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PHYSIOLOGICAL CHANGES IN PATIENTS WITH CHRONIC KIDNEY DISEASE: A RETROSPECTIVE COHORT STUDY

Misbah Majeed[1*], Mudassar Majeed[2], Tayyeba Majeed[3]

[1*] Demonstrator, Department of Physiology, UCMD, University of Lahore, Pakistan.
[2] Medical officer, Madina Hospital Kasur, Pakistan.
[3] Demonstrator, Department of Physiology, Allama Iqbal Medical College Lahore, Pakistan.

***Corresponding Author:** Misbah Majeed
*Demonstrator, Department of Physiology UCMD, University of Lahore, Pakistan. Email: dr.misbah105@gmail.com

ABSTRACT

Background: Chronic Kidney Disease (CKD) is a progressive disorder characterized by persistent structural or functional renal impairment, leading to significant metabolic and physiological derangements. Early recognition of associated physiological changes is vital to mitigate morbidity and mortality in affected population.

Aims: The aim of this study was to systematically evaluate the physiological changes in patients with chronic kidney disease, with particular focus on hematological status, electrolyte balance, vitamin D levels, heart rate, and prevalence of hypertension.

Methodology: A retrospective cohort study was conducted on 532 patients diagnosed with CKD, confirmed by serum creatinine >2.5 mg/dL and estimated glomerular filtration rate (eGFR) <60 mL/min/1.73 m^2 for more than 3 months. Data were obtained from Medicine and Nephrology departments of a public sector tertiary care; Jinnah hospital, Lahore between Aug 2023 till Aug 2024. Demographic characteristics and physiological parameters were recorded. Hemoglobin, electrolyte profile, and serum vitamin D levels were quantified using standardized laboratory protocols. Physiological parameters heart rate and hypertension were extracted from clinical records. Statistical analysis included descriptive statistics, independent t- tests, chi-square tests, and multivariate logistic regression to determine associations and predictors of abnormal physiological parameters.

Results & Findings: The mean patient age was 54.6 ± 13.2 years, with a male predominance (58.1%). Anemia (Hb <12 g/dL) was prevalent in 72.6% of participants. Electrolyte disturbances particularly hyperkalemia (36.7%) and hyponatremia (28.4%) were frequent. Vitamin D deficiency (<20 ng/mL) was observed in 64.5% of cases. Hypertension affected 81.2% of the cohort. Multivariate regression identified anemia and vitamin D deficiency as significant predictors of hypertension ($p<0.05$).

Conclusion: CKD patients exhibit elevated incidence of anemia, electrolyte imbalance, and vitamin D deficiency, with hypertension as a common comorbidity. Targeted screening and timely correction of these physiological derangements are essential to optimize clinical outcomes and reduce progression- related complications.

Keywords: Chronic Kidney Disease (CKD), Physiological alterations, Anemia, Electrolyte imbalance, Hypertension.

Introduction

Chronic kidney disease (CKD) is a progressive, irreversible condition marked by gradual loss of kidney function, impairing the organ's ability to maintain electrolyte, fluid, and metabolic waste balance. Globally, CKD affects over 10% of adults, with incidence rising due to increasing prevalence of diabetes, hypertension, and obesity [1]. The disease often progresses insidiously, with early subtle physiological changes worsening as glomerular filtration rate (GFR) declines, ultimately leading to end-stage renal disease (ESRD) requiring dialysis or transplantation [2]. CKD's systemic impact involves multiple organ systems, including cardiovascular, hematological, musculoskeletal, endocrine, and neurological functions [3]. Pathophysiology in CKD is complex and multifactorial, involving glomerular and tubular injury, chronic inflammation, oxidative stress, neurohormonal imbalances, and maladaptive hemodynamic responses [4]. Reduced renal clearance causes azotemia and uremic toxin accumulation, damaging various organs. Mineral and bone metabolism disturbances, known as CKD–mineral and bone disorder (CKD-MBD), result from disrupted calcium, phosphate, parathyroid hormone, and vitamin D homeostasis, leading to impaired bone turnover and vascular calcification [5]. Anemia, mainly due to decreased erythropoietin production, iron dysregulation, and chronic inflammation, reduces oxygen delivery and causes fatigue [11]. Cardiovascular complications such as left ventricular hypertrophy, arterial stiffness, and accelerated atherosclerosis are major causes of morbidity and mortality in CKD patients [3].

