

Associations Between Dietary Patterns, Lifestyle Factors, and Metabolic Syndrome Components in a Ghanaian Cohort at Baseline of Freeze-Dried Beta Vulgaris (Beetroot) Powder Intervention Study

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ASSOCIATIONS BETWEEN DIETARY PATTERNS, LIFESTYLE FACTORS, AND METABOLIC SYNDROME COMPONENTS IN A GHANAIAN COHORT AT BASELINE OF FREEZE-DRIED *BETA VULGARIS* (BEETROOT) POWDER INTERVENTION STUDY.

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Abstract

Introduction: Metabolic syndrome (MetS) is emerging as a significant issue in Sub-Saharan Africa, including Ghana. This is linked to the nutrition transition and changing lifestyle.

Objective: This study examines the predominant factors contributing to metabolic syndrome at the Abuakwa Polyclinic and Suntreso Government Hospital in the Ashanti Region of Ghana.

Method: A cross-sectional evaluation of 214 participants was conducted using a standard questionnaire, anthropometric measurements, and biochemical analyses. Inferential analyses were conducted using t-tests, chi-square/Fisher's exact tests, binomial exact test, Cohen's kappa, and McNemar's test. Effect sizes were reported, with significance set at $p < 0.05$ using Python 3.12 (SciPy 1.12). Dietary patterns were assessed using a 24-hour recall and food frequency questionnaire (FFQ). Principal component analysis (PCA) and Goldberg analysis were used to determine dietary pattern and whether the reported energy intake is physiologically plausible based on the estimated energy requirement. MetS parameters were defined based on IDF and NCEP ATP III criteria. Descriptive statistics, bootstrap validation, prevalence calculation, risk stratification, analysis were employed for this study.

Results: MetS prevalence was 17.8% and 19.6% based on the IDF and NCEP ATP III criteria respectively, both criteria showed a perfect agreement ($\kappa = 0.877$; 95% CI: 0.794–0.961; $p < 0.001$), whereas 19.6% of the sampled participants have no MetS. Notable gender disparities were observed, with higher MetS prevalence among females than males for IDF and NCEP ATP III (19.4%, 21.1% and 8.8% and 11.8% respectively. Waist circumference and systolic blood pressure were significantly above the clinical threshold ($p < 0.001$), with a higher prevalence observed among female participants. Majority (76.2%) of the participants had El: BMR ratio above the upper cut-off (2.28) based on the Goldberg analysis with higher prevalence among females (78.7%) than males (68.0%). Five dietary patterns were identified, accounting for 3.130 of eigenvalue and total variance and a Phi coefficient of 0.966. Alcohol consumption was linked to elevated triglycerides (OR: 2.31, 95% CI: 1.32–4.05). The overall significant nutrient imbalances were identified, including very high sodium intake (mean 5723 mg/day), with inadequate calcium (452 mg/day) intake.

Conclusion: This baseline analysis identifies distinct dietary patterns and a high burden of MetS components among Ghanaian adults. Findings highlight the importance of culturally tailored dietary interventions targeting specific MetS risk factors in transitioning cohorts.

Trial registration: Pan African Clinical Trial Registry (PACTR) PACTR202512555953324, registered 11th November 2025.

Keywords: Dietary patterns, Metabolic Syndrome, lifestyle factors, principal component analysis.

Introduction

Metabolic syndrome (MetS) is emerging as a significant issue in Sub-Saharan Africa and in Ghana. Individuals afflicted with MetS are projected to have a higher mortality risk from conditions such as stroke and myocardial infarction compared to those unaffected by MetS (Krishna et al., 2024). MetS is characterised by the presence of three or more of the following conditions: elevated plasma glucose, dyslipidemia, elevated blood pressure, abnormal obesity (Zimmet et al., 2005). Abdominal obesity poses a greater risk for heart disease compared to excess fat located in other areas of the body (Chatterjee et al., 2020). Hypertension or prolonged elevation of blood pressure may adversely affect the heart and vascular system (Grundy et al., 2005; Alberti et al., 2009). Elevated blood pressure can also lead to the accumulation of plaque in the arteries (Lien et al., 2025). Atherosclerosis can lead to cardiovascular complications, including myocardial infarctions and cerebrovascular accidents (Lien et al., 2025). This can also impair blood vessels and heighten the risk of thrombosis.

Elevated blood triglyceride levels may increase low-density lipoprotein cholesterol (LDL-C), often referred to as bad cholesterol (Grundy et al., 2005; Alberti et al., 2009). Conversely, reduced high-density lipoprotein cholesterol (HDL-C), often referred to as good cholesterol, impairs reverse cholesterol transport, reducing the removal of excess cholesterol from the walls and enhancing LDL-C clearance. Blood cholesterol levels are essential for cardiovascular health. HDL cholesterol helps remove harmful LDL-C from blood vessels.

Adverse LDL-C levels may promote plaque accumulation in blood vessels (Grundy et al., 2005; Alberti et al., 2009).

The prevalence of MetS is rising speedily globally, especially in underdeveloped countries, due to a shift from traditional diets rich in whole foods to an increased intake of processed, energy-dense foods (Palimaru et al., 2026). In Ghana, increasing westernisation of lifestyles has paralleled the upsurge of cardiometabolic disorders and obesity (Osei-Yeboah et al., 2017). There is a scarcity of national data on MetS prevalence, however, demographic studies report varying findings; 43.8% in the Volta Region and 25.6% in the Ashanti Region by the NCEP ATP III criteria (Osei-Yeboah et al., 2017; Arthur et al., 2013).

In 2007, the prevalence of MetS among diabetics in Ghana was reported as 55.9% based on NCEP-ATP-III criteria (Val-Titty et al., 2008). This prevalence has doubled alongside malnutrition and the upsurge of non-communicable diseases. There is an urgent need to understand the link between dietary patterns, lifestyle factors and MetS components, to tailor interventions and identify high-risk subgroups. This study conducted a cross-sectional baseline analysis of patients at Abuakwa Polyclinic in the Atwima Nwabiagya District and Suntreso Government Hospital in the Kumasi Metropolis, in the Ashanti Region of Ghana, prior to a randomised controlled trial investigating the effects of freeze-dried beetroot powder on the MetS parameters.

2. Materials and Methods

2.1 Study Population

A quantitative cross-sectional design was employed involving 214 participants aged 18 to 65 years sampled from the Outpatients Department of the Abuakwa Polyclinic in the Atwima

Nwabiagya District and the Suntreso Government Hospital in the Kumasi Metropolis, in the Ashanti Region of Ghana. The data was collected as a pre-randomisation baseline for a freeze-dried beetroot powder intervention trial. The International Diabetes Federation (IDF) and the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) diagnostic criteria were used to screen the participants for metabolic syndrome (MetS). Adults seeking medical care at the selected health centres during the recruitment period and met inclusion criteria such as aged between 18-65, has capacity to consent, have one or MetS conditions, are not seriously ill, not pregnant, or convalescing from a recent major surgery, or have no medical condition diagnosed by a medical doctor to preclude safe participation. However, participants with no MetS conditions, pregnant, convalescing from a major surgery, have complicated comorbid conditions were excluded from the study.

2.2 sample size calculations

The sample size calculation for a cross-sectional study was estimated using a single and essentially infinite population, the least sample size is calculated with this formula (Cochran, 1977; Naing et al, 2006):

$n = Z^2 \times P \times (1 - P) \div d^2$

where $Z = 1.96$ for a 95% confidence level, $d = 0.06$ as the absolute margin of error and P is the assumed baseline prevalence of MetS (25.6%), this gives a

calculation

substituting the parameter values into the formula gives

$n = (1.96)^2 \times 0.256 \times (1 - 0.256) \div (0.06)^2$

$n = 3.8416 \times 0.256 \times 0.744 \div 0.0036$

$$n - 0.73717 \text{ divided by } 0.0036$$

n= 204 (rounded up to the nearest whole participants).

The minimum sample was inflated by 10% to complement for anticipated nonresponse, incomplete records and biochemical assay failures. The recruited adjusted recruitment target is

$$n \text{ adjusted} = 204 \text{ divided by } (1 \text{ minus } 0.10) = 204 / 0.90 = 227$$

(Cochran 1977; Naing et al., 2006).

2.3 Data collection

A total of six (6) interviewers or study investigators were trained by registered dietitians for one week prior to the commencement of the study, after which all the interviewers or study investigators conducted a mock interview with the standardised questionnaire and data collection tools for the study. Further to this, an inter-rater reliability checks were also conducted among the six interviewers to establish accuracy among the interviewers in anthropometry measurements such as weight, height, waist circumference and other important anthropometric measurements. The six interviewers measured a subset of the of the participants (30) independently and the resulting measurements were compared to determine consistency between the interviewers. The research data were gathered using an informed-consent questionnaire, clinical assessment, anthropometric measurements, and blood collection for analysis of fasting blood glucose and lipid profiles of the participants. The questionnaire was used to gather data on demographic characteristics, socio-economic status, health conditions, family medical history, smoking and drinking behaviours, physical activity and dietary practices. The physical activity was assessed using an adopted version of the International Physical Activity Questionnaire (IPAQ) to include common Ghanaian activities such as fetching water, pounding fufu, sweeping among others (Craig et al., 2003).

Again, a study specific food frequency questionnaire (FFQ) was developed for this study, some selected foods from MEDFICTS (Meat, eggs, dairy, fried foods, fats in baked foods, convenience foods, fats added at table and snacks) dietary assessment were selected to assess the dietary practices of the study participants (Taylor et al.,2003). The complete MEDFICTS instrument was not used for this present study rather selected food items relevant to cardiovascular health and dietary fat intake were maintained coupled with commonly consumed foods in the Ghanaian food matrix. A 3-day, 24-hour dietary recall was used, and nutrient intake was calculated using the Ghana Food Composition Table.

2.4 Measurement of the Anthropometry and Blood Pressure

Height, weight, waist circumference, hip circumference and blood pressure were measured using standardized protocols and calibrated equipment; a Seca stadiometer (Model: Seca217; India), an Omron blood pressure monitor (Model: HEM-172CM2; Omron, China) and a smart body fat scale (Model: FG2663L, China). Blood pressure measurements were taken in duplicate and averaged. The respondent's waist circumference (WC) was measured at the level of the iliac crest. WC was measured by wrapping a non-elastic tape measure around the top of the hip, mostly around the umbilical cord, while the hip circumference was measured at the widest point of the hips, with the tape measure stretched horizontally and not pressed tightly against the body. Participants were instructed to remove heavy clothing and any unnecessary items that could influence the accuracy of the measurements. Measurements were taken and recorded twice, and the average was used. Waist-to-hip ratio (WHR) was calculated as waist circumference divided by hip circumference, rounded to 1 decimal place.

