

Original Article <https://doi.org/10.70084/mru/pmrcc/00044.P34>

Epidemiology of Metabolic Syndrome in Western Sudan

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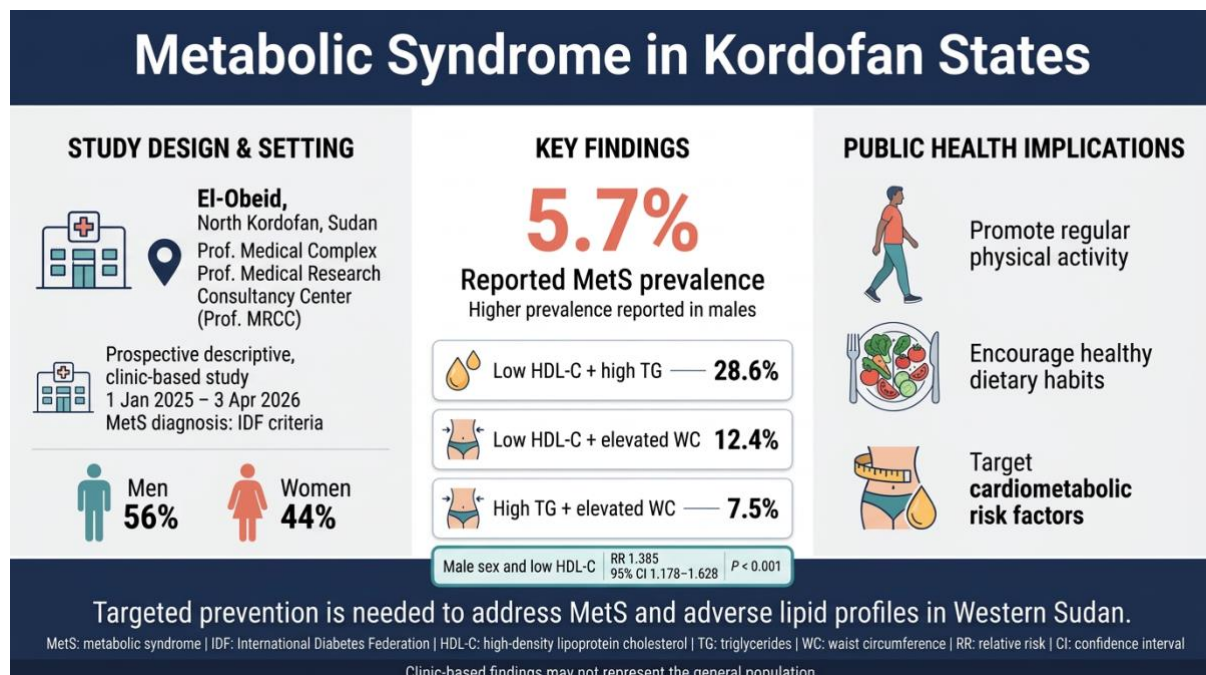
Cite: Humida, et al. Epidemiology of Metabolic Syndrome in Western Sudan. Medical Research Updates Journal 2026;4(4):25-35.

<https://doi.org/10.70084/mru/pmrcc/00044.P34>

ABSTRACT

Background: Metabolic Syndrome (MetS), associated with hyperinsulinemia and insulin resistance, represents a significant global health concern. This study aimed to explore the epidemiology of MetS in Western Sudan. **Methodology:** This study is a prospective descriptive clinic-based investigation conducted at Prof. Medical Complex in Prof. Medical Research Consultancy Center (Prof. MRCC) located in El-Obeid city, the capital of North Kordofan State, Sudan, covering the period from January 1, 2025, to April 3, 2026. We applied the International Diabetes Federation (IDF) criteria for diagnosing MetS. **Results:** Men made up 56% of the total, whereas women accounted for 44%. The analysis of waist circumference (WC) among participants, alongside high-density lipoprotein cholesterol (HDL-C) and triglyceride (TG) levels, revealed that 5.7% exhibited abnormalities indicative of metabolic syndrome. Additionally, 28.6% had low HDL-C levels coupled with high TG levels, while 12.4% presented with low HDL levels and elevated WC. Individuals exhibiting elevated TG levels and high WC constituted 7.5% of individuals. The relationship between male sex and the risk of low HDL-C is demonstrated by a relative risk (RR) of 1.385, with a 95% confidence interval (95% CI) spanning from 1.178 to 1.628 and a P-value of <.001. **Conclusion:** The prevalence of MetS in Western Sudan was 5.7%, with a notably higher rate observed in males. The prevalence of low HDL-C levels surpassed global averages, although it was marginally lower than findings from sub-Saharan Africa. Hypertriglyceridemia levels aligned with sub-Saharan data and were slightly elevated compared to the global range. The findings underscore the necessity for public health interventions, particularly in promoting regular physical activity and encouraging healthy dietary habits.