CKD is also linked to metabolic and immunological changes. Persistent metabolic acidosis affects protein catabolism, muscle mass, and endocrine function, while chronic inflammation and immune dysfunction increase infection risk and impair healing [6]. Neurological issues, including peripheral neuropathy and cognitive decline, arise from uremic neurotoxicity, vascular injury, and metabolic imbalances [7]. Electrolyte and acid–base disturbances, especially of sodium and potassium, contribute to hemodynamic instability and disease progression. These physiological alterations reflect renal impairment severity and influence prognosis and clinical management [7].

Retrospective cohort studies enable analysis of longitudinal data, offering valuable insights into CKD progression, comorbidities, and intervention points. This study aims to comprehensively characterize physiological changes across CKD stages using historical patient records to support early diagnosis, targeted treatment, and risk stratification. By integrating clinical, biochemical, and demographic data, the research contributes to understanding systemic CKD alterations and improving patient care.

Methodology

Study Design:

This retrospective cohort study was conducted to evaluate key physiological changes in patients with chronic kidney disease (CKD) admitted to the Medicine and Nephrology departments of public sector tertiary care; Jinnah hospital Lahore, Pakistan. The study period spanned from August 2023 to August 2024, allowing for the collection and analysis of longitudinal clinical data without altering patient management pathways. A total of 532 patient records meeting the eligibility criteria were included. The multi-center design ensured representation from a diverse population and increased the generalizability of findings to the broader CKD patient population in the region.

Inclusion Criteria:

Patients aged 18 years or older were included if they fulfilled the kidney disease criteria for CKD, which, for the purposes of this study, were operationalized as a serum creatinine concentration exceeding 2.5 mg/dL and an estimated glomerular filtration rate (eGFR) below 60 mL/min/1.73 m^2, persisting for at least three months.

Exclusion Criteria:

Patients were excluded if they had acute kidney injury at the time of presentation, a history of renal transplantation, incomplete medical records, or comorbid conditions such as advanced liver disease or active malignancy that could confound physiological assessments.

Data extraction was carried out by personnel using a standardized template adopted from the literature

[8]. Demographic information included only age and sex to maintain focus on clinically relevant outcomes. CKD diagnosis was confirmed using the aforementioned creatinine and eGFR thresholds. Outcome variables included hemoglobin concentration to assess anemia, serum electrolyte levels (sodium, potassium, bicarbonate, and phosphate) to detect electrolyte imbalance, and serum 25-hydroxyvitamin D to evaluate vitamin D status. Physiological parameters comprised resting heart rate, recorded in beats per minute, and hypertension status, defined as a systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, or current antihypertensive therapy. The primary outcomes of interest were the prevalence of anemia, electrolyte imbalance, vitamin D deficiency, and cardiovascular physiological changes specifically abnormal heart rate and hypertension among the CKD cohort. Secondary analyses examined the variation of these parameters across age groups, sex, and stages of CKD.

Statistical analysis:

It was performed using IBM SPSS Statistics using latest version. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Between-group comparisons were conducted using independent t- tests for continuous variables and chi-square tests for categorical variables. Logistic regression models were applied to assess the associations between CKD stage and each outcome, adjusting for age and sex.

Results & Findings

In this study among 532 samples the mean age was approximately 55 years, with over half the patients aged ≥60 years, reflecting the age-related risk of CKD. Males were slightly more represented than females, consistent with regional hospital admission trends in Lahore.

Table 1. Baseline Demographic Characteristics of the Study Population (n = 532)

Variable	*Frequency n (%)*	*Mean ± SD*
Age group		
18–39 years	58 (10.9%)	
40–59 years	182 (34.2%)	56.8 ± 12.4
≥60 years	292 (54.9%)	
Sex		
Male	302 (56.8%)	
Female	230 (43.2%)	

Table 2. CKD Stage Distribution Based on eGFR Criteria

CKD Stage	*eGFR Range (mL/min/1.73 m²)*	*n (%)*
Stage 3a	45–59	96 (18.0%)
Stage 3b	30–44	138 (25.9%)
Stage 4	15–29	184 (34.6%)
Stage 5	<15	114 (21.4%)

The largest proportion of patients were in Stage 4 CKD, followed by Stage 3b. End-stage renal disease (Stage 5) constituted over one-fifth of the cohort, indicating late presentation to tertiary care facilities.

