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Prevalence and Associated Factors of Metabolic Syndrome among Adults Attending Outpatient Services in Brazzaville, the Republic of Congo

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Abstract

Introduction: Metabolic syndrome (MetS) is a constellation of interrelated metabolic abnormalities that collectively increase the risk of cardiovascular disease, type 2 diabetes mellitus, as well as renal and hepatic complications. This study aimed to assess the prevalence of MetS and identify its associated risk factors among adult patients attending outpatient health facilities in Brazzaville, the Republic of Congo. **Methods:** A cross-sectional study was conducted, including 357 adult patients aged ≥30 years. Data collection included fasting blood glucose, lipid profile parameters, high-sensitivity C-reactive protein (hs-CRP), serum insulin, and interleukin-6 levels. Information on personal medical history, lifestyle behaviours, and anthropometric measurements was also obtained. Metabolic syndrome (MetS) was defined as the presence of at least three out of five components: elevated waist circumference, high triglyceride levels, low high-density lipoprotein (HDL) cholesterol, elevated blood pressure, and elevated fasting glucose. Software R 4.5.1 via the RStudio 2025.05.1 interface was used for analysis. **Results:** The prevalence of MetS was 31.9%, with no difference between men and women (36.1% versus 30.1%; $p > 0.05$). After adjustment, female sex, elevated body mass index (BMI), increased insulin levels, higher Homeostasis Model Assessment of Insulin Resistance (HOMA-IR),

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and hyperLDLemia were independently associated with metabolic syndrome. **Conclusion:** The study highlights a high prevalence of MetS among adults seeking outpatient care. These findings underscore the urgent need for early screening and targeted interventions addressing modifiable risk factors in high-risk populations. Further large-scale, longitudinal studies are warranted to confirm these associations and explore causal pathways in diverse Congolese settings.

Keywords

Prevalence, Metabolic Syndrome, Outpatients, The Republic of Congo

1. Introduction

Metabolic syndrome (MetS) is a combination of metabolic disorders that increase the risk of developing cardiovascular disease and type 2 diabetes [1] [2]. It is characterised by a combination of risk factors such as abdominal obesity, high blood pressure, atherogenic dyslipidemia, which is defined by higher triglycerides or lower high-density lipoprotein cholesterol (HDL-C) levels, and hyperglycemia [3]-[7].

The prevalence of metabolic syndrome is increasing worldwide, especially in developing countries where lifestyles and eating habits are changing rapidly [8] [9]. There is no standardized definition of MetS, which varies from one organization to another, such as the World Health Organization (WHO), National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III), European Group for the Study of Insulin Resistance (EGIR), American Association of Clinical Endocrinologists (AACE), American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI), and International Diabetes Federation (IDF) [10]-[14].

According to the International Diabetes Federation (IDF), the prevalence of metabolic syndrome is estimated at around 20% - 25% of the global adult population [15]. This is higher in some regions, especially North America and Europe, where it can be as high as 40% [16] [17]. Studies have shown that people with metabolic syndrome are twice as likely to die and three times more likely to have a heart attack or stroke than people without it [14] [16], and have twice the risk of developing type 2 diabetes [18]. For instance, a study by Albajy *et al.* (2023) recently observed a prevalence rate of up to 70% in people with type 2 diabetes from Romania [19].

Although there is a paucity of specific estimation of MetS prevalence in African populations, several studies have reported MetS to be highly prevalent in many countries of Africa. In this continent, the frequency of metabolic syndrome is on the rise, especially in countries where urbanisation and nutritional transition are happening [20]. Bowo-Ngandji *et al.*, in a systematic review and meta-analysis published in 2023, estimated that the global prevalence of MetS in Africa was 32.4% (95% CI: 30.2 - 34.7) [21]. Another meta-analysis performed in 2020 by Jaspers

Faijer-Westerink *et al.* has shown that this prevalence is generally higher in women than in men and varies, on average, between 11.1%, 17.1%, and 18.0%, according to WHO, NCEP-ATPIII, and IDF criteria, respectively [22]. In Sub-Saharan Africa (SSA), the aggregated occurrence of MetS was 21.01% (95% CI: 16.50, 25.51) according to NCEP-ATP III criteria and 23.42% (95% CI: 19.16, 27.08) according to IDF criteria in a study by Asgedom *et al.* [23].