2.5 Biochemical Data

Respondents' blood samples were collected after an 8–12-hour overnight fast from the left antecubital vein by a qualified phlebotomist. Five millilitres (5 mL) of blood samples were drawn, 1 mL was placed in a fluoride tube and used for the fasting blood sugar (FBS) analyses, and 4 mL were placed into serum gel separator for the analysis of kidney and liver function and lipid profile parameters, specifically total cholesterol, triglycerides and HDL-C. the biochemical analysis were performed at the Central laboratory (CanLAB) at Kwame Nkrumah University of Science and technology.

2.6 Data analysis

Data were analysed using the IBM Statistical Package for the Social Sciences (SPSS) version 25. Descriptive statistics, PCA for dietary patterns, and logistic regressions were performed. Categorical variables were presented as frequencies and percentages, continuous variables as means $\pm$ SD. Inferential analysis was performed using t-tests, chi-square/Fisher's exact tests, binomial exact test, Cohen's kappa, and McNemar's test. Effect sizes were reported, with significance set at $p < 0.05$ using Python 3.12 (SciPy 1.12).

2.7 Human Ethics and consent to Participate declaration

Ethical approval was obtained from the Committee on Human Research, Publication, and Ethics, School of Medical Sciences, Kwame Nkrumah University of Science and Technology (KNUST) (CHRPE/AP/1010/25). The KNUST ethical review process firmly adheres to the international standards stipulated for human subject's research. The study strictly followed and conducted the research in full accordance with the ethical principles stated in declaration of Helsinki. Prior to the commencement of the study, all the participants were

explicitly educated about the aims and other standards that governs participation in the study including right to cease participation at any time without providing a reason or facing any penalty. Written informed consent was obtained from all participants prior to the commencement of the study.

The clinical trial was registered with Pan African Clinical Trial Registry (PACTR) under registration number (PACTR202512555953324) submitted on 11th November 2025 and approved on the 4th of December 2025.

3. RESULTS

3.1 Demographics

Table 1 shows that majority (41.12%) of the participants were mainly between 50-59 years, while 7.48% of the sample participants were young adults below 30 years. Females outnumbered the men by a ratio of 3.3 to 1. 76.6% and 23.4% respectively.

The majority (51.87%) had completed Junior High School, while a small number (14.5%) completed tertiary education.

Table 1: sample demographics (N=214)

Variable	Category	N	%
Age group	Less than 30	16	7.5
	30 to 39	19	8.9
	40 to 49	49	22.90
	50 to 59	88	41.1
	60 or greater	42	19.6
Sex	Female	164	76.6

	Male	50	23.4
Education	Junior High School	111	51.87
	Senior High School	36	16.82
	Tertiary	31	14.5
	Primary	26	12.15
	Vocational	2	0.93
	Technical	3	1.40
	Never attended	5	2.34
Marital status	Married	124	57.94
	Single	51	23.83
	Widowed	23	10.75
	Divorced	16	7.48
Employment (n = 197)	Informal	168	78.50
	Formal	46	21.50

3.2 Disease Knowledge & Lifestyle

Table 2 presents participants' knowledge and education related to chronic disease management. More than half of the participants (55.6%) reported being aware of side effects associated with their chronic condition, whereas 31.8% indicated no such knowledge. The majority (83.6%) reported having received nutritional education. With respect to behavioural factors, 6.5% reported current smoking, while 39.3% and 21.5 % reported past and current alcohol consumption, respectively.

Table 2: Disease Knowledge & Lifestyle (n=214)

Variable	Category	Count	Percentage (%)
Experienced Drug Side Effects?	No	157	73.4
	Yes	37	17.3

Variable	Category	Count	Percentage (%)
Do you know the long-term effects?	Not applicable	20	9.3
	Yes	119	55.6
	No	68	31.8
Received Disease Education?	Not applicable	27	12.6
	Yes	125	58.4
	No	62	29.0
Received Nutritional Education?	Not applicable	27	12.6
	No	179	83.6
	Yes	35	16.4
Ever Smoked?	No	200	93.5
	Yes	14	6.5
Ever Used Alcohol?	No	130	60.7
	Yes	84	39.3
Currently Drinks Alcohol?	No	168	78.5
	Yes	46	21.5

3.3 Chronic Disease & Medication

Figures 1 and 2 present medications and adherence among the participants. The majority (87.4%) reported at least one chronic condition, with hypertension (75.2%) and diabetes (60.7%) being the most prevalent. Medication adherence was reported (73.8%) for those

receiving treatment. Amlodipine was the most used medication (52.8%, n=113), followed by Nifedipine (38.8%, n=83), while other medications were used by 31.3% (n=67).

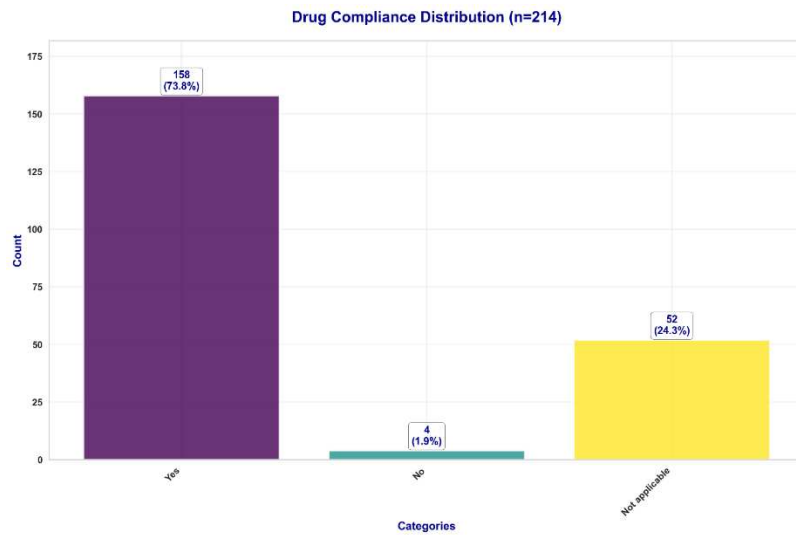


Figure 1: Drug compliance among participants

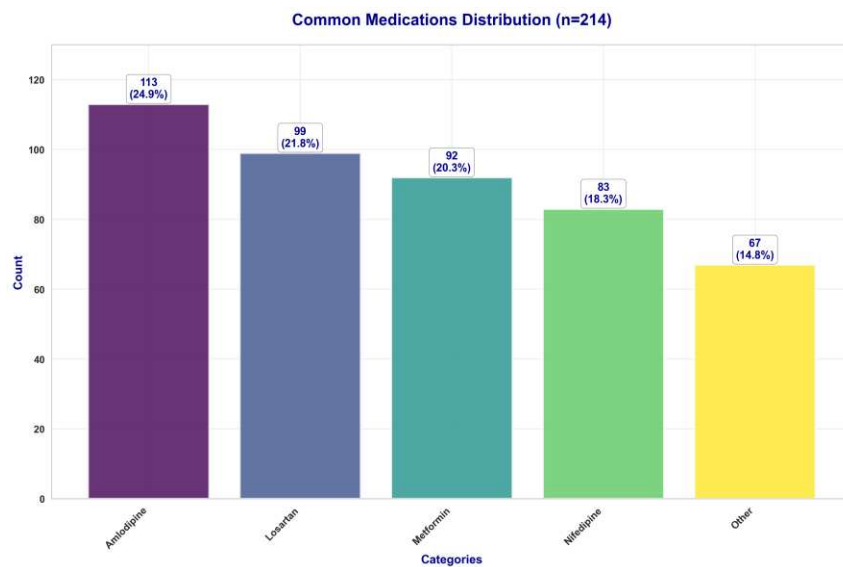


Figure 2: The most used medications among participants

3.4 Physical Activity

Figure 3 shows a 7-day mode for all activities used to assess the frequency of physical activity among the respondents. Engagement in vigorous activity, recreational physical activity and walking/dancing was reported, indicating the presence of potentially protective lifestyle behaviours relevant to chronic disease management

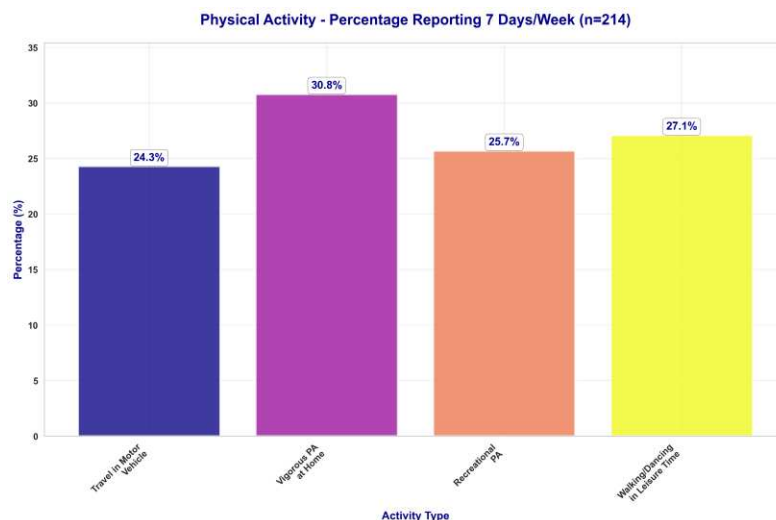


Figure 3: Physical activity levels among participants

3. 5 Dietary Intake and Reporting Validity (Goldberg Analysis)

Table 3 presents a predictive equation by Schofield, Harris Benedict and Mifflin St Jeor to estimate basal metabolic rate (kcal per day) among the participants.

Table 3. Predictive equations used to estimate basal metabolic rate (kcal per day).