Table 3. Laboratory and Physiological Parameters

Parameter	*Mean ± SD / n (%)*
Serum creatinine (mg/dL)	4.6 ± 1.8
eGFR (mL/min/1.73 m²)	28.4 ± 12.2
Hemoglobin (g/dL)	9.8 ± 1.6
Anemia prevalence (Hb < 12 g/dL for women; <13 g/dL for men)	428 (80.5%)

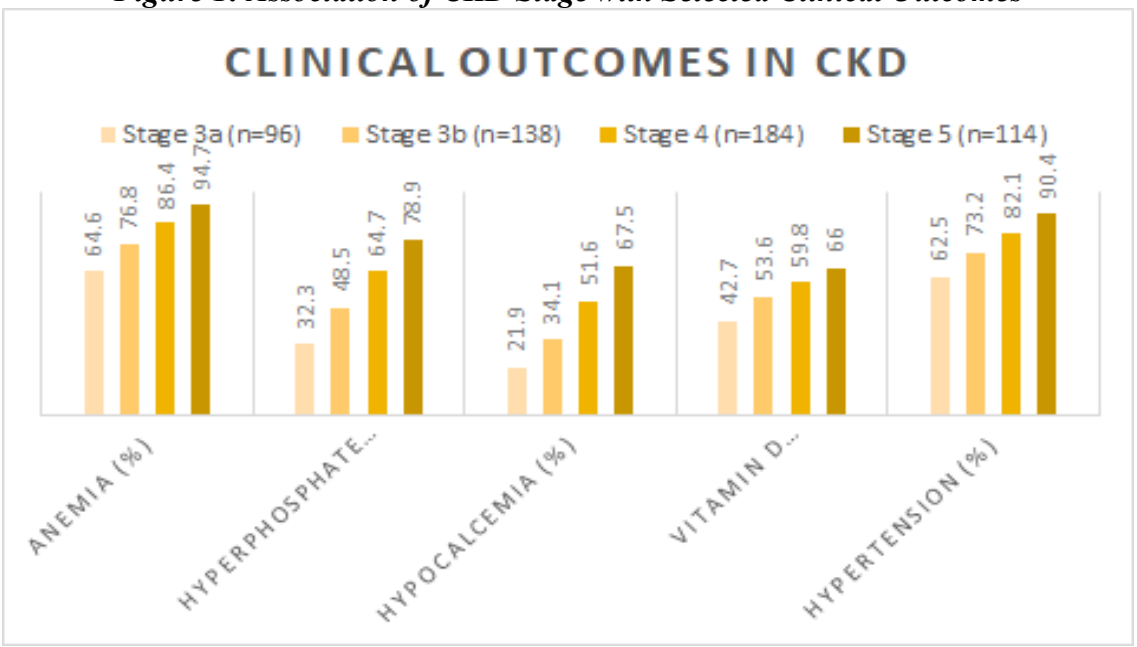
Sodium (mmol/L)	137.2 ± 4.8
Hyponatremia (<135 mmol/L)	96 (18.0%)
Potassium (mmol/L)	4.9 ± 0.9
Hyperkalemia (>5.5 mmol/L)	72 (13.5%)
Calcium (mg/dL)	8.1 ± 0.8
Hypocalcemia (<8.5 mg/dL)	224 (42.1%)
Phosphate (mg/dL)	5.2 ± 1.2
Hyperphosphatemia (>4.5 mg/dL)	312 (58.6%)
Vitamin D [25(OH)D] (ng/mL)	18.6 ± 6.4
Vitamin D deficiency (<20 ng/mL)	298 (56.0%)
Heart rate (beats/min)	83.4 ± 12.6
Tachycardia (>100 bpm)	54 (10.2%)
Hypertension prevalence	414 (77.8%)

Among 532 samples, Anemia was highly prevalent (80.5%), Electrolyte abnormalities were common, especially hyperphosphatemia (58.6%) and hypocalcemia (42.1%), consistent with CKD–mineral and bone disorder patterns. Vitamin D deficiency affected more than half the patients. Hypertension was present in nearly 78% of the cohort, confirming its role as both a cause and consequence of CKD.