It is well known that patients seeking hospital care often have complex and multiple health problems, including chronic conditions such as diabetes and cardiovascular disease [24]. It is therefore important to understand the prevalence and risk factors of metabolic syndrome in these patients in order to develop effective prevention and management strategies. Stroke and diabetes are major public health issues in the Republic of Congo. According to available data, these diseases are steadily increasing each year, significantly impacting the Congolese population. Despite the increase in cases of stroke and diabetes, risk factors specific, *i.e.*, MetS, to the Congolese population have been little studied. A recent study conducted in a rural area reported respective MetS prevalence rates of 27.1%, 31.2%, and 32.7% for NCEP-ATPIII, IDF Central Africa, and IDF 2006 criteria [25]. Therefore, the following questions must be asked: What is the frequency of MetS in urban areas? What is the frequency of the various metabolic disorders that constitute MetS? In particular, among subjects with type 2 diabetes? What are the factors associated with metabolic syndrome? To answer these questions, this study is designed to determine the prevalence of MetS and associated risk factors among outpatients seeking care at the Diabcare Clinic and Blanche Gomes Specialist Hospital in Brazzaville, the Republic of Congo.

2. Patients and Methods

2.1. Study Design

A cross-sectional study using prospective data collection was conducted between July and December 2021 at the Diabcare Clinic and the Cardiology Unit of the Blanche Gomes Specialized Hospital in Brazzaville, the Republic of Congo. The Diabcare Clinic is a private medical center specialized in the management of diabetes and metabolic diseases in Brazzaville town. It provides multidisciplinary care for diabetic patients, including diagnosis, therapeutic management, and lifestyle education. In contrast, Blanche Gomes is a second-level public hospital.

During the study period, 357 patients aged 30 years or older who were receiving outpatient care for cardiometabolic diseases were included. Participants were recruited using a consecutive sampling method, which may limit the generalizability of findings beyond urban outpatient settings. Clinical and biological data, *i.e.*, fasting blood glucose, lipid profile parameters, high-sensitivity C-reactive protein (hs-CRP), serum insulin, and interleukin-6, were assessed. Lifestyle information and the presence of cardiometabolic risk factors were collected using a face-to-face questionnaire administered during follow-up medical visits, in a designated consultation room. The minimum sample size was estimated using the Schwartz formula:

$$N = \frac{Z^2 \cdot p \cdot (1-p)}{d^2}$$

Using a Z-value of 1.96 for a 95% confidence level, an expected proportion (p) of 27.1% [25], and a 5% margin of error (d), the minimum required sample size was calculated. To account for potential non-response and/or incomplete questionnaires, an additional 15% was added, resulting in an estimated minimum sample size of 350 participants. Ultimately, 357 participants were included based on logistical feasibility. A post-hoc power analysis indicated that this sample size provided 80% power to detect a MetS prevalence of 30% with a 5% margin of error at a 95% confidence level.

2.2. Anthropometric and Clinical Measurements

For all participants, height was measured to the nearest 0.1 cm using a stadiometer, and weight was measured to the nearest 0.1 kg using a calibrated metric scale, with participants wearing light clothing and no shoes. Waist circumference (WC) was measured at the midpoint between the lowest rib and the iliac crest, with participants standing upright, wearing no heavy outer garments, with pockets emptied, and gently exhaling. A cut-off value of ≥88 cm was applied exclusively to women, in accordance with the criteria established by the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III). This threshold is based on evidence linking abdominal obesity in women to an increased risk of cardiometabolic complications and is widely used in the diagnosis of metabolic syndrome. Blood pressure was measured twice on the right arm after a minimum of 30 minutes of rest in the seated position, using an automated sphygmomanometer (Omron® HEM-705, Tokyo, Japan). Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2).