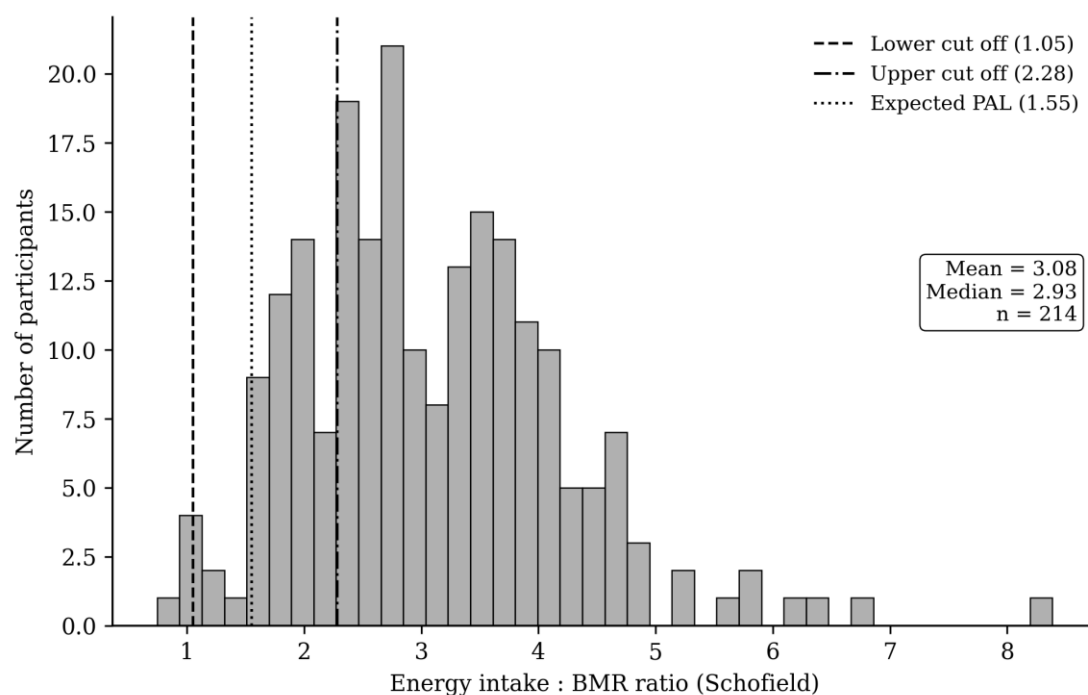
Equation and sex or age band	Formula
Schofield, Female, less than 30 y	$BMR = 14.818 W + 486.6$
Schofield, Female, 30 to 60 y	$BMR = 8.126 W + 845.6$
Schofield, Female, greater than 60 y	$BMR = 9.082 W + 658.5$
Schofield, Male, less than 30 y	$BMR = 15.057 W + 692.2$
Schofield, Male, 30 to 60 y	$BMR = 11.472 W + 873.1$
Schofield, Male, greater than 60 y	$BMR = 11.711 W + 587.7$
Harris Benedict revised, Female	$BMR = 447.593 + 9.247 W + 3.098 H$, minus 4.330 A
Harris Benedict revised, Male	$BMR = 88.362 + 13.397 W + 4.799 H$, minus 5.677 A
Mifflin St Jeor, Female	$BMR = 10 W + 6.25 H$, minus 5 A, minus 161
Mifflin St Jeor, Male	$BMR = 10 W + 6.25 H$, minus 5 A, plus 5

Note. W = weight in kg, H = height in cm, A = age in years

3.5.1` Determiation of the individual cut offs

Participants' individual energy needs were classified based on a 3 day 24-hour recall, with an assumed physical activity level (PAL =1.55) in accordance with a standard protocol, within subject coefficients of variation of 23% for energy intake, 8.5% for BMR and 15% for PAL. The confidence factor is the exponential of plus and minus 2 times the pooled standard deviation of the ratio. This yields a lower cut of 1.05 and upper cut off of 2.28 as over reporters, and those in the closed intervals as plausible reporters.

Figure 4 shows the distribution of the energy intake -t- BMR (EI: BMR) ration among the participants Only a very small percentage of the participants fell within or below the accepted Goldberg cutoff range whereas the majority were classified as overreporting of energy intake.



. Note. Dashed line: lower cut off of 1.05. Dash dotted line: upper cut off of 2.28. Dotted line: expected PAL of 1.55 for a moderately active adult. $n = 214$.

Figure 4. Distribution of the EI:BMR ratio (Schofield equation) and individual cut-offs on Black (2000). The lower cut-off (1.05) shows underreporting, the upper cut-off (2.28) shows upper cut-off, and the expected PAL is 1.55.

3.5.2 Descriptive Statistics of Energy Intake and BMR

Table 4 shows a mean energy intake among the participants showing the mean and media values for all the participants and also for male ale and females used for the study.

Table 4. Descriptive statistics of reported energy intake estimated BMR, and EI:BMR ratio ($n = 214$).

Variable and subgroup	Mean	SD	Median	Q1	Q3	Min	Max
Energy intake (kcal per day), all	4,571	1,587	4,308	3,472	5,719	1,244	11,321
BMR Schofield (kcal per day), all	1,503	183	1,457	1,385	1,602	1,137	2,035
EI:BMR ratio, all	3.08	1.13	2.93	2.31	3.77	0.75	8.39

Energy intake (kcal per day), female	4,497	1,560	4,231	3,446	5,462	1,414	11,321
BMR Schofield (kcal per day), female	1,430	111	1,429	1,356	1,489	1,137	1,816
EI:BMR ratio, female	3.17	1.16	2.96	2.35	3.87	1.05	8.39
Energy intake (kcal per day), male	4,815	1,666	4,636	3,600	6,009	1,244	7,967
BMR Schofield (kcal per day), male	1,743	168	1,772	1,641	1,847	1,297	2,035
EI:BMR ratio, male	2.79	0.99	2.67	1.98	3.55	0.75	4.87

Note. Female n = 164; male n = 50.

3.5.3 Goldberg Classification of Reporters

Figure 5 shows the classification of dietary reporters among the 214 participants with majority of the participants classified as over reporters (76.2%) and plausible reporters (22.4%) with higher prevalence among females (78.7%) than males (68.0%).

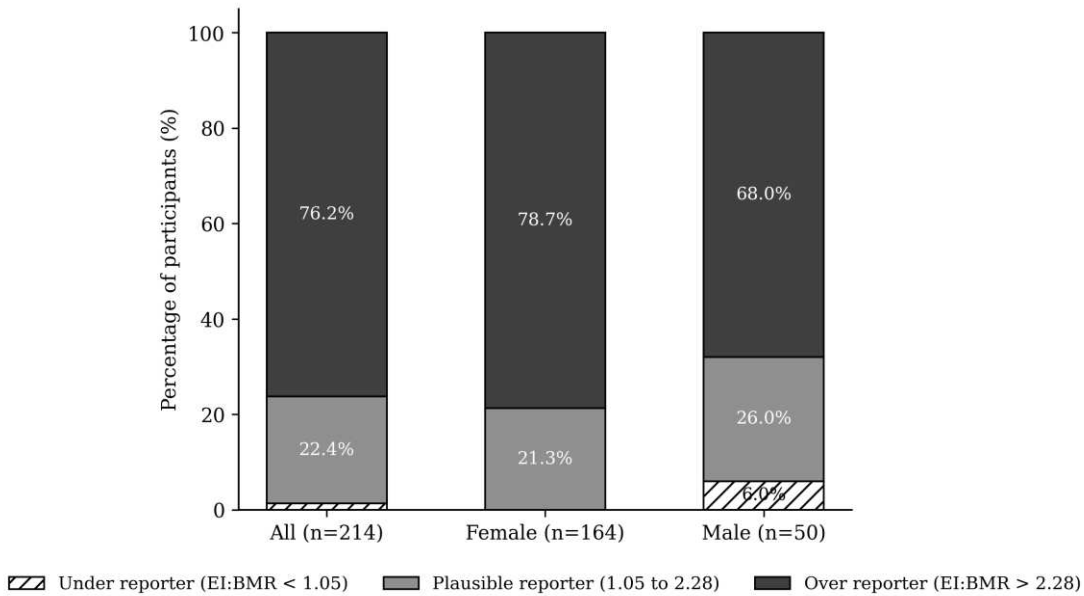


Figure 5. Goldberg reporter classification overall and by sex.

Table 5 shows the confidence intervals for the various reporting categories among the participants with its gender disparities

Table 5. Goldberg reporter classification with 95% confidence intervals (n = 214).

Reporting category	All n (%) [95% CI]	Female n (%) [95% CI]	Male n (%) [95% CI]
Under reporter (EI:BMR less than 1.05)	3 (1.4%) [0.5, 4.0]	0 (0.0%) [0, 2.3]	3 (6.0%) [2.1, 16.2]
Plausible reporter (1.05 to 2.28)	48 (22.4%) [17.4, 28.5]	35 (21.3%) [15.8, 28.2]	13 (26.0%) [15.9, 39.6]
Over reporter (EI:BMR greater than 2.28)	163 (76.2%) [70.0, 81.4]	129 (78.7%) [71.8, 84.2]	34 (68.0%) [54.2, 79.2]
Total	214 (100.0%)	164 (100.0%)	50 (100.0%)

Note. 95% CIs are Wilson score intervals for a binomial proportion.

Table 6 shows numerical summary for the classification of dietary reporters derived from Mifflin St Joer, Harris Benedict and Schofield equations. The results show that a very large majority of participants were classified as over reports, plausible reporters and under reporters with (163, 76.2%), 48 (22.4%), 3 (1.4%) respectively.

Table 6. Numeric summary of Goldberg classification under three BMR predictive equations (n = 214).

Reporting category	Schofield n (%)	Harris Benedict n (%)	Mifflin St Jeor n (%)
Under reporter (EI:BMR less than 1.05)	3 (1.4%)	3 (1.4%)	2 (0.9%)
Plausible reporter (1.05 to 2.28)	48 (22.4%)	47 (22.0%)	37 (17.3%)
Over reporter (EI:BMR greater than 2.28)	163 (76.2%)	164 (76.6%)	175 (81.8%)

Figure 6 shows classification of dietary reporters derived from Mifflin St Jeor, Harris Benedict and Schofield equations. The figure shows that Mifflin St Jeor equation shows the least value for under reporter, plausible reporter and a highest value for over reporter whereas Schofield's equation had the highest value for plausible report and equal value just as Harris Benedict's equations.