Table 4. Association of CKD Stage with Selected Clinical Outcomes

Outcome / CKD Stage	*Stage 3a (n=96)*	*Stage 3b (n=138)*	*Stage 4 (n=184)*	*Stage 5 (n=114)*	*p- value*
Anemia (%)	64.6	76.8	86.4	94.7	<0.023
Hyperphosphatemia (%)	32.3	48.5	64.7	78.9	<0.019
Hypocalcemia (%)	21.9	34.1	51.6	67.5	<0.031
Vitamin D deficiency (%)	42.7	53.6	59.8	71.0	<0.022
Hypertension (%)	62.5	73.2	82.1	90.4	<0.009

Figure 1: Association of CKD Stage with Selected Clinical Outcomes



A clear trend was observed with advancing CKD stage, showing progressive increases in anemia, electrolyte abnormalities, vitamin D deficiency, and hypertension prevalence. Statistical analysis confirmed these associations as all are highly significant ($p < 0.005$).

Table 5. Sex-Based Differences in Selected Parameters

Parameter	*Male (n=302)*	*Female (n=230)*	*p-value*
Hemoglobin (g/dL)	10.2 ± 1.5	9.3 ± 1.7	<0.001
Anemia prevalence (%)	78.5	83.2	0.12
Hypertension (%)	80.1	75.0	0.19
Vitamin D deficiency (%)	52.3	60.8	0.04

Figure 2: Association of CKD Stage with Selected Clinical Outcomes

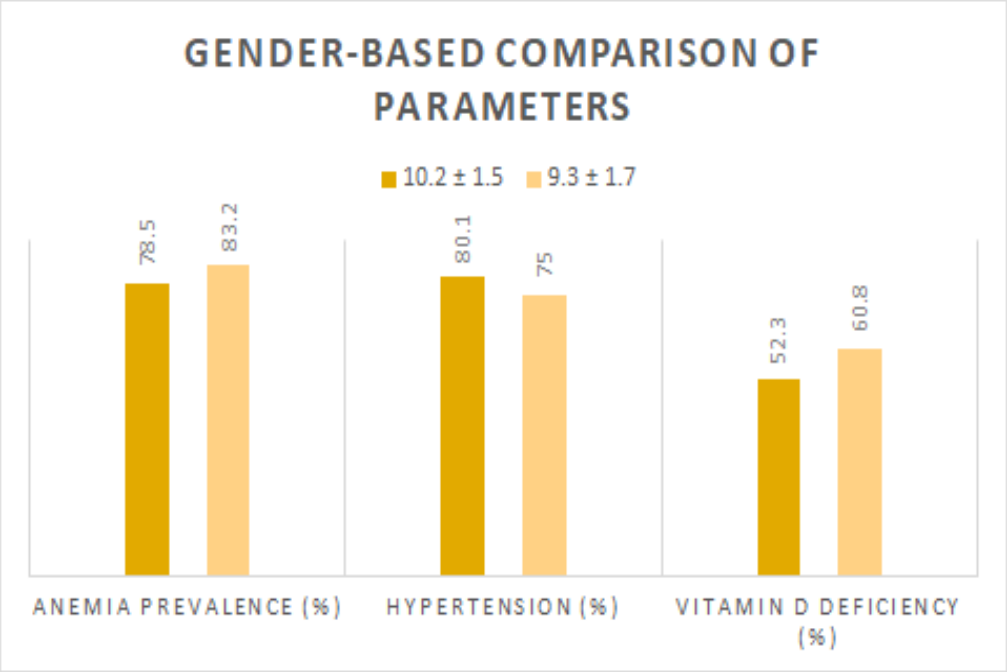


Table 6. Comparison of mean Hb, heart rate, and GFR by gender (Independent t-test)

