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Original Article

# Association of Liver Function Tests and Inflammatory Biomarkers with eGFR in Chronic Kidney Disease Patients on Hemodialysis in Erbil City

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## ABSTRACT

**Background and Objective:** Chronic Kidney Disease is a global public health concern, particularly in patients undergoing hemodialysis, who face elevated cardiovascular risks and progressive renal dysfunction. These patients often exhibit disrupted lipid metabolism, impaired glycemic control, and altered body composition. However, the sex-specific associations between these metabolic factors and kidney function remain unclear. This study aimed to evaluate the relationship between anthropometric measurements, glycemic markers, and lipid profile components. It estimated the Glomerular Filtration Rate (eGFR) in male and female Chronic Kidney Disease patients on maintenance hemodialysis in Erbil City.

**Methods:** A cross-sectional study was conducted at Erbil Teaching Hospital between November 2024 and April 2025. It included 70 adult patients with Chronic Kidney Disease undergoing regular hemodialysis and 70 healthy controls. Body mass index (BMI), glycemic markers (fasting blood sugar and HbA1c), lipid profiles (total cholesterol, triglycerides, high-density lipoprotein, low-density lipoprotein, and very-low-density lipoprotein), and eGFR (calculated using the 2021 CKD-EPI formula) were analyzed. Correlation analyses were performed separately for genders using GraphPad Prism.

**Results:** BMI showed a statistically significant but clinically weak negative relationship with eGFR in both men and women. Glycemic markers (blood sugar and HbA1c) were inversely correlated with eGFR in males, whereas in females they showed a positive correlation, possibly reflecting early hyperfiltration. TC was weakly positively associated with eGFR in males but not in females. HDL showed a strong positive correlation with eGFR in males only. LDL was marginally positively associated with eGFR in females, while TG and VLDL showed no significant correlation in either sex.

**Conclusion:** In individuals undergoing hemodialysis, metabolic indicators exhibited sex-specific correlations with eGFR levels. Glycemic parameters and HDL had a stronger correlation with eGFR than BMI and other lipid indices. These findings emphasize the significance of sex-specific assessment in the metabolic management of chronic renal disease patients.

**Keywords:** Chronic Kidney Disease; Estimated Glomerular Filtration Rate; Lipid Profile

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## INTRODUCTION

Chronic kidney disease (CKD) is a serious public health concern that raises morbidity and mortality rates globally; about 10% of adults suffer from CKD. Significant changes in body composition and lipid metabolism are observed in patients with CKD, particularly those undergoing maintenance hemodialysis. These changes are closely associated with decreasing renal function and an increased risk of cardiovascular disease [1]. Recent studies highlight the potential of newer anthropometric indices like the Body Shape Index (ABSI) and Body Roundness Index (BRI) in predicting CKD progression, often outperforming traditional measures like BMI. For instance, a 2025 analysis of NHANES data indicated that measures of central obesity, including ABSI and the Conicity Index, were significantly associated with reduced eGFR and a higher prevalence of CKD. Similarly, research by Yang L et al. (2025 [2] showed that elevated Waist-to-Height Ratio (WHtR) and Conicity Index were strongly associated with impaired kidney function, further emphasizing the role of visceral adiposity in CKD. In addition to being a progressive loss of renal function, CKD is a condition that is greatly impacted by metabolic abnormalities, especially dyslipidemia, which raises the risk of cardiovascular morbidity and mortality in this population [3]. Elevated TG, decreased HDL-C, and changed lipoprotein composition are the hallmarks of dyslipidemia in CKD, with remnant cholesterol (RC) evolving as a new and significant metric [4].According to recent studies, a strong link exists between higher HbA1c levels and a more rapid decline in GFR. According to Warren et al. 2018 [5], patients with type 2 diabetes with CKD and higher $HbA_1c$ variability, rather than just mean levels, strongly predicted poor renal outcomes and the development of end-stage kidney disease (ESKD). A recent study from 2025 found that individuals with severe CKD who had $HbA_1c$ between 6.7% and 7.1% had fewer cardiovascular and microvascular issues, whereas those with levels above 7.2% were at higher risk [6]. In 2020, Kidney Disease Improving Global Outcomes (KDIGO) guidelines, which consider the trade-off between glycemic management and hypoglycemia risk, indicate customized targets between 6.5% and 8.0% [7]. There is no study that has discovered a connection between $HbA_1c$ and the onset of ESKD. [8] A study by Limkunakul et al. 2019 found that poorly managed $HbA_1c$ increased all-cause mortality but did not independently predict progression to ESKD in CKD patients with type 2 diabetes. This study is important because it investigates how metabolic parameters involving lipid levels, blood sugar, and body composition affect kidney performance differently in male and female hemodialysis patients. The findings, which revealed various sex-specific patterns — including higher connections between hyperglycemia, dyslipidemia, and lower eGFR in males and possible hyperfiltration in women — suggest that men and women may experience kidney deterioration via separate mechanisms. These findings highlight the need for more personalized, sex-specific monitoring and management strategies in patients with advanced chronic kidney disease.

