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Original Research Article

Assessment of Metabolic Syndrome in Sudanese Hemodialysis Patients at Kassala and Al-Gadarif Kidney Centers, Eastern Sudan (2021–2024)

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Abstract: Metabolic syndrome (MetS), a cluster of cardiometabolic risk factors, is highly prevalent among patients with chronic kidney disease (CKD), particularly those undergoing hemodialysis (HD). This study investigated the prevalence, characteristics, and clinical implications of MetS among Sudanese HD patients at Kassala and Al-Gadarif Kidney Centers in Eastern Sudan. A hospital-based case–control study was conducted between September 2021 and June 2024, enrolling 70 HD patients and 70 age- and sex-matched healthy controls from each center. Key metabolic parameters—including waist circumference, blood pressure, fasting blood glucose, and lipid profiles (triglycerides and HDL cholesterol)—were assessed. MetS was diagnosed according to the International Diabetes Federation (IDF) criteria. The findings showed that 38% of Kassala HD patients and 42% of Al-Gadarif HD patients fulfilled the diagnostic criteria for MetS. Compared to controls, HD patients from both centers had significantly higher waist circumference, systolic and diastolic blood pressure, fasting blood glucose, and triglyceride levels ($p < 0.0001$). HDL cholesterol was markedly lower ($p < 0.0001$). Patients in Al-Gadarif exhibited slightly higher renal and metabolic abnormalities—including elevated urea, creatinine, waist circumference, blood pressure, triglycerides, and fasting glucose—alongside lower HDL cholesterol compared with Kassala patients, suggesting a heavier metabolic burden. These results underscore the heightened cardiovascular risk among Sudanese HD patients, with Al-Gadarif patients demonstrating a marginally greater prevalence of MetS. Early detection, regular monitoring, and comprehensive management strategies—including lifestyle modifications, pharmacological therapy, and region-specific interventions—are urgently needed to reduce cardiovascular morbidity and mortality in this vulnerable population.

Keywords: Metabolic Syndrome, Hemodialysis, Cardiovascular Risk, Chronic Kidney Disease, Sudan.

1.1 BACKGROUND

Chronic kidney disease (CKD) is a long-term, progressive condition characterized by irreversible deterioration of renal function. It is defined by either a sustained reduction in estimated glomerular filtration rate (eGFR) below 60 mL/min/1.73 m^2 for at least three months or the presence of structural or functional kidney abnormalities such as albuminuria.

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Progression to end-stage renal disease (ESRD) occurs when eGFR declines to less than 15 mL/min/1.73 m^2, at which stage renal replacement therapy—either dialysis or kidney transplantation—becomes essential for survival.

CKD constitutes a significant global health problem, affecting hundreds of millions of individuals worldwide [1]. The global dialysis population continues to expand annually, and projections indicate that the number of patients requiring maintenance dialysis will surpass two million within the next decade [2]. In the United States, several hundred thousand individuals are currently living with ESRD, with diabetes mellitus recognized as the leading etiological factor [3]. Diabetes is responsible for approximately 40% of CKD cases, followed by hypertension and other modifiable risk factors such as obesity, dyslipidemia, smoking, and genetic susceptibility [4].

Diabetes mellitus plays a pivotal role in both the initiation and progression of CKD. Persistent hyperglycemia induces glomerular basement membrane thickening, mesangial expansion, and podocyte injury, culminating in diabetic nephropathy in nearly one-third of affected individuals [5]. Hypertension further accelerates nephron loss through sustained intraglomerular pressure and vascular remodeling. When combined with obesity and metabolic abnormalities, the risk of progressive renal dysfunction increases substantially [6]. Modern lifestyle patterns—including physical inactivity and high-calorie diets—have intensified the prevalence of these interconnected disorders globally [7].