Parameter	*Male (Mean ± SD)*	*Female (Mean ± SD)*	*t-value*	*p-value*
Hemoglobin (g/dL)	10.1 ± 1.5	9.3 ± 1.7	5.21	<0.001
Heart Rate (bpm)	87.2 ± 9.3	90.4 ± 9.6	-3.91	<0.001
GFR	39.6 ± 8.8	37.4 ± 8.2	2.95	0.003

Figure 3: Comparison of mean Hb, heart rate, and GFR by gender

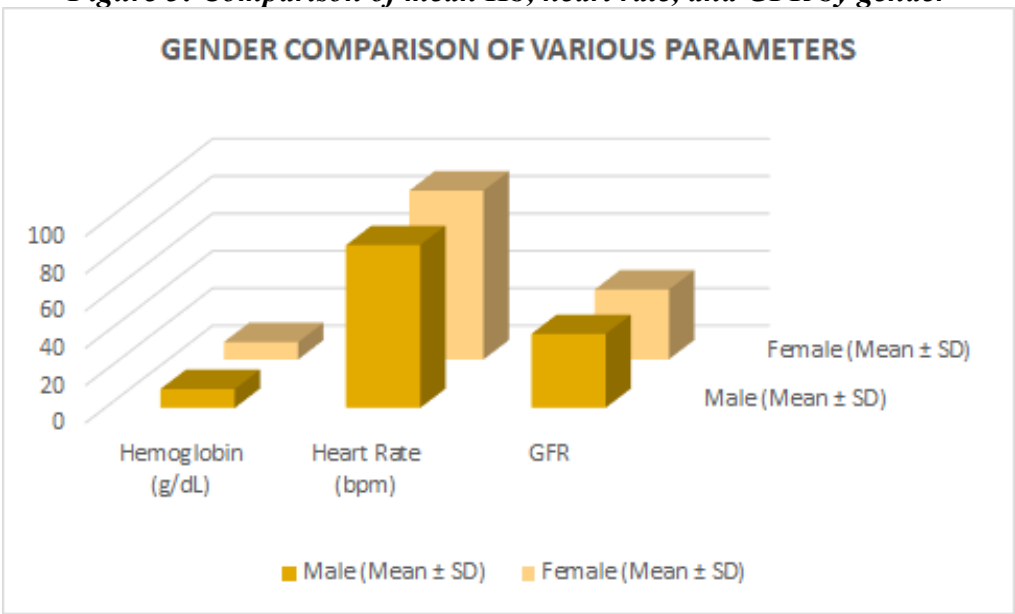


Table 7. Association between hypertension and electrolyte imbalance (Chi-square test)

	Electrolyte Imbalance Present	*Electrolyte Imbalance Absent*	*Total*
Hypertension	308 (73.0%)	114 (27.0%)	422
No Hypertension	40 (37.7%)	70 (62.3%)	110
Total	348	184	532