## METHOD

This study was conducted at the Dialysis Unit/ Erbil Teaching Hospital, Erbil City, from November 10, 2024, to April 10, 2025. The objective was to examine correlations between anthropometric measures, glycemic control (HbA1c, blood sugar), lipid profiles, and eGFR in patients with end-stage renal disease (ESRD) undergoing maintenance hemodialysis.

The study population inclusion criteria were adults aged ≥18 years, diagnosed with chronic kidney disease (CKD), and on regular hemodialysis for at least six months, who provided written informed consent. Exclusion criteria included acute kidney injury, peritoneal or irregular dialysis, active infection, malignancy, thyroid dysfunction, systemic inflammatory disease, viral illnesses such as AIDS, or recent hospitalization within the past month. The study's subjects were divided into two categories: (Case group) 70 patients with CKD, and patients on dialysis machines, and (Control group) 70 healthy subjects served as controls; all were healthy volunteers and had no evidence of any renal disease. Regarding ethical considerations, the study was approved by the College of Health Science /Hawler Medical University Ethics Committee (Sc.E.C.12A), and written informed consent was obtained from all participants. Data collection procedures involved clinical evaluations, anthropometric measurements, and laboratory assessments performed before dialysis sessions to reduce fluid and metabolic variability. Anthropometric measurements: weight (kg) measured using a calibrated digital scale, height (cm) measured with a stadiometer, and BMI calculated as weight (kg) / height² ($m^2$)Glycemic parameters: fasting blood sugar (FBS) measured after 10–12 hours of fasting, using the One-Care Blood Glucose Meter, and HbA1c: analyzed via HPLC using a Cobas Integra 400 Plus and Bio-Tek ELx800 microplate reader. Lipid Profile: Collected after overnight fasting and before dialysis, parameters such as TC, TG, HDL-C, LDL-C, and VLDL were analyzed using the Cobas Integra 400 Plus analyzer. Renal Function: Serum creatinine was measured pre-dialysis, and eGFR was calculated using the 2021 CKD-EPI equation. The creatinine-based equation for estimating eGFR is a race-free formula that assesses kidney function via serum creatinine (SCr), age, and sex, replacing prior race-based equations to improve precision and equity. It is stated as eGFR = 142 × min (SCr/κ, 1)^α × max (SCr/κ, 1)^-1.200 × 0.9938^Age × 1.012 (if female), with κ (kappa) = 0.7 (female) or 0.9 (male) and α (alpha) = -0.241 (female) or -0.302 (male). Kidney healthcare groups endorse this formula for immediate clinical application. All data were analyzed using GraphPad version 9.0.0.121. Continuous variables were expressed as mean ± standard deviation (SD) based on distribution normality. Correlation between eGFR and continuous variables (BMI, HbA1c, blood sugar, lipid parameters) was assessed using Pearson's correlation for normally distributed data. Spearman's rank correlation for non-normally distributed data. A p-value ≤0.05 was considered statistically significant.

## RESULTS

Scatter plots were used to investigate the correlation between body mass index (BMI) and estimated glomerular filtration rate (eGFR) in both male and female subjects (Figure 1). Female BMI had a small but significant negative correlation with eGFR ($r = -0.1643$, $P < 0.0001$), suggesting that higher BMI was linked with somewhat lower eGFR values (Figure 1A). Despite reaching statistical significance, the strength of the connection was low. In males, BMI revealed a statistically significant but mild negative connection with eGFR ($r = -0.1708$, $P < 0.0001$) (Figure 1B). This finding implies that rising BMI was also related to a small drop in eGFR in males. Overall, although statistically significant associations were observed in both sexes, the correlations were weak, suggesting limited clinical relevance.

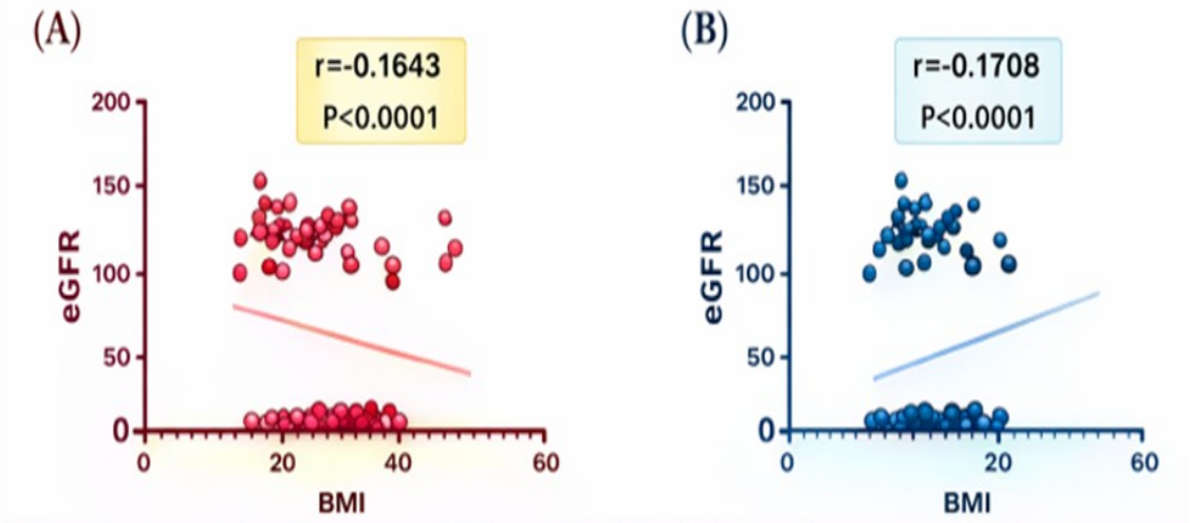


Figure 1: Correlation between eGFR and BMI in: (A) female group and (B) male group