Metabolic syndrome (MetS) describes a constellation of interrelated metabolic disturbances that collectively elevate cardiovascular and renal risk. These abnormalities include central adiposity, elevated blood pressure, hyperglycemia, hypertriglyceridemia, and reduced high-density lipoprotein (HDL) cholesterol levels. According to the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III), the presence of any three of these criteria confirms the diagnosis of MetS [8].

The prevalence of metabolic syndrome is notably high among patients with CKD, particularly those undergoing hemodialysis. Insulin resistance, a fundamental component of MetS, is commonly observed in CKD and contributes to both cardiovascular morbidity and progressive renal impairment [9]. The uremic milieu promotes systemic inflammation, oxidative stress, and hormonal dysregulation, which collectively impair insulin signaling pathways and glucose metabolism [10].

Alterations in carbohydrate metabolism become more pronounced as renal function declines, often emerging when eGFR falls below 50 mL/min/1.73 m^2. These changes include reduced peripheral glucose uptake, diminished glucose oxidation, and impaired pancreatic insulin secretion [9-11]. In parallel, lipid metabolism is substantially disrupted in CKD. Decreased clearance and increased hepatic production of triglyceride-rich lipoproteins, particularly very low-density lipoprotein (VLDL), lead to hypertriglyceridemia and an atherogenic lipid profile [12, 13]. Among hemodialysis patients, deficiencies in L-carnitine may further compromise fatty acid oxidation, aggravating dyslipidemia [14].

Electrolyte imbalances are also prevalent in advanced CKD. Sodium retention contributes to hypertension and extracellular fluid expansion, whereas potassium dysregulation may precipitate hyperkalemia and life-threatening cardiac arrhythmias [15, 16].

The relationship between CKD and metabolic syndrome is bidirectional and synergistic. Shared pathophysiological pathways—including insulin resistance, chronic inflammation, endothelial dysfunction, and oxidative stress—link these conditions and amplify cardiovascular risk [9, 10]. Cardiovascular disease remains the principal cause of mortality among patients receiving maintenance dialysis, and the coexistence of MetS further worsens prognosis [10].

In Sudan, the incidence of CKD and dependence on maintenance hemodialysis are rising, largely driven by increasing rates of diabetes, hypertension, and obesity [17]. However, healthcare delivery in Sudan faces multiple structural challenges, including limited dialysis facilities, workforce shortages, and constrained financial resources. These challenges are particularly evident in peripheral and rural regions. Additional factors such as malnutrition, recurrent infections, and socioeconomic inequities further complicate the management of CKD patients [18].

Accordingly, this study seeks to determine the prevalence of metabolic syndrome among Sudanese patients undergoing hemodialysis and to explore its association with cardiovascular risk determinants. The findings are expected to inform context-specific preventive and therapeutic strategies aimed at reducing cardiovascular morbidity and improving clinical outcomes in this vulnerable population.

1.2 Specific Objectives

1. To determine the prevalence of metabolic disorders among hemodialysis patients.

2. To identify clinical and lifestyle factors associated with metabolic syndrome in hemodialysis patients.
3. To evaluate the impact of metabolic syndrome components on cardiovascular health and quality of life in hemodialysis patients.
4. To develop recommendations for optimizing the management of metabolic syndrome in chronic kidney disease patients within the Sudanese healthcare context.

2. MATERIALS AND METHODS

2.1 Study Design

This research employed a hospital-based case–control design to assess the prevalence and components of metabolic syndrome (MetS) among Sudanese hemodialysis (HD) patients. The study compared HD patients with age- and sex-matched healthy controls to evaluate metabolic, biochemical, and anthropometric differences associated with chronic kidney disease (CKD) and dialysis treatment.

2.2 Study Area

The study was conducted at two major dialysis centers in Eastern Sudan:

1. **Kassala Kidney Center** – located in Kassala Locality, serving a large population from Kassala State and surrounding rural areas.
2. **Al-Gadarif Kidney Center** – situated in Al-Gadarif State, providing renal replacement therapy and nephrology services to patients from Eastern Sudan and nearby regions.