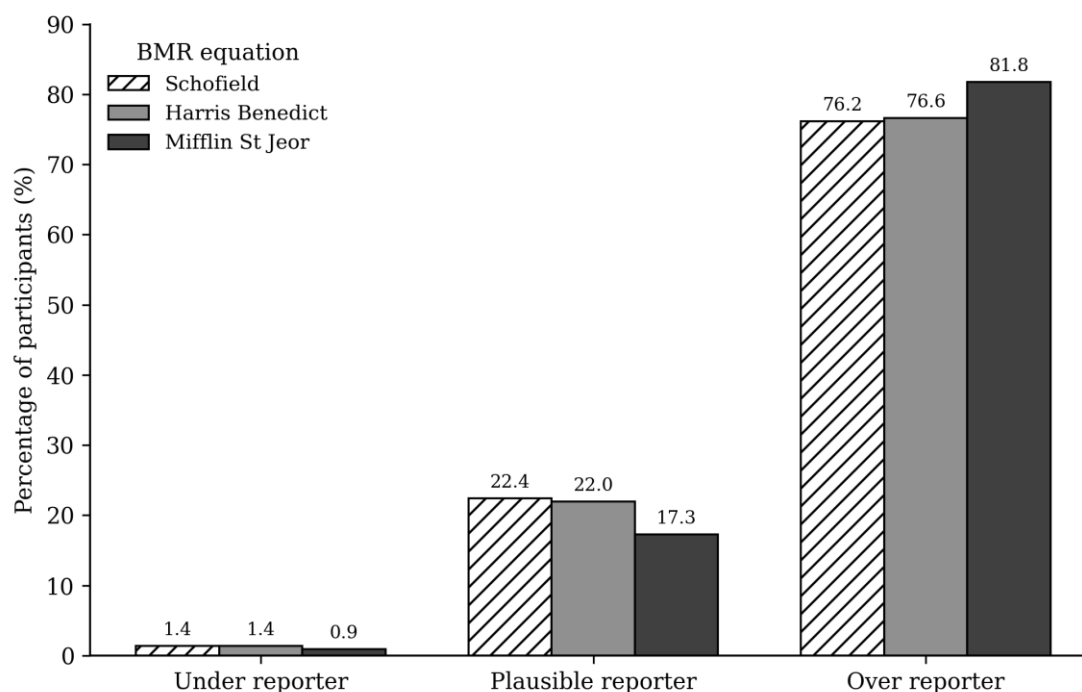


Figure 6. Sensitivity of Goldberg classification to the choice of BMR equation (n = 214).

3.5.2.1 Nutrient intake summary

Table 7 shows high energy and carbohydrates intake and very high sodium intake. Calcium intake was low with individual protein and fat intake.

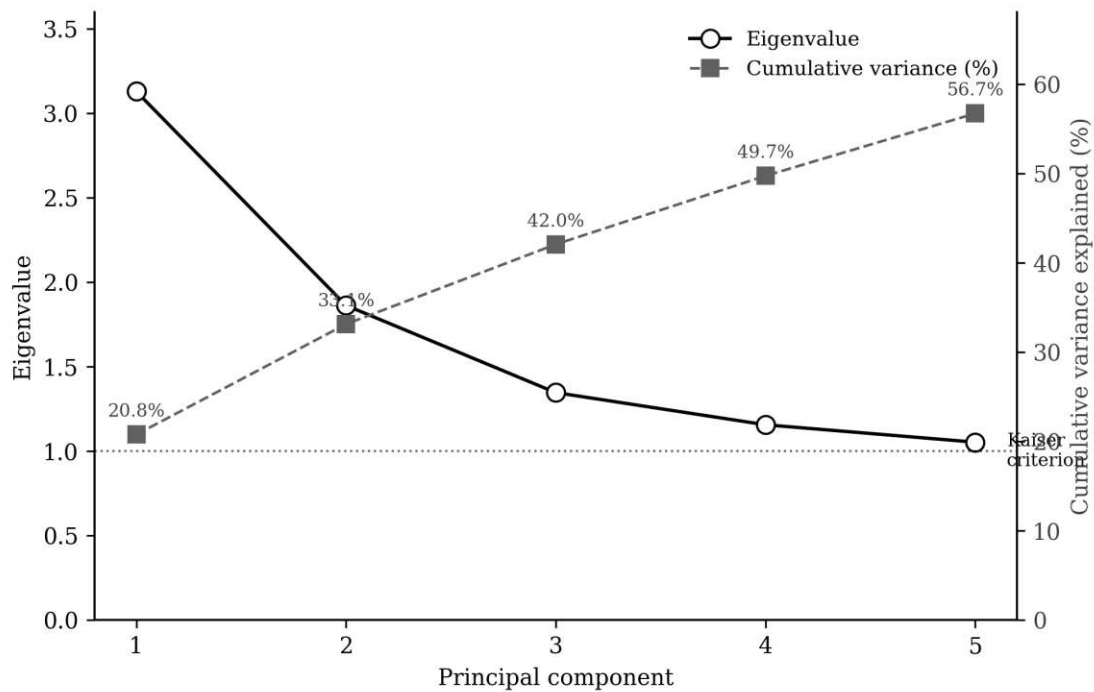
Table 7: summarizes key macronutrient and mineral intakes of the participants

Variable	Mean	SD	Median	Range
Energy intake (kcal per day)	2,847	570	2,820	1,414 to 4,169
Protein (g per day)	78.03	22.85	74.72	36.66 to 152
Total fat (g per day)	77.30	34.96	71.55	15.21 to 173
Carbohydrates (g per day)	476	105	483	287 to 786
Dietary fibre (g per day)	41.76	11.62	42.76	11.42 to 77.13
Sodium (mg per day)	5,723	1,640	5,955	1,557 to 8,468
Calcium (mg per day)	452	205	393	160 to 1,293
EI:BMR (Schofield)	1.83	0.29	1.87	1.05 to 2.27

4.5 Dietary Patterns

4.5.1 Component Extraction and Variance Explained

A standard questionnaire was used to obtain and code frequency data for 15 food groups for principal component analysis (PCA) by the participants who responded to the food frequency questionnaire. Figure 7 shows the eigenvalue and cumulative variance of the PCA. 1-5. The dotted horizontal line shows Kaiser criterion which shows that all the five components have eigenvalue greater than one 1, all the five components explained 56.7% of the total variance in the FFQ data.



Note. Dotted horizontal line marks the Kaiser criterion (eigenvalue of 1). Five components exceed this threshold and were retained.

Figure 7. Scree plot of principal component eigenvalues and cumulative variance explained.

Table 8 further shows the eigenvalue for all the components of the PCA 1-5 against its individual variance explained and the cumulative variance.

Table 8. Eigenvalues and variance explained by the five retained principal components (n = 199).

Component	Eigenvalue	Variance explained (%)	Cumulative variance (%)
PC1	3.130	20.76	20.76
PC2	1.863	12.36	33.12
PC3	1.347	8.93	42.05
PC4	1.156	7.67	49.72
PC5	1.053	6.98	56.70

4.5.2 Interpretation of Extracted Patterns

Table 9 gives interpretations to the various components of PCA 1-5. PC1 (20.8% variance): Traditional Whole Foods Pattern. Highest positive loadings for soups (0.422), leafy vegetables (0.366), stews or sauces (0.350), traditional staples (0.343), and rice-based staples (0.340). This pattern is consistent with culturally familiar home prepared meals.

PC2 (12.4% variance): Modern and Processed Foods versus Traditional Vegetables. Positive loadings for nonalcoholic beverages (0.388), dairy (0.376), processed foods (0.367), and meat or poultry (0.318), with negative loadings for other staples (-0.330) and other vegetables (-0.291). This contrast reflects the ongoing nutrition transition.

PC3 (8.9% variance): Fruits and Beverages versus Oils. Positive loadings for fruits (0.535) and non- alcoholic beverages (0.460), with a strong negative loading for oils and fats (-0.505).

PC4 (7.7% variance): Alcohol and Other Staples versus Other Vegetables. Positive loadings for alcoholic beverages (0.572) and other staples (0.347), and a negative loading for other vegetables (-0.443).

PC5 (7.0% variance): Seafood versus Alcohol. Positive loading for fish or seafood (0.735), with a negative loading for alcoholic beverages (-0.451).

Table 9. Component loadings for the five principal components retained across the 15 food group frequency variables.

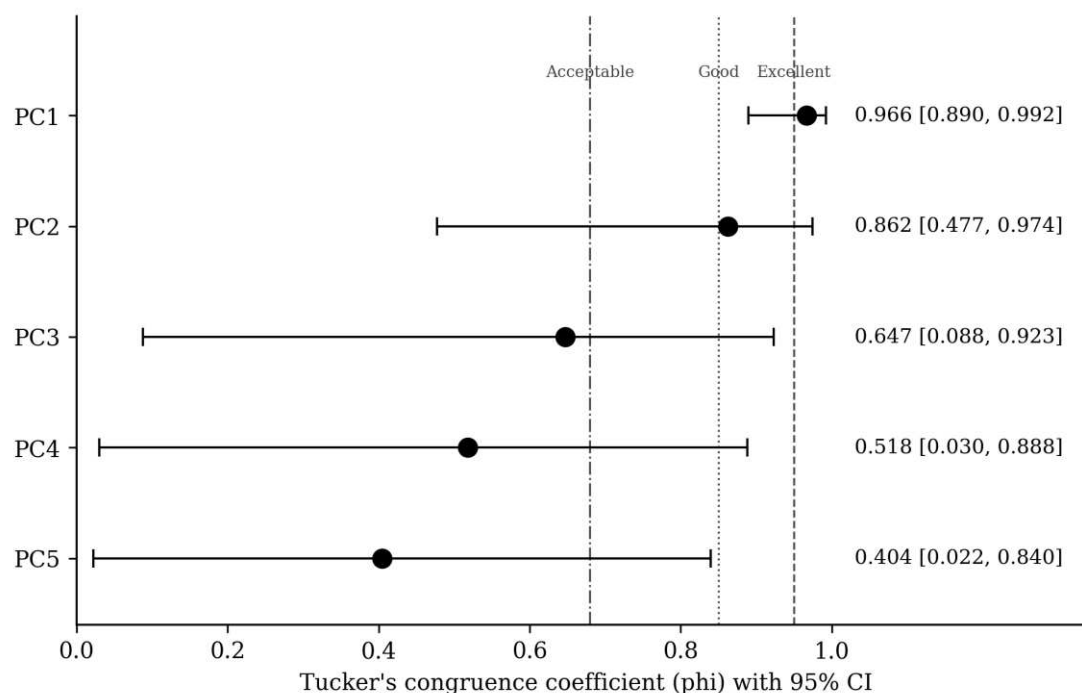
Food group	PC1	PC2	PC3	PC4	PC5
Fruits	+0.165	-0.072	+0.535	+0.097	+0.229
Other vegetables	+0.285	-0.291	-0.025	-0.443	-0.098
Leafy vegetables	+0.366	-0.266	+0.098	-0.157	-0.168
Stews or sauces	+0.350	-0.202	-0.154	-0.094	-0.042
Soups	+0.422	-0.050	+0.144	+0.209	-0.095
Traditional staples	+0.343	-0.010	+0.067	+0.083	+0.014
Rice staples	+0.340	+0.275	-0.183	-0.002	-0.054
Other staples	+0.213	-0.330	-0.124	+0.347	-0.111
Oils or fats	+0.187	+0.273	-0.505	+0.242	+0.168
Fish or seafood	+0.182	-0.060	-0.014	+0.265	+0.735
Meat or poultry	+0.140	+0.318	-0.186	-0.275	-0.149
Dairy	+0.210	+0.376	+0.252	+0.066	-0.233
Alcoholic beverages	-0.059	-0.078	-0.160	+0.572	-0.451
Non alcoholic beverages	+0.058	+0.388	+0.460	+0.160	-0.118
Processed foods	+0.199	+0.367	-0.124	-0.167	+0.142