Figure 2 indicates the connection between HbA1c (%) and estimated glomerular filtration rate (eGFR) in women and men. Females (Figure 2A) showed a strong positive connection between HbA1c and eGFR ($r = 0.6445$, $P < 0.0001$), showing that greater HbA1c levels were linked to higher eGFR values.

Males (Figure 2B) showed a moderate positive correlation between HbA1c and eGFR ($r = 0.4193$, $P < 0.0001$). These data indicate a sex-specific difference in the intensity of the correlation between glycemic status and kidney function, with females showing a stronger relationship than males.

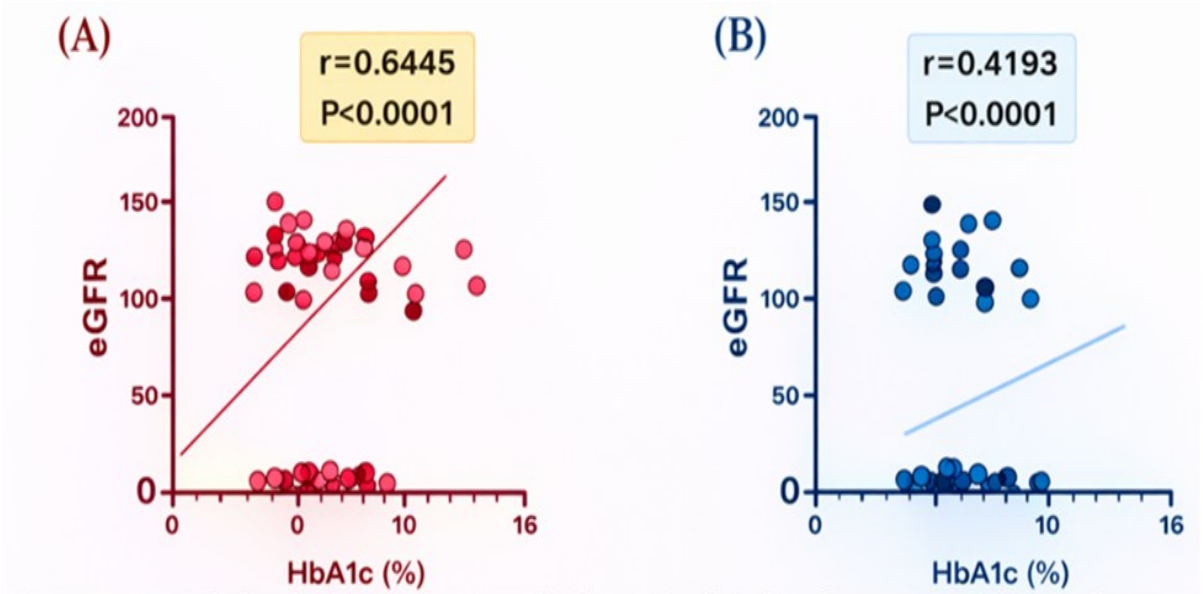


Figure 2: Correlation between eGFR and HbA1c in: (A) female group and (B) male group

Regarding blood sugar levels in females, there was a significant positive correlation between blood sugar levels and the rate of eGFR (r = 0.4110, P < 0.0001). This indicates that higher blood sugar levels were associated with higher eGFR values, as in Figure 3A.In males, there was a significant negative correlation between blood sugar levels and eGFR (r = -0.5585, p < 0.0001). This indicates that higher blood sugar levels were associated with lower eGFR values, suggesting a potential link between hyperglycemia and reduced kidney function in this group, as shown in Figure 3B.