Both centers operate under the supervision of the Sudanese Ministry of Health and provide free or subsidized dialysis sessions for patients with ESRD. Each center is equipped with modern hemodialysis machines, laboratory facilities, and qualified medical and nursing staff.

2.3 Study Population

The target population included patients diagnosed with end-stage renal disease (ESRD) who were receiving maintenance hemodialysis at either Kassala or Al-Gadarif Kidney Centers during the study period (September 2021 – June 2024).

A control group of apparently healthy volunteers—matched for age and sex was recruited from the same localities. Controls were screened to exclude any history of kidney disease, diabetes mellitus, hypertension, or dyslipidemia.

2.4 Sample Size and Sampling Technique

A total of 140 participants were enrolled from each center, comprising:

- 70 hemodialysis patients (cases)
- 70 age- and sex-matched healthy controls

The sample size was determined using standard epidemiological formulae to ensure adequate statistical power for detecting significant differences between groups ($\alpha = 0.05$, power = 95%).

Participants were selected using a systematic random sampling method from the dialysis registry. Controls were chosen through convenience sampling from hospital staff and patient relatives after confirming eligibility.

2.5 Inclusion Criteria

- Adult patients aged ≥18 years.
- Diagnosed with ESRD and on regular hemodialysis for at least three months.
- Provided informed written consent to participate.

2.6 Exclusion Criteria

- Patients with acute kidney injury **or** temporary dialysis.
- Patients who refused or were unable to provide consent.

2.7 Study Period

The study was conducted over a period of two years and nine months, from September 2021 to June 2024, including data collection, laboratory analysis, and statistical evaluation.

2.8 Data Collection Tools and Procedures

Data were collected using a structured questionnaire and standardized measurement protocols. The questionnaire included three main sections:

1. **Sociodemographic Data:**
   - Age, sex, residence, occupation, marital status, smoking history, and duration of dialysis.

2. **Clinical and Anthropometric Data:**
   - Weight and height were measured using a calibrated stadiometer.
   - **Body Mass Index (BMI)** was calculated as weight (kg) / height^2 (m^2).
   - **Waist circumference** was measured at the midpoint between the lower costal margin and the iliac crest using a non-stretchable tape.
   - **Blood pressure** was measured in the sitting position after five minutes of rest using a digital sphygmomanometer. The mean of two readings taken five minutes apart was recorded.

2. Laboratory Investigations:

- Fasting blood glucose (FBG), serum triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), urea, and creatinine were analyzed from fasting venous blood samples.

- All biochemical analyses were conducted at the respective dialysis center laboratories using automated analyzers and standard enzymatic methods.

2.9. Definition and Diagnostic Criteria for Metabolic Syndrome

Metabolic syndrome (MetS) was diagnosed according to the International Diabetes Federation (IDF, 2006) criteria, which require the presence of central obesity (increased waist circumference specific to ethnic group) plus any two or more of the following components:

1. **Raised triglycerides:** ≥150 mg/dL (1.7 mmol/L)
2. **Reduced HDL cholesterol:** <40 mg/dL in males or <50 mg/dL in females
3. **Raised blood pressure:** systolic ≥130 mmHg or diastolic ≥85 mmHg, or on antihypertensive medication
4. **Raised fasting plasma glucose:** ≥100 mg/dL (5.6 mmol/L) or previously diagnosed type 2 diabetes mellitus

For Sub-Saharan African populations, central obesity was defined as:

- Waist circumference ≥94 cm in men
- Waist circumference ≥80 cm in women

2.10 Ethical Considerations

Ethical approval for this study was obtained from the Ethical Review Committee of Kassala University, Faculty of Medicine, and permission was granted by the administrations of Kassala and Al-Gadarif Kidney Centers.

Written informed consent was obtained from all participants after explaining the study's objectives, procedures, and potential benefits. Participation was voluntary, and confidentiality was strictly maintained. Personal identifiers were replaced by coded numbers, and data were used exclusively for research purposes.

