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Comparative Cross-Sectional Study Of Electrolyte Profiles In Diabetes, Chronic Kidney Disease, And Cardiovascular Disease

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ABSTRACT

Background

Cardiovascular disease (CVD), diabetes mellitus (DM), and chronic kidney disease (CKD) are major global health issues, each influenced by demographic factors and electrolyte imbalances. Research connects age, gender, and electrolyte levels (sodium, potassium, chloride, calcium, phosphorus) to these conditions, underscoring the importance of identifying specific trends across these diseases.

Aim

The aim of the study is to comprehensively compare the electrolyte profiles in individuals with CVD, DM and CKD.

Method and Material

This cross-sectional study at Sree Balaji Medical College and Hospital, Chennai, involved 150 patients divided into three groups of 50, each diagnosed solely with CVD, DM, or CKD. Participants aged 39–60 were selected based on strict inclusion and exclusion criteria. Demographic information was gathered via questionnaire, and Serum sample was used for analysis. Test were performed using the fully automatic analyser.

Results
The age distribution analysis showed CVD peaking in ages 46–65, DM in 46–55, and CKD across 36–65. Electrolyte results indicated that calcium levels were slightly reduced in CVD patients, while sodium and chloride remained within normal ranges. DM patients exhibited no significant chloride or calcium deviations, though contrasts appeared with lower sodium levels in other studies. CKD patients displayed normal sodium ranges, though past studies reported a risk of hyponatremia in advanced stages. Significant differences were noted in potassium, calcium, and phosphorus levels across the disease groups ($p < .05$).

Conclusion
These findings underscore the importance of demographic and electrolyte monitoring in managing CVD, DM, and CKD, emphasizing the need for tailored management strategies based on disease-specific electrolyte trends.

Introduction

Electrolytes are vital for numerous physiological functions, including maintaining electrical balance within cells and enabling the transmission of electrical impulses in nerves and muscles. Key electrolytes in the body include sodium, potassium, chloride, calcium, magnesium, phosphate, and bicarbonate. These electrolytes are primarily obtained from our diet and fluids. Imbalances in electrolyte levels, whether too high or too low, can interfere with normal body functions and may lead to serious, potentially life-threatening complications [1]. Imbalances in electrolyte levels, whether elevated or decreased, can disrupt normal bodily functions and lead to severe, life-threatening consequences. For instance, hyponatremia (low sodium) can result in symptoms such as fatigue, confusion, seizures, and even coma, while hypernatremia (high sodium) can lead to dehydration, high blood pressure, and neurological issues. Similarly, disturbances in other electrolytes like potassium, calcium, and magnesium can affect heart rhythm, muscle contraction, and nerve signaling. Electrolyte levels can vary throughout the day based on factors such as diet, hydration, and the use of medications. Individuals with hypertension and diabetes require careful management of their calcium and magnesium levels, while patients with congestive heart failure must also monitor their sodium and potassium levels. Electrolytes are compounds that dissociate into ions when dissolved in solution, allowing them to conduct electricity. These ions are crucial for several vital processes, including regulating body fluid volume and osmotic balance (Na^+, K^+ and Cl^-), supporting heart rhythm and contractility, facilitating neuromuscular excitability (K^+), and maintaining acid-base balance (K^+ and Cl^-) [2].

In DM, hyperglycemia raises serum osmolality, causing water to shift out of cells, which leads to a dilution of serum sodium (Na+) levels[3]. Likewise, the movement of potassium from the intracellular to the extracellular space (shift hyperkalemia) can cause elevated potassium levels without an overall increase in total body potassium. The kidneys are crucial in regulating body fluids, electrolytes, and acid-base balance. As a result, CKD and ESRD often cause various imbalances, such as hyperkalemia, metabolic acidosis, and hyperphosphatemia. These imbalances can lead to severe complications, including muscle wasting, bone mineral disorders, vascular calcification, and increased risk of mortality [4]. Dysnatremia and dysmagnesemia are also common electrolyte disturbances observed in CKD & ESRD [4]. Electrolyte imbalances can negatively impact the prognosis of stroke patients [5]. Hypocalcemia and hypomagnesemia are more prevalent in ischemic strokes, while hyponatremia is commonly observed in intracerebral hemorrhage strokes. Timely identification and correction of these electrolyte disturbances can help reduce morbidity and mortality during the acute phase of a stroke [6].

