Razi Med J. 2026;2(2):224-228
https://doi.org/10.69667/rmj.26209
Razi Medical Journal
https://razi.edu.ly/rmj/index.php/hm

Original article

Gender and Age Effects on Serum Calcium, Phosphorus, and Alkaline Phosphatase in Hemodialysis Patients: An Analytical Study

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Abstract
Patients on maintenance hemodialysis frequently develop chronic kidney disease–mineral and bone disorder (CKD-MBD), characterized by abnormalities in calcium, phosphorus, and alkaline phosphatase (ALP). Despite routine calcium and vitamin D supplementation, the influence of age and gender on these parameters remains poorly understood. This study aimed to evaluate serum calcium, phosphorus, and ALP levels in hemodialysis patients and compare them across gender and age groups. A total of 100 patients undergoing maintenance hemodialysis were enrolled. All participants received regular calcium and vitamin D supplementation. Serum calcium, phosphorus, and ALP levels were measured. Comparisons were made between male and female patients using independent t-tests or Mann-Whitney U tests based on data normality. Differences across three age groups (<40 years, 41–59 years, and ≥60 years) were analyzed using one-way ANOVA or Kruskal-Wallis test, with post-hoc pairwise comparisons adjusted by Bonferroni correction. The mean serum calcium was 9.44 ± 0.67 mg/dL, the mean phosphorus was 6.53 ± 1.78 mg/dL, and the mean ALP was 192.2 ± 241.8 U/L. No significant gender differences were observed for calcium (p = 0.578), phosphorus (p = 0.929), or ALP (p = 0.799). Age-based analysis showed no significant differences in calcium (p = 0.371) or phosphorus (p = 0.076). However, ALP levels differed significantly across age groups (p = 0.009). Post-hoc analysis revealed that patients aged <40 years had significantly higher ALP compared to those aged 41–59 years (p = 0.003) and those aged ≥60 years (p = 0.017). No significant difference was found between the 41–59 and ≥60 years groups (p = 0.750).
Keywords.

Received: 20/02/26
Accepted: 17/04/26
Published: 24/04/26

Introduction

Chronic kidney disease (CKD) represents a progressive and irreversible decline in renal function, ultimately necessitating renal replacement therapy such as hemodialysis in its end-stage. Patients undergoing maintenance hemodialysis face numerous metabolic complications, with mineral and bone disorders (CKD-MBD) being among the most prevalent and clinically significant [1]. CKD-MBD is characterized by abnormalities in calcium, phosphorus, parathyroid hormone, and vitamin D metabolism, leading to bone disease, vascular calcification, and increased cardiovascular morbidity and mortality [2].

Despite routine supplementation with calcium and vitamin D, many hemodialysis patients continue to exhibit derangements in biochemical parameters, particularly hyperphosphatemia and elevated alkaline phosphatase (ALP) levels, the latter often serving as a surrogate marker of high bone turnover [3,4]. Age and gender have been suggested as potential modifiers of these parameters, yet existing evidence remains inconclusive. Some studies report higher phosphorus levels in younger dialysis patients due to better dietary intake, while others find no significant age-related differences [5]. Similarly, gender-based comparisons have yielded conflicting results, possibly due to hormonal influences and differences in body composition [6].

Understanding the distribution of calcium, phosphorus, and ALP across different age groups and between genders in a well-defined hemodialysis population is essential for individualizing treatment strategies and improving long-term outcomes. Therefore, this study aimed to evaluate these biochemical parameters in a cohort of maintenance hemodialysis patients receiving uniform calcium and vitamin D supplementation. This study was conducted to assess the levels of serum calcium, phosphorus, and alkaline phosphatase in patients undergoing maintenance hemodialysis.

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Materials and Methods

Study Design and Setting

This was a cross-sectional analytical study conducted at the Hemodialysis Unit of Elkhoms Kidney Services Center: 150 ESRF (end-stage renal failure) hemodialysis patients; 100 sampled in June 2025 (investigations done within one week). The study protocol was approved by the Institutional Review Board (IRB), and all participants provided written informed consent.

Study Population

In this study, A total of 100 patients (aged >18 years) with end-stage renal failure (ESRF) who had been on maintenance hemodialysis for more than six months at Alkhoms Kidney Services Center and who provided informed consent were included. Patients were excluded if they had acute renal failure, acute infections, malignancies, were receiving medications known to affect bone metabolism (such as heparin, warfarin, cyclosporine, glucocorticoids, or anticancer drugs), were under 18 years of age, or were unwilling to participate or did not provide consent.