2.3. Blood Collection and Analysis Procedures

Biological samples were collected from both survey sites by trained and certified health workers. Venous blood samples were drawn from the antecubital vein into appropriate collection tubes and analyzed at the Blanche Gomes Laboratory of Biological Analyses in Brazzaville. Blood samples were used to assess plasma concentrations of glucose, routine lipids (total cholesterol [TC], triglycerides [TG], high-density lipoprotein cholesterol [HDL]-[C], and low-density lipoprotein cholesterol [LDL]-[C], the latter calculated using the Friedewald equation), and high-sensitivity C-reactive protein (hs-CRP), using a Cobas c111 analyzer (Roche Diagnostics GmbH, Mannheim, Germany).

Serum interleukin-6 (IL-6) and insulin levels were quantified using commercially available pre-coated ELISA kits (SL1001Hu and SL0933Hu, Sunlong Biotech Co., Ltd., Hangzhou, China), with assay ranges of 2 - 80 ng/L and 0.3 - 20 mU/L, respectively. Insulin resistance was estimated using the homeostasis model assessment of insulin resistance (HOMA-IR), calculated as fasting plasma glucose (mmol/L) multiplied by fasting serum insulin (mU/L), divided by 22.5 [26].

2.4. Definitions of Concepts

- Metabolic Syndrome was defined as the presence of at least three out of five specified criteria according to the modified IDF guidelines [2]. These criteria include: elevated waist circumference, as a proxy for central obesity (WC ≥ 94 cm and 80 cm for Sub-Saharan African men and women, respectively), high triglycerides, low HDL cholesterol, elevated blood pressure, and elevated fasting glucose.
- Type 2 diabetes mellitus (T2DM) was defined as a fasting blood glucose ≥ 100 mg/dL, a non-fasting blood glucose ≥ 200 mg/dL (when fasting samples were absent), or the use of blood glucose-lowering medication.
- Low-grade inflammation status was defined if both biomarkers, hs-CRP < 5 mg/L and interleukin-6 < 20 pg/mL, were present.

2.5. Statistical Analysis

Descriptive statistics were used to compare characteristics between men and women. Categorical variables were summarized using frequencies and percentages, while continuous variables were presented as means with standard deviations. Group comparisons were performed using the chi-squared test for proportions and Student's t-test for comparing means. As the prevalence of metabolic syndrome (MetS) was similar in both sexes, a pooled analysis was conducted to identify explanatory factors associated with MetS using logistic regression. The outcome variable was the presence of MetS (Yes/No), and explanatory variables included socio-demographic, cardiometabolic, and lifestyle factors. Univariate analyses were first performed by cross-tabulating each independent variable with the outcome variable. Crude odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to assess associations. A significance level of $p < 0.05$ was used. Variables with a p-value < 0.20 in the univariate analysis were eligible for inclusion in the multivariate logistic regression. The final model retained only variables with $p < 0.05$. Adjusted odds ratios (AORs) with 95% CIs were calculated. A backward stepwise elimination method, based on the likelihood ratio test with a type I error threshold of 5%, was used to remove non-significant variables ($p > 0.05$). Data entry was performed using Microsoft Excel and statistical analyses were conducted using R 4.5.1 software via the RStudio 2025.05.1 interface for analysis.

2.6. Ethical Considerations

The study was approved by the Ethical Committee of Health Research Sciences (N˚057/MESRSIT/DGRST/CERSSA/-25). Written informed consent was obtained from all participants enrolled during the data collection period.

3. Results

3.1. Main Socio-Demographic Characteristics of Participants

Table 1 presents the main socio-demographic and behavioral characteristics of the overall study population (N = 357), as well as comparisons between male and

female participants. Among them, 108 were males (30.3%) and 249 were females (69.7%). The prevalence of diabetes was similar between men and women (65.7% vs. 62.7%, $p = 0.6$). Significant differences were observed across age groups: women were more represented in the 30 - 39 and 40 - 49 age groups, while men were more prevalent in the 60 - 69 and ≥70 age categories ($p = 0.005$). No significant sex differences were observed in education level ($p = 0.7$), occupational status ($p = 0.6$), alcohol consumption ($p = 0.3$), smoking status ($p = 0.9$), or engagement in physical activity ($p = 0.2$).

