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Analysis of Biochemical Profiles in Healthy Individuals, Chronic Kidney Disease, and Diabetic Kidney Disease Patients Undergoing Hemodialysis: A Cross-Sectional Study in Tarhuna, Libya

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تحليل المؤشرات الكيميائية الحيوية لدى الأفراد الأصحاء ومرضى القصور الكلوي المزمن ومرضى اعتلال الكلى السكري الخاضعين للغسيل الكلوي: دراسة مقطعية في ترهونة، ليبيا

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Abstract

Chronic kidney disease (CKD), particularly when complicated by type 2 diabetes mellitus (T2DM), constitutes a major global public health burden due to the progressive decline in renal function and the accumulation of metabolic waste products. Regular assessment of biochemical parameters in patients undergoing hemodialysis is essential for evaluating dialysis adequacy, monitoring metabolic and nutritional status, and facilitating early detection of cardiovascular and systemic complications. This cross-sectional study aimed to compare selected biochemical parameters among healthy individuals, patients with chronic kidney disease undergoing hemodialysis, and patients with diabetic kidney disease receiving hemodialysis in Tarhuna, Libya. A total of 87 participants were enrolled and categorized into three groups: 45 patients with CKD on regular hemodialysis, 25 patients with diabetic kidney disease on hemodialysis, and 17 apparently healthy individuals. Sociodemographic characteristics and medical histories were obtained using a structured questionnaire, and venous blood samples were collected for

the determination of fasting blood glucose, creatinine, blood urea nitrogen, uric acid, calcium, and serum albumin using standard laboratory methods. Statistical comparisons were performed using one-way analysis of variance, with significance set at $p < 0.05$. The findings revealed significantly elevated levels of creatinine, blood urea nitrogen, and uric acid in both patient groups compared with healthy controls. Patients with diabetic kidney disease exhibited markedly higher fasting blood glucose levels than both non-diabetic CKD patients and healthy individuals. Serum albumin levels were unexpectedly higher among hemodialysis patients relative to controls, while no statistically significant differences were observed in serum calcium levels across the study groups. These results highlight distinct biochemical alterations associated with chronic kidney disease and diabetic kidney disease in hemodialysis patients and underscore the importance of continuous biochemical monitoring to optimize clinical management and reduce the risk of complications.

Keywords: : Chronic Kidney Disease, Diabetic Kidney Disease, Hemodialysis, Biochemical Markers, Creatinine, Blood Urea Nitrogen, Uric Acid, Hyperglycemia.

الملخص

يُعدّ مرض الكلى المزمن، ولا سيما عندما يترافق مع داء السكري من النوع الثاني، من أبرز التحديات الصحية العامة على المستوى العالمي، نظرًا لما يسببه من تدهور تدريجي في الوظيفة الكلوية وتراكم الفضلات الأيضية في الجسم. وتُعد المتابعة الدورية للمؤشرات الكيميائية الحيوية لدى المرضى الخاضعين للغسيل الكلوي أمرًا بالغ الأهمية لتقييم كفاءة الغسيل، ومراقبة الحالة الغذائية والمعدنية، والكشف المبكر عن المضاعفات القلبية والاضطرابات الجهازية الأخرى. هدفت هذه الدراسة المقطعية إلى مقارنة بعض المؤشرات الكيميائية الحيوية المختارة بين الأفراد الأصحاء، ومرضى القصور الكلوي المزمن الخاضعين للغسيل الكلوي، ومرضى اعتلال الكلى السكري الذين يتلقون الغسيل الكلوي في مدينة ترهونة، ليبيا. شملت الدراسة 87 مشاركًا جرى تقسيمهم إلى ثلاث مجموعات: 45 مريضًا بالقصور الكلوي المزمن يخضعون لغسيل كلوي منتظم، و25 مريضًا باعتلال الكلى السكري يتلقون الغسيل الكلوي، و17 فردًا سليمًا ظاهريًا. جُمعت البيانات الديموغرافية والتاريخ الطبي باستخدام استبيان منظم، كما سُحبت عينات دم وريدية لقياس سكر الدم الصائم، والكرياتينين، ونيتروجين يوريا الدم، وحمض اليوريك، والكالسيوم، وألبومين المصل باستخدام الطرق المخبرية القياسية. أُجريت المقارنات الإحصائية باستخدام تحليل التباين الأحادي، مع اعتماد مستوى دلالة إحصائية قدره ($p < 0.05$). أظهرت النتائج ارتفاعًا ذا دلالة إحصائية في مستويات الكرياتينين ونيتروجين يوريا الدم وحمض اليوريك لدى مجموعتي المرضى مقارنةً بالمجموعة الضابطة السليمة، كما سُجّل ارتفاع ملحوظ في مستوى سكر الدم الصائم لدى مرضى اعتلال الكلى السكري مقارنةً ببقية المجموعات. وعلى نحو غير متوقع، كانت مستويات ألبومين المصل أعلى لدى مرضى الغسيل الكلوي مقارنةً بالأفراد الأصحاء، في حين لم تُسجّل فروق ذات دلالة إحصائية في مستويات الكالسيوم بين المجموعات المدروسة. وتؤكد هذه النتائج وجود تغيرات كيميائية حيوية مميزة مرتبطة بمرض الكلى المزمن واعتلال الكلى السكري لدى المرضى الخاضعين للغسيل الكلوي، مما يبرز أهمية المتابعة المنتظمة لهذه المؤشرات لتحسين التدبير العلاجي والحد من المضاعفات الصحية.

