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Chronic kidney disease–mineral and bone disorder among maintenance hemodialysis patients in Addis Ababa, Ethiopia: prevalence, guideline adherence, complications, and quality of life

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Abstract

Background Chronic kidney disease–mineral and bone disorder (CKD-MBD) contributes substantially to morbidity and reduced quality of life among patients receiving maintenance hemodialysis. Data regarding CKD-MBD burden and management in Ethiopia remain limited. This study assessed the prevalence of CKD-MBD biochemical abnormalities, adherence to KDIGO recommendations, CKD-MBD–related complications, and quality of life among maintenance hemodialysis patients in Addis Ababa, Ethiopia.

Methods We conducted an institution-based cross-sectional study among adult patients receiving maintenance hemodialysis at St Paul's Hospital Millennium Medical College and affiliated private dialysis centers from 1 September 2025 to 28 February 2026. Sociodemographic, clinical, laboratory, treatment, and quality-of-life data were collected through structured interviews and medical record review. Multivariable logistic and linear regression analyses were performed to identify factors independently associated with CKD-MBD complications and lower quality of life.

Results A total of 302 patients were included (response rate 89.1%). Elevated intact parathyroid hormone was observed in 47.4% of participants, hyperphosphatemia in 28.0%, hypocalcemia in 27.7%, and vitamin D deficiency in 19.6%. Adherence to KDIGO-recommended biochemical monitoring ranged from 53.6% to 62.9%. The most common CKD-MBD-related complications were bone pain and pruritus, both of which were independently associated with lower quality-of-life scores. Hyperphosphatemia, hypocalcemia, elevated iPTH, older age (≥60 years), and longer dialysis duration were independently associated with CKD-MBD complications. Older age, longer dialysis duration, hyperphosphatemia, hypocalcemia, and elevated iPTH were also independently associated with lower quality-of-life scores.

Conclusions CKD-MBD abnormalities and related complications are highly prevalent among maintenance hemodialysis patients in Ethiopia, with suboptimal adherence to KDIGO monitoring recommendations. Improved

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access to biochemical monitoring, guideline-concordant treatment, and multidisciplinary symptom management may help improve patient outcomes and quality of life.

Keywords CKD-MBD, Dialysis, KDIGO adherence, Prevalence, Quality of life, Ethiopia, Hemodialysis

Introduction

Chronic kidney disease–mineral and bone disorder (CKD-MBD) is a systemic complication of chronic kidney disease characterized by abnormalities in calcium, phosphorus, parathyroid hormone (PTH), and vitamin D metabolism, together with disturbances in bone turnover and extraskeletal calcification [1, 2]. CKD-MBD is highly prevalent among patients with advanced chronic kidney disease and is associated with increased cardiovascular morbidity, fractures, hospitalization, and mortality [3–5].

Patients receiving maintenance hemodialysis are particularly vulnerable to CKD-MBD because dialysis only partially corrects disturbances in mineral homeostasis. Persistent hyperphosphatemia, secondary hyperparathyroidism, hypocalcemia, and vitamin D deficiency contribute to renal osteodystrophy, vascular calcification, cardiovascular disease, and reduced quality of life [6, 7]. In addition to biochemical abnormalities, CKD-MBD commonly manifests with bone pain, pruritus, muscle weakness, and functional impairment that substantially affect patient well-being and daily activities [4, 8].

The burden of CKD-MBD is especially important in low- and middle-income countries, where access to routine biochemical monitoring, phosphate binders, active vitamin D analogues, calcimimetics, and dietetic support may be limited [7–11]. Studies from African dialysis populations have demonstrated a high prevalence of CKD-MBD biochemical abnormalities and substantial variability in adherence to Kidney Disease: Improving Global Outcomes (KDIGO) recommendations [7–11]. Resource limitations, treatment costs, and inconsistent availability of laboratory testing often compromise guideline-concordant care in these settings [12–14].

Despite the growing number of patients receiving maintenance hemodialysis in Ethiopia, there remains limited local evidence regarding the epidemiology, management, and patient-reported impact of CKD-MBD. Previous Ethiopian studies have mainly focused on dialysis outcomes and mortality, with little emphasis on CKD-MBD burden, treatment practices, or quality of life [15, 16]. Understanding local patterns of CKD-MBD is essential for improving resource allocation, optimizing dialysis care, and guiding context-appropriate management strategies.

Quality of life is an important but underexplored outcome in CKD-MBD research [17]. Complications such as bone pain and pruritus may significantly impair physical, emotional, and social functioning among patients receiving hemodialysis [4, 8]. Evaluating quality of life alongside biochemical abnormalities and treatment practices provides a more comprehensive understanding of disease burden and may help identify clinically meaningful targets for intervention.

Therefore, this study aimed to determine the prevalence of CKD-MBD biochemical abnormalities, evaluate adherence to KDIGO monitoring and treatment recommendations, assess CKD-MBD–related complications, and examine associations with quality of life among maintenance hemodialysis patients in Addis Ababa, Ethiopia.

Methods

Study design and setting

An institution-based cross-sectional study was conducted among adult patients receiving maintenance hemodialysis at St Paul's Hospital Millennium Medical College (SPHMMC) and affiliated private dialysis centers in Addis Ababa, Ethiopia, from 1 September 2025 to 28 February 2026. SPHMMC is one of the major tertiary referral hospitals in Ethiopia and provides nephrology and dialysis services for patients with end-stage kidney disease (ESKD). In addition to patients dialyzing at SPHMMC, the study included patients receiving dialysis at private centers who had routine nephrology follow-up at SPHMMC.

The study was designed to assess the prevalence of chronic kidney disease–mineral and bone disorder (CKD-MBD), adherence to kidney disease: Improving Global Outcomes (KDIGO) monitoring and treatment recommendations, CKD-MBD–related complications, and quality of life among maintenance hemodialysis patients.

This manuscript was prepared in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline for cross-sectional studies.

Eligibility criteria

Participants were eligible if they were aged 18 years or older, had been receiving maintenance hemodialysis for at least three months, attended regular follow-up at SPHMMC or affiliated dialysis centers, and were able and willing to provide written informed consent. Patients were excluded if they had acute kidney injury requiring temporary dialysis, had been on dialysis for less than three months, were hospitalized for severe acute illness during the recruitment period, had cognitive impairment

or communication difficulties preventing reliable interview participation, or declined participation.

Sample size determination and sampling procedure

The sample size was calculated using the single population proportion formula:

$n = Z^2\, p(1-p)/d^2$

where:

- n = minimum required sample size;
- Z = standard normal deviate at 95% confidence interval (1.96);
- p = assumed prevalence of CKD-MBD abnormalities among maintenance hemodialysis patients;
- d = margin of error.