Keywords: metabolic syndrome; dyslipidemia; hypertriglyceridemia; low HDL cholesterol; visceral obesity; Sudan.



Introduction

Metabolic syndrome refers to the aggregation of several disorders, including central obesity, hypertension, dyslipidemia, insulin resistance, and type 2 diabetes (T2DM) or impaired glucose metabolism. Any combination of three of the aforementioned metabolic disorders can influence the condition. Numerous reports have associated this shared pathophysiology with the subsequent emergence of cardiovascular disorders and malignancies [1, 2]. These risk factors greatly increase CVD risk in multiple ways, making it a public health issue. Vascular dysfunction, atherosclerosis, oxidative stress, and chronic inflammation caused by MetS contribute to CVD. Atherosclerosis is caused by dyslipidemia, specifically excessive triglycerides (TG) and low HDL cholesterol. Chronic inflammation and oxidative stress worsen hypertension and insulin resistance, which damage blood vessels. These metabolic disorders require strong lifestyle changes, including regular exercise and a Mediterranean diet. MetS syndrome is common worldwide and a major health issue in both developed and developing nations. It is a precursor to many

serious conditions, including cardiovascular-kidney-metabolic syndrome (CKM), which is a vicious cycle of damage to these vital organs. There is no clear definition of metabolic syndrome, making it difficult to determine its regional and global impact. Some studies show prevalence rates of 0.2% to 38.9%. Overweight and obesity, insulin resistance and hyperinsulinemia, high blood pressure, and dyslipidemia usually precede the syndrome. [3-6]. Previous studies associate high consumption of whole grains, fruits, and vegetables with a reduced risk of T2DM and MetS, while increased intake of processed meat, red meat, and sugar-sweetened beverages correlates with elevated risks of T2DM [7]. Various criteria established by multiple panels and organizations have been utilized for the diagnosis of MetS. These include the National Cholesterol Education Program Adult Treatment Panel (NCEP ATP 3), the World Health Organization (WHO), the European Group for the Study of Insulin Resistance (EGIR), the International Diabetes Federation (IDF), and the American Association of Clinical Endocrinologists (AACE) [8]. Information concerning this MetS

from Sudan is scarce. The present study aimed to explore the epidemiology of MetS in Western Sudan.

Materials and Methods

A prospective descriptive clinic-based study was carried out at Prof. Medical Complex in the Prof. Medical Research Consultancy Center (Prof. MRCC) located in El-Obeid city, the capital of North Kordofan State, Sudan, from January 1, 2025, to April 3, 2026. Participants were included based on their willingness, without considering any demographic characteristics, from the total visitors to the Prof. MRCC medical complex for routine medical checkups. Individuals who declined to take part in this series, along with the exceptionally affluent, were omitted. A well-structured self-administered questionnaire was employed for data collection. While diagnosing MetS using various criteria typically necessitates the presence of three or more of the following factors: We applied the criteria established by the International Diabetes Federation (IDF) [9] to assess abdominal obesity, high triglycerides, elevated blood pressure, low HDL

Results

In this series, we examined 570 cases ranging in age from 12 to 95, with a mean age of 46.8 years and a standard deviation (SD) of 16.6%. Males accounted for 423/750 (56%) of the total, while females made up 327/750 (46%). The bulk of the subjects were

cholesterol, and abnormally high fasting blood glucose levels.

