometabolic risk. The harmonized definition demonstrated better alignment with the WHO-based classification and may be a useful screening approach in this population. These findings highlight the need for early screening and targeted lifestyle interventions amongst university students.

Keywords: Metabolic syndrome; university students; prevalence; diagnostic criteria; Ghana; cardiometabolic risk.

Introduction

Metabolic syndrome (MetS) refers to the coexistence of several cardiometabolic abnormalities, such as excess abdominal fat, elevated blood pressure, abnormal lipid levels, and disturbances in glucose regulation, which together increase the likelihood of chronic diseases [1-3]. Globally, MetS has emerged as a major public health concern, contributing substantially to the burden of non-communicable diseases (NCDs), which account for nearly 70% of all deaths worldwide [4,5]. The increasing prevalence of MetS has been largely attributed to rapid urbanisation, unhealthy dietary patterns, physical inactivity, and other lifestyle changes [6]. Although MetS has traditionally been associated with middle-aged and older populations, there is growing evidence that its risk factors begin to develop earlier in life [7- 9]. University students represent a particularly vulnerable population due to lifestyle transitions characterised by irregular eating habits, reduced physical activity, increased academic stress, and in some cases, alcohol consumption [10,11]. These behavioural patterns may predispose students to early metabolic abnormalities that may progress into overt MetS if not identified and managed early [12-15]. In sub-Saharan Africa, including Ghana, the epidemiological transition towards NCDs has intensified the importance of early detection of cardiometabolic risk factors [16]. However, the reported prevalence of MetS varies considerably depending on the diagnostic criteria used [17]. Commonly applied definitions include those proposed by the World Health Organisation (WHO), National Cholesterol Education Programme Adult Treatment Panel III (NCEP ATP III), International Diabetes Federation (IDF), and the Harmonised (H_MS) criteria. These definitions differ in their thresholds and required components, leading to inconsistencies in prevalence estimates and challenges in clinical and public health decision-making. Despite the growing burden of MetS in Ghana, there is limited evidence on its prevalence and biochemical risk profile amongst university students, particularly in upper regions of Ghana. Furthermore, few studies have systematically compared the diagnostic performance and agreement of different MetS criteria within this population [18]. Besides, there is no consensus regarding the best criteria for the estimation of MetS prevalence amongst

university students in Ghana. Hence, comparisons of these criteria are essential for identifying the most appropriate screening approach for early detection in young adults. This study therefore aimed to determine the prevalence and biochemical risk components of MetS amongst undergraduate students at the University of Technology and Applied Sciences (UTAS) in Navrongo, Ghana, and to compare the diagnostic performance and agreement of WHO, NCEP ATP III, IDF and H_MS criteria in this population.

Methods

Study design and setting

This study employed a cross-sectional design and was conducted at the UTAS campus located at Navrongo in the Kassena-Nankana municipality of the Upper East Region of Ghana. Specifically, data collection was carried out at the UTAS Hospital. The university comprises students from diverse ethnic and academic backgrounds, thereby providing a suitable population for assessing cardiometabolic risk amongst young adults.

Study population and eligibility criteria

The study population consisted of undergraduate students aged 18-36 years enrolled at UTAS. The participants were recruited from different schools within the university using random sampling method.

Inclusion criteria: Registered undergraduate students of UTAS and aged between 18 and 36 years were included in this study. Also, students who were willing to participate and provided written informed consent were included.

Exclusion criteria: Students who have a history of known chronic medical conditions such as diabetes mellitus, hypertension, or autoimmune diseases and current medications that could affect metabolic parameters were excluded.

Sample size determination

The sample was determined using the Cochran's formula for estimating a proportion in a cross-sectional study [19].

$$N = \frac{Z^2 P(1-p)}{E^2}$$

N = the desired sample size

Z = the Z-score representing the desired confidence level (95% confidence level corresponds to a Z-score of 1.96)

P = the prevalence of MetS in the Ghanaian population (17%) [20]

E = margin of error (5%)

$$n = \frac{(1.96)^2(0.17)(1-0.17)}{(0.05)^2}$$

N = 217

Therefore, a minimum sample size (n) of 217 participants was required, but in total, 219 UTAS undergraduate students were recruited into the study.

Data collection procedures

Questionnaire and socio-demographic data

A structured questionnaire was used to collect information on socio-demographic characteristics (such as age, sex, marital status, and employment status), lifestyle factors, and family history of chronic diseases. The questionnaire was pre-tested and administered by trained research assistants.

Anthropometric measurement

Anthropometric measurement such as height, weight, waist circumference (WC), hip circumference (HC) and thigh circumference (THC) of the study participants were measured with the help of a trained nurse at the UTAS hospital. Height was measured using stadiometer (Hospitex international Srl, HM200P, Italy) to nearest cm without participants wearing footwear and the head of the study participants held straight. The weight of the study participants was taken with a bathroom scale to closest 0.1 kilogram (kg) in light clothing (Greenlife scale, Nanjing Greenlife, China). The body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2), using the WHO interpretation used as a guide[21]. The study participants standing with light clothing and a non-stretchable measuring tape had their waist circumference (WC) measured at the mid-point between the last rib and the iliac crest. The broadest hip circumference (HC) was measured above great trochanters, while waist-to-hip ratio (WHtR) was computed by dividing the WC (cm) by the HC (cm). Thigh circumference (THC) was taken on the left limb of the study participants [22] below gluteal fold and the waist-to-thigh ratio (WTR) carried out as a division between the WC (cm) and the THC (cm). All the WHR, WHtR and WTR measurements were written down to the nearest 2 decimal places. Each measurement was repeated three times and the averages were recorded.

Blood pressure measurement

Blood pressure was measured using a validated automated sphygmomanometer (OMRON) in accordance with American Heart Association guidelines [23]. Participants were seated and rested for at least 10 minutes before measurement. Three readings were taken at 2-minutes intervals, and the average systolic blood pressure (SBP), diastolic blood pressure (DBP) and pulse pressure (PP) were recorded.