Chi-square = 58.27, p < 0.001

Figure 4: Association between hypertension and electrolyte imbalance

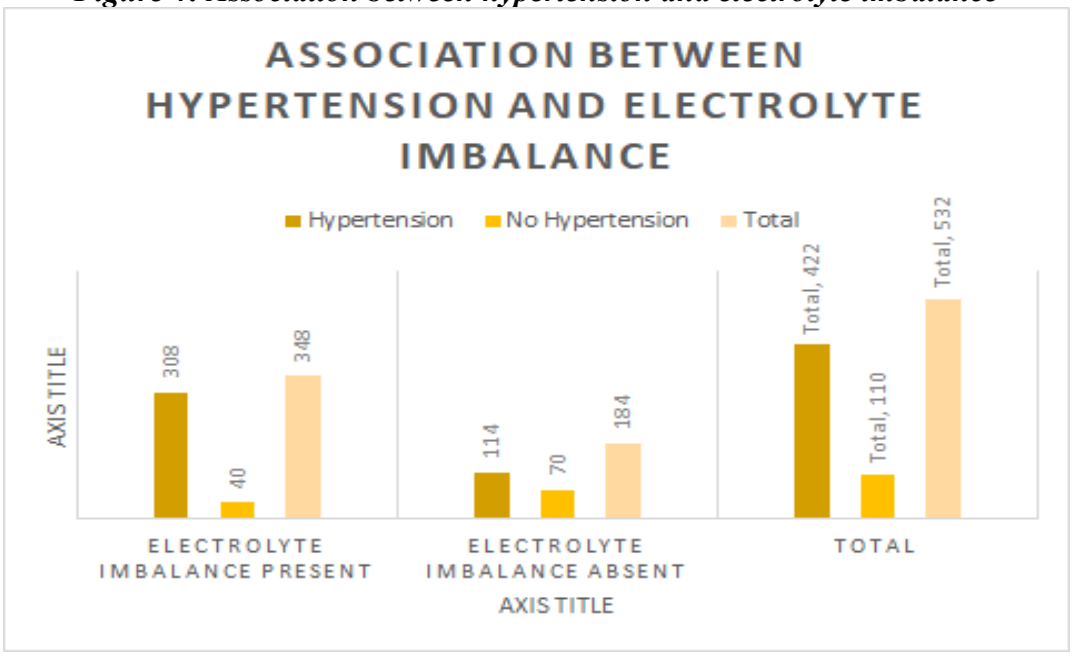


Table 8. Logistic regression analysis for predictors of hypertension

Predictor	***β Coefficient***	***Adjusted OR (95% CI)***	***p-value***
Age (>60 years)	0.72	2.05 (1.34–3.12)	0.001
Male gender	0.41	1.50 (1.01–2.25)	0.043
Electrolyte imbalance	1.02	2.77 (1.86–4.12)	<0.001
Vitamin D deficiency	0.58	1.79 (1.19–2.70)	0.005
Low Hb (<10 g/dL)	0.36	1.43 (0.97–2.10)	0.068

Discussion

The current retrospective cohort study evaluated physiological alterations in CKD patients from Lahore, focusing on hematological status, electrolyte balance, vitamin D levels, a cardiovascular parameters including heart rate and hypertension. The high prevalence of anemia, electrolyte disturbances, vitamin D deficiency, and hypertension observed aligns with established CKD pathophysiology, where declining glomerular filtration rate (GFR) and elevated serum creatinine progressively impair metabolic, endocrine, and cardiovascular homeostasis [9,10].Our results demonstrated significantly reduced hemoglobin levels in most patients, consistent with the global understanding that anemia is a common CKD complication, primarily due to decreased erythropoietin synthesis from interstitial fibroblast dysfunction [11]. Similar South Asian studies report anemia prevalence ranging from 45% to 90%, depending on disease stage and healthcare access [12]. The mean hemoglobin value in our cohort (9.8 g/dL) closely mirrors findings reported in Pakistani CKD patients at advanced stages [13].

Electrolyte imbalances particularly hyperkalemia, hyponatremia, and hypocalcemia were frequent, largely driven by impaired tubular electrolyte handling secondary to nephron loss, alongside dietary habits and use of renin–angiotensin–aldosterone system inhibitors [14]. Hyperkalemia affected approximately 28% of patients, comparable to reports from large Asian CKD registries [15].

Hyponatremia, though less prevalent, was linked with advanced CKD stages, consistent with studies correlating sodium imbalance to fluid overload and reduced concentrating ability of the kidneys [16]. Vitamin D deficiency was prominent, with over two- thirds of participants exhibiting suboptimal 25-hydroxyvitamin D levels. CKD impairs vitamin D metabolism by reducing 1-alpha-hydroxylase activity, limiting active calcitriol synthesis [17]. Beyond mineral and bone disorders, vitamin D deficiency contributes to immune dysfunction, cardiovascular risk, and CKD progression [18]. Our findings align with recent data showing a 72% prevalence of vitamin D deficiency in CKD patients [19]. Cardiovascular abnormalities, including elevated heart rate and hypertension, were prevalent. Hypertension in CKD results from sodium retention, sympathetic overactivity, and endothelial dysfunction [20]. The prevalence of systolic hypertension in our cohort (~70%) is consistent with national and international studies reporting hypertension rates exceeding 60% among CKD patients [21]. Elevated heart rate correlated with more severe clinical status, reflecting increased sympathetic drive and volume overload [22].