Abdominal obesity: Waist circumference (WC) exceeding 94 cm in men and 80 cm in women, accompanied by at least two of the following criteria: (1) Triglycerides (TG) $\geq$ 150 mg/dl or treatment for dyslipidemia, (2) HDL cholesterol $<$ 40 mg/dl in men and $<$ 50 mg/dl in women, (3) elevated WC ($>$ 94 cm). In this series, a waist circumference (WC) greater than 94 cm was considered elevated for both genders, whereas a high-density lipoprotein (HDL) level below 40 mg/dl was regarded as deficient for both genders.

Statistical analysis

We recorded the necessary information on a data sheet before entering it into the statistical software package for social science (SPSS) version 31, Chicago, USA. Variables, frequencies, cross-tabulations, relative risk (RR), and chi-squared were calculated. A p-value $<$ 0.05 was considered significant.

between the ages of 50 and 60, followed by 31 to 40 and above 60, with incidence rates of 183/750 (24%), 21%, and 20%, respectively. As indicated in Table 1 and Figure 1.

Table 1. Distribution of the subjects based on their sex and age group.

Variable	Males n= 423	Females n= 327	Total n= 750
Age			
< 30 years	74	74	148
31-40	87	70	157
41-49	69	43	112
50-60	106	77	183
> 60	87	63	150
Total	423	327	750

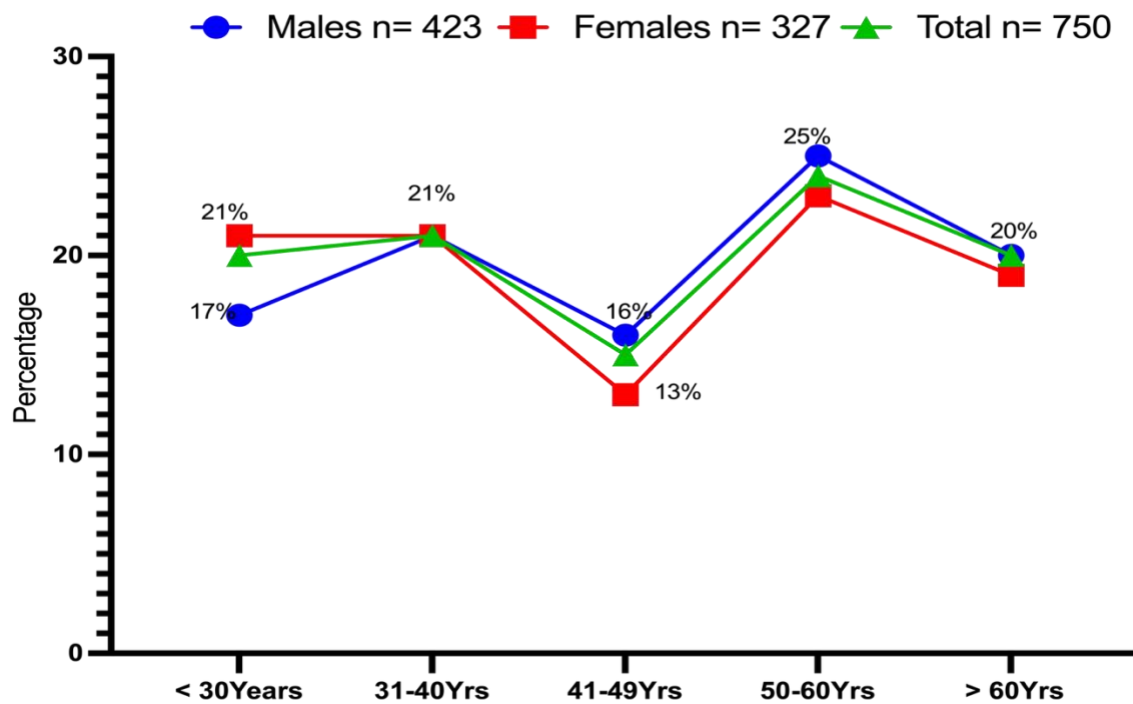


Figure 1: Depiction of the subjects based on their sex and age group.

The analysis of participants' waist circumference (WC) in conjunction with high-density lipoprotein (HDL) and triglyceride (TG) levels revealed that 43 out of 748 individuals (5.7%) exhibited abnormalities indicative of metabolic syndrome. Additionally, 214 out of 748

participants (28.6%) presented with low HDL and elevated TG levels, while 93 out of 748 participants (12.4%) had low HDL and increased WC. Individuals with elevated triglyceride levels and high waist circumference constituted 56 out of 748 (7.5%).