Biochemical analysis

Fasting venous blood samples (3 mL) were collected after an overnight fast of at least 8-12 hours**.** Three millilitres (3 mL) of the blood sample were collected into a Gel Separator tube (Boemed,

China) and centrifuged at a speed of 3000 rpm for 5 minutes to obtain the serum which was used for estimation of lipid profile parameters. Lipid profile parameters that were determined included high density lipoprotein cholesterol (HDL-C), lipoprotein cholesterol (LDL-C), triglyceride (TG), and total cholesterol (TC) with (Mindray Bio-medical Electronics Co., Ltd Shenzhen, China). Fasting blood glucose (FBG) were measured with a Yuwell Blood Glucose Meter 582 [Jiangsu Yuyue Medical Equipment and Supply Co., Ltd, China] (a calibrated glucometer) following manufacturer instructions. Measurement was carried out by inserting appropriate test strips into the meter prior to collection of samples. The tip of the finger of the participant was wiped off with an alcohol swab and left to dry thoroughly [22]. The needle was pricked into the lateral side of the fingertip with a sterile lancet and the tip of the capillary blood was gently scraped without over squeezing so as not to dilute the sample. All analyses were conducted in accordance with standard laboratory procedures.

Definition of MetS

NCEP ATP III definition criterion

According to NCEP ATP III (2001) guideline, an individual is classified as having MetS when any three (3) of the specified metabolic abnormalities are present: (1) abdominal obesity (AO, WC/CO >102 cm for male and >88 cm for female); (2) high TG level (≥1.7 mmol/L); (3) low HDL-C (<1.0 mmol/L in male and <1.3 mmol/L in female); (4) high BP (systolic BP ≥130 mmHg or diastolic BP ≥85 mmHg) and (5) raised FBG (FBG) ≥5.6 mmol/L [24].

WHO definition criterion

The WHO definition criteria include insulin resistance (IR) or glucose intolerance and any other two of the following risk factors; (1) BMI ≥30 kg/m^2 and/or WHR >0.90 for male and >0.85 for female; (2) high BP (systolic BP ≥140 or diastolic BP ≥90 mmHg or treating hypertension; (3) TG ≥1.7 mmol/L and/or HDL-C <0.92 mmol/L for male and <1.01 mmol/L for females [25].

IDF definition criterion

According to the IDF (2005) definition criteria an individual is diagnosed with MetS if there is central obesity (WC >94 cm for men and >80 cm for female) plus any two of the following risk factors; (1) TG ≥1.7 mmol/L; (2) HDL-C<1.0 mmol/L for male and <1.3 mmol/L for female; (3) BP ≥130/85 mmHg or diagnosed of hypertension and (4) FBG ≥5.6 mmol/L or diagnosed of type 2 diabetes [26].

H_MS definition criterion

The H_MS definition criterion was established to unify the various criteria. An individual is considered to be diagnosed with MetS if they have at least any of three risk factors of the following five; (1) AO (WC >94 cm for male and >80 cm for female); (2) high TG level (≥1.7 mmol/L); (3) low HDL-C (<1.0 mmol/L in male and <1.3 mmol/L in female); (4) high BP (systolic BP ≥130 mmHg or diastolic BP≥85 mmHg) and (5) raised FBG (FBG) ≥5.6 mmol/L [1].

Statistical analysis

Normality of all the study variables was assessed before the statistical analysis was performed using the D'Agostino-pearson test and the variable were found to be normally distributed. Continuous variables are described using the mean and standard deviation (SD), while categorical variables are expressed in the form of proportions. The independent (unpaired) t-tests for continuous variables and chi-square or Fisher exact tests for categorical variables were used to compare the general characteristics of the study participants. A p-value <0.05 was considered to be statistically significant. Cohen kappa (κ) was used to measure agreement in the WHO, NCEP ATP III, IDF and HM diagnostic criteria of MetS. The level of agreement was classified as poor (0.20 and below), fair (0.21-0.40), moderate (0.41-0.60), good (0.61-0.80), and very good (0.81-1.00). GraphPad prism version 10.2 (GraphPad software, San Diego California, USA) and SPSS version 27.0 (SPSS IBM incorporation, Chicago, USA) were used for statistical analysis.

Results

General characteristics of the study population

It was observed that 104 (47.5%) and 115 (52.5%) of the 219 participants were respectively males and females. The general characteristics are shown in Table 1. The overall mean age of the students was 23.39 ± 0.38 years. A statistically significant difference ($p < 0.001$) was observed between both sexes, with male students (24.89 ± 0.670 years) being older than female cohorts (22.03 ± 3.86 years). The mean BMI for all the students was 23.84 ± 0.31 (males 23.17 ± 0.46 and 24.45 ± 0.42, $p = 0.038$). Female students exhibited a higher BMI compared to male students (Table 1). The overall mean of WC was 75.13 ± 0.70 cm, with no significant difference between males (74.79 ± 1.01cm) and females (75.44 ± 0.97cm) ($p = 0.643$). WHR and WTR did not differ significantly between the sexes. However, WHtR was significantly higher in females (0.46 ± 0.01) compared to male (0.44 ± 0.01) ($p = 0.041$). The overall mean of SBP was 120 ± 0.94 mmHg, which was significantly higher amongst males (123.08 ± 1.59 mmHg) than in females (118.02 ± 1.00) ($p = 0.007$). The mean of DBP for the students was (72.18 ± 0.58 mmHg), with no significant sex difference ($p = 0.477$). No significant difference was found between the sexes ($p = 0.105$) in terms of PP. Most of the students, 200 (91.30%) were single and only 19 (8.70%) were married. The number of single females constituted 109 (94.8%), which was higher compared to their male counterparts, 91 (87.5%). In the contrary, more males were married 13 (12.50%) compared to females 6 (5.2%), amid insignificant difference between sexes (p = 0.056). Majority of the students were unemployed 176 (80.40%) with only 43 (19.60%) of them employed. More females 43 (19.60%) were employed compared to males 15 (13.0%, $p < 0.001$) (Table 1). Analysis of the family history of the study participants revealed hypertension 187 (85.4%) and diabetes 193 (88.1%) as the two main diseases. A smaller proportion showed a family history of hepatitis 8 (3.7%), which was significantly different between sexes (p=0.020). The family history of kidney disease 6 (2.7%) and CVD 4 (1.8%) also indicated small proportion, amid no significant difference between sexes ($p = 0.978$) and ($p = 0.104$), respectively. The dietary and lifestyle of the students showed that a total of 55 (25.1%) consume pro-inflammatory foods, while 157 (71.68%) do not consume this type of food. Similarly, 37 (25.1%) consumed anti-inflammatory foods, while 174 (71.70%) did not. Alcohol consumption was relatively low with only 8 (3.7%) reporting alcohol