Variance explained (%)	20.76	12.36	8.93	7.67	6.98
Cumulative variance (%)	20.76	33.12	42.05	49.72	56.70

Note. Loadings represent the correlation between each food group frequency variable and the principal component. Absolute values greater than 0.30 are conventionally considered salient contributors to component interpretation and are bolded in the pattern descriptions in Section 4.5.2. Signs are informative for interpretation: variables with the same sign co occur, those with opposite signs are inversely related within the component. Extraction method: PCA on the sample correlation matrix. Rotation: unrotated component loadings.

4.5.3 Bootstrap Validation of Component Structure

Figure 8 shows the Tucker phi with 95% Confidence Interval (CI) for each of the five retained components. The interpretive thresholds are phi of 0.95 or greater for excellent, 0.85 to 0.95 for good, 0.68 to 0.85 for acceptable, and less than 0.68 for poor. PC1 (Traditional Whole Foods) is highly stable (phi = 0.966) whereas PCA 5 have wider confidence intervals extending well into the poor stability range and should be treated as exploratory.



Note. Reference lines mark Lorenzo Seva and ten Berge (2006) thresholds: ϕ of 0.68 (acceptable), 0.85 (good), and 0.95 (excellent). PC1 (Traditional Whole Foods) is highly stable ($\phi = 0.966$); PC2 also reaches good stability on average ($\phi = 0.862$), while PC3 through PC5.

Figure 8. Bootstrap validation of principal components using Tucker's congruence coefficient (ϕ) with 95% CIs (B = 1,000 iterations).

3.7 Metabolic Syndrome Analysis

3.7.1 Risk stratification analysis

Risk stratification in table 10 shows that 80.4% of the sampled participants have at least one MetS component. Only 19.6% of participants have no metabolic abnormalities, suggesting that most of the population would benefit from some form of metabolic health intervention. The results evidence the need for effective dietary interventions based on individual profiles.

Table 10: Risk Stratification by Number of MetS Components

Number of Components	Count	Percentage	Risk Level
0	42	19.6%	Low Risk
1	65	30.4%	Moderate Risk
2	65	30.4%	High Risk
3+ (MetS)	42	19.6%	Very High Risk

3.7.2 Classification and Diagnostic agreement: IDF vs NCEP ATP III

A cross-tabulation in table 11 indicate that IDF and NCEP ATP III used to define MetS among the 214 participants; 36 participants had MetS for both criteria, while 170 did not. Again, 2 of the participants were classified as IDF positive (+) but NCEP ATP III negative (-), whereas 6

participants were classified as MetS-positive (+) for NCEP ATP III negative and MetS-negative (-) for IDF.

Table 11: Classification cross-table: IDF vs NCEP ATP III (N= 214)

	NCEP MetS (+)	NCEP MetS (-)	Row Total
IDF MetS (+)	36	2	38
IDF MetS (-)	6	170	176
Column Total	42	172	214

Table 12 explains further to this, the two criteria (IDF AND NCEP ATP III) showed perfect agreement ($\kappa = 0.877$; 95% CI: 0.794–0.961; $p < 0.001$), with 96.2% overall concordance. McNemar's test confirmed no systematic directional bias ($\chi^2 (1) = 2.000$, $p = 0.157$). NCEP ATP III identified slightly more MetS cases ($n = 42$, 19.6%) than IDF ($n = 38$, 17.8%), consistent with NCEP's more inclusive fasting glucose threshold. Both criteria provide equivalent MetS classification in this Ghanaian outpatient population.

Table 12. Agreement statistics: IDF vs NCEP ATP III MetS classification.

Statistic	Value	95% CI	p-value	Interpretation
Observed agreement (P_o)	0.962	—	—	High concordance
Cohen's kappa (κ)	0.877	[0.794, 0.961]	$< 0.001^*$	Almost perfect
McNemar $\chi^2(1)$	2.000	—	0.157	No systematic bias
IDF MetS prevalence	17.8%	[12.8, 23.6%]	—	38/214
NCEP ATP III prevalence	19.6%	[14.4, 25.6%]	—	42/214

Note. * $p < 0.05$. kappa benchmarks (Landis & Koch, 1977): 0.81–1.00 = almost perfect agreement. McNemar H_0 : no systematic directional asymmetry in discordant classifications.

The corresponding figure 9 gives a visual representation of the agreement matrix and summarizes the major agreement statistics between IDF and NCEP ATP III diagnostic criteria.

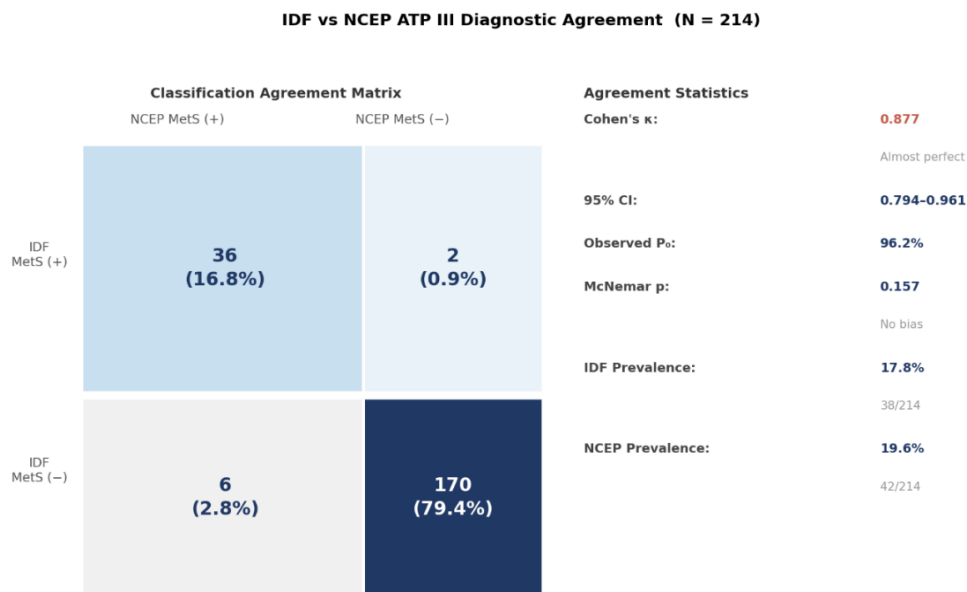


Figure 9. Classification agreement matrix and agreement statistics for IDF vs NCEP ATP III MetS criteria (N = 214). *Left: heatmap of cross-classified MetS counts with proportions. Right: summary of agreement statistics including Cohen's κ , 95% CI, and McNemar test result.*

3.7.3 Risk stratification by MetS component burden

Figure 10 present the risk stratification of the studied population. 80.4% of participants had at least one MetS component, indicating a high overall cardiometabolic risk. Only 19.6% (n = 42) had no MetS components (low risk); 30% (n = 65) had one component (moderate risk), and a further 30.4% (n = 65) had two components (high risk), placing them at the threshold for MetS

diagnosis. 19.6% classified as having MetS (≥ 3 components; $n = 42$) represent the highest-risk subgroup requiring immediate clinical intervention. Participants were categorised by the number of MetS components present to characterise the distribution of cardiometabolic risk burden across the full baseline sample.