Table 2: Illustration of the individuals according to their WC, HDL level, and TG level

Variable	Normal WC	High WC	Total
Low HDL			
Low TG	261	50	311
High TG	171	43	214
Total	432	93	525
Normal HDL			
Low TG	127	18	145
High TG	65	13	78
Total	192	31	223
Total HDL			
Low TG	388	68	456
High TG	236	56	292
Total	624	124	748

Most of the individuals in this study had low HDL levels of 527/750 (70%), with males at 324/527 (61%) and females at 203/527

(39%). While 99/223 (44% of those with normal HDL levels) were males, 124/223 (56%) were females. Males have a relative

risk (RR) of 1.385 for low HDL-C, with a 95% confidence interval (CI) of 1.178 to 1.628 and a P-value of $<.001$. In terms of TG levels, most subjects (457/750, or 61%) had normal TG levels, with 249/457 (54%) being males and 56% females. While 293/750 (39%) had elevated TG levels, 174/293 (59%) were men, and 41% were women. The relative risk (RR) of acquiring high TG in males is 0.917, with a 95% confidence interval (95% CI) of 0.809 to 1.041 and a P-value of 0.107. As

shown in Table 3 and Figure 2, most of the participants in this series had normal WC at 624/748 (83%), with 345/624 (55%) males and 45% females. While 124/748 (17%) had high WC, 77/124 (62%) were male. The relative risk (RR) of males having a high WC is 0.890, with a 95% confidence interval (95% CI) ranging from 0.763 to 1.039 and a P-value of 0.097. This trend is clearly seen in Table 3 and Figure 2.

Table 3: Distribution of the participants according to their sex, HDL level, TG level, and WC.

Variable	Males n= 423	Females n= 327	Total n= 750
HDL level			
Low	324	203	527
Normal	99	124	223
Total	423	327	750
TG level			
Normal	249	208	457
High	174	119	293
Total	423	327	750
WC			
Normal	345	279	624
High	77	47	124
Total	422	326	748