intake. The mean FBG was 5.10 ± 0.05 mmol/L, with no significant sex difference (p = 0.623, Table 1**)**. The overall mean for lipid profile was TG (0.96 ± 0.03 mmol/L), HDL-C (0.44 ± 0.03 mmol/L), TC (4.32±0.08 mmol/L), and LDL-C (2.64 ± 0.07mmol/L), amid no significant differences between males and females (Table 1**)**. The prevalence of MetS for the overall study population was estimated to be 12 (5.50%),16 (7.30%), 22 (10.10%) and 18 (8.20%) using WHO, NCEP ATP III, IDF and H_MS criteria respectively (Figure 1**)**. Sex -based analysis demonstrated differences in prevalence across the various diagnostic criteria. Using WHO criteria, prevalence was found to be 6.7% amongst males and 4.3% amongst females, with no statistical difference (p = 0.439). According to NCEP ATP III criteria, prevalence was 3.8% in males and 10.4% in females (p = 0.061). The largest disparity was discovered when IDF criteria were used, wherein the prevalence was estimated to be 2.9% amongst males and 16.5% amongst females with the difference being statistically significant (p = 0.001). However, based on the H_MS criteria, prevalence was 7.7% in males and 10.7% in females, with no significant difference between the sexes (p=0.787, Figure 2).

Table 1. General characteristics of the study participants (n=219)

Parameters	Total (n=219)	Male (n=104)	Female (n=115)	p-value
Age (Years)	23.39±0.380	24.89±0.670	22.03±3.86	<0.001*
Anthropometric				
WC (cm)	75.13±0.70	74.79±1.01	75.44±0.97	0.643
WHR	1.23±0.01	1.22±0.18	1.24±0.18	0.508
WTR	1.47±0.20	1.49±0.31	1.45±0.03	0.283
WHtR	0.45±0.01	0.44±0.01	0.46±0.01	0.041*
BMI ($kg/m^{2)}$	23.84±0.31	23.17±0.46	24.45±0.42	0.038*
Hemodynamic parameters				
SBP (mmHg)	120.42±0.94	123.08±1.59	118.02±1.00	0.007*
DBP (mmHg)	72.18±0.58	72.62±0.89	71.79±0.75	0.477
PP (mmHg)	80.80±0.86	79.34±1.32	82.12±1.10	0.105
Socio-demographic parameters				
Marital status				
Single	200(91.3%)	91 (87.5%)	109 (94.8%)	0.056
Married	19 (8.7%)	13 (12.5%)	6 (5.2%)	
Occupation				
Employed	43 (19.6%)	15 (13.0%)	43 (19.6%)	0.010*
Unemployed	176 (80.4%)	100 (87.0%)	176 (80.4%)	
Family history				
Hypertension				
Yes	187 (85.4%)	83 (79.8%)	104 (90.4%)	
No	28 (12.8%)	18 (17.3%)	10 (8.7%)	0.078
Do not know	4 (1.8%)	3 (2.9%)	1 (0.9%)	
Diabetes				
Yes	193 (88.1%)	92 (88.5%)	101 (87.8%)	0.530
No	16 (7.3%)	6 (5.8%)	10 (8.7%)	

Do not know	10 (4.6%)	6 (5.8%)	4 (3.5%)	
Hepatitis				
Yes	8 (3.7%)	5 (4.8%)	3 (2.6%)	
No	196 (89.5%)	87 (83.7%)	109 (94.8%)	0.020*
Do not know	15 (6.8%)	12 (11.5%)	3 (2.6%)	
Kidney disease				
Yes	6 (2.7%)	3 (2.9%)	3 (2.6%)	
No	203 (92.7%)	96 (92.3%)	107 (93.0%)	0.978
Do not know	10 (4.6%)	5 (4.8%)	5 (4.3%)	
Cardiovascular disease				
Yes	4 (1.8%)	4 (3.8%)	0 (0.0%)	
No	209 (95.4%)	97 (93.3%)	112 (97.4%)	0.104
Do not know	6 (2.7%)	3 (2.9%)	3 (2.6%)	
Consumption				
Pro-inflammatory foods				
Yes	55 (25.1%)	26 (25.0%)	29 (25.2%)	
No	157 (71.7%)	74 (71.2%)	83 (72.2%)	0.873
Do not know	7 (3.2%)	4 (3.8%)	3 (2.6%)	
Anti-inflammatory foods				
Yes	37 (25.1%)	18 (25.0%)	19 (25.2%)	
No	174 (71.7%)	83 (71.2%)	91 (72.2%)	0.842
Do not know	8 (3.2%)	3 (3.8%)	5 (2.6%)	
Alcohol				
Yes	8 (3.7%)	7 (6.7%)	1 (0.9%)	
No	209 (95.4%)	96 (92.3%)	113 (98.3%)	0.069
Do not know	2 (0.9%)	1 (0.9%)	1 (0.9%)	
Biochemical Assay				
FBG (mmol)	5.10±0.05	5.08±0.08	5.13±0.07	0.623
TG	0.96±0.03	0.99±0.04	0.92±0.04	0.224
HDL-C	0.44±0.03	0.50±0.05	0.39±0.05	0.107
TC	4.32±0.O8	4.22±0.12	4.41±0.12	0.26
LDL-C	2.64±0.07	2.56±0.10	2.70±0.09	0.318
VLDL-C	0.48±0.02	0.50±0.04	0.46±0.02	0.304
HDL-C/TC	0.34±0.01	0.34±0.02	0.33±0.06	0.672
TG/HDL-C	0.82±0.04	0.86±0.05	0.79±0.06	0.364

Continuous data were presented in mean ± standard deviation. Categorical data are presented as frequency with percentages in parenthesis. The continuous data were compared using unpaired t-test whilst categorical data were compared using Fischer's exact test. VLDL-C: Very Low Density-Lipoprotein-Cholesterol, LDL-C: Low Density Lipoprotein- Cholesterol, HDL-C: High Density Lipoproteins – Cholesterol, TG: Triglyceride, TC: Total Cholesterol, FBG: Fasting Blood Glucose, HDL-C/TC: High Density Lipoproteins-Cholesterol-to- Total Cholesterol ratio, TG/HDL-C: Triglyceride-to- High Density Lipoproteins-Cholesterol, WC: Waist circumference, WHR: Waist-to-Hip ratio, WTR: Waist-to-Thigh ratio, WHtR: Waist-to-Height-ratio, BMI: Body Mass index, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, PP: Pulse Pressure. **p*-value: statically significant.