Because no prior Ethiopian study had comprehensively assessed CKD-MBD prevalence among maintenance hemodialysis patients, a conservative prevalence estimate of 50% ($p = 0.5$) was used to maximize sample size, with a margin of error of 5%.

After adjustment for the finite study population and anticipated nonresponse, the final target sample size was determined. Consecutive sampling was used to recruit eligible participants attending dialysis sessions or nephrology follow-up during the study period until the required sample size was achieved. A total of 339 patients were screened for eligibility. Thirty-seven patients were excluded because of acute illness, dialysis duration less than three months, cognitive impairment, or refusal to participate. Ultimately, 302 participants were included in the final analysis (supplementary figure 1).

Data collection procedures

The questionnaire encompassed sociodemographic characteristics, clinical and dialysis history, medication use, dietary adherence, CKD-MBD–related symptoms and complications, and quality-of-life assessment (supplementary tool). These domains were selected to provide a comprehensive overview of patient background, treatment practices, and disease burden.

Laboratory measurements

No laboratory investigations were performed specifically for this study. Laboratory data were obtained by reviewing participants' medical records and extracting the most recent routinely performed biochemical test results available within the three months preceding data collection. The extracted parameters included serum calcium, serum phosphorus, intact parathyroid hormone (iPTH), and serum 25-hydroxyvitamin D. These tests had been performed as part of routine clinical care at the participating dialysis centers using their respective standard laboratory procedures. To facilitate comparison across centers, laboratory results were interpreted using KDIGO 2017 guideline recommendations together with the corresponding local laboratory reference ranges.

Operational definitions

Chronic kidney disease–mineral and bone disorder (CKD-MBD) was defined according to the KDIGO 2017 Clinical Practice Guideline Update as abnormalities in mineral metabolism associated with chronic kidney disease, including disturbances in calcium, phosphorus, parathyroid hormone, and vitamin D metabolism [18]. Hyperphosphatemia was considered present when serum phosphorus exceeded 5.5 mg/dL, consistent with KDIGO recommendations for patients on maintenance hemodialysis [18]. Hypocalcemia was defined as corrected serum calcium below 8.4 mg/dL; this threshold was harmonized with KDIGO guidance but also reflected the local laboratory reference range used in Addis Ababa. Elevated intact parathyroid hormone (iPTH) was defined using a threshold of >300 pg/mL, which was the threshold adopted in routine clinical practice at the participating dialysis centers and interpreted in accordance with the KDIGO 2017 Clinical Practice Guideline Update for CKD-MBD. Vitamin D deficiency was defined as a serum 25-hydroxyvitamin D level below 20 ng/mL, in line with KDIGO recommendations and widely accepted clinical thresholds [18]. Adherence to KDIGO monitoring recommendations was determined by whether patients had undergone the recommended biochemical tests within guideline-specified intervals, namely serum calcium and phosphorus every one to three months, intact PTH every three to six months, and vitamin D testing as clinically indicated [18]. Furthermore, we report point prevalence of CKD-MBD biochemical abnormalities at the time of participant interview. For each participant, we extracted laboratory results performed as part of routine care during the 3-month window preceding the interview. If more than one measurement was available within that window, we used the most recent (last) value to classify the participant's biochemical status. This approach was chosen because the most recent value best reflects the participant's clinical status at the time of assessment and aligns with KDIGO monitoring intervals for patients on maintenance hemodialysis. To assess robustness, we performed sensitivity analyses using alternative selection rules (first value within the 3-month window, highest value, and mean of values) (supplementary table S1).

Assessment of adherence to KDIGO recommendations

Adherence to the KDIGO 2017 Clinical Practice Guideline Update for CKD-MBD was assessed using documented laboratory monitoring practices recorded in participants' medical records. For patients receiving maintenance hemodialysis (CKD G5D), adherence was

evaluated based on the recommended monitoring frequency for biochemical parameters. Serum calcium and phosphorus measurements were considered adherent if performed at least once every 1–3 months, while intact parathyroid hormone (iPTH) measurements were considered adherent if performed at least once every 3–6 months, in accordance with KDIGO 2017 recommendations [18]. Monitoring frequency was determined by reviewing laboratory records during the study period. Participants meeting the recommended monitoring intervals for each parameter were classified as adherent; those who did not were classified as non-adherent. Dialysis duration was also categorized as ≤24 months versus >24 months. We selected > 24 months as the operational definition of longer dialysis duration because the cohort median vintage was 36 months (IQR 24–60 months), making 24 months a clinically meaningful split that separates shorter – from longer-term patients in this population. This approach is consistent with prior studies that examine multi-year vintage thresholds when assessing dialysis-related complications and outcomes.

Quality of life assessment

Quality of life was assessed using a study-specific questionnaire developed for this study and informed by previously published QoL instruments for patients receiving maintenance hemodialysis. The instrument included five items covering physical well-being, emotional well-being, social functioning, daily functioning, and overall quality of life. Each item used a five-point Likert scale (1 = poorest; 5 = best). Item scores were summed to produce a total QoL score ranging from 5 to 25, with higher scores indicating better perceived quality of life. The questionnaire was translated into Amharic, back-translated, and pretested in a pilot sample ($n = 30$) to ensure clarity and cultural relevance; minor wording adjustments were made after pilot testing. Formal psychometric validation in the Ethiopian dialysis population was not performed and is acknowledged as a limitation.

Data quality assurance

To ensure data quality, all data collectors received standardized training before implementation. The questionnaire was pretested and refined based on pilot feedback. Supervisors reviewed completed questionnaires daily, and data entry incorporated range and consistency checks. Double entry and random verification were performed to minimize transcription errors, while incomplete records were cross-checked against source documents whenever possible.

Data processing and statistical analysis

Collected data were coded and entered into EpiData version 3.1 and subsequently exported to SPSS version 27 for statistical analysis. Continuous variables were summarized using mean ± standard deviation or median with interquartile range, depending on distribution, while categorical variables were presented as frequencies and percentages. Initial univariate analyses were conducted using chi-square tests, Fisher's exact tests, independent t-tests, or Mann–Whitney U tests as appropriate. Variables with p-values < 0.20 in univariate analysis and clinically relevant covariates identified from previous literature were included in the multivariable models.

Multivariable logistic regression analysis was performed to identify factors independently associated with CKD-MBD complications and low quality of life. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were reported. Multiple linear regression analysis was used to identify factors associated with continuous QoL scores, with regression coefficients (β), 95% confidence intervals, and p-values presented. Model assumptions were assessed before analysis, and multicollinearity was evaluated using variance inflation factors. The goodness-of-fit of logistic regression models was assessed using the Hosmer–Lemeshow test ($\chi^2 = 7.84$, df = 8, $p = 0.45$), confirming adequate model fit.