Methods and Materials:
This cross-sectional study was conducted at Sree Balaji Medical College and Hospital, Chennai, over a six-month period. Using random sampling, 150 patients were selected, with 50 participants each in three study groups: cardiovascular disease (CVD), diabetes mellitus (DM), and chronic kidney disease (CKD). Selection criteria included specific inclusion and exclusion parameters tailored to each group. Demographic details were gathered through a questionnaire.

INCLUSION CRITERIA: Adult individuals with conditions such as those listed below:

- Diabetes mellitus: Individuals aged between 39 and 60 with a known condition of diabetes and no known condition of CKD or CVD.
- Chronic kidney disease: Individuals aged between 39 and 60 with a known condition of CKD and no known condition of DM or CVD.
- Cardiovascular disease: Individuals aged between 39 and 60 with a known condition of CVD and no known condition of CKD or DM.

EXCLUSION CRITERIA:

- Patients with no known conditions of Diabetes mellitus, chronic kidney disease, cardiovascular disease.
- Patients with type I diabetes.
- Individuals with more than one condition.

SPECIMEN COLLECTION AND PREPARATION:

- Serum and heparin plasma are suitable for sample. Do not use oxalate, EDTA, or citrate plasma. Whole blood and hemolytic not recommended for use as a sample. Freshly drawn serum is the preferred specimen.
- 3ml of blood samples were collected from the antecubital vein of patient.
- Use the suitable tubes (plain tube) or collection containers and follow the instruction of the manufacturer; avoid effect of the materials of the tubes or other collection containers.
- Centrifuge samples containing precipitate before performing the assay for 10 minutes at 3000 rpm (Revolution per minute).
- The samples were processed after the separation of serum from blood.

Tests were done using the instruments Erba EC90 which works under the principle of ISE (Ion Selective Electrode) Method and Mindray 430 analyzer which works under the principle of Beer-Lamberts law.

Table 1: Methods and Reference range of electrolytes

PARAMETER	METHOD	Reference Range
Sodium, Potassium, Chloride	Ion Selective Electrode (ISE) Method	Sodium: 136 – 145 mEq/L Potassium:3.5 – 5.1 mEq/L Chloride: 96 – 106 mEq/L
Calcium	Arsenazo III Method	8.8 – 10.2 mEq/L
Phosphorus	Phosphomolybdate Method	2.5 – 4.8 mEq/L

Results

The analysis examined the distribution of age, gender, and electrolyte levels across three patient groups—those with cardiovascular disease (CVD), diabetes mellitus (DM), and chronic kidney disease (CKD). Electrolyte levels, including sodium, potassium, chloride, calcium, and phosphorus, were compared using the Kruskal-Wallis test to assess any statistically significant differences among groups.

Table 2: AGE DISTRIBUTION

AGE	25-35	36-45	46-55	56-65	66-75	76-85
CVD	2	0	26	19	2	1
DM	0	2	29	14	5	0
CKD	3	12	14	13	7	1

Table 3: GENDER DISTRIBUTION

GENDER	MALE	FEMALE
CVD	27	23
DM	23	27
CKD	27	23

Table 4: Electrolytes Distribution

DISEASE	CVD	DM	CKD
SODIUM (mEq/L)	136.046	135.218	137.264
POTASSIUM (mEq/L)	4.2522	4.3392	4.7302
CHLORIDE (mEq/L)	102.358	102.112	102.462
CALCIUM (mEq/L)	8.6312	8.9456	8.9174
PHOSPHORUS (mEq/L)	4.4276	3.759	4.7388

Table 5: KRUSKAL WALLIS TEST VALUES OF SODIUM

Pair	Mean Rank difference	Z	SE	Critical value	p-value
x1-x2	7.27	0.8437	8.6167	20.6275	0.3988
x1-x3	-13.4592	1.5542	8.6601	20.7314	0.1201
x2-x3	-20.7292	2.4057	8.6167	20.6275	0.01614

#P<0.05 is significant. *Group1(CVD), Group2(DM), Group3(CKD)

The Kruskal-Wallis H test indicated that there is a non-significant difference in the dependent variable between the different groups, $\chi 2(2) = 5.95$, $p = .051$, with a mean rank score of 72.5 for Group1, 65.23 for Group2, 85.96 for Group3.