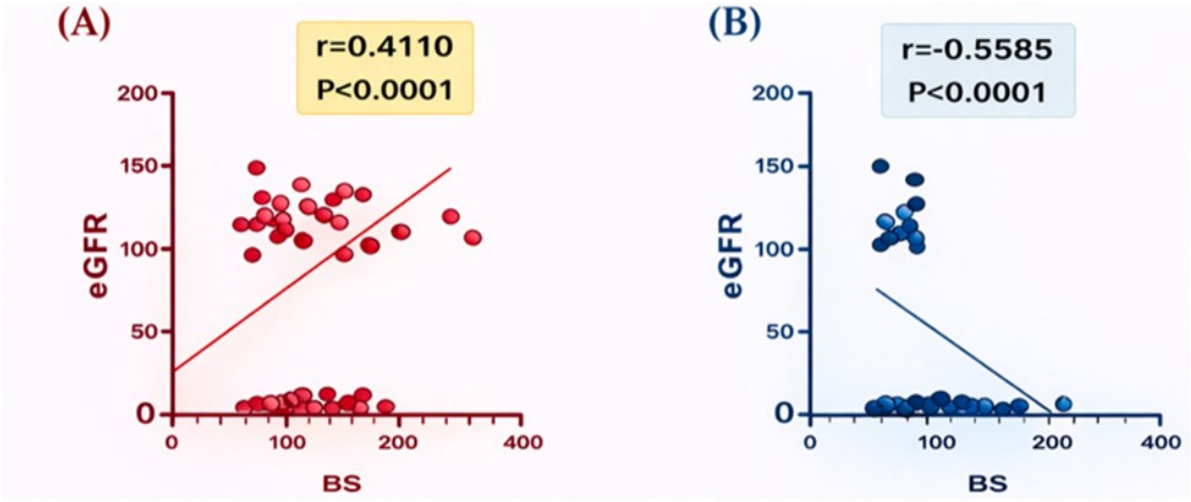


Figure 3: Correlation between eGFR and blood sugar in: (A) female group and (B) male group

Total cholesterol had a statistically significant but small correlation with eGFR in females (r = 0.03285, p < 0.0001), indicating minimal clinical significance. Despite the statistical significance, the correlation coefficient indicates a negligible relationship between total cholesterol levels and eGFR, as shown in Figure 4A. In males, there was a statistically significant but weak positive correlation between total cholesterol levels (mg/dL) and eGFR (r = 0.2236, p < 0.0001). This suggests that higher total cholesterol levels were associated with slightly higher eGFR values, though the strength of the association was modest, as shown in Figure 4B.

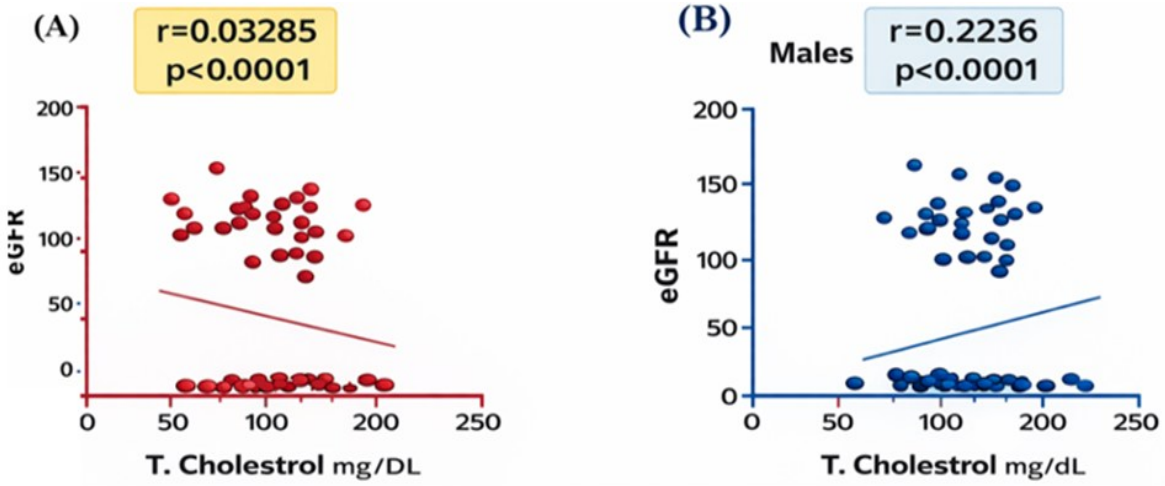


Figure 4: Correlation between eGFR and total cholesterol in: (A) female group and (B) male group

In females, although the correlation between triglyceride levels (mg/dL) and eGFR reached statistical significance ($p < 0.0001$), the strength of the association was extremely weak ($r = 0.1483$), indicating no clinically meaningful relationship between triglyceride levels and eGFR in this group, as shown in Figure 5A.

Similarly, in males, there was a statistically significant but weak connection between triglyceride levels and eGFR ($r = 0.09134$, $p = 0.0008$). Despite statistical significance, the small effect size indicates that triglyceride levels were not significantly related to changes in eGFR in males (Figure 5B).