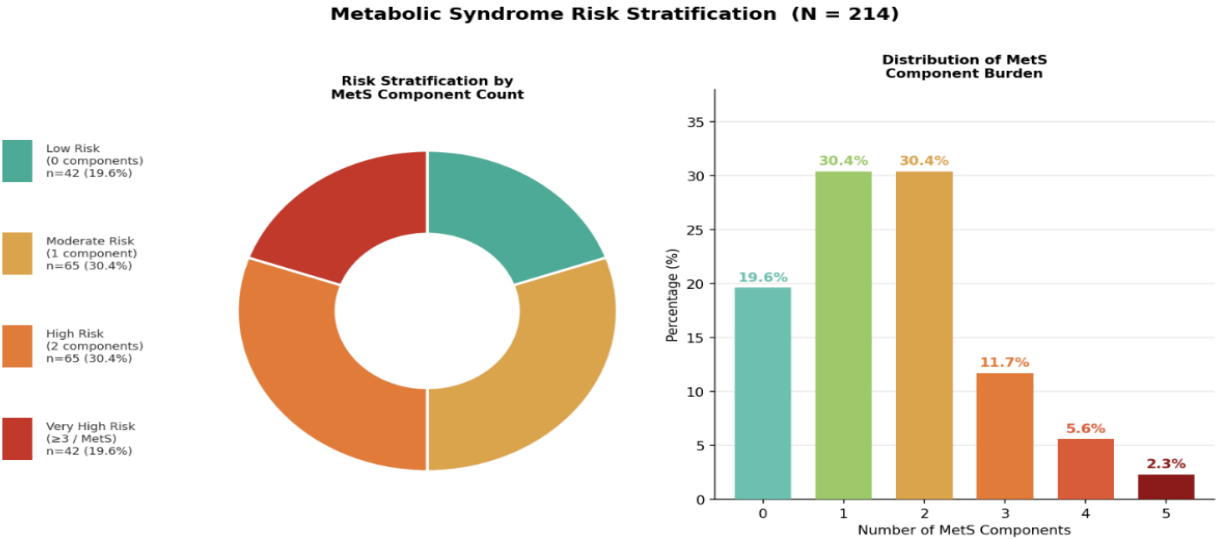


Figure 10. Risk stratification by MetS component burden (N = 214). *Left: donut chart showing distribution across risk categories. Right: bar chart of MetS component burden distribution. Colours: green = low risk, yellow green = moderate, orange = high, red = very high (MetS).*

3.8 Individual MetS Component Analysis

The analysis of the individual MetS components, as shown in table 13, reveals distinct patterns of metabolic dysfunction that will inform targeted dietary interventions. The table presents individual prevalence, and case counts for MetS risk parameters among participants. Participants were

grouped based on a standard criterion to assess whether they met or exceeded the diagnostic threshold using IDF and NCEP ATP III. Further to this, the table provides insight into which MetS conditions are most prevalent in the studied population, serving as an important indicator of the population's overall categorical health risk.

Table 13: Individual MetS Component Prevalence

Component	Cases	Prevalence (%)	Criteria Used
Elevated Waist Circumference	160	74.8%	♀ ≥ 80 cm, ♂ ≥ 94 cm
Low HDL Cholesterol	70	32.7%	♀ < 1.3 , ♂ < 1.03 mmol/L
Elevated Blood Pressure	66	30.8%	$\geq 130/85$ mmHg
Elevated Fasting Glucose	44	20.6%	≥ 5.6 mmol/L
Elevated Triglycerides	25	11.7%	≥ 1.7 mmol/L

3.9 Metabolic Parameters and Clinical Reference Values

Table 14 present a one-sample t-test comparing nine MetS parameter baselines against their clinical thresholds. Waist circumference (WC) was compared with IDF WC threshold (≥ 80 cm), given that 76.6% of the sample were female. Significant departures from clinical norms are highlighted.

Table 14: One-sample t-test results for baseline metabolic parameters (N=214).

Parameter	Mean $\pm$ SD	Reference	t (213)	p-value	95% CI	Cohen's d

Waist Circumference (cm)	97.8 ± 15.2	< 80 (F)	17.13	< 0.001*	[95.76, 99.84]	1.171
Fasting Glucose (mmol/L)	5.8 ± 2.4	≤ 5.5	1.83	0.069	[5.48, 6.12]	0.125
HbA1c (%)	5.6 ± 1.6	< 5.7	-0.91	0.362	[5.39, 5.81]	-0.063
Triglycerides (mmol/L)	1.2 ± 0.4	< 1.7	-18.29	< 0.001*	[1.15, 1.25]	-1.250
HDL Cholesterol (mmol/L)	1.8 ± 0.3	> 1.3 (F)	24.38	< 0.001*	[1.76, 1.84]	1.667
Total Cholesterol (mmol/L)	4.8 ± 1.0	< 5.2	-5.85	< 0.001*	[4.67, 4.93]	-0.400
LDL Cholesterol (mmol/L)	2.4 ± 0.8	< 3.4	-18.29	< 0.001*	[2.29, 2.51]	-1.250
Systolic BP (mmHg)	136.1 ± 19.8	< 130	4.51	< 0.001*	[133.45, 138.75]	0.308
Diastolic BP (mmHg)	84.3 ± 12.3	< 85	-0.83	0.406	[82.65, 85.95]	-0.057

Note. * $p < 0.05$. F = female-specific reference. Cohen's d: |0.2| small, |0.5| medium, |0.8| large.

Reference sources: IDF (waist), AHA/ACC (BP), NCEP ATP III (lipids), WHO (glucose), ADA (HbA1c).

3.10 Gender Differences in MetS Prevalence

Figure 11 show the relationship between biological sex and MetS parameters under both IDF and NCEP-ATP III diagnostic criteria. A higher prevalence rate was observed among females (19.4; 21.1%%) than males (8.8%;11.8%) for both IDF and NCEP ATP III diagnostic criteria respectively.

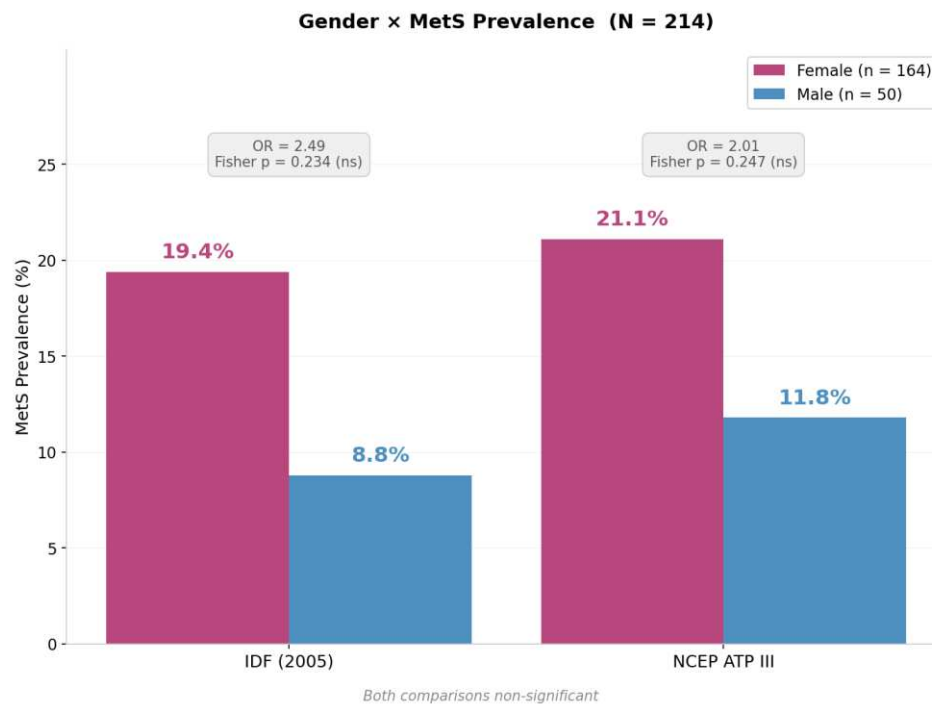


Figure 11: Gender-stratified MetS prevalence under IDF and NCEP ATP III criteria (N = 214). *Bar heights = group prevalence (%). OR and Fisher p displayed above bars. Both comparisons non-significant, though females show approximately twice the odds of MetS.*

3.10.1 Age -stratified MetS Prevalence

Tables 15 show the prevalence of MetS under both criteria (IDF & NCEP ATP III), across the various age groups with age bracket. The prevalence of MetS is 17.8% and 19.6% based on IDF and NCEP ATP III respectively.

Table 15: Age-stratified prevalence (N= 214).

Age Group	N	IDF Cases	IDF Prev.	NCEP Cases	NCEP Prev.
< 30 years	28	2	7.1%	2	7.1%
30–39 years	20	2	10.0%	3	15.0%
40–49 years	70	13	18.6%	14	20.0%
50–59 years	91	19	20.9%	21	23.1%
≥ 60 years	5	2	40.0%	2	40.0%
Total	214	38	17.8%	42	19.6%

Table 16 shows the chi-square tests of independence to assess significant associations between the variables and a Spearman's rank correlation test using age-group midpoints.

Table 16. Chi-square and trend test results for age-stratified MetS prevalence.

Test	Criterion	Statistic	Df	p-value	Interpretation
Chi-square	IDF	$\chi^2 = 5.32$	4	0.256	Non-significant
Chi-square	NCEP ATP III	$\chi^2 = 5.05$	4	0.283	Non-significant
Trend (Spearman r_s)	IDF	$r_s = 1.000$	—	$< 0.001^*$	Perfect monotonic trend
Trend (Spearman r_s)	NCEP ATP III	$r_s = 1.000$	—	$< 0.001^*$	Perfect monotonic trend

Note. * $p < 0.05$. Spearman trend test uses age-group midpoints: 25, 34.5, 44.5, 54.5, 65 years.

Chi-square non-significance is partly attributable to a small ≥ 60 group ($n = 5$).

Figure 12 shows a monotonic increasing trend in the prevalence of MetS as the study population ages. The figure shows that prevalence begins at approximately 7.1% in the youngest population (Age < 30) and increases steeply to 40% in the oldest population (Age ≥ 60). The graph further shows that the prevalence of MetS increases with age. The Spearman's rank correlation coefficient of $r_s = 1.000$ ($p < 0.001$).