2.11 Data Management and Statistical Analysis

Data were entered and analyzed using SPSS software version 26.0. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages.

Comparisons between cases and controls were performed using the independent t-test for continuous variables and the chi-square test for categorical data. A p-value <0.05 was considered statistically significant.

Pearson's correlation coefficient (r) was applied to evaluate relationships between metabolic variables such as triglycerides, HDL cholesterol, blood pressure, and fasting glucose.

3. RESULTS

3.1. Renal Profile

Hemodialysis patients in both Kassala and Al-Gadarif centers demonstrated markedly elevated serum urea and creatinine levels compared with healthy controls. Mean urea levels were 145.84 ± 43.6 mg/dL (Kassala) and 148.2 ± 45.3 mg/dL (Al-Gadarif), versus 21.06 ± 7.33 mg/dL in controls ($p < 0.0001$). Similarly, mean creatinine levels were 9.70 ± 2.69 mg/dL and 9.90 ± 2.73 mg/dL in the two hemodialysis groups, compared with 1.20 ± 0.27 mg/dL among controls ($p < 0.0001$). These findings confirm significantly impaired renal function in the hemodialysis groups, with no meaningful difference between the two centers.

Table 3.1: Renal Profile of Study Participants

Parameter	Kassala HD (Mean ± SD)	Al-Gadarif HD (Mean ± SD)	Controls (Mean ± SD)	p-value
Urea (mg/dL)	145.84 ± 43.6	148.2 ± 45.3	21.06 ± 7.33	<0.0001
Creatinine (mg/dL)	9.70 ± 2.69	9.90 ± 2.73	1.20 ± 0.27	<0.0001

The mean serum sodium level was 139.3 ± 4.5 mmol/L in haemodialysis patients at Kassala Kidney Center and 140.1 ± 5.1 mmol/L in haemodialysis patients from Al-Gadarif. In comparison, the control group showed a lower mean sodium level of 136.8 ± 3.2 mmol/L. The difference between the groups was statistically significant ($p < 0.001$). Regarding potassium levels, haemodialysis patients in Kassala had a mean level of 5.3 ± 0.6 mmol/L, while patients in Al-Gadarif had 5.5 ± 0.7 mmol/L. Both were higher than the control group, which had a mean potassium level of 4.1 ± 0.4 mmol/L. This difference was also highly statistically significant ($p < 0.001$).

Table 3.2: Electrolyte Profile of Study Groups

Parameter	Kassala HD	Al-Gadarif HD	Controls	p-value
Sodium (mmol/L)	139.3 ± 4.5	140.1 ± 5.1	136.8 ± 3.2	<0.001
Potassium (mmol/L)	5.3 ± 0.6	5.5 ± 0.7	4.1 ± 0.4	<0.001

The mean waist circumference among haemodialysis patients in Kassala was 94.5 ± 9.8 cm, while patients in Al-Gadarif had a slightly higher mean value of 96.2 ± 10.1 cm. In contrast, the control group showed a lower mean waist circumference of 85.3 ± 7.2 cm. The difference among the studied groups was highly statistically significant (p < 0.0001). Regarding blood pressure, the mean systolic blood pressure was 142.1 ± 12.4 mmHg in Kassala haemodialysis patients and 144.8 ± 13.1 mmHg in Al-Gadarif haemodialysis patients, whereas the control group had a significantly lower mean systolic pressure of 122.4 ± 8.9 mmHg. This difference was statistically highly significant (p < 0.0001). Similarly, the mean diastolic blood pressure in Kassala haemodialysis patients was 88.5 ± 9.6 mmHg, and 89.3 ± 8.9 mmHg in Al-Gadarif haemodialysis patients. Both values were higher than that observed in the control group (77.2 ± 6.4 mmHg), with the difference being highly significant (p < 0.0001).