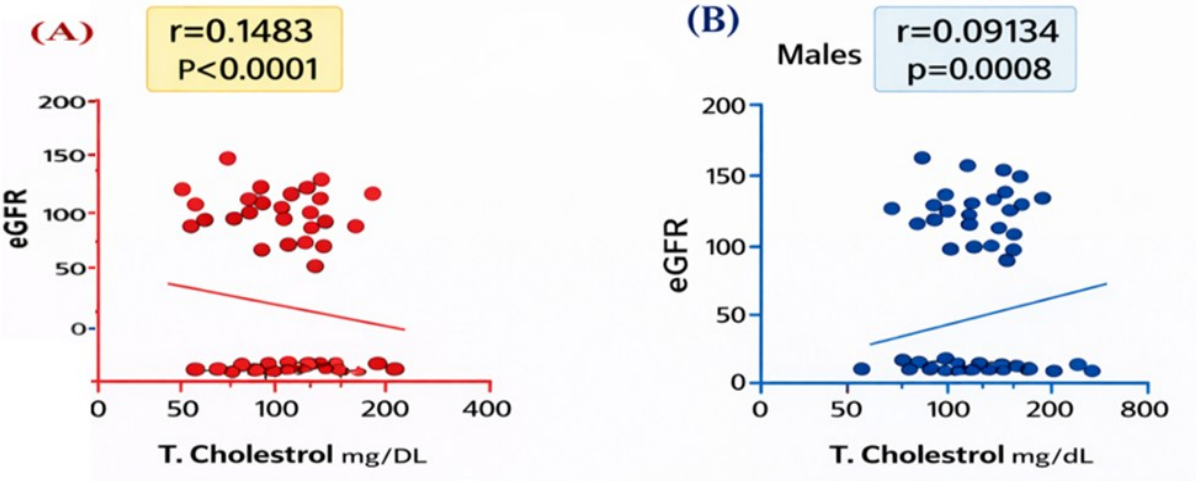


Figure 5: Correlation between eGFR and triglyceride in: (A) female group and (B) male group

Females had a statistically significant positive connection between HDL levels (mg/dL) and eGFR ($r = 0.65344$, $p < 0.0001$), showing that greater HDL levels were related to higher eGFR values (Figure 6A).

Male HDL levels showed a substantial and positive correlation with eGFR ($r = 0.5949$, $p < 0.0001$). This finding shows that greater HDL levels are related to better kidney function in men, as seen in Figure 6B.

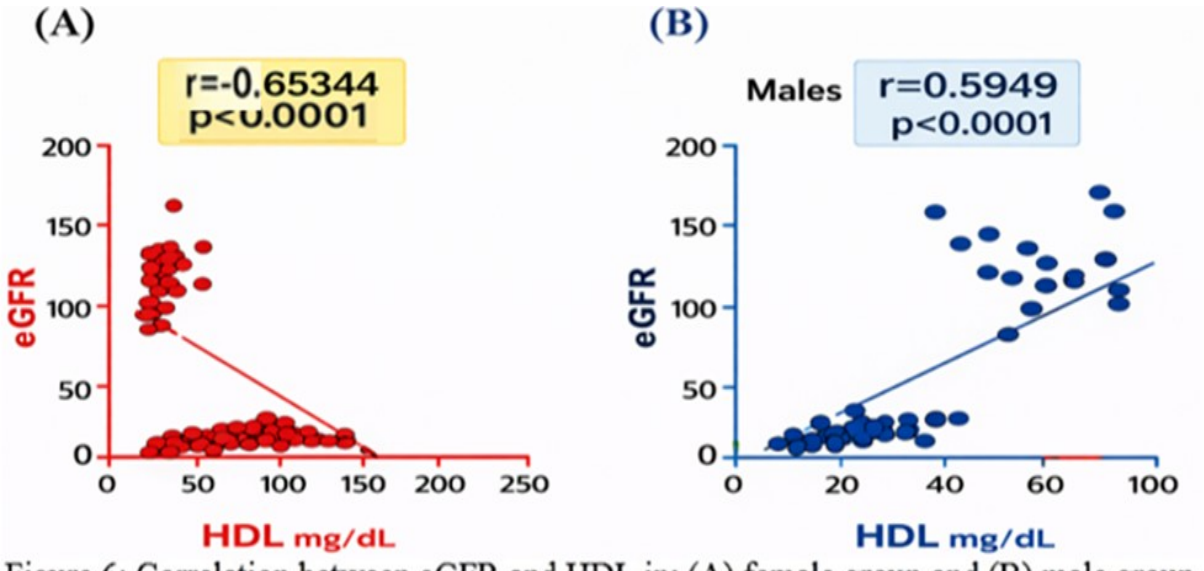


Figure 6: Correlation between eGFR and HDL in: (A) female group and (B) male group

In females, there was a statistically significant but weak positive correlation between LDL levels (mg/dL) and eGFR (r = 0.1550, P < 0.0001). This suggests that higher LDL levels were associated with slightly higher eGFR, although the strength of this relationship was minimal, as shown in Figure 7A.

In males, as shown in Figure 7B, p = 0.0008, there was no significant correlation between LDL levels (mg/dL) and eGFR (r = -0.1280). This indicates that LDL levels were not associated with changes in eGFR in this group.