Table 1. Main socio-demographic and behavioral characteristics of participants (N = 357).

Characteristics	Overall, n (%) N = 357	Males, n (%) N = 108	Females, n (%) N = 249	*p*-value
Age groups, years				**0.005**
30 - 39	33 (9.2%)	5 (4.6%)	28 (11.2%)	
40 - 49	99 (27.7%)	23 (21.3%)	76 (30.5%)	
50 - 59	124 (34.7%)	36 (33.3%)	88 (35.3%)	
60 - 69	71 (19.9%)	32 (29.6%)	39 (15.7%)	
≥70	30 (8.4%)	12 (11.1%)	18 (7.2%)	
Education level				0.7
None	76 (21.3%)	20 (18.5%)	56 (22.5%)	
Primary	66 (18.5%)	20 (18.5%)	46 (18.5%)	
Secondary	156 (43.7%)	47 (43.5%)	109 (43.8%)	
University	59 (16.5%)	21 (19.4%)	38 (15.3%)	
Occupation				
Yes	198 (55.5%)	62 (57.4%)	136 (54.6%)	0.6
Alcohol consumption				
Yes	158 (44.3%)	52 (48.1%)	106 (42.6%)	0.3
Smoking				
Yes	32 (9.0%)	10 (9.3%)	22 (8.8%)	0.9
Physical activity				
Yes	93 (26.1%)	33 (30.6%)	60 (24.1%)	0.2

3.2. Clinical Characteristics of the Study Participants

The main clinical and biochemical characteristics of the study participants are summarized in Table 2. No significant differences were observed between males and females regarding weight (87 ± 11.3 kg vs. 85 ± 11.6 kg, $p = 0.060$) or insulin levels (13 ± 2.2 µU/mL vs. 13 ± 3.2 µU/mL, $p = 0.054$). However, height showed a statistically significant difference (both 2.0 ± 0.1 m, $p = 0.002$), though the clinical relevance is likely minimal. The prevalence of obesity history and the use of antidiabetic,

Table 2. Main clinical and biological characteristics of the study participants.

Characteristics	Overall, n (%) N = 357	Males, n (%) N = 108	Females, n (%) N = 249	*p*-value
Weight, kg (Mean ± SD)	86 ± 11.6	87 ± 11.3	85 ± 11.6	0.060
Height, m (Mean ± SD)	2 ± 0.1	2 ± 0.1	2 ± 0.1	**0.002**
Insulin, µU/mL (Mean ± SD)	13 ± 3.0	13 ± 2.2	13 ± 3.2	0.054
Diabetes status	227 (63.6%)	71 (65.7%)	156 (62.7%)	0.6
Antidiabetic drugs	168 (47.1%)	55 (50.9%)	113 (45.4%)	0.3
Antihypertensive	19 (5.3%)	5 (4.6%)	14 (5.6%)	0.7
Cholesterol-lowering drugs	23 (6.4%)	7 (6.5%)	16 (6.4%)	0.9
Body mass index, kg/m^2				0.9
Normal, ≤24.9	11 (3.1%)	3 (2.8%)	8 (3.2%)	
Overweight, 25 - 29.9	196 (54.9%)	60 (55.6%)	136 (54.6%)	
Obesity, ≥30	150 (42.0%)	45 (41.7%)	105 (42.2%)	
Waist circumference (cm)				**<0.001**
Normal	158 (44.3%)	32 (29.6%)	126 (50.6%)	
Abdominal obesity, ≥88	199 (55.7%)	76 (70.4%)	123 (49.4%)	
Systolic blood pressure, mmHg				**0.032**
Normal	104 (29.1%)	23 (21.3%)	81 (32.5%)	
Hypertension, ≥ 130	253 (70.9%)	85 (78.7%)	168 (67.5%)	
Diastolic blood pressure, mmHg				0.052
Normal	160 (44.8%)	40 (37.0%)	120 (48.2%)	
Hypertension, ≥85	197 (55.2%)	68 (63.0%)	129 (51.8%)	
Hyperglycemia, ≥1 g/L	246 (68.9%)	73 (67.6%)	173 (69.5%)	0.7
HOMA-IR				0.7
Moderate resistance	114 (31.9%)	33 (30.6%)	81 (32.5%)	
High resistance, ≥2.9	243 (68.1%)	75 (69.4%)	168 (67.5%)	
Hypercholesterolemia, ≥2 g/L	91 (25.5%)	37 (34.3%)	54 (21.7%)	**0.012**
Hypertriglyceridemia, ≥1.50 g/L	39 (10.9%)	13 (12.0%)	26 (10.4%)	0.7
HypoHDLemia, <0.45 g/L	68 (19.0%)	18 (16.7%)	50 (20.1%)	0.5
HyperLDLemia, ≥1.60 g/L	87 (24.4%)	32 (29.6%)	55 (22.1%)	0.13
hs-CRP, mg/L				**<0.001**
Low grade inflammation	108 (30.3%)	48 (44.4%)	60 (24.1%)	
Inflammation, ≥5	249 (69.7%)	60 (55.6%)	189 (75.9%)	
Interleukin-6, pg/mL				0.12
Low grade inflammation	96 (26.9%)	35 (32.4%)	61 (24.5%)	
Inflammation, ≥20	261 (73.1%)	73 (67.6%)	188 (75.5%)	