Table 6: KRUSKAL WALLIS TEST VALUES OF POTASSIUM

Pair	Mean Rank difference	Z	SE	Critical value	p-value
x1-x2	-5.49	0.6319	8.6885	20.7995	0.5275
x1-x3	-26.82	3.0868	8.6885	20.7995	0.002023
x2-x3	-21.33	2.455	8.6885	20.7995	0.01409

#P<0.05 is significant. *Group1(CVD), Group2(DM), Group3(CKD)

The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi2(2) = 10.64$, $p = .005$, with a mean rank score of 64.73 for Group1, 70.22 for Group2, 91.55 for Group3.

Table 7: KRUSKAL WALLIS TEST VALUES OF CHLORIDE

Pair	Mean Rank difference	Z	SE	Critical value	p-value
x1-x2	2.83	0.3257	8.688	20.7982	0.7446
x1-x3	-0.4	0.04604	8.688	20.7982	0.9633
x2-x3	-3.23	0.3718	8.688	20.7982	0.7101

#P<0.05 is significant. *Group1(CVD), Group2(DM), Group3(CKD)

The Kruskal-Wallis H test indicated that there is a non-significant difference in the dependent variable between the different groups, $\chi2(2) = 0.16$, $p = .921$, with a mean rank score of 76.31 for Group1, 73.48 for Group2, 76.71 for Group3.

Table 8: KRUSKAL WALLIS TEST VALUES OF CALCIUM

Pair	Mean Rank difference	Z	SE	Critical value	p-value
x1-x2	-21.13	2.4319	8.6886	20.7997	0.01502
x1-x3	-19.22	2.2121	8.6886	20.7997	0.02696
x2-x3	1.91	0.2198	8.6886	20.7997	0.826

#P<0.05 is significant. *Group1(CVD), Group2(DM), Group3(CKD)

The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi2(2) = 7.24$, $p = .027$, with a mean rank score of 62.05 for Group1, 83.18 for Group2, 81.27 for Group3.

Table 9: KRUSKAL WALLIS TEST VALUES OF PHOSPHORUS

Pair	Mean Rank difference	Z	SE	Critical value	p-value
x1-x2	20.16	2.3203	8.6886	20.7997	0.02033
x1-x3	-12.96	1.4916	8.6886	20.7997	0.1358

x2-x3	-33.12	3.8119	8.6886	20.7997	0.0001379

#P<0.05 is significant. *Group1(CVD), Group2(DM), Group3(CKD)

The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi2(2) = 14.76$, $p < .001$, with a mean rank score of 77.9 for Group1, 57.74 for Group2, 90.86 for Group3.

The Kruskal-Wallis test results further enrich this analysis by highlighting variations in electrolyte levels across groups. Sodium levels showed a non-significant difference ($\chi2(2) = 5.95$, $p = .051$) across disease groups, suggesting consistent sodium levels despite disease type. Potassium levels, however, were significantly different across groups ($\chi2(2) = 10.64$, $p = .005$), with Group 3 showing notably higher mean ranks than Groups 1 and 2, as confirmed by the Post-Hoc Dunn's test. Chloride also showed no significant variation ($\chi2(2) = 0.16$, $p = .921$). Calcium demonstrated significant variation ($\chi2(2) = 7.24$, $p = .027$), with Group 1 differing significantly from Group 2, while phosphorus levels exhibited the most substantial differences ($\chi2(2) = 14.76$, $p < .001$), with Group 2 significantly lower than Group 3. These findings provide a clearer understanding of how electrolyte imbalances are distributed across CVD, DM, and CKD, underlining the importance of tailored electrolyte monitoring in managing these conditions.