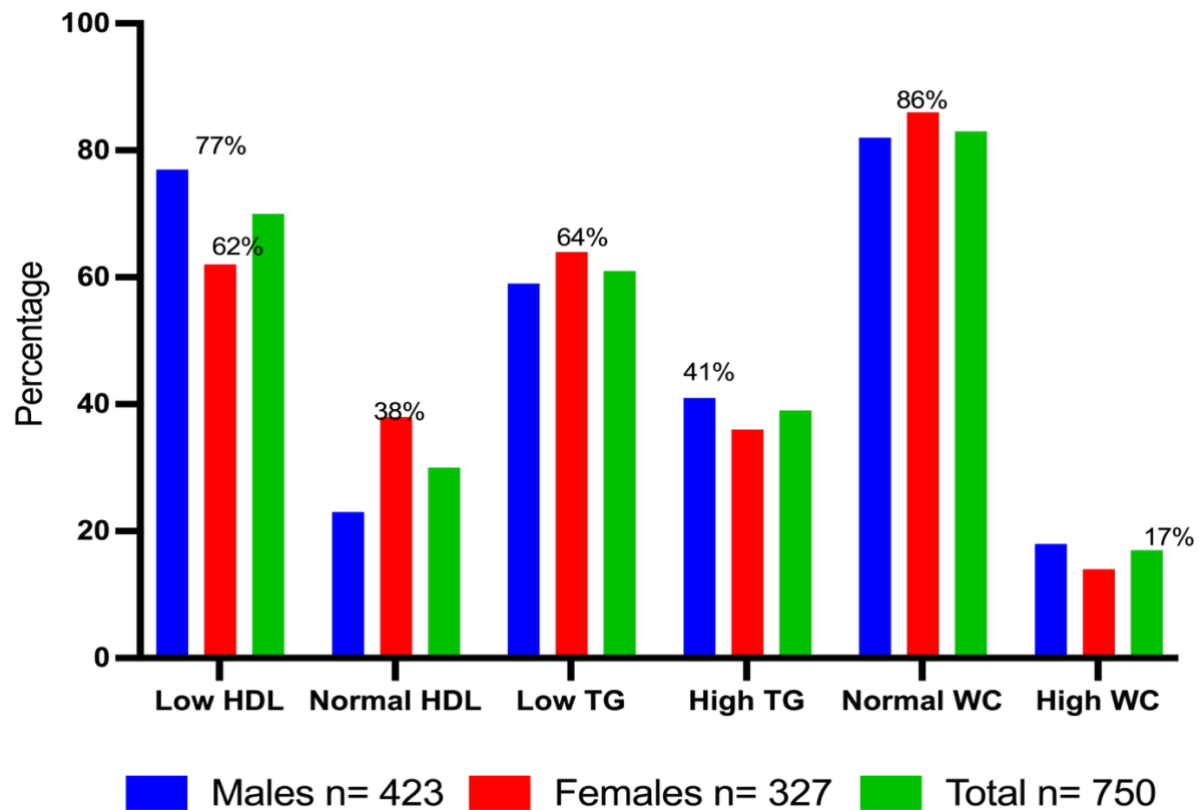


Figure 2. Illustration of the participants according to their sex, HDL level, TG level, and WC.

The bulk of participants with low HDL values were between the ages of 50 and 60, with > 60- and 31-40 years accounting for 126/527 (24%), 20.4%, and 20%, respectively. The majority of people with normal HDL levels are between the ages of 50 and 60, with 57/223 (26%), followed by 31 to 40, with 51 (23%), and under 30 years, with 48 (22%). The majority of participants with normal TG levels were between the ages of 50-60, followed by <30 and 31-40 years, with 102/457 (22.3%), 101 (22%), and 94 (21%),

respectively. Conversely, those with high TG levels were mostly between the ages of 50-60 (27.6%) and 31-40 years (64, 21.8%). The most common age category for normal WC is <30 years, followed by 50-60 and 31-40 years, with incidence rates of 142/624 (23%), 140 (22%), and 135 (21.6%), respectively. As shown in Table 4 and Fig. 4, the age group of 50-60 years constitutes the majority of participants with high WC (42/124, or 34%), followed by 41-49 at 29 (23%).

Table 4 represents the description of the subjects' age, HDL level, and WC.

Variable	< 30 years	31- 40	41- 49	50- 60	> 60	Total
HDL level						
Low	100	106	87	126	108	527
Normal	48	51	25	57	42	223
Total	148	157	112	183	150	750
TG level						
Normal	101	93	67	102	94	457
High	47	64	45	81	56	293
Total	148	157	112	183	150	750

WC						
Normal	142	135	83	140	124	624
High	6	21	29	42	26	124
Total	148	156	112	182	150	748