Regression diagnostics were performed to ensure the validity of the models. Normality of residuals, linearity of continuous factors associated with the model, and homoscedasticity were assessed. Multicollinearity was evaluated using variance inflation factors (all < 2.5). Influential observations were checked using Cook's distance. These procedures confirmed that model assumptions were adequately met. Statistical significance was considered at $p < 0.05$.

Results

Participant characteristics

A total of 339 patients receiving maintenance hemodialysis were screened for eligibility during the study period. Of these, 302 participants fulfilled the inclusion criteria and were included in the final analysis, yielding a response rate of 89.1%. The mean age of participants was 52.6 ± 14.2 years, and 178 (59.0%) were male. The median duration on dialysis was 36 months (interquartile range [IQR] 24–60 months). Hypertension was the most common comorbidity, affecting 246 (81.5%) participants, while diabetes mellitus was present in 112 (37.1%). The mean serum calcium level was 8.9 ± 0.8 mg/dL, and the mean serum phosphorus level was 5.2 ± 1.1 mg/dL. The median intact parathyroid hormone (iPTH) level was 310 pg/mL (IQR 220–420 pg/mL) (Table 1). The most frequently reported CKD-MBD-related complications were bone pain and pruritus. Because vascular calcification was not assessed, vascular access complications were not considered CKD-MBD-related outcomes and were excluded from all CKD-MBD-specific analyses (Table 1).

Table 1 Baseline sociodemographic and clinical characteristics of maintenance hemodialysis patients (*N* = 302)

Characteristic	Total (N = 302)
Age, years (mean ± SD)	52.6 ± 14.2
Male sex, n (%)	178 (59.0)
Duration on dialysis, months (median [IQR])	36 [24–60]
Hypertension, n (%)	246 (81.5)
Diabetes mellitus, n (%)	112 (37.1)
Serum calcium, mg/dL (mean ± SD)	8.9 ± 0.8
Serum phosphorus, mg/dL (mean ± SD)	5.2 ± 1.1
Intact PTH, pg/mL (median [IQR])	310 [220–420]
25-OH vitamin D deficiency, n (%)	55 (19.6)

NB: Values are presented as mean ± standard deviation (SD), median [interquartile range (IQR)], or frequency (%). Abbreviations: SD, standard deviation; IQR, interquartile range; PTH, parathyroid hormone

Prevalence of CKD-MBD biochemical abnormalities

Biochemical investigations were available for most study participants, although the number tested varied slightly across parameters. Serum calcium measurements were available for 296 participants, serum phosphorus for 295 participants, intact parathyroid hormone (iPTH) for 290 participants, and serum 25-hydroxyvitamin D for 280 participants. The variation in denominators reflects the fact that data were abstracted from existing laboratory records rather than newly performed assays; not all patients had every test performed within the three-month window before data abstraction. Missing values occurred due to differences in routine ordering practices, occasional test unavailability, and incomplete documentation in medical records, and therefore represent secondary data collection.

Prevalence estimates reflect point prevalence at the time of interview using the most recent laboratory value within the prior 3 months. Sensitivity analyses using the first, highest, and mean values within the same window produced similar prevalence estimates and did not materially change the direction or significance of associations. Elevated intact PTH was the most common biochemical abnormality, identified in 137 of 290 participants (47.4%). Hyperphosphatemia was observed in 83 of 295 participants (28.0%), while hypocalcemia was present in 82 of 296 participants (27.7%). Vitamin D deficiency was identified in 55 of 280 participants (19.6%) (Table 2).

In this study population, elevated intact parathyroid hormone was observed in 47.4% of participants, while hyperphosphatemia was present in 28.0%. These findings indicate that abnormalities in parathyroid hormone and phosphorus metabolism contributed substantially to the burden of CKD-MBD among maintenance hemodialysis patients in Addis Ababa (Fig. 1).

Distribution of biochemical abnormalities according to complication groups

Participants with CKD-MBD–related complications demonstrated less favorable biochemical profiles compared with participants without complications. Median iPTH levels progressively increased across complications. Similarly, mean serum phosphorus levels were higher among participants with bone pain and pruritus than among participants without complications (Fig. 2 and supplementary figure 2). In contrast, mean serum calcium levels tended to be lower among participants with CKD-MBD–related complications, particularly among that pruritus. These findings suggest that worsening biochemical derangements were associated with increased symptom burden and clinical complications.

Quality-of-life measurements

Quality-of-life (QoL) scores varied substantially according to complication status. Participants without CKD-MBD–related complications had the highest mean QoL scores across physical, emotional, social, and overall domains. The mean total QoL score among participants without complications was 19.0 ± 2.2, compared with 15.0 ± 2.4 among participants with bone pain, and 14.4 ± 2.2 among participants with pruritus. Similar patterns were observed across physical, emotional, and social QoL domains (Table 3; Fig. 3). These findings indicate that CKD-MBD-related complications were associated with substantial multidimensional impairment in patient-reported quality of life.

Factors associated with low quality of life and CKD-MBD complications

Multivariable logistic regression analysis identified several independent factors associated with lower quality of life and CKD-MBD complications. Age ≥ 60 years was

Table 2 Prevalence of CKD-MBD biochemical abnormalities among maintenance hemodialysis patients (*N* = 302)

Biochemical Marker	Number Tested	Definition of Abnormality	Abnormal, n (%)
Elevated intact PTH	290	iPTH > 300 pg/mL	137 (47.4)
Hyperphosphatemia	295	Serum phosphorus > 5.5 mg/dL	83 (28.0)
Hypocalcemia	296	Corrected serum calcium < 8.4 mg/dL	82 (27.7)
Vitamin D deficiency	280	25-OH vitamin D < 20 ng/mL	55 (19.6)

NB: Values are presented as frequency (%). Definitions of biochemical abnormalities were based on the kidney disease: Improving Global Outcomes (KDIGO) 2017 CKD-MBD guideline recommendations and local laboratory reference ranges. **Abbreviations**: CKD-MBD, chronic kidney disease–mineral and bone disorder; iPTH, intact parathyroid hormone