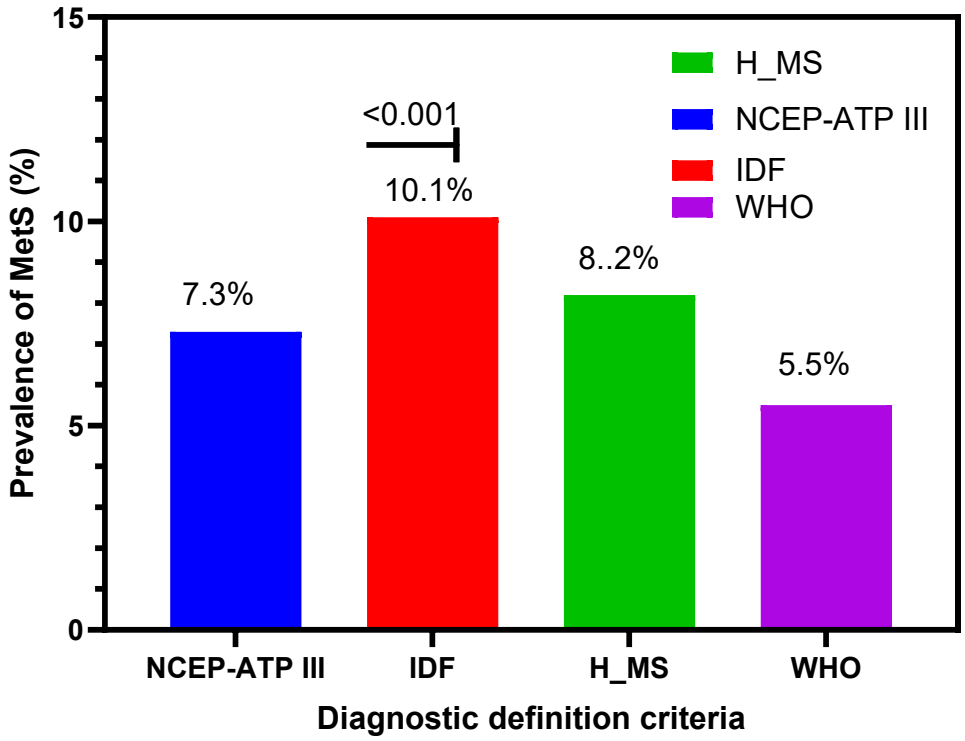


Figure 1: Overall prevalence of metabolic syndrome amongst the study participants.

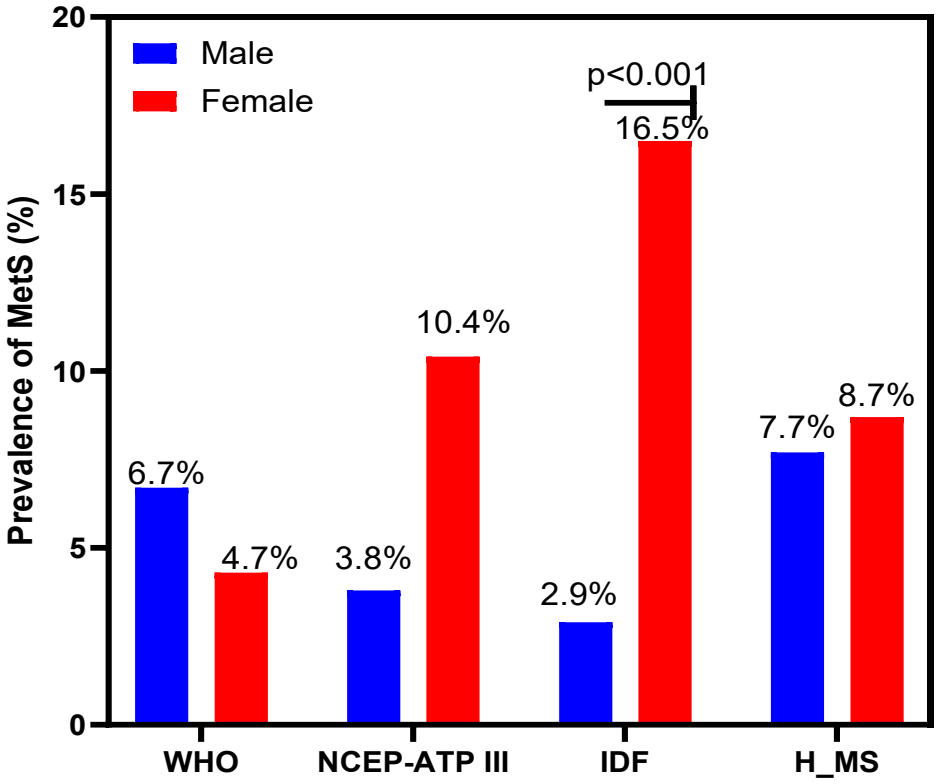


Figure 2: Prevalence of metabolic syndrome amongst study participants stratified by sex.

Figure 3 illustrates the distribution of MetS components clustering amongst the study participants. Most students (65.8%) displayed no MetS components with 62.50% and 68.70% of males and 68.70% of females. However, 23% had one component, that shows early presence of metabolic risk. Additionally, 9.10% of students exhibited two components. Notably, 1.8% displayed three or more components, meeting the diagnostic criteria for MetS according to IDF, NCEP ATP III, H_MS and WHO. One MetS components was displayed by 25.0% of males and 21.70% of females, while two components were exhibited by 10.6% of males and 7.8% of females. This observation shows slightly higher risk component clustering amongst males (Figure 4**).** The prevalence of three or more components met the diagnostic criteria for MetS according to the IDF, NCEP ATP III, and WHO.