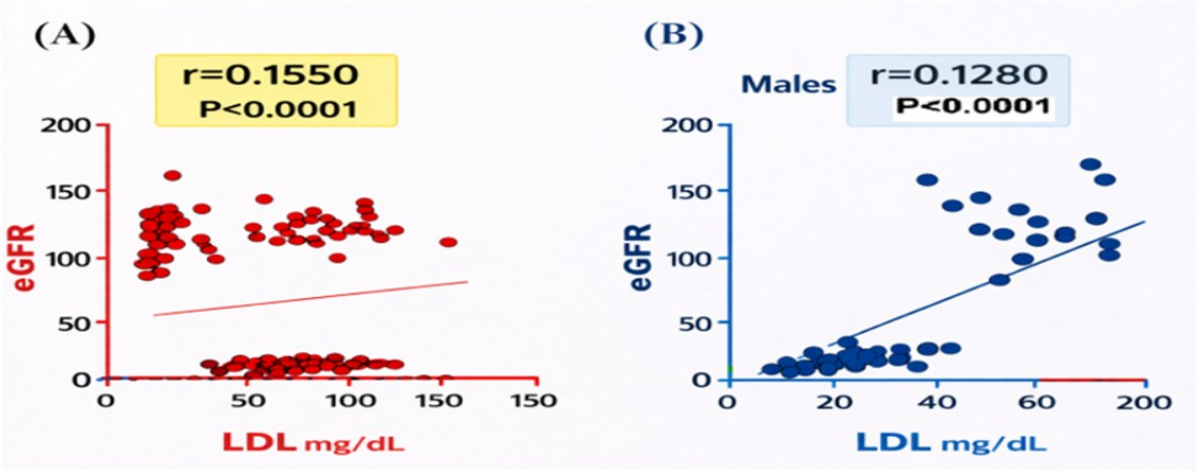


Figure 7: Correlation between eGFR and LDL in: (A) female group and (B) male group

Higher VLDL levels in females were inversely connected with eGFR (r = -0.2429, P < 0.0001), suggesting worse kidney function (Figure 8A). In males, VLDL levels were negatively linked with eGFR (r = -0.1821, P = 0.008), indicating a statistically significant but weaker connection (Figure 8B). These findings suggest that rising VLDL levels are linked to lowering eGFR in both sexes.

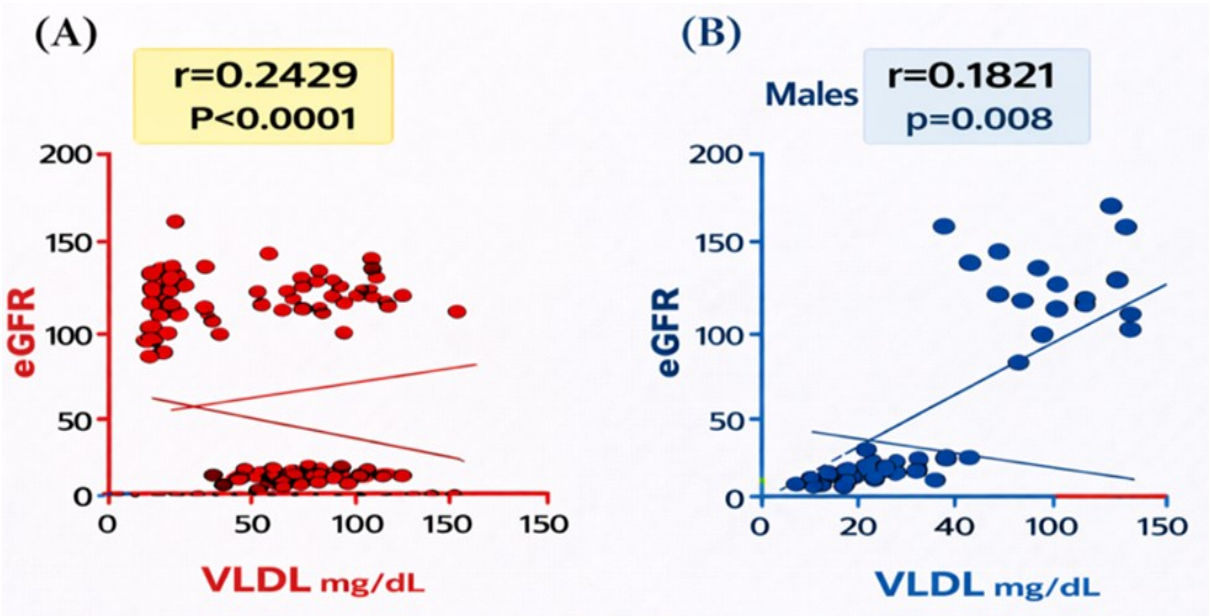


Figure 8: Correlation between eGFR and VLDL in: (A) female group and (B) male group

Table 1 shows substantial differences (P < 0.0001) between control and case groups for all parameters in both males and females. The case group exhibits significantly higher HbA1c and blood sugar levels, indicating poor glycemic management, whereas the control group had normal values. In addition, patients exhibited a more unfavorable lipid profile, characterized by higher total cholesterol and lower HDL levels, along with altered LDL, VLDL, and triglyceride concentrations, indicating an elevated cardiovascular risk. BMI varies significantly between groups, but the differences are less pronounced than those in glucose and lipid indices. The correlation coefficients show that glycemic indicators (HbA1c and blood sugar) and HDL had the highest relationships with eGFR, supporting the intimate relationship between hyperglycemia and dyslipidemia.