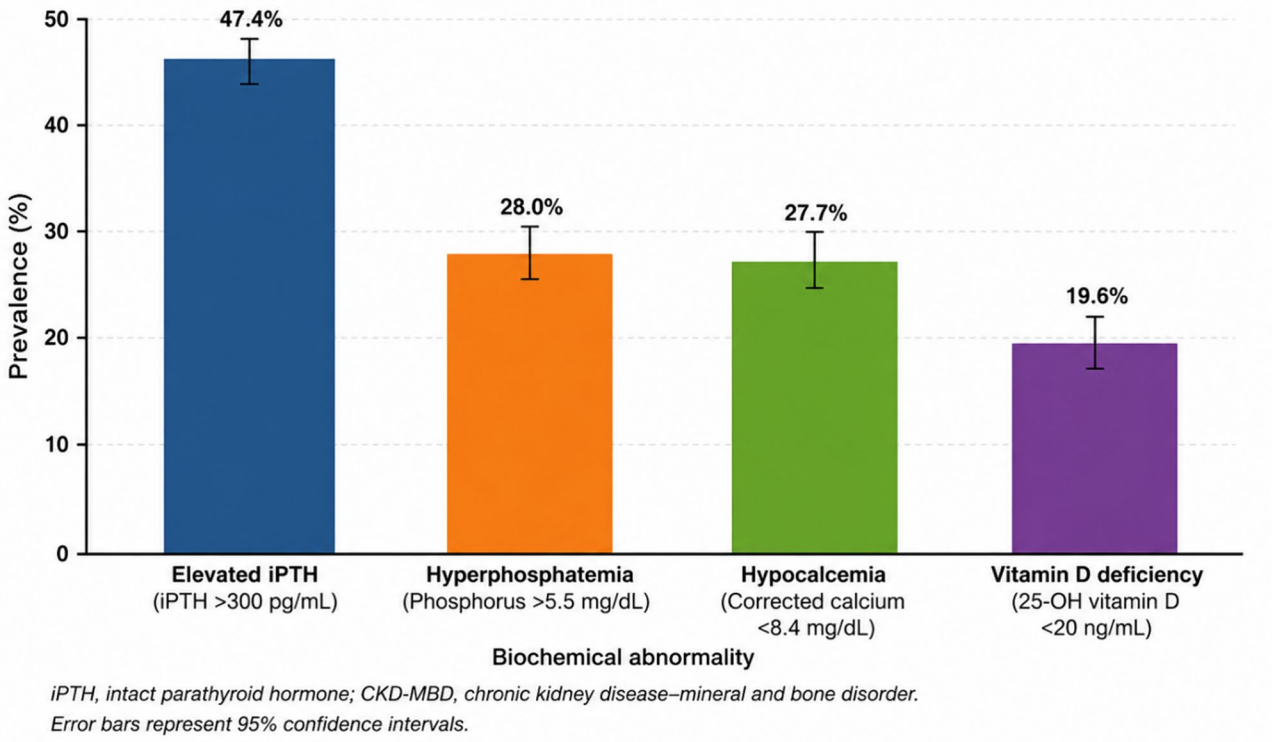


Fig. 1 Clustered vertical bar chart showing prevalence of CKD-MBD biochemical abnormalities among maintenance hemodialysis patients. Elevated iPTH was the most common biochemical abnormality (47.4%), followed by hyperphosphatemia (28.0%), hypocalcemia (27.7%), and vitamin D deficiency (19.6%). Error bars represent 95% confidence intervals

significantly associated with lower QoL (adjusted odds ratio [AOR] 1.42, 95% confidence interval [CI] 1.05–1.92, $p = 0.021$). Dialysis duration greater than 24 months was also independently associated with CKD-MBD complications (AOR 1.58, 95% CI 1.12–2.23, $p = 0.009$).

Among biochemical markers, hyperphosphatemia was the strongest independent factor associated with CKD-MBD complications (AOR 1.76, 95% CI 1.21–2.56, $p = 0.003$). Elevated iPTH levels were independently associated with lower quality of life (AOR 1.62, 95% CI 1.13–2.32, $p = 0.010$), while hypocalcemia was significantly associated with bone pain (AOR 1.44, 95% CI 1.01–2.05, $p = 0.046$).

Female sex and diabetes mellitus were associated with higher odds of reduced QoL in adjusted analyses; however, these associations did not reach statistical significance.

In linear regression analysis, higher iPTH levels were inversely associated with total QoL scores ($\beta = -0.32$, 95% CI −0.45 to −0.19, $p < 0.001$), indicating that worsening secondary hyperparathyroidism was associated with poorer patient-reported quality of life (Table 4).

The most frequently reported CKD-MBD-related manifestations were bone pain and pruritus. Vascular access complications were recorded separately and were not included in the CKD-MBD complication analyses because vascular access events are not specific manifestations of CKD-MBD in the absence of documented vascular calcification. After excluding vascular access events from the CKD-MBD outcome, participants with CKD-MBD complications had higher median iPTH and phosphorus levels compared with participants without complications. In multivariable logistic regression (outcome = CKD-MBD complications, vascular access excluded), hyperphosphatemia and elevated iPTH remained independently associated with CKD-MBD complications.

In the multivariable logistic regression model (Table 5), age ≥ 60 years, dialysis duration greater than 24 months, hyperphosphatemia, hypocalcemia, and elevated iPTH remained independently associated with CKD-MBD complications after adjustment, whereas sex was not significantly associated. Similarly, in the multivariable linear regression model evaluating quality-of-life scores (Table 6), older age, longer dialysis duration, hyperphosphatemia, hypocalcemia, and elevated iPTH were independently associated with lower quality-of-life scores, while sex did not retain statistical significance after adjustment. These findings indicate that disturbances in mineral metabolism, together with older age and prolonged dialysis exposure, are important determinants of