الكلمات المفتاحية : مرض الكلى المزمن، اعتلال الكلى السكري، الغسيل الكلوي، المؤشرات الكيميائية الحيوية، الكرياتينين، نيتروجين يوريا الدم، حمض اليوريك، فرط سكر الدم.

Introduction

Type 2 diabetes mellitus (T2DM) has emerged as one of the most critical global health challenges, characterized by chronic hyperglycemia and insulin resistance that exert deleterious effects on multiple organ systems. Among these complications, the kidneys are particularly vulnerable, with diabetic nephropathy recognized as a leading microvascular disorder and the predominant driver of end-stage renal disease (ESRD) worldwide (Dabla, 2010; Zhang *et al*., 2025). The clinical trajectory of diabetic kidney disease (DKD) is typically defined by persistent albuminuria and progressive declines in glomerular filtration rate (GFR), underscoring the necessity of early detection and timely intervention to mitigate renal deterioration (Morales *et al*., 2023; Zhao *et al*., 2025).

The global burden of diabetes continues to escalate, with prevalence rising from approximately 4% in 1995 to an estimated 5.4% by 2025, and a substantial proportion of affected individuals expected to develop renal impairment during their lifetime (Dabla, 2010; Lu Zhang *et al*., 2025). Epidemiological analyses further highlight disparities in susceptibility, with African American and Hispanic populations demonstrating higher rates of DKD compared to Caucasians, reflecting the complex interplay of genetic predisposition, socioeconomic determinants, and lifestyle factors (Hoogeveen, 2022; Jha *et al*., 2024).

Recent advances in nephrology have emphasized the need to reconceptualize DKD as "chronic kidney disease with diabetes as a risk factor," a framework that facilitates individualized treatment strategies and improved patient outcomes (Speeckaert & Rossing, 2025). Moreover, integrative approaches that combine biochemical monitoring of renal function with metabolic profiling, including lipid parameters, have been shown to enhance clinical decision-making in diabetic care (Comprehensive Journal of Science, 2025). Such perspectives reinforce the interconnectedness of diabetes management and kidney health, highlighting the importance of multimodal assessment in improving prognosis and reducing the societal burden of DKD (Zhao *et al*., 2025; Zhang *et al*., 2025).

- **Materials and Methods**

Study Design and Sample Collection

This cross-sectional comparative study was conducted in Tarhuna, Libya, from June 2025 to September 2025, targeting three distinct population groups to assess biochemical changes associated with renal insufficiency and type 2 diabetes mellitus. The study included a total of 87 participants, divided as follows:

Group I: Patients with chronic renal failure undergoing regular hemodialysis (n = 45)

Group II: Patients with renal failure coexisting with type 2 diabetes mellitus (n = 25)

Control Group: Apparently healthy individuals with normal renal indicators and no medical history of renal disease (n = 17)

Participants were selected from local healthcare centers and dialysis units in Tarhuna. Data collection involved two components:

Structured questionnaire

Used to document sociodemographic information, medical history, and relevant clinical variables. Blood sampling: Venous blood (5 mL) was drawn from each participant using sterile polypropylene tubes without anticoagulant. Samples were allowed to clot naturally to preserve serum integrity, followed by centrifugation. The extracted serum was transferred to sterile, dry containers and stored at appropriate conditions until analysis.