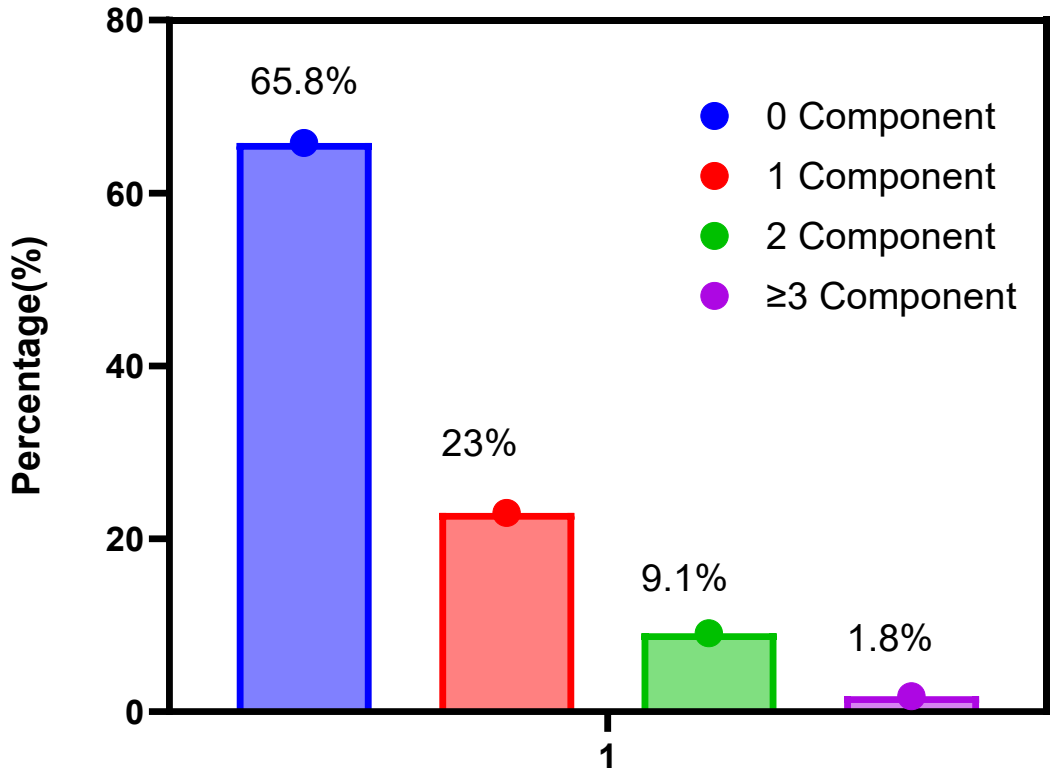


Figure 3: Clustering of risk components for metabolic syndrome amongst students

Prevalence of the risk components of MetS

Low HDL-C was the most prevalent MetS components across all diagnostic criteria, with a prevalence of 76.30% amongst the study participants, thus emerging as the dominant abnormality. WC / AO varied considerably by definition, with lower prevalence when NCEP ATP III and WHO (6.40%) were used, but higher estimates were observed when IDF (16.40%) and H_MS (22.40%) were applied. Elevated FBG ranged from 25.60% to 29.9% using NCEP ATP III, IDF, and H_MS, but was lower when WHO (12.9%) was applied (Table 2). Similarly, high blood pressure was 18.7% with NCEP ATP III, IDF and H_MS as the criteria, but decreased to 5.0% when WHO criterion was used. Analysis of sex -specific revealed notably differences. Low HDL-C was significantly more common in females (100%) than males (50%) across all definition criteria (p<0.001). AO/WC was also more prevalent among females, particularly using the IDF and H_MS criteria (26.10%), compared to males (5.8% and 18.3%) (p<0.001, Table 2). Elevated FBG showed only slight sex variation, while elevated BP consistently remained higher in males than females across all definitions (Table 2).

Table 2. Prevalence of the risk components of metabolic syndrome

Parameters	Total (n=219)	Male (n=104)	Female (n=115)	P-value
NCEP ATP III				
Abdominal obesity	14(6.4%)	3(2.9%)	11(9.6%)	0.054
High triglyceride	11(5.0%)	6(5.8%)	5(4.3%)	0.76
Low HDL-C	167(76.3%	52(50.0%)	115(100%)	<0.001*
High blood pressure	41(18.7%)	23(22.1%)	18(15.7%)	0.23
High FBG	64(29.2%)	28(26.9%)	36(31.3%)	0.552
WHO				
Abdominal obesity	14(6.4%)	3(2.9%)	11(9.6%)	0.054
Impaired glucose	28(12.9%)	15(14.4%)	13(11.3%)	0.546
High triglyceride	11(5.0%)	6(5.8%)	5(4.3%)	0.76
High blood pressure	11(5.0%)	8(7.7%)	3(2.6%)	0.121
Low HDL-C	167(76.3%	52(50.0%)	115(100%)	<0.001*
IDF				
High blood pressure	41(18.7%)	23(22.1%)	18(15.7%)	0.230
Abdominal obesity	36(16.4%)	6(5.8%)	30(26.1%)	<0.001*
High triglyceride	11(5.0%)	6(5.3%)	5(4.3%)	0.76
High FBG	64(29.9%)	28(26.9%)	36(31.3%)	0.552
Low HDL-C	167(76.3%	52(50.0%)	115(100%)	**<0.001***
H_MS				
Abdominal obesity	49(22.4%)	19(18.3%)	30(26.1%)	0.195
Low HDL-C	167(76.3%)	52(50.0%)	115(100%)	**<0.001***
High triglyceride	10(4.6%)	5(4.8%)	5(4.3%)	0.871
High blood pressure	41(18.7%)	23(22.1%)	18(15.7%)	0.230
High FBG	56(25.6%)	25(24.0%)	31(27.0%)	0.645

Data are presented as proportion with corresponding percentages in parenthesis *p-values <0.05.

The proportion were compared using Fischer's exact test.