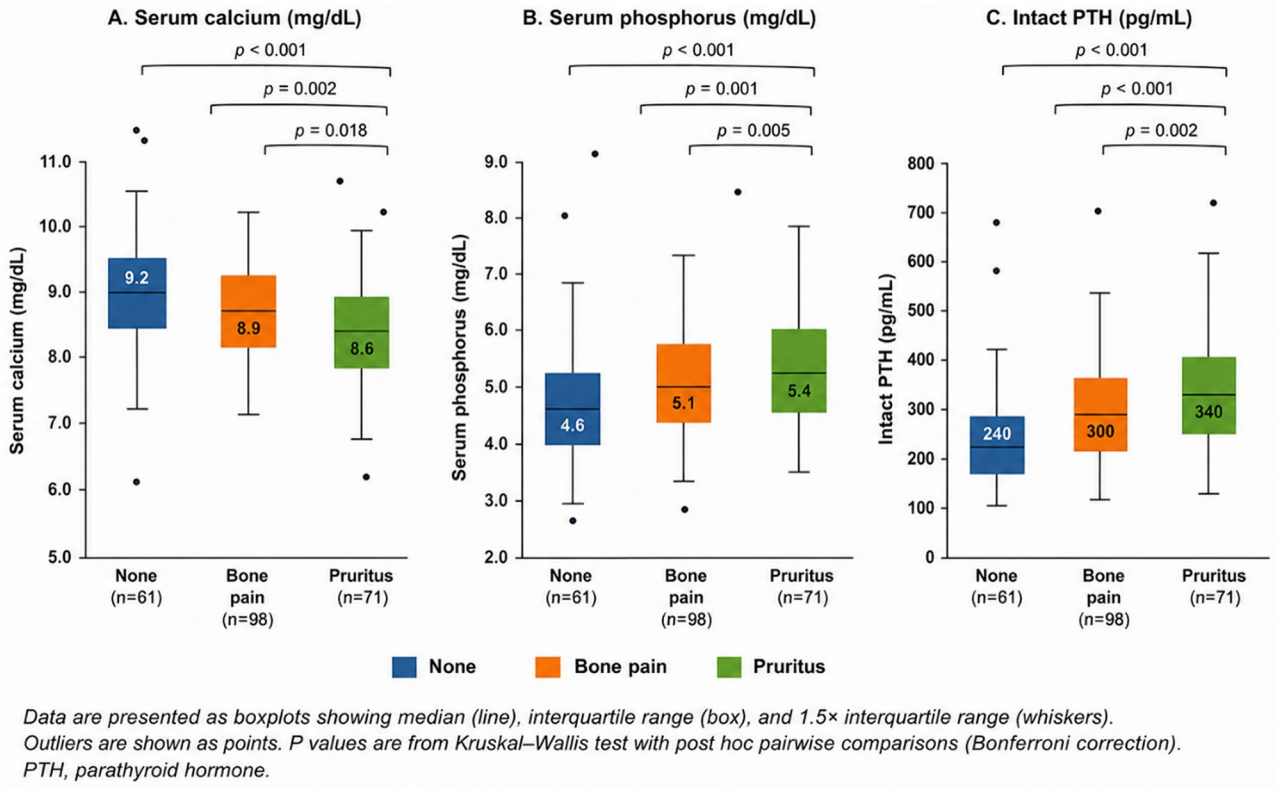


Fig. 2 Distribution of serum calcium, phosphorus, and intact parathyroid hormone (iPTH) levels across CKD-MBD complication groups among maintenance hemodialysis patients. Boxplots demonstrate median values (central line), interquartile ranges (boxes), and 1.5× interquartile ranges (whiskers) for serum calcium (**A**), serum phosphorus (**B**), and intact parathyroid hormone (**C**) according to complication status. Participants with pruritus demonstrated higher phosphorus and iPTH levels and lower calcium levels compared with participants without complications. *p* values were calculated using the Kruskal–Wallis test with post hoc pairwise comparisons. Abbreviations: CKD-MBD, chronic kidney disease–mineral and bone disorder; iPTH, intact parathyroid hormone

Table 3 Quality-of-life domain scores according to CKD-MBD complication groups among maintenance hemodialysis patients (scores range 5–25; higher = better)

QoL Domain	No Complications (*n* = 61)	Bone Pain (*n* = 98)	Pruritus (*n* = 71)	p-value
Physical functioning	19.4 ± 2.0	16.0 ± 2.4	15.0 ± 2.2	<0.001
Emotional functioning	18.8 ± 2.2	15.4 ± 2.0	14.6 ± 2.0	<0.001
Social functioning	19.2 ± 1.8	15.8 ± 2.2	14.2 ± 2.0	<0.001
Total QoL score	19.0 ± 2.2	15.0 ± 2.4	14.4 ± 2.2	<0.001

NB: Instrument: Scores obtained using a study-specific five-item QoL instrument (each item scored 1–5; total score range **5–25**). **Interpretation:** Higher scores indicate better perceived quality of life. **Statistics:** Means ± SD shown; *p*-values from one-way ANOVA or Kruskal–Wallis test as appropriate. **Conversion note:** Values above were converted from a 0–100 presentation using $\mathrm{QoL}_{5-25} = \mathrm{QoL}_{0-100} \times 0.20 + 5$; SDs were multiplied by 0.20

both CKD-MBD complications and poorer quality of life among maintenance hemodialysis patients.

Laboratory assay characteristics

Laboratory assays and reference ranges varied slightly across participating dialysis centers; however, all biochemical measurements were harmonized using KDIGO-aligned thresholds. Intact PTH was measured using chemiluminescent immunoassay techniques, phosphorus was assessed using automated colorimetric assays, corrected calcium was measured using the Arsenazo III method, and serum 25-hydroxyvitamin D was measured using ELISA or liquid chromatography–tandem mass spectrometry methods. The prevalence of abnormal laboratory findings based on these standardized thresholds remained high across all participating centers, supporting the overall consistency of the study findings.

Additional analytical findings

Correlation analyses demonstrated an inverse relationship between intact PTH levels and total QoL scores, indicating that increasing severity of secondary hyperparathyroidism was associated with worsening patient-reported outcomes. Serum phosphorus showed weaker