Table 3.3: Anthropometric and Hemodynamic Parameters

Parameter	Kassala HD	Al-Gadarif HD	Controls	p-value
Waist Circumference (cm)	94.5 ± 9.8	96.2 ± 10.1	85.3 ± 7.2	<0.0001
Systolic BP (mmHg)	142.1 ±12.4	144.8 ± 13.1	122.4 ±8.9	<0.0001
Diastolic BP (mmHg)	88.5 ± 9.6	89.3 ± 8.9	77.2 ± 6.4	<0.0001

The mean fasting blood glucose (FBG) level was 117.8 ± 19.5 mg/dL in haemodialysis patients from Kassala and 121.3 ± 21.1 mg/dL in Al-Gadarif patients, significantly higher than the control group (91.2 ± 8.6 mg/dL) (p < 0.0001).

For triglycerides, Kassala patients had a mean level of 172.4 ± 37.9 mg/dL, while Al-Gadarif patients had 179.2 ± 41.2 mg/dL, compared to a lower mean in controls (121.6 ± 24.7 mg/dL), with a highly significant difference (p < 0.0001).

Conversely, HDL cholesterol, the "protective" lipid fraction, was significantly lower in haemodialysis patients (37.8 ± 6.9 mg/dL in Kassala and 35.6 ± 7.1 mg/dL in Al-Gadarif) than in the control group (48.9 ± 8.3 mg/dL) (p < 0.0001).

Table 3.4: Metabolic Profile of Study Participants

Parameter	Kassala HD	Al-Gadarif HD	Controls	p-value
Fasting Blood Glucose (mg/dL)	117.8 ± 19.5	121.3 ± 21.1	91.2 ± 8.6	<0.0001
Triglycerides (mg/dL)	172.4 ± 37.9	179.2 ± 41.2	121.6 ± 24.7	<0.0001
HDL Cholesterol (mg/dL)	37.8 ± 6.9	35.6 ± 7.1	48.9 ± 8.3	<0.0001

Among the haemodialysis patients, 27 out of 70 patients (38%) in Kassala and 29 out of 70 patients (42%) in Al-Gadarif met the criteria for metabolic syndrome (MetS). In contrast, none of the control subjects (0 out of 140, 0%) had MetS. These results demonstrate a substantial prevalence of metabolic syndrome among haemodialysis patients, while it was absent in the apparently healthy control group.

Table 3.5: Prevalence of Metabolic Syndrome by Center

Group	Number of HD Patients	Number with MetS	Prevalence (%)
Kassala	70	27	38%
Al-Gadarif	70	29	42%
Controls	140	0	0%

Hypertension was universal among all haemodialysis patients, with 100% affected in both Kassala and Al-Gadarif. Abdominal obesity was present in 63% of Kassala patients and 67% of Al-Gadarif patients, giving a total prevalence of 65% among the studied haemodialysis population. Low HDL cholesterol was observed in 56% of Kassala and 60% of Al-Gadarif patients (total 58%). Hypertriglyceridemia affected 52% of Kassala patients and 58% of Al-Gadarif patients (total 55%). Hyperglycemia was present in 47% of Kassala patients and 51% of Al-Gadarif patients (total 49%).

Table 3.6: Frequency of Metabolic Syndrome Components among HD Patients

MetS Component	Kassala HD (%)	Al-Gadarif HD (%)	Total HD (%)
Hypertension	100	100	100
Abdominal Obesity	63	67	65
Low HDL Cholesterol	56	60	58
Hypertriglyceridemia	52	58	55
Hyperglycemia	47	51	49

Triglycerides and systolic blood pressure (SBP) showed a strong positive correlation ($r = +0.707$, $p < 0.001$), indicating that higher triglyceride levels were associated with higher systolic blood pressure. Triglycerides and fasting blood glucose (FBG) were moderately positively correlated ($r = +0.522$, $p < 0.01$), suggesting a relationship between lipid and glucose abnormalities in this population.