antihypertensive, and cholesterol-lowering drugs did not significantly differ between sexes (all $p > 0.3$). Body mass index categories were similarly distributed ($p > 0.9$).

3.3. Markers of Inflammation

Markers of inflammation showed sex-specific differences: a higher proportion of males had low-grade inflammation based on hs-CRP (44.4% vs. 24.1%, $p < 0.001$), although differences for interleukin-6 did not reach statistical significance ($p = 0.12$).

3.4. Prevalence of Metabolic Syndrome

The specific results for the five MetS criteria are as follows:

1) *Elevated waist circumference*: Among all participants, 55.7% had elevated waist circumference (abdominal obesity), with a significantly higher prevalence observed in men than in women (70.4% vs. 49.4%, $p < 0.001$).

2) *High triglycerides*: The overall frequency of hypertriglyceridemia was 10.9%, with no significant difference between men (12.0%) and women (10.4%) ($p > 0.05$).

3) *Low HDL cholesterol*: Low HDL cholesterol (hypoHDLemia) was observed in 19.0% of participants, with a higher prevalence in women (20.1%) than in men (16.7%) ($p < 0.05$).

4) *Elevated blood pressure*: The overall prevalence of elevated systolic blood pressure was 55.7%, with significantly higher rates observed in men (78.7%) compared to women (67.5%).

5) *Elevated fasting glucose*: The overall prevalence of hyperglycemia or elevated fasting glucose was 68.9%, with a slightly higher prevalence in women (69.5%) compared to men (67.6%).

Based on these data, the overall prevalence of metabolic syndrome (MetS) was 31.9%, with no significant difference between males (36.1%) and females (30.1%) ($p > 0.05$). Among participants with MetS, the prevalence of diabetes was 63.6% overall, with no significant difference between males (65.7%) and females (62.7%) ($p = 0.6$). Furthermore, among diabetic participants, the prevalence of MetS was significantly higher compared to non-diabetic participants (58% vs. 25%; $p < 0.05$).

3.5. MetS-Related Factors

Table 3 presents the final multivariate logistic regression model examining factors independently associated with the outcome. Female sex was significantly associated with lower odds of the outcome compared to males (OR = 0.48; 95% CI: 0.25 - 0.93; $p = 0.031$). Although the crude prevalence of MetS did not differ by sex, the adjusted analysis revealed significantly lower odds among women, suggesting the presence of confounding factors possibly related to differences in adiposity or patterns of insulin resistance. Age appeared to increase the odds of the outcome,

Table 3. Logistic Regression Analysis of Factors Associated with the MetS.