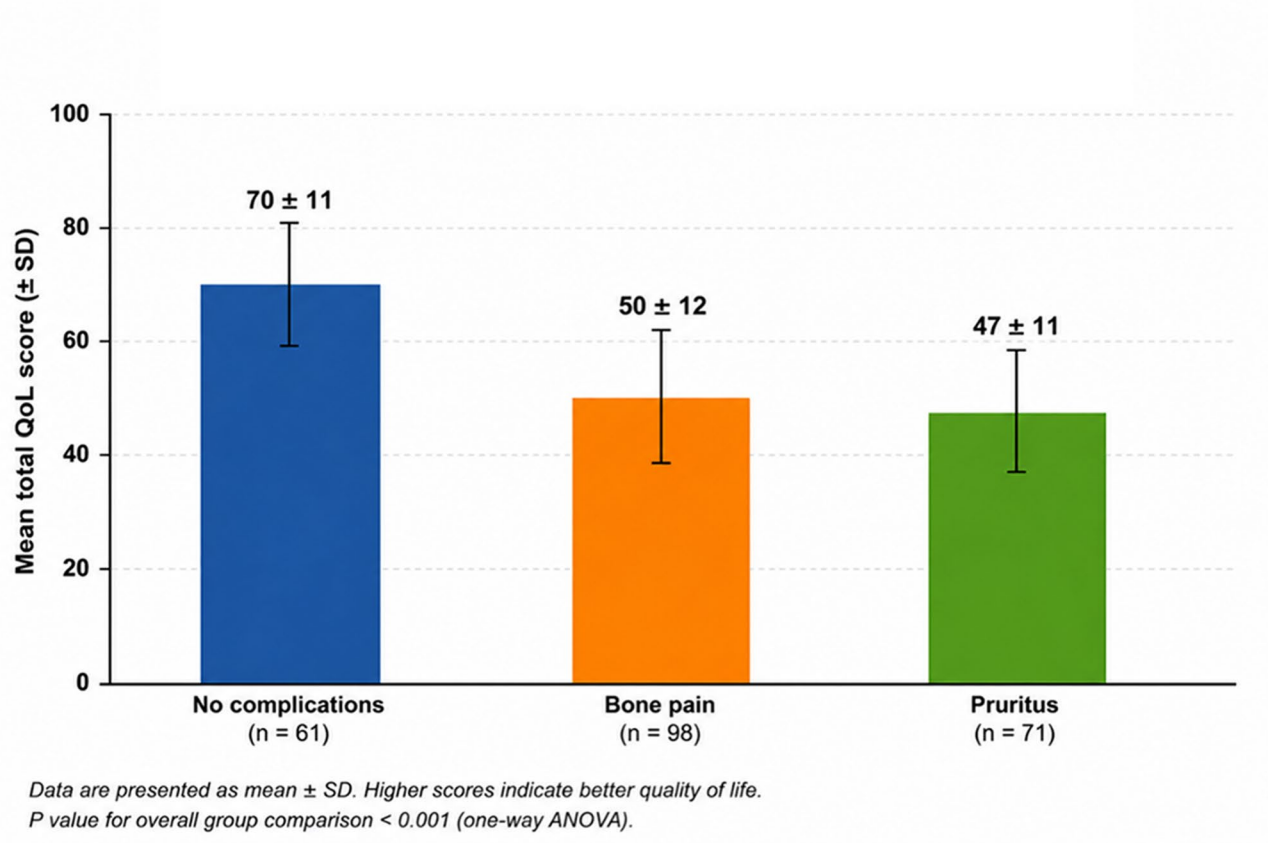


Fig. 3 Mean total quality-of-life (QoL) scores according to CKD-MBD complication groups among maintenance hemodialysis patients. Participants with bone pain and pruritus had significantly lower quality-of-life scores than participants without CKD-MBD-related complications across all assessed domains. Progressive reductions in QoL were observed among participants with bone pain and pruritus. Error bars represent standard deviations. Higher scores indicate a better quality of life. *p*-values were calculated using one-way ANOVA or the Kruskal–Wallis test, as indicated by superscript symbols (* indicates statistical significance based on one-way analysis of variance (ANOVA) ($p < 0.05$); ** indicates statistical significance based on the Kruskal–Wallis test ($p < 0.05$)

Table 4 Distribution of CKD-MBD complications across sociodemographic and biochemical characteristics among maintenance hemodialysis patients in Addis Ababa, Ethiopia

Variable	Category	Complications Present (n, %)	No Complications (n, %)	Total (N)
Age	\<60 years	95 (45.2)	115 (54.8)	210
	≥60 years	52 (59.1)	36 (40.9)	88
Sex	Male	80 (44.9)	98 (55.1)	178
	Female	67 (54.0)	57 (46.0)	124
Dialysis duration	≤24 months	60 (41.1)	86 (58.9)	146
	>24 months	87 (55.8)	69 (44.2)	156
Hyperphosphatemia	Yes	58 (69.9)	25 (30.1)	83
	No	89 (41.9)	123 (58.1)	212
Hypocalcemia	Yes	47 (57.3)	35 (42.7)	82
	No	100 (45.9)	118 (54.1)	218

negative associations with physical and emotional QoL domains, whereas vitamin D demonstrated weak positive associations with social and emotional functioning. Receiver operating characteristic analyses suggested modest discriminatory ability of iPTH for identifying participants with lower QoL scores. However, these analyses should be interpreted cautiously because the cross-sectional design limits predictive inference. Similarly, mortality and survival analyses are not presented in the primary interpretation of this study because the cross-sectional design does not adequately support longitudinal survival inference. These exploratory analyses may be considered supplementary and hypothesis-generating only (see supplementary figures 1& 2).

Table 5 Factors associated with CKD-MBD complications among maintenance hemodialysis patients in Addis Ababa, Ethiopia

Variable	Category	Crude OR (95% CI)	Adjusted OR (95% CI)	p-value
Age	\<60 years	Reference	Reference	
	≥60 years	1.76 (1.05–2.95)	1.42 (1.05–1.92)	0.021
Sex	Male	Reference	Reference	
	Female	1.44 (0.91–2.28)	1.38 (0.84–2.27)	0.12
Dialysis duration	≤24 months	Reference	Reference	
	>24 months	1.80 (1.15–2.82)	1.58 (1.12–2.23)	0.009
Hyperphosphatemia	No	Reference	Reference	
	Yes	3.20 (1.87–5.47)	1.76 (1.21–2.56)	0.003
Hypocalcemia	No	Reference	Reference	
	Yes	1.58 (0.95–2.63)	1.44 (1.01–2.05)	0.046
Elevated iPTH	No	1.00 (ref)	Reference	
	Yes	1.61 (1.01–2.56)	1.62 (1.13–2.32)	0.010

NB: Crude OR = univariable logistic regression (computed from available 2 × 2 counts where possible). Adjusted OR = multivariable logistic regression (model reported in manuscript). Bold indicates statistically significant adjusted associations ($p < 0.05$). NA indicates the crude 2 × 2 counts were not available in the provided draft; please supply counts or univariable outputs to populate these cells

Table 6 Factors associated with quality-of-life (QoL) scores among maintenance hemodialysis patients in Addis Ababa, Ethiopia

Variable	Category	Mean QoL Score (± SD)	Crude β (95% CI)	Adjusted β (95% CI)	p-value
Age	<60 years	58.4 ± 12.1	Ref	Ref	—
	≥60 years	52.7 ± 11.8	−5.7 (−9.2 to −2.2)	−4.9 (−8.5 to −1.3)	0.01*
Sex	Male	57.9 ± 12.0	Ref	Ref	—
	Female	54.2 ± 11.7	−3.7 (−7.1 to −0.3)	−3.2 (−6.6 to 0.2)	0.07
Dialysis duration	≤24 months	59.1 ± 12.3	Ref	Ref	—
	>24 months	53.6 ± 11.5	−5.5 (−8.9 to −2.1)	−4.8 (−8.2 to −1.4)	0.005*
Hyperphosphatemia	No	59.3 ± 12.2	Ref	Ref	—
	Yes	49.8 ± 11.0	−9.5 (−13.2 to −5.8)	−8.7 (−12.4 to −5.0)	<0.001*
Hypocalcemia	No	58.7 ± 12.1	Ref	Ref	—
	Yes	52.1 ± 11.6	−6.6 (−10.3 to −2.9)	−5.9 (−9.6 to −2.2)	0.002*
Elevated iPTH	No	59.0 ± 12.0	Ref	Ref	—
	Yes	53.4 ± 11.8	−5.6 (−9.1 to −2.1)	−4.7 (−8.2 to −1.2)	0.01*