Biochemical Analysis

The biochemical parameters selected for evaluation were based on their relevance to renal and diabetic conditions:

Blood glucose level Serum urea concentration Creatinine Calcium concentration Serum albumin

Statistical Analysis

Data entry and analysis were performed using IBM SPSS Statistics (version 27). Descriptive statistics were generated to present the biochemical parameters, expressed as mean and

standard deviation for each group. Differences among the three study groups were assessed using one-way analysis of variance (ANOVA), with statistical significance defined at $p < 0.05$.

- **Results**

Demographic and Clinical Characteristics of the Study Participants

The study included a total of 87 participants, with a mean age of 46.06 years (SD = 15.132), ranging from 18 to 84 years. This age variability reflects a diverse sample across adult age groups, which may influence disease progression, treatment response, and the interpretation of biochemical parameters, particularly in patients undergoing hemodialysis with coexisting type 2 diabetes mellitus.

Gender Distribution

The gender distribution of the participants revealed a predominance of male participants, accounting for 58.6% (n = 51) of the sample, while females represented 41.4% (n = 36). This gender imbalance may reflect the demographic characteristics of patients undergoing hemodialysis with type 2 diabetes mellitus in Tarhuna.

Group Distribution The study cohort was composed of three distinct groups for comparative analysis of biochemical markers:

- **Control Group:** 17 participants (19.5%)
- **Chronic Kidney Disease (CKD) Group:** 45 participants (51.7%)
- **Diabetic Kidney Disease (DKD) Group:** 25 participants (28.7%)