Risk factors associated with MetS

Amongst the risk factors associated with MetS, FBG was found to be strongest and most consist predictor of MetS. The odds ratio was particularly high, ranging from 8.60 under NCEP ATP III criterion to 29.20 under WHO criterion (p<0.001, Table 3a and 3d**)**. Central obesity, as measured using WC is also a key determinant, though its significance varied across criteria. Under the NCEP ATP III (OR=1.187, p=0.002), IDF (OR=1.745, p<0.001), and H_MS (OR=1.161, p=0.002) definitions (Table 3a, 3b and 3c), increasing WC significantly associated with higher odds of MetS. The BP showed varying association depending on the diagnostic criteria. SBP was significant under NCEP ATP III (OR=1.051, p=0.034) and H_MS (OR=1.064, p=0.011, Table 3a) with the result suggesting that elevated SBP could contribute independently to MetS risk under these

definitions. On the other hand, DBP was only significant under the WHO definition (OR=1.231, *p*=0.015), thereby indicating a stronger contribution of diastolic abnormalities when IR is prioritised in the diagnosis. These variations show how definition criteria influence which haemodynamic parameters are flagged as critical risk factors. Dyslipidaemia also emerged as a consistent risk domain, though with different emphasis across the definitions. TG significantly predicted MetS under NCEP ATP III (OR=12.434, *p*<0.001), H_MS (OR=7.993, *p*=0.016, (Table 3a and 3c) and WHO (OR=5.382, *p*=0.023) criteria, indicating the central role of hypertriglyceridaemia in cardiometabolic clustering. In terms of the demographic and anthropometric variables, sex and BMI showed inconsistent associations. Sex was only significant under the IDF criteria (*p*=0.002), where females were likely to meet the diagnostic threshold compared to males. Age did not show significant association under any of the definition, which may be owing to the relatively young age of the students.

Table 3a. Risk factors associated with metabolic syndrome according to National Cholesterol Education Programme Adult Treatment Panel III criterion

	NCEP ATP III		
Risk factors	**Odds ratio**	**95% CI**	***p*-value**
Gender			
Female	Reference		
Male	0.343	0.107 - 1.100	0.072
Age (years)	0.868	0.712 - 1.057	0.160
BMI (kg/m^2)			
Normal weight	Reference		
Underweight	0.185*	0.045 - 0.763	**0.045***
Overweight	0.121	0.013 - 1.175	0.069
Obese	0.522	0.130 - 2.089	0.358
WC (cm)	1.187*	1.067 -1.321	**0.002***
SBP (mmHg)	1.051	1.004 – 1.100	0.034
DBP (mmHg)	1.0017	0.934 – 1.106	0.703
FBG (mmol/L)	8.622*	3.169 -23.459	**<0.001***
HDL-C(mmol/L)	0.115	0.021 - 0.628	**0.012***
TG (mmol/L)	12.434	3.042 -50.826	**<0.001***

***p*-values: <0.05**

Table 3b. Risk factors associated with metabolic syndrome according to International Diabetes Federation criterion

	IDF		
Risk factors	**Odds ratio**	**95% CI**	***p*-value**

Gender			
Female	Reference		
Male	0	0.000 - 0.044	0.002*
Age (years)	1.02	0.838 - 1.241	0.845
BMI (kg/m^2)	0.944	0.756 - 1.179	0.613
WC (cm)	1.745*	1.318 - 2.311	<0.001*
SBP (mmHg)	1.033	0.931 - 1.147	0.540
DBP (mmol/L)	1.038	0.895 - 1.203	0.624
FBG (mmol/L)	15.991	2.074 - 123.278	0.008
HDL-C(mmol/L)	6.966	0.746 - 65.045	0.089
TG (mmol/L)	0.455	0.081 - 2.546	0.370

***p*-values <0.05**

Table 3c. Risk factors Associated with metabolic syndrome according to Harmonised metabolic syndrome criterion

	H_MS		
Risk factors	**Odds ratio**	**95% CI**	***p*-value**
Gender			
Female	Reference		
Male	0.396	0.079 - 1.984	0.26
Age (years)	1.003	0.847 - 1.188	0.969
BMI (kg/m^2)	1.057	0.906 - 1.233	0.483
WC (cm)	1.161*	1.056 - 1.277	0.002*
SBP	1.064*	1.014 - 1.116	0.011*
DBP	1.064	0.885 - 1.096	0.775
FBG	11.117*	2.984 - 41.424	<0.001*
HDL-C	69.721	5.080 - 950.966	<0.001*
TG	7.993	1.482 - 43.105	0.016

***p*-values <0.05**

Table 3d. Risk factors associated with metabolic according to World Health Organization criterion

	WHO		
Risk factors	**Odds ratio**	**95% CI**	***p*-value**
Gender			
Female	Reference		
Male	2.954	0.437 - 19.984	0.267

Age (years)	0.853	0.657 - 1.109	0.236
BMI (kg/m	1.081	0.859 - 1.361	0.507
WC (cm)	1.009	0.937 - 1.088	0.806
SBP	0.968	0.883 - 1.062	0.495
DBP	1.231*	1.042 - 1.454	0.015*
FBG	29.161*	4.632 -183.570	<0.001*
HDL-C	12.188	0.993 - 149.598	0.051
TG	5.382*	1.256 - 23.055	0.023*

***p*-values <0.05**

Prevalence of obesity, hypertension, diabetes and dyslipidaemia amongst study participants

Table 4 depicts that although most students had normal BMI and WHtR, notable proportions exhibited underweight, overweight, obesity and impaired FBG. Females exhibited higher levels of overweight, obesity and elevated WHtR, with the difference in WHtR showing statistical significance (p=0.017), and suggesting greater central adiposity amongst female students. In contrast, males showed slightly higher prevalences of impaired FBG, hypertension, and dyslipidaemia, although these differences were not statistically significant (p=0.085). Overall, the findings indicate a low-to-moderate burden of cardiometabolic risk factors, with sex-specific variations in adiposity and metabolic profiles.

Table 4. Prevalence of obesity, hypertension, diabetes and dyslipidaemia amongst study participants

Parameters	Total (n=219)	Male ((n=104)	Female (n=115)	P-value
BMI				
Underweight	35(16.0%)	18(17.3%)	17(14.8%)	
Normal	112(51.1%)	57(54.8%)	55(47.8%)	0.332
Overweight	52(23.7%)	23(22.1%)	29(25.2%)	
Obese	20(9.1%)	6(5.8%)	14(12.2%)	
WHtR				
Normal	179(81.7%)	92(88.5%)	87(75.7%)	
Overweight	30(13.7%)	7(6.7%)	23(20.0%)	0.017*
Obese	10(4.6%)	5(4.8%)	5(4.3%)	
WHR				
Normal	219(100.0%)	104(47.5%)	115(52.5%)	0.000
Overweight	00(000.0%)	00(000.0%)	00(000.0%)	
Obese	00(000.0%)	00(000.0%)	00(000.0%)	
FBG				
Hyperglycaemia	3(1.4%)	1(1.0%)	2(2.0%)	0.621