NB: Values are presented as mean ± standard deviation, crude regression coefficient (β), and adjusted regression coefficient (Aβ) with 95% confidence intervals. Multiple linear regression was used to identify independent factors associated with QoL scores. * Indicates statistical significance at $p < 0.05$

Discussion

Serum phosphorus was elevated in 83 of 295 participants (28.0%), defined according to KDIGO guideline thresholds (>5.5 mg/dL). Elevated intact parathyroid hormone (iPTH), hyperphosphatemia, hypocalcemia, and vitamin D deficiency were frequently observed, while adherence to Kidney Disease: Improving Global Outcomes (KDIGO) monitoring recommendations remained suboptimal. In addition, CKD-MBD–related complications, particularly bone pain and pruritus, were strongly associated with reduced quality of life (QoL). These findings highlight the substantial burden of CKD-MBD among patients receiving maintenance hemodialysis in resource-limited settings.

The prevalence of elevated iPTH observed in this study (47.4%) is consistent with reports from other dialysis populations in sub-Saharan Africa and other low- and middle-income countries, where secondary hyperparathyroidism remains highly prevalent among patients receiving maintenance dialysis [5, 7, 11, 12]. Similar findings have been reported from studies conducted in Nigeria, South Africa, Egypt, and other African dialysis cohorts, where limited access to phosphate binders, vitamin D analogues, calcimimetics, and routine biochemical monitoring contributes to poor CKD-MBD control [9, 11, 13]. Persistent elevation of iPTH in hemodialysis patients reflects ongoing disturbances in phosphorus retention, calcium homeostasis, and vitamin D metabolism associated with advanced kidney disease [2, 18].

Hyperphosphatemia was identified in 28.0% of study participants and was independently associated with CKD-MBD complications and lower QoL scores. This finding is clinically important because elevated serum phosphorus has consistently been associated with vascular calcification, cardiovascular disease, hospitalization, and mortality among hemodialysis patients [3, 15, 19]. Although the prevalence observed in the present study was somewhat lower than reports from some international dialysis registries, it still represents a substantial burden considering the limited availability of phosphorus-lowering therapies in Ethiopia. Variability in dialysis

adequacy, dietary counseling, medication adherence, and access to phosphate binders may partially explain differences across studies [10, 13, 16]. Overall, our findings are consistent with reports from several sub-Saharan African countries, where CKD-MBD remains a substantial challenge because of limited access to routine biochemical monitoring, phosphate binders, vitamin D analogues, and calcimimetics. Similar barriers have been described in dialysis cohorts from Nigeria, South Africa, Senegal, and other low-resource settings, where financial constraints and restricted nephrology resources contribute to delayed diagnosis and suboptimal management of CKD-MBD. Compared with large international dialysis registries, the prevalence of some biochemical abnormalities in our study was lower; however, this likely reflects differences in patient characteristics, laboratory testing practices, treatment availability, and healthcare infrastructure rather than true differences in disease burden.

Hypocalcemia was present in approximately one-quarter of participants and was significantly associated with bone pain and lower QoL scores. Disturbances in calcium metabolism contribute to abnormal bone turnover, neuromuscular symptoms, and worsening secondary hyperparathyroidism among dialysis patients [18, 20]. The observed relationship between hypocalcemia and symptom burden in this study supports previous evidence demonstrating that calcium abnormalities are clinically relevant determinants of skeletal symptoms and patient well-being in CKD-MBD populations [17, 19]. The observed association between CKD-MBD complications and poorer quality of life is also consistent with evidence from both African and international studies, which have shown that symptom burden, particularly bone pain and pruritus, substantially impairs physical functioning, emotional well-being, and social participation among patients receiving maintenance hemodialysis. These findings underscore that improving CKD-MBD management is particularly important in resource-limited settings, where treatment options and supportive services are often constrained.

Vitamin D deficiency was identified in 19.6% of participants. Although this prevalence was lower than reported in some regional studies, vitamin D deficiency remains clinically important because impaired vitamin D metabolism contributes to secondary hyperparathyroidism, impaired bone mineralization, muscle weakness, and immune dysfunction among patients with advanced kidney disease [2]. Differences in prevalence between studies may reflect variability in assay methods, nutritional status, sunlight exposure, dialysis duration, and local treatment practices. In Ethiopia, limited access to routine vitamin D testing and treatment may contribute to underrecognition of vitamin D deficiency in dialysis populations.

An important finding of this study was the relatively low adherence to KDIGO-recommended biochemical monitoring intervals. Adherence to recommended monitoring ranged from approximately 53% to 63%, depending on the laboratory parameter assessed. Similar challenges have been reported in other low-resource settings where financial barriers, inconsistent laboratory availability, and limited nephrology resources compromise implementation of CKD-MBD guidelines [9, 10, 13]. In Ethiopia, the high out-of-pocket costs associated with dialysis care and laboratory testing may significantly limit routine monitoring practices. Inadequate biochemical monitoring may delay recognition and treatment of CKD-MBD abnormalities, potentially increasing the risk of complications and worsening long-term outcomes.

The study also demonstrated substantial associations between CKD-MBD complications and impaired quality of life. Participants with pruritus and bone pain had significantly lower QoL scores across physical, emotional, and social functioning domains. These findings are consistent with previous studies showing that CKD-MBD symptoms contribute substantially to patient distress, impaired daily functioning, sleep disturbance, psychological burden, and reduced social participation among maintenance dialysis patients [8, 20, 21]. Although vascular calcification is a recognized manifestation of CKD-MBD, vascular calcification was not systematically evaluated in the present study. Therefore, vascular access complications were not interpreted as CKD-MBD-related outcomes because they may arise from multiple causes unrelated to mineral and bone disorders. In general, bone pain and pruritus were the principal CKD-MBD-related complications evaluated in this study and were consistently associated with poorer physical, emotional, and social quality-of-life domains.

The inverse relationship observed between elevated iPTH levels and total QoL scores further supports the clinical importance of secondary hyperparathyroidism in CKD-MBD management. Elevated iPTH reflects high-turnover bone disease and is associated with bone pain, skeletal fragility, muscle weakness, and vascular calcification [2, 19]. The present findings suggest that inadequate biochemical control may directly contribute to symptom burden and poorer patient-reported outcomes.