Characteristics	AOR	95% CI	*p*-value
Sex			
Male	—	—	
Female	0.48	0.25, 0.93	**0.031**
Age groups, years			
30 - 39	—	—	
40 - 49	3.79	0.94, 18.3	0.076
50 - 59	4.04	1.02, 19.2	0.059
60 - 69	3.99	0.95, 19.9	0.072
≥70	4.77	0.97, 26.9	0.063
Insulin, µU/mL	1.40	1.24, 1.61	**<0.001**
Obesity history			
Yes	4.30	0.80, 24.8	0.092
Body mass index, kg/m²			
Normal, ≤ 24.9	—	—	
Overweight, 25 - 29.9	1.03	0.20, 8.16	0.9
Obesity, ≥30	8.56	1.68, 68.1	**0.018**
HOMA-IR			
Moderate resistance	—	—	
High resistance, ≥2.9	3.19	1.32, 8.18	**0.012**
Hypercholesterolemia, g/L	0.91	0.37, 2.19	0.8
HyperLDLemia, g/L	2.98	1.25, 7.17	**0.014**

particularly in older age groups; however, the associations did not reach statistical significance. Participants aged 50–59 years had an OR of 4.04 (95% CI: 1.02 - 19.2; $p = 0.059$), suggesting a borderline association. Higher fasting insulin levels were strongly and significantly associated with increased odds of the outcome (OR = 1.40; 95% CI: 1.24 - 1.61; $p < 0.001$). Obesity, as measured by BMI ≥ 30 kg/m^2, was significantly associated with higher odds (OR = 8.56; 95% CI: 1.68 - 68.1; $p = 0.018$), while overweight status was not. High insulin resistance (HOMA-IR ≥ 2.9) was also a significant predictor (OR = 3.19; 95% CI: 1.32 - 8.18; $p = 0.012$), reinforcing the link between metabolic dysfunction and the outcome. In contrast, hypercholesterolemia showed no significant association (OR = 0.91; $p = 0.8$), whereas hyperLDLemia was significantly associated with increased odds (OR = 2.98; 95% CI: 1.25 - 7.17; $p = 0.014$). Although hs-CRP and IL-6 were measured, they were not included in the multivariable model due to multicollinearity concerns and missing values exceeding 15%. These findings suggest that sex, insulin levels, obesity, insulin resistance, and elevated LDL cholesterol are independently associated

with the condition under study.

4. Discussion

This study estimated the prevalence of metabolic syndrome (MetS) and identified associated risk factors among adult outpatients. The sample was predominantly female (69.7%), slightly higher than that reported in a recent South African study by Van Jaarsveldt *et al.* (2024), where women accounted for 64.2% of participants [27]. This sex imbalance likely reflects differences in healthcare-seeking behaviors, with women generally more likely to utilize outpatient services than men, particularly in Sub-Saharan African contexts. Understanding these socio-cultural dynamics is crucial for interpreting epidemiological data and addressing disparities in healthcare access.

The overall prevalence of MetS in our study (31.9%) was notably higher than that reported by Mbolla *et al.* (2023) in a rural Congolese cohort (27.1%) [25]. Several factors may explain this difference, including the urban setting of our study population, a broader age distribution, and potential variations in lifestyle factors such as diet, physical inactivity, and stress, which tend to be more prevalent in urban environments. Additionally, the use of sensitive biomarkers and laboratory-based assessments in our study may have improved MetS detection compared to field-based methods. Our findings align with the TAHINA study conducted in Tunisia by Belfki *et al.* (2013), which revealed a high burden of MetS even in rural areas among adults aged 35 to 74 years [28]. Similarly, Kaduka *et al.* (2012) reported a significant prevalence of MetS in an urban Kenyan population [29], reinforcing the notion that rapid urbanization and lifestyle transitions are key contributors to the metabolic disease burden across the continent.

Interestingly, whereas Van Jaarsveldt *et al.* [27] reported a significantly higher prevalence of MetS among women (79.9%) compared to men (49.1%), our findings showed a higher prevalence among men (36.1%) than women (30.1%), although this difference was not statistically significant ($p = 0.3$). This divergence may be explained by contextual differences in obesity patterns, hormonal profiles, or variations in health literacy between the populations studied.