Impaired Glucose	25(11.4%)	14(13.5%)	11(9.6%)	0.598
Hypertension	11(5.0%)	8(7.7%)	3(2.6%)	0.085
Dyslipidaemia	11(5.0%)	6(5.8%)	5(4.3%)	0.631

N=number of subjects, four categories of BMI (≤20,20-24.9,25-29.9, and ≥30 kg/m^2) were used based on the WHO recommendations to define individuals with a healthy weight (BMI 20-25), overweight (BMI 25-29.9) and obese (BMI≥30). Students with a BMI ≤20 kg/m^2 were considered as underweight. Females with WHR <0.80, 0.80-0.84 and ≥0.85 were classified as normal weight, overweight and obese respectively. Males with <0.90, 0.90-0.99 and ≥0.96 were considered as normal weight, overweight and obese respectively, both male and female with WHtR=<0.53 and >0.53 were classified as normal and obese respectively; Hyperglycaemia= fasting blood glucose ≥6.1mmol/l, Impaired Glucose = fasting blood glucose between 6.1 to 6.9 mmol/l, Diabetes=fasting blood glucose greater or equal to 7.0mmol/l and Dyslipidaemia=TG≥1.70mmol/l and HDL-C≤1.01mmol/l.

ROC curve and Kappa agreement (Cohen's Kappa)

Figure 4 illustrates the ROC curve analysis comparing the diagnostic performance of the NCEP ATP III, IDF and H_MS definition against the WHO definition, which served as the reference standard. Among the three criteria, the H_MS definition demonstrated the highest discriminatory ability, with an AUC of 0.677, indicating fair diagnostic accuracy in identifying WHO- classified MetS. The NCEP ATP III definition also showed fair performance with an AUC of 0.638, indicating a moderate level of agreement with the WHO criterion. In contrast, the IDF definition exhibited poor discriminatory ability, with an AUC of 0.491, which is approximately equivalent to chance, indicating poor alignment with the WHO definition. The ROC curve for H_MS and NCEP ATP III were positioned above the reference line (Figure 5). This result indicates acceptable predictive performance relative to WHO, whereas the IDF curve largely overlapped with the reference line, reflecting poor diagnostic ability. The Kappa agreement analysis showed fair agreement between WHO and NCEP ATP III (k=0.238, *p<0.001*), WHO and H_MS (k=0.286, *p<0.001*), IDF and NCEP ATP III (k=0.368, *p<0.001*), IDF and H_MS (k=0.395, *p<0.001*), and NCEP ATP III and H_MS (k=0.362, *p<0.001*). However, WHO and IDF showed poor agreement (k=-0.013, *p=1.00*), confirming the weak concordance between these two definitions.

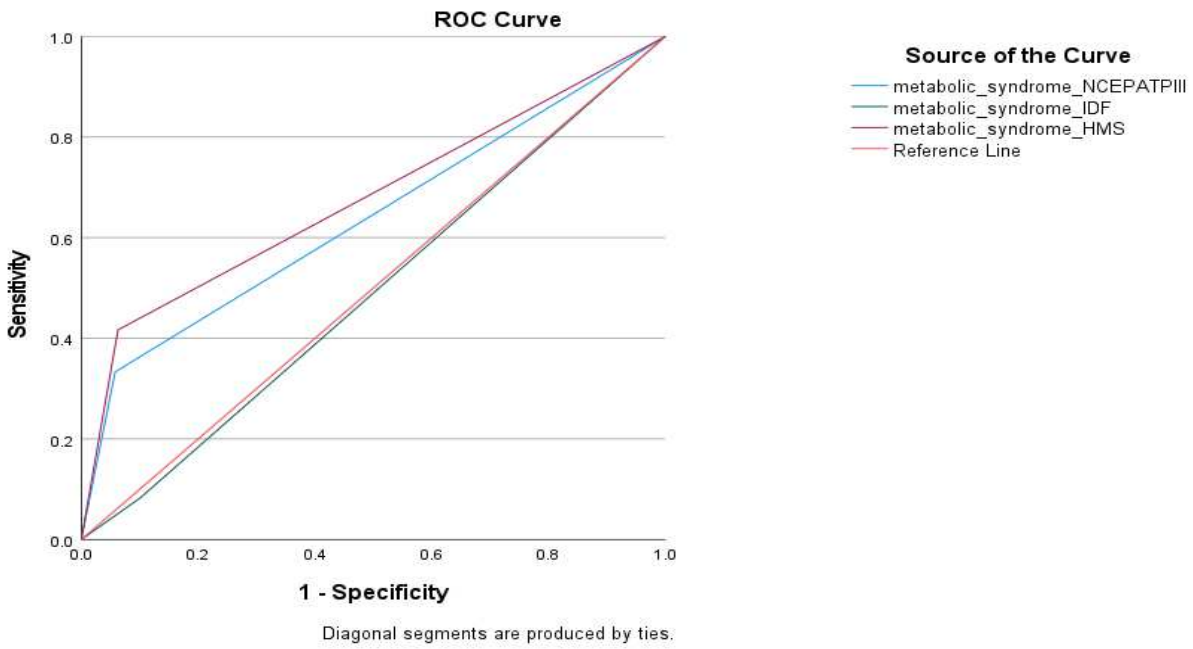


Figure 4: Receiver operating characteristics curves comparing three diagnostic criteria of metabolic syndrome (National Cholesterol Education Panel Adult Treatment Panel III, International Diabetes Federation, and Harmonised) against the World Health Organisation definition as the reference standard.