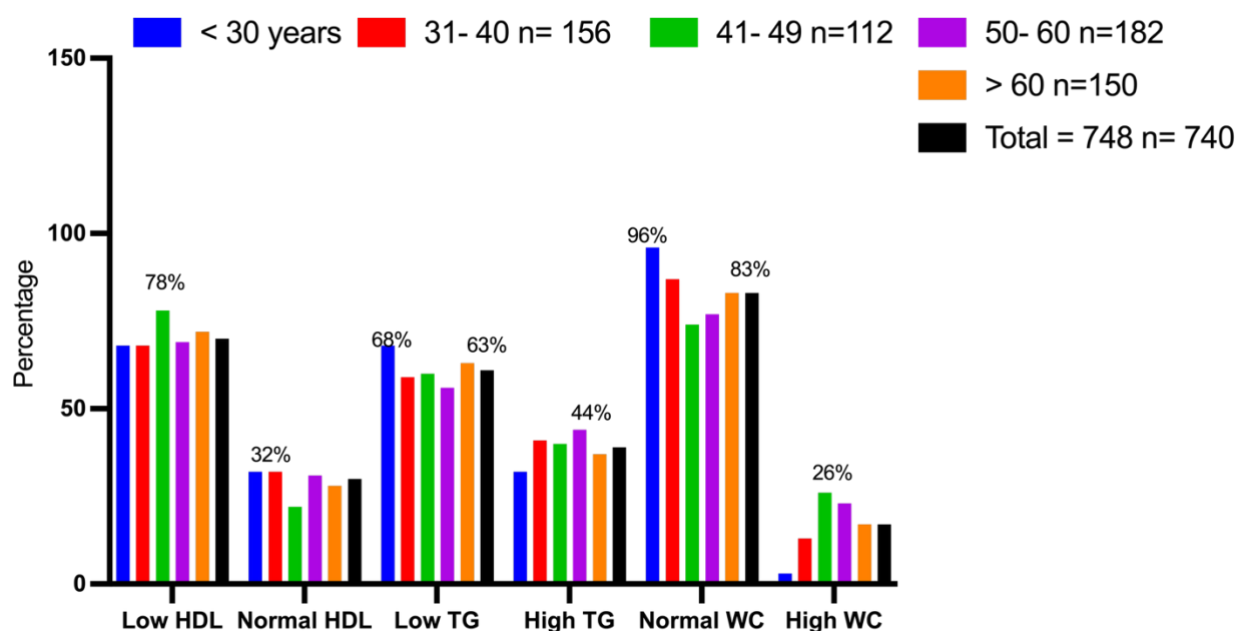


Figure 3. Represents the depiction of the subject's age, HDL level, and WC.

Discussion

The worldwide rise in body weight and obesity poses a substantial challenge to health organizations at both regional and global levels, particularly in the prevention of non-communicable diseases. Metabolic Syndrome (MetS) typically initiates with overweight and obesity, which precede hyperinsulinemia and insulin resistance. This subsequently results in T2DM and other metabolic disturbances, including dyslipidemia. This disorder leads to the future prevalence of atherosclerosis affecting essential organs, particularly the heart, brain, kidneys, and central nervous system (CNS). Consequently, the present study offers the first set of data on MetS in Western Sudan.

The prevalence of MetS in this cohort was 5.7%. Prior reports from Sudan indicate a prevalence rate of 2.3%. These studies employ the same criteria as the present study (International Diabetes Federation

criteria); however, the study population consisted of early adolescents with a mean age of 12.6 ± 1.2 years [6]. A further study from Sudan involving university students indicates a prevalence of 8.4% according to IDF standards, 7.5% according to National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III) criteria, and 6.1% according to WHO criteria [10]. In Sudan, chronic kidney disease populations exhibit a higher prevalence rate of 19% [11]. About one in five people in the United States has MetS, and about one in four people in Europe has it. Furthermore, Southeast Asia exhibits the lowest prevalence rate globally. The intricacy and interconnections among the elements of MetS, or insulin resistance syndrome, designate the condition as a priority for several health-related organizations. Insufficient physical activity and a sedentary lifestyle are considered primary contributors to the development of

visceral obesity and insulin resistance, which are the foundational elements of MetS. Various literature demonstrates the significance of diet and nutrients, indicating that a Western diet elevates the risk of MetS, while Nordic and Mediterranean diets mitigate MetS by reducing oxidative stress and inflammation, attributed to their high content of dietary fiber, omega-3 and omega-9 fatty acids, complex carbohydrates, antioxidants, minerals, and vitamins [12, 13].

The prevalence of low high-density lipoprotein cholesterol (HDL-C) in this group was 70%, which is lower than the prevalence in sub-Saharan Africa (77%) and globally (38.4%) [15].

High-density lipoprotein cholesterol (HDL-C) serves as the primary mechanism for retrieving low-density lipoprotein (LDL) cholesterol from tissues and transporting it back to the liver in LDL or very low-density lipoprotein (VLDL) for ultimate processing. HDL plays a crucial role by including antioxidant properties, anti-inflammatory effects, and the preservation of arterial endothelial function, which, along with other factors, is the primary mechanism in the prevention of atheroma development and the pathogenesis of atherosclerosis. Research indicates that for every 1 mg/dL rise in HDL-C, there is a 2% to 3% decrease in atherosclerosis. The studies indicate, by both observational and genetic analyses, an elevated risk of infectious illnesses, mortality during sepsis, chronic kidney disease (CKD), and diabetes in persons with low HDL-C levels. Furthermore, observational studies associate low HDL-C levels with several autoimmune disorders, cancer, and overall mortality [16-20].