Older age and prolonged dialysis duration were independently associated with both CKD-MBD complications and lower QoL scores. Similar associations have been reported in previous dialysis studies, where cumulative exposure to mineral metabolism abnormalities and long-term dialysis-related complications were associated with worsening clinical outcomes over time [15, 22]. Older patients may also have greater cardiovascular comorbidity, reduced physical functioning, and increased frailty, all of which may compound the

impact of CKD-MBD on quality of life. The multivariable analyses further demonstrated that older age, longer dialysis duration, hyperphosphatemia, hypocalcemia, and elevated iPTH remained independently associated with both CKD-MBD complications and poorer quality of life after adjustment for potential confounders. These findings underscore the central role of persistent mineral metabolism abnormalities in the development of CKD-MBD manifestations and their adverse impact on patient-reported outcomes.

This study has important clinical and public health implications. First, the findings highlight the need for improved implementation of KDIGO-aligned CKD-MBD monitoring and treatment practices in Ethiopian dialysis centers. Second, expanding access to phosphate binders, vitamin D analogues, and routine biochemical testing may help improve CKD-MBD control and reduce complications. Third, integrating symptom-focused care and quality-of-life assessment into routine dialysis management may help inform patient-centered outcomes. Multidisciplinary approaches involving nephrologists, dialysis nurses, dietitians, and mental health professionals may be particularly important for addressing the complex burden of CKD-MBD in resource-limited settings.

The present study also contributes important local evidence regarding CKD-MBD among maintenance hemodialysis patients in Ethiopia, where published data remain limited. By simultaneously evaluating biochemical abnormalities, guideline adherence, complications, and patient-reported outcomes, this study provides a more comprehensive assessment of CKD-MBD burden than many previous regional studies. Although CKD-MBD is recognized as a global complication of advanced chronic kidney disease, its impact may be amplified in low-resource settings because of delayed referral to nephrology services, limited availability of diagnostic tests and CKD-MBD therapies, and high out-of-pocket treatment costs. Consequently, the present findings contribute important evidence from Ethiopia and reinforce the need to strengthen implementation of KDIGO recommendations across sub-Saharan Africa. Future prospective studies should incorporate dialysis adequacy, nutritional status, medication use, and other treatment-related factors to more comprehensively evaluate determinants of CKD-MBD complications and patient-reported quality of life.

This study has several limitations. First, the cross-sectional design precludes establishing temporal or causal relationships between CKD-MBD biochemical abnormalities, complications, and quality-of-life outcomes; therefore, the observed associations should not be interpreted as evidence of causality. Second, laboratory data were obtained from routine clinical records rather than generated through a standardized research protocol. Consequently, laboratory measurements reflected routine clinical practice, and the timing of blood sample collection in relation to dialysis sessions, assay methods across participating centers, and laboratory quality control procedures were not standardized or independently verified, which may have introduced measurement variability. Third, biochemical parameters were based on the most recent laboratory results available within the preceding three months and therefore may not accurately reflect long-term fluctuations in mineral metabolism among maintenance hemodialysis patients. Fourth, because data were abstracted from existing clinical records, some laboratory variables were unavailable for all participants, resulting in missing data for certain analyses. Fifth, several potentially important determinants of CKD-MBD, including dialysis adequacy (e.g., Kt/V or urea reduction ratio), dialysate calcium concentration, nutritional status, detailed medication use (including phosphate binders, vitamin D analogues, calcimimetics, and calcium supplements), and vascular calcification assessments, were not consistently available and therefore could not be included in the analyses. Finally, the study was conducted at a tertiary referral hospital and affiliated dialysis centers in Addis Ababa, which may limit the generalizability of the findings to other regions of Ethiopia and similar resource-limited settings.

Despite these limitations, the study included a relatively large sample of maintenance hemodialysis patients and provides one of the first comprehensive assessments of CKD-MBD in Ethiopia by simultaneously evaluating biochemical abnormalities, adherence to KDIGO recommendations, CKD-MBD–related complications, and patient-reported quality of life. These findings provide important baseline evidence to inform clinical practice and future prospective studies in similar low-resource settings.

In conclusion, CKD-MBD biochemical abnormalities and related complications were common among maintenance hemodialysis patients in Addis Ababa and were significantly associated with poorer quality of life. These findings highlight important areas for improving CKD-MBD monitoring and management in routine clinical practice. However, because of the cross-sectional design, the observed associations should not be interpreted as causal, and prospective longitudinal studies are warranted to confirm these relationships. The study did not include radiographic or other objective assessments of vascular calcification. Consequently, cardiovascular manifestations of CKD-MBD could not be directly evaluated.

Conclusion

CKD-MBD biochemical abnormalities and related complications were highly prevalent among maintenance hemodialysis patients in Addis Ababa, Ethiopia. Older

age, prolonged dialysis duration, hyperphosphatemia, hypocalcemia, and elevated iPTH were independently associated with CKD-MBD complications and poorer quality of life. Strengthening access to routine biochemical monitoring, timely treatment of mineral metabolism abnormalities, and multidisciplinary patient-centered care may improve outcomes among maintenance hemodialysis patients in resource-limited settings.

Abbreviations

AOR	Adjusted odds ratios
CI	Confidence Interval
CKD-MBD	Chronic kidney disease–mineral and bone disorder
ESRD	End-stage renal disease
KDIGO	Kidney disease: Improving Global Outcomes
iPTH	Intact parathyroid hormone
PTH	Parathyroid hormone
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
SPMMC	Saint Paul Hospital Millennium Medical College
QoL	Quality of Life

Supplementary information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

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Author contributions
The paper was conceived and written collaboratively by authors K.N.T, D.R.B, and A.A.G, with T.B.G taking the lead on the initial draft. The analysis of the cases involved contributions from K.N.T, D.R.B, and A.A.G, while all authors participated in the revision process and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Ethical approval for this study was obtained from the Institutional Review Board of St Paul's Hospital Millennium Medical College (Reference No: SPHMMC-ERC346/25). All procedures involving human participants were conducted in accordance with relevant guidelines and regulations, including the Declaration of Helsinki. Permission letters were secured from each participating dialysis center prior to data collection. Written informed consent to participate was obtained from all study participants before enrollment. Participation was entirely voluntary, and confidentiality was strictly maintained throughout the study. Unique study identification numbers were used in place of personal identifiers, and all collected data were stored securely and used solely for research purposes. Participants identified with clinically important abnormal laboratory findings during the study were promptly referred to their treating physicians for appropriate clinical management.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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