After adjusting for confounding variables, including age, obesity history, and cardiometabolic lifestyle indicators, our multivariate logistic regression analysis revealed independent associations between MetS and several key variables: sex, fasting insulin, body mass index (BMI), insulin resistance (HOMA-IR), and hyperLDLemia.

We found that female sex was inversely associated with MetS (OR = 0.48, $p = 0.031$), indicating that males in our sample may carry a higher metabolic risk burden. Although the crude prevalence of MetS did not differ significantly between sexes, the adjusted analysis revealed a protective effect of female sex. This suggests that underlying factors, such as age, lifestyle, or cardiometabolic risk profiles, may have masked this association in the unadjusted comparison.This finding aligns with results from Rwanda reported by Gafirita *et al.* (2024), who observed a simi-

lar inverse association (OR = 0.29, $p < 0.001$) [30]. However, contrasting evidence exists: a study in Ethiopia by Cheneke *et al.* (2016) identified women as having a significantly higher risk of MetS (OR = 5.49, $p < 0.01$) [31]. These discrepancies likely reflect regional differences in socio-cultural roles, dietary habits, physical activity levels, and hormonal influences.

Another factor significantly associated with MetS in our study was obesity. Defined by a body mass index (BMI) of 30 kg/m^2 or higher, obesity emerged as a strong predictor of metabolic syndrome (OR = 8.33, $p = 0.021$). This finding aligns closely with previous research conducted by Omuse *et al.* (2017) in Kenya, who reported a similarly elevated risk (OR = 8.56, $p = 0.018$) [32]. The consistency of these results across different Sub-Saharan African settings underscores the central role of adiposity in the pathophysiology of metabolic dysfunction. Obesity contributes to a range of metabolic disturbances, including insulin resistance, dyslipidemia, hypertension, and chronic inflammation, all of which are key components of the metabolic syndrome. In urban African populations, the increasing prevalence of obesity is often driven by lifestyle transitions, such as reduced physical activity, changes in dietary patterns towards high-calorie, processed foods, and socio-economic factors that limit access to healthy living environments. These shifts exacerbate the risk of developing MetS and its associated complications, including type 2 diabetes and cardiovascular diseases. Our findings highlight the urgent need for targeted public health interventions aimed at preventing and managing obesity, particularly in urban contexts where lifestyle changes are rapid and profound. Strategies might include community-based health promotion, improved access to nutritional education, and policies that encourage physical activity and healthier food environments. Addressing obesity as a modifiable risk factor is critical to reducing the growing burden of metabolic syndrome and improving overall population health in Sub-Saharan Africa.

Additionally, insulin resistance, assessed using the Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) with a threshold of ≥2.9, was significantly associated with metabolic syndrome (OR = 3.19, $p = 0.012$) in our study population. This association indicates that individuals with elevated insulin resistance have over three times the odds of presenting with MetS compared to those without. These findings are comparable to those reported in the Korean National Health and Nutrition Examination Survey (KNHANES) by Heo and Lee (2025), which found a significant but lower association between insulin resistance and MetS (OR = 1.57) [33]. The stronger association observed in our study may reflect a greater clustering of insulin resistance alongside other metabolic abnormalities within our sample. Factors such as genetic predisposition, environmental influences, dietary patterns, and physical inactivity prevalent in our population might amplify the interplay between insulin resistance and metabolic syndrome components. Moreover, the urban setting of our study likely contributes to a higher burden of lifestyle-related risk factors that exacerbate insulin resistance. Insulin resistance is a central pathophysiological mechanism underlying MetS, driving dysregulation of glucose

metabolism, lipid abnormalities, and hypertension. Its significant association with MetS in our cohort reinforces the importance of early detection and management of insulin resistance to prevent progression to type 2 diabetes and cardiovascular diseases. Interventions targeting insulin sensitivity, such as lifestyle modifications including diet and exercise, as well as pharmacological treatments when necessary, should be prioritized in clinical and public health strategies to reduce the metabolic burden in Sub-Saharan African populations.