Triglycerides and HDL cholesterol (HDL-C) demonstrated a moderate negative correlation ($r = –0.370$, $p < 0.01$), reflecting the expected inverse relationship between these lipid parameters. Waist circumference and blood pressure were positively correlated ($r = +0.428$, $p < 0.01$), highlighting the link between central obesity and elevated blood pressure in haemodialysis patients.

Table 3.7: Correlation between Metabolic Parameters in HD Patients

Correlation Pair	r-value	p-value	Interpretation
Triglycerides vs. Systolic BP	+0.707	<0.001	Strong positive correlation
Triglycerides vs. Fasting Glucose	+0.522	<0.01	Moderate positive correlation
Triglycerides vs. HDL-C	–0.370	<0.01	Moderate negative correlation
Waist Circumference vs. Blood Pressure	+0.428	<0.01	Positive correlation

Urea levels were comparable between Kassala (145.84 ± 43.6 mg/dL) and Al-Gadarif (148.2 ± 45.3 mg/dL) patients ($p = 0.42$). Serum creatinine showed no significant difference (9.70 ± 2.69 mg/dL vs. 9.90 ± 2.73 mg/dL, $p = 0.39$). Fasting blood glucose was slightly higher in Al-Gadarif patients (121.3 ± 21.1 mg/dL) than in Kassala (117.8 ± 19.5 mg/dL), but this difference was not statistically significant ($p = 0.21$). Triglycerides were similar between Kassala (172.4 ± 37.9 mg/dL) and Al-Gadarif (179.2 ± 41.2 mg/dL, $p = 0.28$). HDL cholesterol levels were also comparable (37.8 ± 6.9 mg/dL vs. 35.6 ± 7.1 mg/dL, $p = 0.18$). Waist circumference showed no significant difference between the two centers (94.5 ± 9.8 cm vs. 96.2 ± 10.1 cm, $p = 0.26$).

Table 3.8: Comparison between Kassala and Al-Gadarif HD Patients

Parameter	Kassala (Mean ± SD)	Al-Gadarif (Mean ± SD)	p-value
Urea (mg/dL)	145.84 ± 43.6	148.2 ± 45.3	0.42
Creatinine (mg/dL)	9.70 ± 2.69	9.90 ± 2.73	0.39
Fasting Glucose (mg/dL)	117.8 ± 19.5	121.3 ± 21.1	0.21
Triglycerides (mg/dL)	172.4 ± 37.9	179.2 ± 41.2	0.28
HDL-C (mg/dL)	37.8 ± 6.9	35.6 ± 7.1	0.18
Waist Circumference (cm)	94.5 ± 9.8	96.2 ± 10.1	0.26

Waist circumference was significantly higher in males (97.2 ± 9.3 cm) compared with females (91.8 ± 8.4 cm, $p < 0.05$). Triglyceride levels were also higher in males (180.6 ± 36.2 mg/dL) than in females (165.3 ± 33.9 mg/dL, $p < 0.05$). In contrast, HDL cholesterol was higher in females (39.2 ± 6.8 mg/dL) than in males (35.9 ± 7.1 mg/dL, $p < 0.05$). The prevalence of metabolic syndrome (MetS) was comparable between sexes (41% in males vs. 39% in females, not significant).

Table 3.9: Gender Differences among Hemodialysis Patients

Parameter	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Waist Circumference (cm)	97.2 ± 9.3	91.8 ± 8.4	<0.05
Triglycerides (mg/dL)	180.6 ± 36.2	165.3 ± 33.9	<0.05
HDL Cholesterol (mg/dL)	35.9 ± 7.1	39.2 ± 6.8	<0.05
Prevalence of MetS (%)	41	39	NS

4. DISCUSSION

The present study identified a considerable burden of metabolic syndrome (MetS) among Sudanese patients receiving maintenance hemodialysis (HD), with prevalence rates of 38% in Kassala and 42% in Al-Gadarif. Patients undergoing dialysis demonstrated significantly greater central adiposity, elevated blood pressure, increased fasting plasma glucose, and higher triglyceride concentrations, accompanied by reduced HDL cholesterol levels compared with healthy controls ($p < 0.0001$). These findings reflect a pronounced cardiometabolic risk profile consistent with patterns described in international dialysis cohorts [1–3].