In this study, elevated serum triglycerides (TG) were seen in 39% of cases. Globally, the prevalence rate of crude hypertriglyceridemia (HTG) is 29.6% (36.9% in males, 23.8% in women) [21], but several regions in sub-Saharan Africa have a prevalence above 35% [22]. Our findings reveal a greater prevalence rate of HTG

compared to regional and worldwide perspectives. These differences may be associated with varying demographics or the testing methodologies, particularly the sampling methods during the fasting phase compared to the postprandial phase. While our protocols employ fasting procedures for lipid profile assessment, several locations continue to utilize non-fasting approaches, which may lead to inconsistencies in HTG prevalence rates and affect the accuracy of lipid measurements, ultimately impacting the reliability of clinical decisions based on these lipid profiles. HTG has numerous etiologies, some linked to genetics and others directly associated with an individual's lifestyle, as well as with other dyslipidemias and metabolic diseases. The deficit of the enzyme lipoprotein lipase (LPL), which catalyzes the hydrolysis of plasma triglycerides into free fatty acids and glycerol, is noteworthy. Insulin, an anabolic hormone, controls LPL activity. When insulin resistance, hyperinsulinemia, and related metabolic disorders are present, LPL activity is lower. These conditions will result in HTG and other dyslipidemias observed in patients with MetS [23-25].

The current study reported visceral obesity in 17% of participants. Our findings indicate a reduced prevalence rate compared to earlier publications from Africa, which document a greater rate [26]. Our findings may be associated with the direct impact of the 2023-armed conflict in Sudan, which resulted in the displacement of millions of Sudanese individuals, accompanied by a deficiency of food and essential nutrients, as well as significant emotional repercussions. Visceral obesity is an escalating epidemic, exacerbated by age, sedentary lifestyles, the adoption of unhealthy dietary practices, eating frequency, sleep duration, physical activity levels, and smoking behaviors. It is more common in men; nevertheless, the frequency will rise in postmenopausal women. The condition signifies the initial milestone of metabolic syndrome,

characterized by insulin resistance and cardiovascular syndromes, such as acute coronary syndrome, cerebral atherosclerosis, and peripheral arterial disease. The condition may coexist with hypertriglyceridemia, leading to the accumulation of free fatty acids and the release of proinflammatory mediators from adipose tissue, along with increased synthesis of very-low-density lipoprotein in the liver and decreased high-density lipoprotein cholesterol. This results in a comprehensive manifestation of metabolic syndrome that necessitates immediate intervention to prevent significant vascular damage and debilitating cardiovascular disorders [27-31]. The current study offers significant preliminary data regarding MetS in Sudan; yet it possesses certain limitations due to its clinical-based setting, which restricts the ability to establish causal relationships and may not fully represent the long-term trends of MetS in the population. In conclusion, the prevalence of MetS in Western Sudan was 5.7%, with a significantly elevated rate in males. The prevalence of low HDL-C levels exceeded global averages but was slightly lower than findings from sub-Saharan Africa. Hypertriglyceridemia levels corresponded with sub-Saharan data and were marginally increased relative to the global range. The results highlight the imperative for public health initiatives, especially in advocating for consistent physical activity and fostering nutritious eating practices.

Acknowledgments

The authors extended their sincere gratitude to the people at Prof. Medical Research Consultancy Center (Prof. MRCC) for their invaluable assistance concerning the data collection.

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Ethical Approval: The Prof. Medical Research Consultancy Center's Human Research Ethics Committee (HREC) has approved the study proposal. (Approval #: HREC 0022/MRCC.1/25)

Conflict of interest: The authors declare no conflict of interest.

Data availability: Data regarding this study are available from the corresponding author.

Author's contributions

All the authors have reviewed the publishable version of the manuscript and agreed on the final work.

Humida EHM: Concept and design, Acquisition, analysis, or interpretation of the data, Drafting of the manuscript, and Supervision

Mohamed AA: Concept and design, Drafting of the manuscript, Critical review of the manuscript for important intellectual content, Visualization and validation.

Suliman AA: Concept and design, Critical review of the manuscript for important intellectual content, Drafting of the manuscript, Visualization and validation

Hamid NA: Acquisition, analysis, or interpretation of the data, Drafting of the manuscript, software and validation.

Edres MA: Acquisition, analysis, or interpretation of the data, Drafting of the manuscript, investigation and methodology.

Mohammed AKY: Concept and design, Acquisition, analysis, or interpretation of the data ,drafting of the manuscript, visualization and critical review of the manuscript for important intellectual content.

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