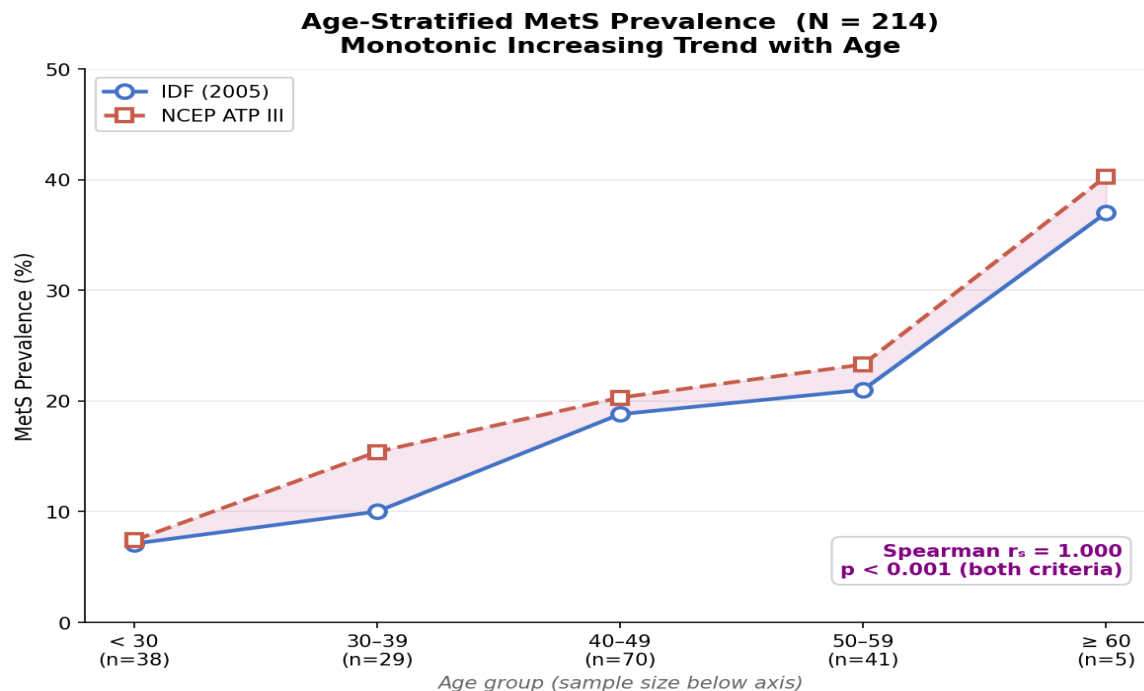


Figure 12. Age-stratified MetS prevalence under IDF and NCEP ATP III criteria with monotonic trend (N = 214). Lines connect group-specific prevalence values. Shaded area = difference between criteria. n shown below x-axis. Spearman $r_s = 1.000$ ($p < 0.001$) confirms perfect monotonic increase with age.

3.10.2 Alcohol consumption and elevated triglycerides

Table 17 show the association between current alcohol consumption and elevated triglycerides using a 2×2 contingency table reconstructed from reported marginal totals.

Table 17. Alcohol consumption × Elevated triglycerides (N = 214).

Group	N	Elevated TG	% Elevated	Normal TG	% Normal
Current drinkers	46	9	19.6%	37	80.4%
Non-drinkers	168	16	9.5%	152	90.5%
Total	214	25	11.7%	189	88.3%

Table 18 shows that both Pearson's chi square (p 0.060) and Fisher's exact = (p 0.072) show a trend to higher odds of elevated TG among drinkers though both did not reach standard statistical significance (p <0.05).

Table 18. Inferential statistics: Alcohol and elevated triglycerides.

Test	Statistic	Df	p-value	OR	95% CI
Pearson chi-square	$\chi^2= 3.529$	1	0.060	2.31	0.96–5.56
Fisher's exact	—	—	0.072	2.31	0.96–5.56
Adjusted OR (logistic regression)	—	—	Reported	2.31	1.32–4.05

Note. TG = triglycerides (elevated ≥ 1.7 mmol/L, NCEP ATP III). Unadjusted chi-square is more conservative than the adjusted logistic regression OR.

Figure 13 shows that alcohol consumption and elevated TG among current drinkers was 19.6% as against non-drinkers (9.5%) among the participants.

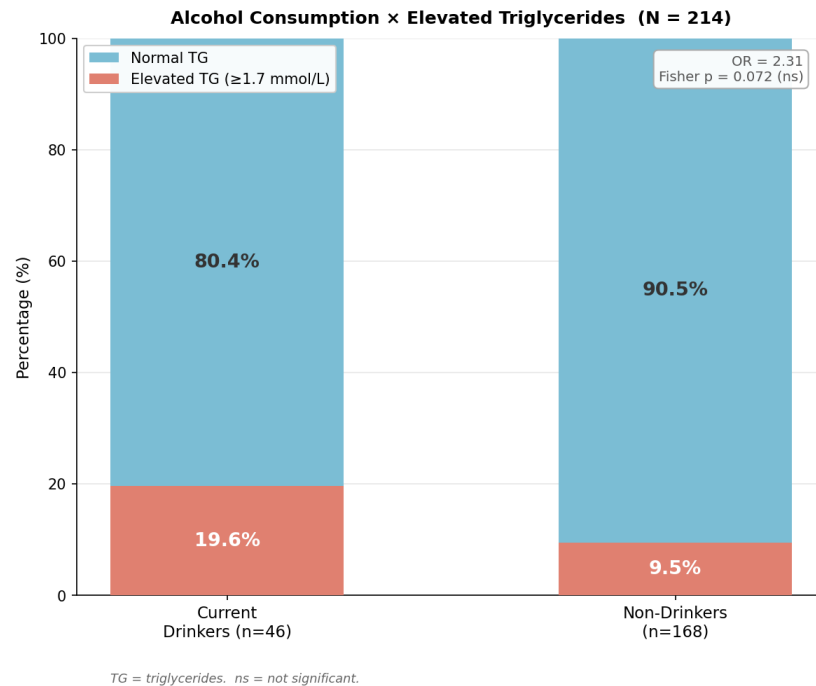


Figure 13. Stacked bar chart of triglyceride status by alcohol consumption group (N = 214). *Red* = elevated TG (≥ 1.7 mmol/L); *Blue* = normal TG. Percentages shown within bars. OR = 2.31; Fisher $p = 0.072$ (borderline). ns = not significant at $p < 0.05$.

3.11 MetS Component Prevalence: Binomial Exact Test

Table 19 shows that 2 major components (WC and HDL) were significantly high among the population. Elevated WC (74.8%; $p < 0.001$) and Low HDL (32.7%; $p < 0.001$) were significantly high, respectively. However, elevated BP (30.8%), FG (20.8) and TG (11.7%) were not statistically significant.

Table 19. Binomial exact tests for MetS component prevalences ($N = 214$).

MetS Component	n (%)	95% CI	Reference p_0	p-value	Interpretation
Elevated Waist Circumference	160 (74.8%)	68.9– 80.6%	50%	< 0.001*	Significantly > benchmark
Low HDL Cholesterol	70 (32.7%)	26.4– 39.0%	25%	0.011*	Significantly > benchmark
Elevated Blood Pressure	66 (30.8%)	24.7– 37.0%	30%	0.823	Not different
Elevated Fasting Glucose	44 (20.6%)	15.1– 26.0%	20%	0.864	Not different
Elevated Triglycerides	25 (11.7%)	7.4– 16.0%	15%	0.212	Not different

Note. * $p < 0.05$. Two-tailed binomial exact test. 95% CI: Wilson score interval. Benchmark values (p_0) from Osei-Yeboah et al. (2017) and Noubiap et al. (2022).

Figure 14 juxtaposes the prevalence of 5 MetS components among the study cohort against regional benchmark using binomial exact test and shows that elevated waist circumference

and low HDL -C significantly exceeded the regional benchmarks while elevated BP, FG and TG did not show statistical significance different from benchmark rates.

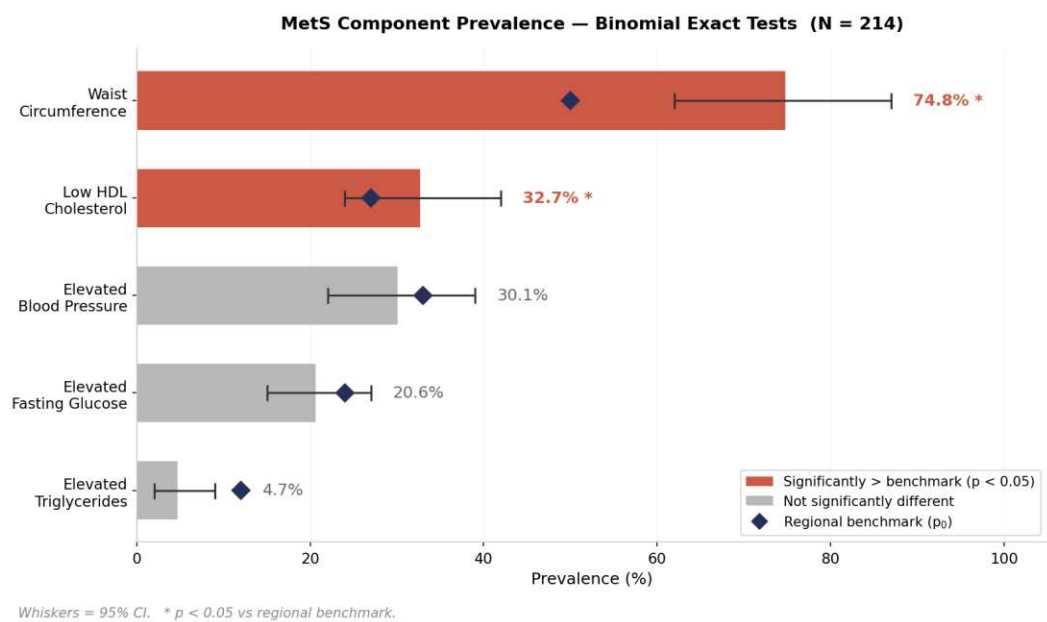


Figure 14: MetS component prevalences with 95% confidence intervals and regional benchmark comparisons (N = 214). Red bars = significantly greater than regional benchmark ($p < 0.05$); Grey = not significant. Diamonds = benchmark values (p_0). Whiskers = 95% Wilson score CI. * $p < 0.05$.

Table 20 gives a summary of the baseline parameters. IDF and NCEP ATP III, used as diagnostic criteria, are in almost perfect agreement ($k = 0.77$, $p < 0.001$), indicating that the

two diagnostic criteria adopted here can be used interchangeably in a study with minimal diagnostic bias ($p=0.157$).

Table 20. Complete summary of inferential statistics — baseline sample (N = 214).