Discussion

This study assessed the prevalence, biochemical risk components, and diagnostic concordance of MetS amongst undergraduate students in the UTAS of Kassena-Nankana municipality of Ghana using four established criteria. The findings demonstrate that the overall prevalence of MetS was relatively low with a substantial proportion of students exhibiting one or more metabolic abnormalities, indicating emerging cardiometabolic risk in this young population. The prevalence of MetS varied considerably depending on the diagnostic criteria applied, with the highest prevalence observed using the IDF definition and the lowest under the WHO criterion (Figure 1). Differences in prevalence estimates across diagnostic definitions have been reported elsewhere and demonstrated how the choice of diagnostic criteria can substantially influence MetS classification [24]. The higher prevalence under the IDF criterion is likely attributable to its emphasis on CO as a mandatory component, which may overestimate risk in populations with relatively low overall adiposity but increasing WC. Sex-specific differences were also evident, with females demonstrating higher prevalence across most criteria (Figure 2). This aligns with findings from other studies in sub-Saharan African and may reflect differences in fat distribution, hormonal influences, and lifestyle factors [27].The higher burden of AO observed amongst females further supports the role of central adiposity as a key driver of metabolic risk in this study population. Compared to studies on the prevalence of MetS amongst young population, our finding

was much lower comparative to Iraq (41.30%, IDF) [28], Bangladesh (27.70% NCEP ATP III) [29], India (11.2%, NCEP-ATP III)[30]. However, a comparison amongst studies within Africa showed that our findings was higher than a study conducted in Kenya amongst university students, which reported a prevalence to be 1.90% using the Harmonised Joint Scientific Statement (HJSS) criterion [27]. Conversely, our MetS prevalence was slightly lower than that determined amongst Cameroon undergraduate students using H_MS definition, which was 11.33% [31]. Although the prevalence of overt MetS was low, the clustering of individual components (Figure 3) is of significant public health concern. Nearly one-third of participants had at least one metabolic abnormality, suggesting that cardiometabolic risk may begin early in adulthood (Figure 3 and 4). This cluster prevalence is lower than the 12.4% reported amongst diabetic patients [14,32]. The differences in prevalence may be ascribed to various factors including different diagnostic criteria and ethnicity. This finding underscores the importance of early detection and intervention strategies within university settings, where lifestyle behaviours such as poor dietary habits and physical inactivity are common. Low HDL-C emerged as the most prevalent abnormality (Table 2), affecting a substantial proportion of the study participants, particularly females. This pattern has been reported in other young adult populations and suggests that dyslipidaemia (rather than hypertriglyceridaemia) may be the dominant lipid abnormality in this cohort [33, 34]. The high prevalence of low HDL-C may be linked to dietary patterns, physical inactivity, and genetic factors, although further investigation is required. Elevated FBG was also common and consistently identified as the strongest predictor of MetS across all diagnostic criteria. This finding highlights the central role of glycaemic dysregulation in the early development of MetS and suggests that interventions targeting glucose metabolism may be particularly effective in this study population. The presence of impaired glucose regulation in a relatively young cohort is concerning and may indicate early IR and subsequent hoarding of energy in the form fat and promotion of central adiposity around the abdomen. The diagnostic performance analysis revealed that the H_MS criterion demonstrated the best agreement with the WHO definition, while the IDF criterion showed poor concordance. The superior performance of H_MS criterion is consistent with a study conducted in southeast Nigeria, where the H_MS definition was also reported as the best-performing screening tool amongst WHO, NCEP ATP III, IDF and H_MS [35]. This suggests that the H_MS definition may provide a more balanced and practical approach for screening MetS in young adult populations. Comparable students -based evidence from Nepal showed that H_MS definition criterion identified more MetS cases amongst health science students than IDF, NCEP ATP III, and WHO, which further supports the value of broader criteria in young adults [30-36]. The poor performance of the IDF criterion may be due to its reliance on CO, which may not adequately capture early metabolic abnormalities in this age group. In contrast, studies in young adults from the United Arab Emirates (UAE) have reported strong agreement between IDF and H_MS criterion, suggesting that the performance of IDF may be population specific and strongly influenced by the burden of CO [37,38]. University students represent a critical population for early intervention, including health education, good dietary, and promotion of physical activity, to prevent progression to overt MetS and related non-communicable diseases (NCDs).

Study strengths and Limitation

This study has several strengths, including the use of multiple diagnostic criteria to assess MetS and comprehensive evaluation of biochemical and anthropometric parameters. However, some limitations should be acknowledged. The cross-sectional design limits causal inference, and the study was conducted in a single institution, which may limit generalizability. Additionally, lifestyle factors were self-reported and may be subject to recall bias. The absence of direct measures of IR may also affect the interpretation of the WHO criterion.

Conclusion

This study found a relatively low prevalence of MetS amongst undergraduate students at UTAS, Navrongo, Ghana, although the estimated prevalence varied according to the diagnostic criteria applied. The prevalence was moderate with the IDF criterion identifying the highest proportion of students with Mets. Female students had a higher prevalence of MetS than male students across the diagnostic definitions. Regarding diagnostic performance, the H_MS criterion demonstrated modest discriminatory ability against the WHO criterion as the reference standard. Cohen's Kappa coefficients showed that agreement amongst the diagnostic criteria generally ranged from low to moderate. Overall, these findings demonstrate that the choice of diagnostic criteria influences the estimated prevalence and classification of MetS in the student population. MetS has become a significant public health problem in the contemporary world and great efforts and interventions should be made to create awareness, early health education, lifestyle modifications programs and routine metabolic screening should therefore be prioritised amongst university students and young adults to prevent future cardiometabolic complications.

Declarations

Human Ethics and Consent to Participate

The study protocol was approved by the Institutional Review Board (IRB) of the Navrongo Health Research Centre (NHRC) with study **ID: NHRCIRB667**. The study was conducted in accordance with the relevant ethical guidelines and regulations. Written informed consent was obtained from all participants before data collection.

Clinical trial number

not applicable

Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form that could be used to identify an individual participant.

Data availability

The datasets analysed in this study are obtainable from the corresponding author upon reasonable request.

Competing interests

The authors declare no competing interest.

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Author contributions

Gabriel Nyaaba Donzooya: conceptualisation, methodology, investigation, validation, writing-original manuscript, draft, and review; **Kingsley Enock Nyaah**: conceptualisation, methodology, investigation, validation, writing-original manuscript, draft, and review; **Adonai Yin-Anaab Kunduzore:** conceptualisation, methodology, investigation, validation, writing-original manuscript, draft, and review **Muftawu Yusif Mohammed:** methodology, investigation, supervision, and review; **Samuel Sunyazi Sunwiale:** conceptualisation, validation, supervision, writing-original manuscript, draft, and review; **Auphedeous Yinme Dang-i:** conceptualisation, validation, supervision, writing-original manuscript, draft, and review**; Michael Adu-Frimpong**: conceptualisation, validation, supervision, writing-original manuscript, draft, and review.

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Supplementary Files

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