Interviewer-Administered Data Collection Instrument

A structured, interviewer-administered information sheet was used to collect participants' demographic data, medical and medication histories, and informed consent. This approach allowed clarification of any ambiguities, particularly among participants with limited literacy. Data collection was conducted through both medical record review and patient interviews. Demographic and clinical variables obtained included age (recorded in years), gender (male or female)

Laboratory Measurements

The methodology for biochemical assessment in this study involved standardized blood collection and laboratory analysis procedures. A venous blood sample of 5 ml was drawn under aseptic conditions prior to dialysis and divided into two separate tubes, one designated for biochemical analysis and the other for hormonal assays. The samples were allowed to clot for 30 minutes, followed by centrifugation at 3000 rpm for 10 minutes. The resulting serum was stored at –20 °C until further examination. Investigations were conducted on 100 hemodialysis patients at the Alkhoms Kidney Services Center laboratory. Serum calcium, phosphorus, and alkaline phosphatase (ALP) levels were measured using the Mindray BS-230 analyzer, ensuring consistency and accuracy in biochemical evaluation. This methodological framework provided reliable data for comparing mineral metabolism markers across gender and age groups in the hemodialysis population.

Parameter	Method	Reference Range
Serum Calcium (total)	Arsenazo III colorimetric method	8.5-10.2 mg/dL
Serum Phosphorus	Ammonium molybdate UV method	2.5-4.5 mg/dL
Alkaline Phosphatase	IFCC kinetic method at 37°C	40-130 U/L

*Serum calcium values were corrected for albumin using the formula: *Corrected Ca = Measured Ca + 0.8 × (4.0 - Albumin)*.*

Group Stratification

To facilitate comparative analysis, patients were stratified into the following groups:
Gender: Male: (n=50), Female: (n=50)
Age Groups:
Group A: < 40 years (n = 25)
Group B: 41-59 years (n = 51)
Group C: ≥ 60 years (n = 24)

Statistical Analysis

Statistical analysis was performed using IBM SPSS version 27). The following tests were applied. Comparison of two groups: Independent samples t-test, Comparison of three or more groups: One-way analysis of variance (ANOVA) with post-hoc Tukey's test. Significance level: $p < 0.05$ is considered statistically significant

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Results

A total of 100 patients undergoing maintenance hemodialysis were included in the study. All participants (100%) were receiving routine calcium and vitamin D supplementation. (Table 1) shows the age distribution of the study population. The majority of patients (51%) were in the 41–59 years age group, while 25% were under 40 years and 24% were aged 60 years or older.

Table 1. Age Distribution of Dialysis Patients

Age group (years)	Frequency (n)	Percentage (%)
< 40	25	25.0
41–59	51	51.0
≥ 60	24	24.0
Total	100	100.0

Table 2 presents the overall biochemical parameters of the dialysis patients. The mean serum calcium level was 9.44 ± 0.67 mg/dL (range: 7.54–10.90 mg/dL). Mean serum phosphorus was 6.53 ± 1.78 mg/dL (range: 2.99–10.50 mg/dL). Alkaline phosphatase showed wide variability with a mean of 192.2 ± 241.8 U/L (range: 32.4–1699.7 U/L).

Table 2. Biochemical Parameters of Dialysis Patients

Parameter	N	Mean ± SD	Minimum – Maximum
Calcium (mg/dL)	100	9.44 ± 0.67	7.54 – 10.90
Phosphorus (mg/dL)	100	6.53 ± 1.78	2.99 – 10.50
Alkaline Phosphatase (U/L)	100	192.2 ± 241.8	32.4 – 1699.7

Table 3 compares biochemical parameters between male and female patients. No statistically significant differences were observed for any parameter. Serum calcium was comparable between males (9.45 ± 0.67 mg/dL) and females (9.38 ± 0.68 mg/dL; t = 0.559, p = 0.578). Phosphorus levels were nearly identical (males: 6.53 ± 1.85 mg/dL; females: 6.56 ± 1.72 mg/dL; t = –0.090, p = 0.929). Alkaline phosphatase median values (males: 110.60 U/L; females: 107.85 U/L) also showed no significant difference (Mann-Whitney U = 1213, p = 0.799).