Analysis	Test	Key Statistic	p-value	Significance
Waist circ. vs 80 cm	One-sample t	$t(213)=17.13$	< 0.001	Yes
Fasting glucose vs 5.5 mmol/L	One-sample t	$t(213)=1.83$	0.069	No
HbA1c vs 5.7%	One-sample t	$t(213)=-0.91$	0.362	No
Triglycerides vs 1.7 mmol/L	One-sample t	$t(213)=-18.29$	< 0.001	Yes
HDL vs 1.3 mmol/L (F)	One-sample t	$t(213)=24.38$	< 0.001	Yes
Total cholesterol vs 5.2	One-sample t	$t(213)=-5.85$	< 0.001	Yes
LDL vs 3.4 mmol/L	One-sample t	$t(213)=-18.29$	< 0.001	Yes
Systolic BP vs 130 mmHg	One-sample t	$t(213)=4.51$	< 0.001	Yes
Diastolic BP vs 85 mmHg	One-sample t	$t(213)=-0.83$	0.406	No
Gender $\times$ MetS (IDF)	Fisher exact	OR=2.49	0.219	No
Gender $\times$ MetS (NCEP)	Fisher exact	OR=2.01	0.247	No
Age group $\times$ MetS (IDF)	Chi-square	$\chi^2(4)=5.32$	0.256	No
Age group $\times$ MetS (NCEP)	Chi-square	$\chi^2(4)=5.05$	0.283	No
Age trend $\times$ MetS (IDF)	Spearman r_s	$r_s=1.000$	< 0.001	Yes
Alcohol $\times$ elevated TG (adj.)	Logistic reg.	OR=2.31	< 0.05	Yes
Alcohol $\times$ elevated TG (unadj)	Fisher exact	OR=2.31	0.072	Borderline

Abdominal obesity vs 50%	Binomial	74.8% vs 50%	< 0.001	Yes
Low HDL vs 25%	Binomial	32.7% vs 25%	0.011	Yes
Elevated BP vs 30%	Binomial	30.8% vs 30%	0.823	No
Elevated FG vs 20%	Binomial	20.6% vs 20%	0.864	No
Elevated TG vs 15%	Binomial	11.7% vs 15%	0.212	No
IDF vs NCEP agreement	Cohen's κ	$\kappa=0.877$	< 0.001	Almost perfect
IDF vs NCEP bias	McNemar	$\chi^2(1)=2.00$	0.157	No bias

Note. Significant at $p < 0.05$. F = female-specific reference. TG = triglycerides; FG = fasting glucose; BP = blood pressure; MetS = metabolic syndrome; IDF = International Diabetes Federation; NCEP = National Cholesterol Education Program ATP III.

4. DISCUSSION

This study was conducted at two secondary health facilities (District Hospitals) in the Ashanti Region to get insight into the high prevalence of MetS and its determinants among outpatients in Ghana. The overall prevalence of MetS among the studied population is 16.8% for both diagnostic criteria used, with NCEP ATP III at 19.6% and IDF at 17.8%. This is consistent with the global ranges for transitioning populations (Noubiap et al., 2022). Palimaru and colleagues reported a higher prevalence of MetS (21.5%). However, MetS prevalence in this study is lower than the prevalence rates of 69.14% and 43.83% based on IDF and NCEP-ATP criteria, respectively in Ho Municipality (Osei-Yeboah et al., 2017). Gyakobo et al. (2012) documented prevalence of 35.9% according to the IDF criteria and 15.0% based on the NCEP-ATP III criteria in a rural community in Ghana. In another study of Ghanaian respondents, the overall prevalence of MetS according to NCEP-ATP III criteria was

23.5% (Fordah, 2017). Arthur and colleagues reported MetS of 25.6%, 29.2%, 14.4% and 30.4% based on NCEP ATP III, IDF, WHO and harmonized criteria. A study conducted in Kumasi by Nsiah et al., 2015 reported a higher prevalence of 58% by NCEP ATP III criteria.

The higher prevalence of MetS observed among females compared with males, irrespective of the diagnostic criteria applied (IDF 19.4% and NCEP ATP III 21.1%; IDF 8.8% and 11/8% respectively), highlights a notable sex disparity in cardiometabolic risk within the study population. This pattern aligns with Jiao et al. (2025), Krishna et al., 2024 and Nsiah et al. (2015) reported a higher prevalence rate among females than males. In contrast, Palimaru et al. (2026) reported a higher prevalence in males (26.7%) than in females (18.5%). This suggests that female sex may represent a notable risk modifier for MetS in this context. The elevated prevalence among females may be attributed to a sedentary lifestyle in the Region, as most women are engaged in trade, while others are unemployed. Further, a higher MetS prevalence was observed among adults aged 50 years. This indicates the need for gender-tailored intervention approaches. Programs should specifically target women aged 40-59 years, who have the highest number of cases this is consistent with study by Manaf and colleagues in 2021. These interventions should address factors unique to women, including hormonal changes, cultural dietary practices, and physical activity patterns common in the Ashanti region. The striking increase in metabolic syndrome prevalence from 7.1% in people under 30 to 40.0% in those aged 60 and above highlights important opportunities for prevention. Primary prevention efforts should focus on individuals in their 30s and 40s, before metabolic syndrome becomes established. Secondary prevention should be intensified for people aged 50-59 years, who have a high prevalence but may still benefit significantly from lifestyle changes.

The identification of five dietary patterns, particularly the contrasting traditional whole foods and Modern processed foods patterns, clearly shows the ongoing nutrition transition in urban Ghana and aligns with findings across Sub-Saharan Africa (Haque et al., 2020; Poddar, 2024). Urbanisation, marketing, socioeconomic status, and convenience are among

the key drivers of nutrition transitions in recent years. There is a need for a dual-pronged strategy tailored to preserve and champion the intake of traditional foods and discourage the sale and consumption of ultra-processed foods and sugar-sweetened beverages with the emergence of potent policy measures such as high taxes, labelling, regulations, and forms of advertisement that govern the production and sale of such unwholesome foods as posited by Zhen et al. (2014) and Sproesser et al., (2019).

The protection of the traditional pattern with fasting glucose and the detrimental association of the modern pattern with abdominal obesity highlight the effects of dietary shifts on health. Again, while the overall diversity scores were adequate for fruits and vegetables, the low dairy intake aligns with the high prevalence of calcium deficiency and may affect MetS risk through its role in vascular health and blood pressure regulation. Irrespective of high reported physical activity, waist circumference was exceptionally prevalent (74.8%). The divergence may be due to the intensity or type of activity not being sufficient to offset excessive caloric intake, mostly from processed foods and sugars. This may reflect social desirability bias in self-reported data. This underscores that in the context of a hypercaloric diet, physical activity alone cannot curb central adiposity, a major driver of MetS.

The study recorded excess sodium intake (mean value of 5,723 mg/day) together with inadequate calcium consumption, indicating a double burden of malnutrition: excess energy coupled with micronutrient deficiency. This nutrient imbalance likely contributes to the elevated blood pressure (30.8%) among the participants and future osteoporosis risk. Majority of the studied participants consumed excess energy this is linked to the development of Mets this result aligns with study by Okube and colleagues in 2020.

Further to this, positive lifestyle interventions should be encouraged against negative attitudes such as excess consumption of alcohol, as well as all forms of smoking. Although the study revealed that 6.5% and 39.3% smoked and drank alcohol, respectively, with 21.5% still taking alcohol, this could explain why 11.7% of the participants had elevated triglyceride levels. This suggests a contextual re-evaluation of lifestyle factors in developing countries and supports more nuanced research on the effects of alcohol consumption on metabolic components in relation to the type of alcohol, drinking pattern and gender differences. Education in various health centres should target alcohol moderation or zero messaging to the public and conduct routine checks for negative alcohol consumption as part of routine NCD care in all health care outlets. Excessive alcohol use is detrimental to all bodily tissues and systems (Aberg et al.,2023).

Pharmacological and nutritional management are crucial in NCD management. The study revealed that 79.4% of the sampled participants adhered to pharmacological management, whereas 83.6% adhered to nutrition education as part of their management strategies. The number of participants who did not receive or follow the interventions underscores a gap in the continuity of comprehensive preventive care.

This highlights a missed opportunity in translational medicine: the disconnect between clinical treatment and lifestyle prevention. This calls for the integration of unified behavioural nutrition into chronic disease research paradigms. Again, there is a need to embed registered dietitians and nutrition educators within the outpatient chronic disease clinics. There should also be structured, culturally tailored nutrition education that is part of the standard components of hypertension and diabetes management.

This result highlights the need for culturally tailored, gender sensitive and nutrition-focused public health strategies to avert the upsurge in diet-related chronic diseases in Ghana and other African countries.

5. LIMITATIONS

The limitation of this study is the potential recall bias in the dietary assessment (3-day 24-hour recall), as some participants reported high energy intake, reflecting occasional consumption or reporting errors. All values were included to preserve population variability, which may have influenced the estimated average energy intake and limited the capture of usual intake. The generalizability of the results may be affected by the gender imbalance in the study sample. Again, the cross-sectional design limits causal inference.

6. CONCLUSION

This comprehensive baseline analysis establishes a substantial burden of metabolic syndrome within the Ashanti region of Ghana, characterised by a high prevalence of Central obesity and significant nutrient imbalances. The findings confirm a critical ongoing nutritional transition and show a double burden of malnutrition, with overnutrition in energy, fat, and sodium coexisting with undernutrition in essential micronutrients such as calcium. This analysis provides a robust epidemiological foundation, highlighting the urgent need for culturally sensitive, evidence-based interventions that specifically target central obesity and associated metabolic risk factors. Again, nutrition-focused public health strategies that augment traditional whole foods, reduce ultra-processed food intake, and embed dietary counselling into regular chronic disease care to prevent the increase of diet-related chronic disease in Ghana and related contexts.

7. FUTURE DIRECTIONS

This study establishes a critical platform for subsequent research. Future investigations should prioritise:

1. The external validation of the identified dietary patterns within independent Ghanaian cohorts.
2. Longitudinal exploration of the associations between these dietary patterns, sociodemographic determinants, and hard clinical health outcomes.
3. The development and rigorous evaluation of targeted, gender-specific, and age-appropriate lifestyle interventions designed to mitigate central obesity and metabolic syndrome.
4. Utilising this baseline data to monitor metabolic health trends and assess the effectiveness of implemented public health strategies within the context of Ghana's ongoing epidemiological transition.

AUTHOR'S CONTRIBUTIONS

Christopher Larbie: Conceptualisation, supervision, methodology, validation, formal analysis, and review of the manuscript.

Marina Tandoh Aferiba: Supervision, manuscript review and editing, project administration and validation.

Herman Erick Lutterodt: Supervision, methodology, visualisation, and project administration.

Elizabeth Boatemaa: Conceptualisation, methodology, investigation, writing of the original draft, and editing.

Michael Asante Fosu: Methodology, formal analysis, validation, visualisation, and manuscript review and editing.

All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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This research received no external funding.

DATA AVAILABILITY

The data supporting the findings of this study can be obtained from the corresponding author upon a reasonable request, subject to appropriate ethical and institutional requirement.

DECLARATION

Consent for Publication

Not Applicable

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