Discussion

This study provides valuable insights into the electrolytic and demographic patterns associated with CVD, DM, and CKD. Analysis of age distribution reveals trends in the prevalence of each condition across age groups, with CVD being most common in individuals aged 46–65, DM peaking in the 46–55 group, and CKD more evenly distributed among those aged 36–65. These findings align with previous studies; for instance, Uddin et al. (2018) [7] reported a higher prevalence of CVD in individuals over 60, while Saranya et al. (2023) [8] observed CKD primarily in those aged 40–60. Electrolyte patterns also differed by disease, providing further insight into disease management and prediction. In CVD patients, calcium levels were slightly below the normal range (8.6312 mEq/L vs. 8.8–10.2 mEq/L), consistent with findings from Uddin et al. (2018) [7], where low calcium was linked to muscle creatine kinase reductions post-myocardial infarction (MI). However, both sodium (136.046 mEq/L) and chloride (102.358 mEq/L) levels remained within their normal ranges, supporting findings from previous studies that showed no significant changes in these electrolytes in cardiac patients.

In DM patients, average chloride (102.112 mEq/L) and calcium (8.9456 mEq/L) levels fell within reference ranges, agreeing with Ugwuja et al. (2016) [9], who found no significant deviations in these electrolytes among diabetic individuals. Contrastingly, Bohara et al. (2021) [10] reported elevated chloride levels (109.71 mEq/L) in type 2 diabetes, possibly due to hypertonicity. Bohara et al. (2021) [10] also observed lower serum sodium in type 2 diabetes, explaining that hyperglycemia-induced frequent urination could lead to excessive sodium excretion. In contrast, this study found mean serum sodium within the normal range, highlighting potential variability in electrolyte patterns among diabetic individuals.

Among CKD patients, mean serum sodium (137.264 mEq/L) also remained within normal limits, aligning with Musleh et al., who found sodium levels stayed stable during early stages of chronic renal failure. However, Saranya et al. (2023) [8] noted significantly lower sodium levels (132.727 mEq/L) in CKD patients, underscoring that as CKD progresses, kidney function diminishes, impairing sodium regulation and increasing hyponatremia risk.

In CVD, sodium imbalances are often linked to impaired kidney function, altered sympathetic activity, and hormonal changes like RAAS activation. In DM, sodium regulation is usually stable, but

dysglycemia and renal issues in later stages can affect electrolyte balance [11]. In CKD, sodium dysregulation arises from reduced kidney function, with advanced stages leading to sodium retention or, occasionally, hyponatremia due to fluid overload [12]. Although no significant differences were observed in this analysis, the variations in sodium ranks suggest potential pathophysiological factors that may require further exploration in larger or more stratified studies. The significant difference in potassium levels across the groups suggests that CVD, DM, and CKD have distinct impacts on potassium homeostasis [13]. In CVD, impaired kidney function and RAAS activation can lead to potassium retention [14], while in CKD, reduced renal clearance and in DM, possible kidney involvement or medications may contribute to electrolyte disturbances. The non-significant differences in chloride levels across the groups suggest that chloride homeostasis remains relatively unaffected by CVD, DM, and CKD [15]. This could be due to the body's ability to maintain chloride balance through compensatory mechanisms, such as renal regulation, despite underlying disease conditions. The significant differences in calcium levels suggest that CVD and CKD may lead to calcium dysregulation [16], potentially due to impaired renal function and altered calcium-phosphate metabolism. In DM, calcium levels may be less affected [17], although kidney involvement in advanced stages could contribute to minor changes. The significant differences in phosphorus levels suggest that CKD leads to elevated phosphorus due to impaired renal excretion[18], while CVD and DM may have less pronounced effects. In CKD, phosphate retention is common due to reduced kidney function [19], contributing to mineral imbalances and vascular calcification.

CONCLUSION

These findings highlight the critical role of age demographics and electrolyte monitoring in the effective management of CVD, DM, and CKD. The distinct age patterns associated with each condition suggest that targeted screening and preventive measures could be more effective if aligned with these demographic trends. Moreover, the specific electrolyte changes observed—such as decreased calcium in CVD and varied potassium, calcium, and phosphorus levels across all groups—indicate the importance of regular electrolyte assessments. Tailoring management strategies to address these disease-specific electrolyte profiles could enhance treatment outcomes and provide more precise care for patients with CVD, DM, and CKD.

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