**Table 1:** Comparison of anthropometric, glycemic, and lipid profile parameters between case and control groups stratified by gender in patients with CKD on hemodialysis in Erbil City.

| Parameters | | Study groups Mean ± SD | | P-value | Correlation (r) |
|---|---|---|---|---|---|
| | | Control | Case | | |
| **BMI (Kg/m$^2$)** | Male | 28.95 ± 4.53 | 25.51 ± 6.78 | P<0.0001 | -0.1708 |
| | Female | 28.89±8.00 | 29.75 ± 4.58 | P<0.0001 | -0.1643 |
| **HbA1C (%)** | Male | 4.74 ± 0.45 | 6.34 ± 1.61 | P<0.0001 | -0.4193 |
| | Female | 4.62 ± 0.57 | 6.89 ± 1.92 | P<0.0001 | 0.6445 |
| **BS (mg/dl)** | Male | 151.11 ± 61.08 | 85.37 ± 12.38 | P<0.0001 | -0.5585 |
| | Female | 149.94 ± 60.35 | 99.64 ± 37.01 | P<0.0001 | 0.4110 |
| **TCH (mg/dl)** | Male | 130.63 ± 40.52 | 158.79 ± 29.24 | P<0.0001 | 0.2236 |
| | Female | 130.71 ± 45.22 | 162.78 ± 30.68 | P<0.0001 | 0.3285 |
| **TGL(mg/dl)** | Male | 193.79 ± 127.96 | 149.03 ± 98.85 | P=0.0008 | -0.009134 |
| | Female | 182.66 ± 89.7 | 150.6 ± 83.41 | P<0.0001 | -0.1483 |
| **HDL (mg/dl)** | Male | 32.41 ± 7.2 | 31.29 ± 11.26 | P<0.0001 | 0.5949 |
| | Female | 47.58 ± 62.21 | 34.01 ± 31.74 | P<0.0001 | -0.65344 |
| **LDL (mg/dl)** | Male | 116.57 ± 28.73 | 84.32 ± 28.94 | P<0.0001 | -0.1280 |
| | Female | 118.96 ± 27.78 | 87.81 ± 33.91 | P<0.0001 | 0.1550 |
| **VLDL (mg/dl)** | Male | 39.21 ± 25.38 | 31.63 ± 19.99 | P=0.0008 | -0.1821 |
| | Female | 38.44 ± 17.91 | 30.52 ± 17.11 | P<0.0001 | -0.2429 |

## DISCUSSION

This study looked at the interaction between numerous metabolic and lipid indices, as well as eGFR, in both men and women, and found sex-specific patterns in the association between kidney function and metabolic markers. In terms of BMI, both males and females showed statistically significant but weak negative associations with eGFR, indicating that higher BMI was linked to somewhat worse kidney function in both sexes. However, the strength of these relationships was low, implying that they had little clinical value.
Notably, whereas the BMI-eGFR association attained statistical significance in females, the amplitude of the correlation was small, showing that BMI alone may be an inadequate predictor of adiposity-related renal risk in women. This attenuation may be due to sex variations in fat distribution, hormonal control, and metabolic responses to obesity. Men tend to accumulate more metabolically active visceral adipose tissue, whereas women often store fat peripherally, which is thought to be less detrimental to metabolic and renal function [9].These findings are consistent with previous research, which found that visceral adiposity indexes outperformed BMI in predicting chronic kidney disease (CKD), particularly in women. A population-based study found that the visceral adiposity index was a better predictor of CKD than BMI in females [10], emphasizing the relevance of body fat distribution over total body mass. Furthermore, research from post-bariatric surgery cohorts suggests that improvements in kidney function among women correspond more closely with visceral fat reductions than with BMI changes alone [9]. Longitudinal studies also show that obesity contributes to CKD development via sex-specific molecular pathways, even in metabolically healthy individuals [11].Similarly, the relationship between HbA1c and eGFR differed by gender. Females showed a substantial positive connection between HbA1c and eGFR, implying that chronic hyperglycemia may contribute to early glomerular hyperfiltration. HbA1c was similarly favorably linked with eGFR in men, albeit at a lower level than in women. These findings highlight sex-specific renal responses to suboptimal glycemic control, with women exhibiting a more pronounced hyperfiltration response. Sex-based disparities in diabetic kidney disease are known to appear early in the disease progression. Women are more prone to glomerular hyperfiltration in the early stages of diabetes, whereas men may advance more quickly to functional deterioration as hyperglycemia persists [12,13]. Estrogen is thought to exert Reno protective effects by modulating angiotensin signaling and enhancing vasodilation, which may contribute to hyperfiltration in females. In contrast, testosterone provides less renal protection in males and may hasten renal injury after chronic hyperglycemic stress [14]. Notably, while men typically show a more consistent deterioration in kidney function over time, higher baseline HbA1c has been linked to faster eGFR drop in women in a Japanese population, indicating heightened renal sensitivity in females despite the presence of early hyperfiltration [12].The relationship between blood sugar and eGFR revealed sex-specific patterns. In females, there was a strong positive connection between higher blood sugar levels and elevated eGFR, which could reflect early glomerular hyperfiltration—a characteristic of preclinical diabetic nephropathy. In contrast, males showed a strong negative connection, with rising blood sugar levels linked to lower eGFR, implying gradual renal impairment. These findings are consistent with previously identified