Figure 1: Demographic and clinical characteristics of study participants

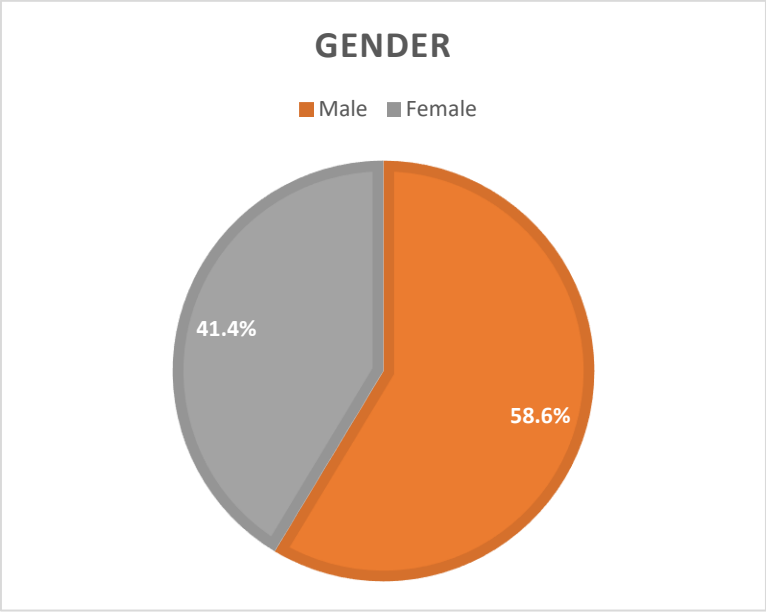

Figure 1: (A) Gender distribution of participants

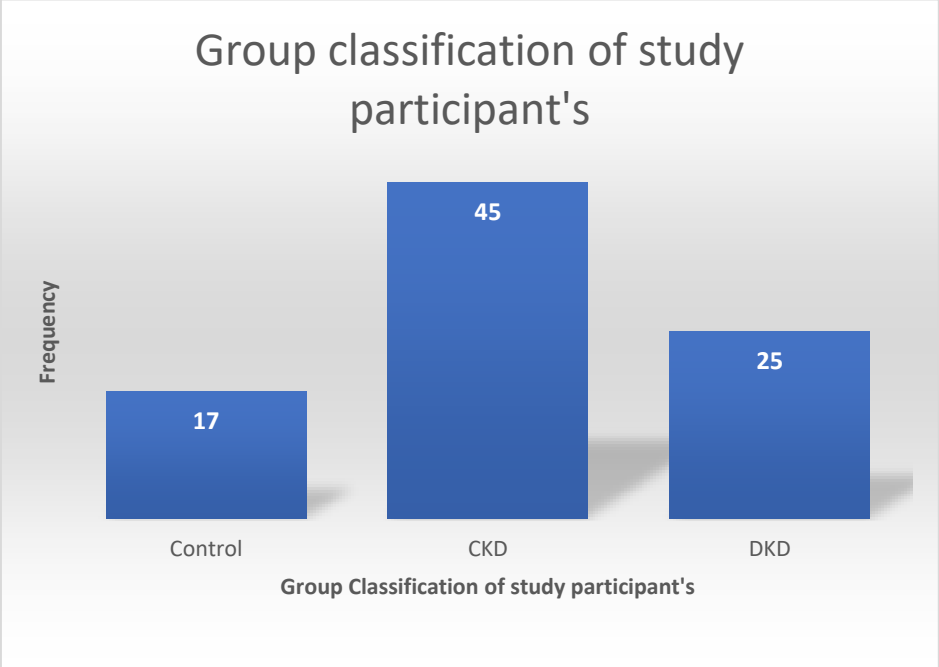

Figure 1: (B) Group classification of study participants

Comparison of Biochemical Parameters Among Control, CKD, and DKD Groups

The analysis of biochemical parameters revealed statistically significant differences among the three study groups: Control, Chronic Kidney Disease (CKD), and Diabetic Kidney Disease (DKD). Specifically, the levels of blood glucose, creatinine, blood urea nitrogen (BUN), uric acid, and serum albumin exhibited significant variations ($p < 0.05$) across the groups.

- **Blood Glucose:** The DKD group demonstrated markedly elevated blood glucose levels compared to both the CKD and Control groups, indicating the impact of diabetes on metabolic regulation.
- **Creatinine:** Creatinine levels were significantly higher in both the CKD and DKD groups, reflecting impaired renal function associated with these conditions.
- **Blood Urea Nitrogen (BUN):** Similar to creatinine, BUN levels were significantly elevated in the CKD and DKD groups, further supporting the presence of renal dysfunction.
- **Uric Acid:** The levels of uric acid were also significantly higher in the CKD and DKD groups, which may indicate impaired renal clearance and contribute to the risk of gout and other complications.
- **Serum Albumin:** Interestingly, serum albumin levels were significantly different among the groups, with the CKD and DKD groups showing higher levels compared to the Control group, which may reflect variations in nutritional status or inflammatory responses.
- **Serum Calcium:** In contrast to the other parameters, serum calcium levels did not show statistically significant differences across the three groups ($p = 0.231$). This suggests that calcium metabolism may remain relatively stable despite the presence of renal impairment, possibly due to effective mineral supplementation or dietary intake among patients undergoing hemodialysis.

Table 1: Comparison of Biochemical Parameters Among Control, CKD, and DKD Groups.

Biochemical Parameter	Control (n=17)	CKD (n=45)	DKD (n=25)	F-value	p-value
BG_LEVEL (mg/dL)	88.12 ± 5.52	89.64 ± 19.80	194.84 ± 87.66	41.290	0.000
Creatinine (mg/dL)	0.841 ± 0.12	11.59 ± 17.66	7.30 ± 1.76	4.439	0.015
BUN (mg/dL)	17.59 ± 4.40	106.13 ± 30.33	103.91 ± 26.55	76.724	0.000
Calcium (mg/dL)	9.27 ± 0.97	8.93 ± 1.38	8.57 ± 1.37	1.490	0.231
Uric Acid (mg/dL)	3.81 ± 0.44	6.67 ± 0.70	6.63 ± 0.75	122.358	0.000
Albumin (g/dL)	3.54± 0.40	4.40 ± 1.22	4.23 ± 0.97	4.313	0.016

Values are expressed as mean ± SD.
CKD = Chronic Kidney Disease, DKD = Diabetic Kidney Disease.
p-values obtained using one-way ANOVA, $p < 0.05$ considered statistically significant