Table 3. Comparison of Biochemical Parameters by Gender

Parameter	Male	Female	Statistic	p-value
Calcium (mg/dL)	9.45 ± 0.67	9.38 ± 0.68	t = 0.559	0.578
Phosphorus (mg/dL)	6.53 ± 1.85	6.56 ± 1.72	t = -0.090	0.929
Alkaline Phosphatase (U/L)	110.60 (32.40-940.20)	107.85 (32.50-1699.70)	U = 1213	0.799

*Note: Data are presented as Mean ± Standard Deviation (SD) for normally distributed variables, as in Calcium & Phosphorus, approximately normally distributed, and Median (Minimum–Maximum) for non-normally distributed variables, as in alkaline phosphatase, which is non-normally distributed. An independent t-test was used for parametric data (Calcium & Phosphorus), while the Mann–Whitney U test was used for non-parametric data (alkaline phosphatase). *Statistically significant at p < 0.05*

Table 4 summarizes the comparison of biochemical parameters across the three age groups. One-way ANOVA showed no statistically significant differences in serum calcium (F = 1.00, p = 0.371) or phosphorus (F = 2.65, p = 0.076) across age groups. Although phosphorus levels demonstrated a trend toward variation, this did not reach statistical significance. As the ANOVA results were not significant, post-hoc comparisons were not required for these parameters. In contrast, Kruskal-Wallis analysis revealed a significant difference in alkaline phosphatase levels across age groups (H = 9.44, p = 0.009). Post-hoc pairwise Mann-Whitney U analyses with Bonferroni correction (α = 0.017) showed that alkaline phosphatase levels were significantly higher in patients aged <40 years compared with those aged 41–59 years (U = 372, p = 0.003). Comparisons between patients aged <40 years and ≥60 years also revealed significantly higher alkaline phosphatase in the younger group (U = 181, p = 0.017). No significant differences were observed between patients aged 41–59 years and those ≥60 years (U = 584, p = 0.750).

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Table 4. Comparison of Calcium, Phosphorus, and Alkaline Phosphatase Across Age Groups

Parameter	F value	p-value
Calcium (mg/dL)	1.00	0.371
Phosphorus (mg/dL)	2.65	0.076
Alkaline Phosphatase (U/L)	9.443	0.009*

**Statistically significant at $p < 0.05$.*

Discussion

The present study investigated serum calcium, phosphorus, and alkaline phosphatase levels in 100 maintenance hemodialysis patients, all of whom received regular calcium and vitamin D supplementation. The key finding was a significant age-related difference in alkaline phosphatase, with younger patients (<40 years) exhibiting substantially higher ALP levels than older age groups, while gender did not influence any of the measured parameters. The mean serum calcium level (9.44 mg/dL) fell within the recommended target range (8.4–10.2 mg/dL) for CKD-MBD management, as suggested by KDIGO guidelines [7]. This likely reflects the universal supplementation protocol. In contrast, mean serum phosphorus (6.53 mg/dL) exceeded the recommended upper limit of 5.5 mg/dL for dialysis patients [8], indicating persistent hyperphosphatemia despite dietary and pharmacological interventions — a common challenge in clinical practice [9]. The absence of gender differences in calcium, phosphorus, and ALP aligns with several earlier reports [10] but contrasts with studies suggesting higher phosphorus in males due to larger muscle mass and dietary intake [11]. The lack of difference here may be attributable to uniform dietary counseling and phosphate binder use. The most notable finding was the significantly higher alkaline phosphatase in patients under 40 years compared to both the middle-aged and elderly groups.

Elevated ALP in younger dialysis patients may reflect high-turnover bone disease, which is more common in younger, healthier individuals with longer dialysis vintage and preserved nutritional status [12]. Conversely, older patients often develop low-turnover bone disease (adynamic bone disease) due to factors such as diabetes, peritoneal dialysis, and excessive use of vitamin D metabolites or calcium-containing binders [13]. Our results are consistent with previous work by Ureña-Torres et al., who reported higher bone ALP in younger hemodialysis cohorts [14]. Interestingly, despite significant ALP differences, phosphorus and calcium did not vary by age. This dissociation suggests that ALP may be a more sensitive marker of underlying bone remodeling than serum calcium or phosphorus alone, especially in patients on stable supplementation [15].

Study limitations

This study is limited by its cross-sectional design, which precludes assessment of temporal changes in biochemical parameters. Additionally, we did not measure intact parathyroid hormone (iPTH), vitamin D metabolites, or bone histomorphometry — the gold standard for diagnosing renal osteodystrophy. The lack of data on dialysis vintage, phosphate binder use, and nutritional intake also restricts causal inference.

Conclusion

In this cohort of hemodialysis patients receiving routine calcium and vitamin D supplementation, younger age (<40 years) was associated with significantly higher alkaline phosphatase levels compared to older age groups, suggesting a higher prevalence of high-turnover bone disease. Gender did not influence any biochemical parameter. Routine monitoring of ALP, along with age-stratified management strategies, may improve the detection and treatment of CKD-MBD in hemodialysis populations.

Conflict of interest. Nil

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