physiological sex differences in diabetic kidney disease (DKD). Hyperfiltration in the early stages of DKD, particularly in females, has been attributed to sex-specific processes such as enhanced sodium-glucose co-transporter activity (SGLT1/2) and estrogen -mediated modulation of renal hemodynamics [14]. Previous research has indicated that DKD progression varies by sex, with males experiencing a faster deterioration in renal function and females more frequently exhibiting early hyperfiltration [15].Further supporting this interpretation, studies on insulin resistance have shown that post-load glucose abnormalities are more strongly related to alterations in GFR in males, whereas insulin resistance is a major driver of hyperfiltration in females [16]. The findings of the current study are consistent with this pattern, with males showing decreased eGFR and females displaying increased eGFR in response to rising blood sugar levels. Although hyperfiltration may be an early adaptive response, chronic hyperglycemia eventually increases glomerular damage and eGFR. The observed sex-based divergence in eGFR at comparable blood sugar levels is most likely due to these different disease trajectories [17].Total cholesterol had little to no association with eGFR in females, despite statistical significance, whereas males had a small but statistically significant positive correlation. These findings indicate that total cholesterol has a small and inconsistent effect on kidney function, with very minor sex differences. Overall, total cholesterol appears to be a poor predictor of renal outcomes in both sexes. These findings are consistent with previous evidence. A Japanese cohort study reported that elevated LDL cholesterol levels were associated with reduced eGFR in healthy males but not females, suggesting sex-specific susceptibility to dyslipidemia-related renal impairment [18]. Estrogen's Reno protective effects-including vasodilation, antioxidant activity, and antifibrotic properties may help shield females from cholesterol-induced kidney impairment. Furthermore, lipid abnormalities are more likely to contribute to renal dysfunction when paired with other risk factors such as diabetes or hypertension, which could explain why total cholesterol has a limited impact in isolation [19].A large CKD cohort further found slower eGFR decline in women, partially attributed to differences in lipid metabolism and cardiovascular risk, consistent with our finding of a weaker association in females [20]. Although TG had significant correlations with eGFR, the impact sizes were exceedingly small and probably clinically unimportant, indicating that TG may not substantially influence kidney function in either sex. This aligns with prior research suggesting limited direct renal impact of hypertriglyceridemia in the general population. A large Korean cohort found that elevated triglyceride (TG) levels were independently associated with adverse renal outcomes, but this association was more pronounced in individuals with pre-existing CKD than in those with normal eGFR [21]. Similarly, a recent meta-analysis reported that hypertriglyceridemia is linked to albuminuria and reduced eGFR primarily in CKD patients, supporting the idea that TG-related renal effects emerge more clearly as kidney disease progresses [22].There was a significant sex difference in the link between HDL levels and eGFR. While both males and females showed statistically significant, favorable relationships between HDL and kidney function, the correlation was slightly stronger in females than in males. These data imply that HDL may have a protective effect on renal function in both sexes, which could be mediated by differences in HDL composition, functionality, and cardiovascular risk profiles. Previous research

suggests sex-specific lipid-renal connections. A longitudinal Chinese cohort found that lower HDL-C and greater TG/LDL ratios were related to faster eGFR reduction in men, although the relationship was less pronounced in women [23]. Studies on the atherogenic index have found that males had higher HDL-related renal protection [11,24]. Hormonal factors may also contribute to these disparities, as estrogen has been proven to improve HDL function and increase endothelial and renal health. In contrast, testosterone has been connected to qualitative differences in HDL particles [25].The amplitude of the LDL-eGFR association was minor and equivalent between males and females, implying that gender does not significantly alter the impact of LDL on renal function. These findings are consistent with evidence from large CKD cohorts, such as the CRIC trial, which demonstrated no independent link between LDL-C and eGFR reduction in either sex [26,27]. Population-based studies have also found no significant sex differences in LDL levels among CKD patients [28], and multivariable analyses correcting for blood pressure, diabetes, and inflammation have revealed that LDL does not independently predict eGFR reduction [18].Although a Chinese CKD cohort found that baseline LDL-C predicted eGFR decline in men but not in women [18], our study's very weak correlations indicate that any sex-specific LDL effect on renal function is likely small and context-dependent, and may be outweighed by other metabolic and inflammatory risk factors. Overall, our findings show that LDL is not a major cause of kidney function decrease in either men or women, despite statistically significant relationships. Although the correlations between VLDL and eGFR were small, the continuous unfavorable connection identified in both males and females implies that triglyceride-rich lipoproteins may be associated with poorer renal function. This is consistent with data that VLDL remnants contribute to metabolic and inflammatory stress, potentially promoting kidney damage. However, as discussed in studies of CKD dyslipidemia, the primary involvement of VLDL in eGFR reduction is unknown, and its contribution may be secondary to other variables such as insulin resistance, hypertension, and systemic inflammation [29]. As a result, while VLDL is related to poor kidney function in this population, it may be more of a marker of metabolic risk than a direct driver of CKD progression.

## CONCLUSION

This study found sex-specific relationships between metabolic parameters and eGFR in individuals with chronic renal disease on maintenance hemodialysis. Body mass index had minor negative relationships with eGFR in both men and women, indicating little clinical importance. Glycemic indicators exhibited divergent patterns by sex, with males having greater blood sugar levels and lower eGFR, whereas females had positive relationships with blood sugar and HbA1c, presumably suggesting differences in residual kidney function. Lipid parameters were typically marginally linked with eGFR; HDL exhibited the strongest connection, while total cholesterol, triglycerides, LDL, and VLDL had little clinical importance. Overall, our data emphasize the significance of sex-specific interpretation of metabolic indicators in advanced CKD, and more extensive investigations are needed to clarify causal associations.

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