- **Discussion**

The biochemical analysis in this cross-sectional study revealed distinct alterations across the three groups, with the DKD cohort exhibiting markedly elevated fasting blood glucose compared to CKD and controls, a finding that concurs with Morales *et al*. (2023) and Papadopoulou-Marketou *et al*. (2023), who emphasized chronic hyperglycemia as a central driver of nephropathy progression. Similar elevations have been reported in diabetic populations in Saudi Arabia (Al-Rubeaan *et al*., 2014), reinforcing the global relevance of our findings, although divergence arises when compared to Speeckaert and Rossing (2025), who noted that intensive glycemic control may attenuate renal decline, contrasting with the poor glycemic regulation observed in our cohort. Creatinine levels were significantly higher in both CKD and DKD groups relative to controls, consistent with Dabla (2010) and Jha *et al*. (2024), who identified serum creatinine as a reliable marker of renal clearance impairment; however, our observation that CKD patients demonstrated higher creatinine than DKD patients diverges from Zhang *et al*. (2025), who reported more pronounced elevations in DKD due to combined metabolic stress, suggesting that dialysis adequacy and nutritional factors may explain this discrepancy. Elevated BUN values in both patient groups corroborate findings by Zhao *et al*. (2025) and Hoogeveen (2022), who emphasized BUN as a sensitive indicator of nitrogenous waste accumulation, with our results fully aligned, though variability has been noted in relation to protein intake (Papadopoulou-Marketou *et al.,* 2023). In contrast, serum calcium levels did not differ significantly across groups, agreeing with Papadopoulou-Marketou *et al*. (2023), who observed stability in well-managed dialysis patients, yet diverging from Morales *et al*. (2023), who documented hypocalcemia in advanced CKD due to secondary hyperparathyroidism, suggesting that local dietary intake or supplementation practices may explain the stability in our cohort. Both CKD and DKD groups demonstrated significant hyperuricemia compared to controls, in agreement with Zhao *et al*. (2025) and Hoogeveen (2022), who identified uric acid as a modifiable risk factor for CKD progression and cardiovascular complications, and

consistent with Al-Rubeaan *et al*. (2014), though Speeckaert and Rossing (2025) highlighted that uric acid levels may vary depending on dialysis frequency and residual renal function. Unexpectedly, serum albumin levels were higher in CKD and DKD groups compared to controls, diverging from Morales *et al*. (2023) and Zhang *et al*. (2025), who reported hypoalbuminemia as a common feature of advanced CKD due to proteinuria and malnutrition; however, our findings may agree with smaller studies suggesting transient hemoconcentration during dialysis or improved nutritional supplementation (Speeckaert & Rossing, 2025), highlighting the need for further investigation into local dietary patterns, dialysis protocols, and inflammatory markers. Collectively, these results demonstrate both concordance and divergence with global literature, underscoring the importance of contextualizing biochemical findings within regional populations and emphasizing the necessity of integrated monitoring strategies to improve patient outcomes (Papadopoulou-Marketou *et al*., 2023; Jha *et al*., 2024; Zhao *et al*., 2025; Zhang *et al*., 2025).

- **Conclusion**

This cross-sectional study effectively delineated the biochemical profiles of healthy individuals, patients with chronic kidney disease (CKD), and those with diabetic kidney disease (DKD) in Tarhuna, Libya. The findings unequivocally indicate that both CKD and DKD patient groups exhibit significant renal dysfunction, as evidenced by markedly elevated levels of blood urea nitrogen (BUN) and creatinine. These elevated markers are consistent with the established understanding of renal impairment in diabetic populations, where the kidneys' ability to filter waste products is compromised (Dabla, 2010; Morales *et al*., 2023).

Furthermore, the study highlights the pronounced pathological effects of diabetes, particularly in the DKD group, which demonstrated a significant state of hyperglycemia. This finding aligns with previous research indicating that chronic hyperglycemia is a major contributor to the progression of diabetic nephropathy, leading to further renal damage and complications (Morales *et al*., 2023). The elevated blood glucose levels observed in the DKD cohort underscore the critical need for effective glycemic control as part of a comprehensive management strategy for patients with diabetes.

Additionally, the results reveal a consistent elevation in uric acid levels across both patient cohorts, suggesting impaired renal clearance as a contributing factor. Elevated uric acid is not only a marker of renal dysfunction but also poses additional risks, including cardiovascular complications, which are prevalent in diabetic patients (Jha *et al*., 2024). This highlights the importance of monitoring uric acid levels in conjunction with other biochemical parameters to provide a more comprehensive assessment of patient health.

These findings underscore the critical need for ongoing monitoring and management of biochemical parameters in patients with CKD and DKD, particularly those with concurrent diabetes. Regular assessments can facilitate timely interventions that may slow disease progression and improve patient outcomes. The implications of this study extend beyond the local context, reinforcing the necessity for targeted public health strategies and clinical interventions aimed at improving outcomes for high-risk populations, particularly in regions with high prevalence rates of diabetes and renal disease (Al-Rubeaan *et al*., 2018).

Future research should focus on longitudinal studies to further elucidate the relationships between biochemical markers, disease progression, and treatment efficacy in these patient groups. Such studies could provide valuable insights into the long-term effects of various therapeutic interventions and help refine clinical guidelines for managing CKD and DKD in

diabetic patients. By enhancing our understanding of these relationships, healthcare providers can better tailor treatment strategies to meet the unique needs of this vulnerable population.

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Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.