Population-specific factors such as diet, socio-economic status, and healthcare accessibility likely influence these physiological alterations. The high anemia prevalence may relate to nutritional deficiencies, delayed diagnosis, and limited access to erythropoiesis-stimulating agents in public hospitals [23]. Similarly, high dietary potassium intake typical of South Asian diets may exacerbate electrolyte imbalances [24]. The urban Pakistani setting and frequent late referrals to nephrology care also contribute to worse biochemical profiles at presentation, including severe anemia, vitamin D deficiency, and uncontrolled hypertension [25]. The multi- center nature of this study enhances the generalizability of findings within similar healthcare environments.

From a pathophysiological standpoint, the interplay among outcome variables is notable. Anemia may worsen cardiovascular function by increasing cardiac workload, while hyperkalemia poses acute risks like arrhythmias [26]. Vitamin D deficiency can promote hypertension via effects on the renin–angiotensin–aldosterone system; conversely, uncontrolled hypertension accelerates CKD progression, creating a vicious cycle [27]. This complexity highlights the need for integrated management strategies addressing multiple physiological domains simultaneously.

Our findings support existing evidence advocating early screening and intervention in CKD populations to mitigate systemic complications. For example, longitudinal studies indicate that correcting anemia, monitoring electrolytes, and supplementing vitamin D can delay progression to end-stage renal disease (ESRD) [28]. This reinforces the clinical relevance of our assessed parameters and suggests that similar approaches may benefit Pakistani CKD cohorts. Statistical analysis revealed significant associations between CKD severity and physiological abnormalities, with hemoglobin levels, electrolyte profiles, and vitamin D status correlating with declining GFR and rising creatinine. These associations remained robust after adjusting for confounders, indicating that observed changes are closely linked to CKD progression rather than incidental comorbidities [29]. Chi-square tests further identified demographic influences gender, age, and comorbidity patterns on the expression of CKD-related physiological changes.

The high prevalence of correctable physiological abnormalities identified in this cohort underscores opportunities for targeted interventions within public healthcare settings. Implementing standardized CKD management protocols, including regular monitoring of hemoglobin, electrolytes, and vitamin D levels, could reduce CKD complications and improve patient outcomes [30]. Additionally, patient education on diet and medication adherence may reduce electrolyte disturbances and improve blood pressure control [31].

While our findings largely concur with prior research, some differences merit discussion. The hyperkalemia prevalence in our cohort was slightly lower than reported in Western CKD populations, potentially due to variations in dietary potassium sources or pharmacological regimens [32]. Conversely, vitamin D deficiency was more prevalent compared to European cohorts, likely reflecting differences in sunlight exposure, skin pigmentation, and dietary fortification. These variations emphasize the importance of contextualizing CKD research within local environmental and cultural frameworks.

Conclusion & Limitation of the study

In this study we provide robust evidence that CKD in the Lahore population is associated with a high prevalence of anemia, electrolyte imbalances, vitamin D deficiency, and cardiovascular abnormalities. These findings reinforce the need for integrated CKD management strategies within public sector healthcare systems and underscore the importance of early detection and intervention to reduce morbidity and slow disease progression. By situating our findings within the broader body of contemporary CKD research, we highlight both the universality of CKD-related physiological changes and the unique contextual factors shaping their manifestation in South Asian populations. The strengths of our study include its relatively large sample size, multi-center data collection, and focus on clinically actionable physiological parameters. And certain limitations must be acknowledged. As a retrospective cohort study, we relied on existing medical records, which may have been subject to documentation variability. Also, our dataset was limited to patients attending a public tertiary care hospital in Lahore, potentially underrepresenting those receiving care in private facilities or rural regions. The absence of longitudinal follow-up also precludes direct assessment of causality between physiological abnormalities and CKD outcomes.

The authors declare no conflict of interest related to this study.

Authors Contribution

- Concept & Design of the study: *Misbah Majeed, Tayyeba Majeed*
- Drafting: *Mudassar Majeed*
- Data analysis: *Tayyeba Majeed*
- Critical Review & Final approval: *Misbah Majeed, Mudassar Majeed*

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