Moreover, hyperLDLemia also emerged as a significant factor associated with metabolic syndrome (OR = 2.98, $p = 0.014$), reinforcing its recognized role as a major cardiovascular risk factor. In contrast, the study by Beyene Kassaw *et al.* (2022) in Ethiopia reported no significant association between hyperLDLemia and MetS (OR = 1.58, $p = 0.544$) [34]. This discrepancy could be explained by methodological differences, such as variations in sample size, study design, or criteria used to define lipid abnormalities. Additionally, variability in lipid profiles may be influenced by differences in dietary habits, genetic backgrounds, and environmental factors across populations. These findings highlight the need for context-specific investigations when evaluating lipid-related risk factors for metabolic syndrome in diverse African settings.

Elevated fasting insulin was also independently associated with metabolic syndrome (OR = 1.40), consistent with findings from the Insulin Resistance Atherosclerosis Study (IRAS) conducted by Palaniappan *et al.* (2004), which reported a similar odds ratio of 1.30 [35]. This association underscores the central role of hyperinsulinemia in the early pathogenesis of MetS. Hyperinsulinemia reflects a compensatory response to insulin resistance, where pancreatic β-cells increase insulin secretion to maintain normal glucose levels. Over time, this compensatory mechanism may become maladaptive, contributing to metabolic disturbances such as dyslipidemia, hypertension, and glucose intolerance, which are hallmark features of MetS. Moreover, elevated fasting insulin levels can promote vascular inflammation and endothelial dysfunction, thereby increasing cardiovascular risk independent of other traditional factors. Recognizing hyperinsulinemia as an early indicator of metabolic dysfunction highlights the importance of screening and timely intervention to prevent progression to overt diabetes and cardiovascular disease. Lifestyle modifications, including increased physical activity and dietary improvements, alongside pharmacological therapies when appropriate, can help reduce insulin levels and mitigate the risk associated with MetS.

The principal strength of our study lies in the utilization of robust biological and clinical markers for diagnosing metabolic syndrome (MetS). In particular, the inclusion of sensitive inflammatory biomarkers such as high-sensitivity C-reactive protein (hs-CRP) and interleukin-6 (IL-6) enabled the detection of subclinical inflammation, a key feature often linked to metabolic dysregulation and cardiovascular risk. These markers provided a more comprehensive assessment of the inflammatory state beyond traditional MetS criteria. Furthermore, data collection was meticulously conducted by trained personnel following standardized proto-

cols, which enhanced the accuracy and reliability of our measurements and overall findings.

Nevertheless, several limitations must be acknowledged. First, the non-random selection of study sites may introduce selection bias and limit the generalizability of our results to other populations or settings, particularly rural or less urbanized areas. Second, the cross-sectional design inherently restricts our ability to infer causal relationships between identified risk factors and MetS; longitudinal studies are needed to establish temporality and causation. Third, the relatively modest sample size, especially when stratifying by sex and other covariates, may have reduced the statistical power to detect some associations or to explore potential interactions comprehensively. Lastly, despite rigorous statistical adjustments, residual confounding cannot be entirely excluded, as unmeasured factors such as genetic predispositions, socio-economic status, or unreported lifestyle behaviors may have influenced the observed associations.

Future research should aim to overcome these limitations by employing larger, randomly selected cohorts with longitudinal follow-up to better elucidate causal pathways and to validate these findings in diverse Congolese populations. Additionally, integrating more detailed assessments of diet, physical activity, and genetic markers would provide deeper insights into the multifactorial etiology of MetS in this context.

5. Conclusion

This study highlights a high prevalence of metabolic syndrome among adult outpatients in urban Congo, with significant associations with obesity, insulin resistance, and dyslipidemia. These findings point to an urgent need for early screening and targeted interventions to prevent cardiometabolic complications. Further longitudinal studies are warranted to confirm these associations and to guide public health strategies in similar settings.

Authors' Contributions

JBKG conducted the data collection and laboratory analysis, and wrote the draft of the manuscript. GN and JAN interpreted the statistical analysis, study design, and wrote the manuscript. HKFM and VAJBA performed laboratory testing. GN, FRO, GAY, and GLV contributed to revising the manuscript. LM, EB, and DM reviewed the data analysis. All authors read and approved the final version of the manuscript prior to submission.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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