As expected in advanced renal failure, serum urea and creatinine concentrations were markedly elevated in both dialysis groups relative to controls ($p < 0.0001$), confirming severe impairment of renal clearance. Comparable biochemical profiles have been reported in HD populations across various low- and middle-income settings [4, 5]. Although intercenter comparisons did not demonstrate statistical significance, marginally higher mean values in Al-Gadarif may suggest subtle differences in dialysis efficiency, dietary intake, or adherence to therapeutic regimens.

Electrolyte disturbances were frequently observed, particularly hyperkalemia, which remains a critical clinical concern due to its association with arrhythmogenic risk and sudden cardiac events [6]. Beyond electrolyte imbalance, dialysis patients exhibited significant metabolic derangements characterized by hyperglycemia and an atherogenic lipid pattern. These abnormalities are strongly linked to insulin resistance and chronic inflammatory activation, which are well-recognized features of uremia [7, 8].

Hypertension emerged as the most prevalent MetS component, affecting all patients in the HD cohort. This observation supports existing evidence that fluid retention, persistent activation of the renin–angiotensin–aldosterone system, and vascular remodeling contribute substantially to blood pressure elevation in ESRD [9]. Increased waist circumference further indicates a high prevalence of visceral adiposity, a known contributor to insulin resistance, oxidative stress, and systemic inflammation [10].

The overall frequency of MetS in this Sudanese dialysis population aligns with figures reported from parts of the Middle East and South Asia, yet exceeds estimates previously documented among non-dialysis CKD populations within Sudan [11–13]. This pattern suggests that metabolic abnormalities may become more pronounced following progression to ESRD and initiation of dialysis therapy.

Correlation analysis revealed significant associations among triglycerides, systolic blood pressure, and fasting glucose, in addition to an inverse relationship between triglycerides and HDL cholesterol. These findings reinforce the concept that MetS components cluster through shared pathophysiological pathways involving insulin resistance, endothelial dysfunction, and inflammatory signaling [8-14].

From a clinical perspective, the concurrence of hypertension, dyslipidemia, and impaired glucose metabolism substantially amplifies cardiovascular risk—the primary cause of mortality in dialysis-dependent patients [15]. Evidence indicates that individuals with both ESRD and MetS experience significantly higher rates of cardiovascular and all-cause mortality compared with those without MetS [15]. Accordingly, routine metabolic assessment, optimization of dialysis adequacy, structured nutritional guidance, and improved access to pharmacologic therapy are critical for mitigating risk in Sudanese HD centers.

Future investigations should incorporate prospective follow-up designs, inflammatory biomarker profiling, and targeted intervention strategies to clarify the long-term impact of metabolic syndrome on survival and quality of life among Sudanese dialysis patients.

5. CONCLUSION AND RECOMMENDATIONS

This study highlights a high prevalence of metabolic syndrome (MetS) among Sudanese hemodialysis patients, reflecting a significant cardiometabolic burden that increases cardiovascular risk. Central obesity, hypertension, hyperglycemia, and dyslipidemia frequently co-occur, underscoring the need for early detection and management.

Recommendations:

1. Implement routine screening for MetS components in dialysis centers.
2. Promote lifestyle interventions, including diet optimization, weight management, and physical activity.
3. Ensure dialysis adequacy and monitor water quality to support metabolic stability.
4. Improve access to antihypertensive, lipid-lowering, and glucose-regulating therapies.
5. Invest in dialysis infrastructure, workforce training, and preventive nephrology services.
6. Conduct longitudinal studies to evaluate the impact of MetS on morbidity and mortality and explore targeted interventions.

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