

Measurement of Serum Levels of Sodium, Potassium and Magnesium in Diabetic Subjects and Establishing Its Role in the Development of Microvascular and Macrovascular Complications

Authors:

Uthra Krishnan¹, Supriya PS², Chethan Subramanya³

¹MBBS, K S Hegde Medical Academy, Affiliated to Nitte Deemed to be university, Mangalore.

^{2,3}Associate Professor, Department of General Medicine, K.S Hegde Medical Academy, Affiliated to Nitte Deemed to be university, Mangalore.

Corresponding Author:

Chethan Subramanya, MD, Associate Professor, Department of General medicine, K S Hegde Medical Academy, Affiliated to Nitte Deemed to be university, Mangalore.

DOI: <https://doi.org/10.5281/zenodo.21737383>

Received: 10 July 2026, Accepted: 29 July 2026, Online First: 01 August 2026

ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycaemia resulting from insulin resistance and progressive pancreatic β -cell dysfunction. The disease has become one of the leading causes of morbidity and mortality worldwide because of its increasing prevalence and the development of disabling microvascular and macrovascular complications. **Objectives:** To determine serum sodium, potassium, and magnesium levels among patients with type 2 diabetes mellitus and to evaluate their association with the presence of microvascular and macrovascular complications. **Materials and Methods:** A hospital-based, single-centre observational study was conducted among 110 adults diagnosed with type 2 diabetes mellitus attending the Department of General Medicine at Justice K.S. Hegde Charitable Hospital, Mangaluru. Participants were divided equally into two groups comprising patients with diabetic complications ($n = 55$) and patients without complications ($n = 55$). Serum sodium, potassium, and magnesium concentrations were measured using standard laboratory techniques. **Results:** Among patients without complications, abnormal serum magnesium, sodium, and potassium levels were observed in 27.3%, 58.2%, and 32.7% of participants, respectively. In patients with diabetic complications, abnormal magnesium, sodium, and potassium levels were detected in 34.5%, 50.9%, and 36.4% of participants, respectively. Mean serum magnesium was marginally lower in patients with complications (1.784 ± 0.421 mmol/L) than those without complications (1.815 ± 0.389 mmol/L; $p = 0.690$). **Conclusion:** Electrolyte abnormalities were common among patients with type 2 diabetes mellitus irrespective of complication status. Although no statistically significant association was observed between serum sodium, potassium, or magnesium levels and diabetic complications, potassium demonstrated a borderline trend towards significance.

Keywords: Type 2 diabetes mellitus; Sodium; Potassium; Magnesium; Electrolytes; Microvascular complications; Macrovascular complications.

INTRODUCTION

Diabetes mellitus is one of the most challenging chronic non-communicable diseases affecting public health worldwide. According to the International Diabetes Federation, over 530 million adults are currently living with diabetes, and this number is projected to exceed 780 million by 2045.[1] India bears a substantial

proportion of the global diabetes burden and has emerged as one of the countries with the largest number of individuals affected by type 2 diabetes mellitus (T2DM).[2] Rapid urbanization, sedentary lifestyles, unhealthy dietary habits, obesity, population ageing, and genetic susceptibility have contributed significantly to the increasing prevalence of T2DM in developing countries. The progressive rise in diabetes has resulted in

considerable healthcare expenditure and has become a major contributor to cardiovascular disease, chronic kidney disease, blindness, neuropathy, and premature mortality.[3]

Persistent hyperglycaemia is the hallmark of T2DM and is responsible for multiple biochemical and metabolic abnormalities affecting virtually every organ system. Chronic elevation of blood glucose leads to oxidative stress, formation of advanced glycation end products, activation of inflammatory pathways, endothelial dysfunction, and vascular injury[4]. These mechanisms collectively contribute to the development of microvascular complications such as diabetic nephropathy, retinopathy, and neuropathy, as well as macrovascular complications including coronary artery disease, cerebrovascular disease, and peripheral arterial disease. Prevention of these complications remains one of the principal objectives of diabetes management.[5]

Sodium is the principal extracellular cation responsible for maintaining plasma osmolality and extracellular fluid volume. Hyperglycaemia causes osmotic shifts of water from the intracellular to the extracellular compartment, resulting in dilutional hyponatraemia. In addition, glycosuria-induced osmotic diuresis leads to increased urinary sodium loss. Persistent sodium abnormalities have been associated with increased hospitalization, cognitive impairment, and mortality among diabetic individuals. Conversely, hypernatraemia may occur in patients with severe dehydration and inadequate water replacement, particularly in elderly patients.[6]

Potassium plays a pivotal role in maintaining resting membrane potential, nerve conduction, skeletal muscle contraction, and cardiac electrical activity. Insulin facilitates intracellular potassium uptake through activation of the sodium-potassium ATPase pump. Consequently, insulin deficiency or resistance can disrupt potassium homeostasis. Both hypokalaemia and hyperkalaemia have been associated with increased cardiovascular morbidity and mortality in patients with diabetes, especially among those with chronic kidney disease or cardiovascular disease. Even minor deviations in serum potassium concentration may predispose susceptible individuals to life-threatening cardiac arrhythmias.[5,6]

Although several international studies have examined electrolyte disturbances in diabetic populations, the available evidence regarding their association with established diabetic complications remains inconsistent.[5,6,7] Differences in study design, ethnicity, duration of diabetes, glycaemic control, nutritional status, renal function, and medication use may account for the variability in reported findings. Furthermore, relatively few studies have evaluated these associations in the Indian population, where demographic characteristics, dietary practices, and

disease patterns differ considerably from Western populations.

The present hospital-based observational study was therefore undertaken to evaluate serum sodium, potassium, and magnesium concentrations among patients with type 2 diabetes mellitus and to compare these electrolyte levels between individuals with and without microvascular or macrovascular complications. Understanding whether electrolyte abnormalities are associated with diabetic complications may contribute to improved risk stratification and encourage routine biochemical monitoring as part of comprehensive diabetes care. The findings of this study may also provide a basis for future large-scale prospective studies investigating the prognostic significance of electrolyte disturbances in the progression of diabetic vascular disease.

MATERIALS AND METHODS

Study Design

This investigation was designed as a hospital-based, single-centre, observational, comparative study conducted over a period of one year.

Study Setting

The study was carried out in the Department of General Medicine at Justice K.S. Hegde Charitable Hospital, a constituent hospital of Nitte (Deemed to be University), Mangaluru, Karnataka, India. This tertiary care teaching hospital caters to patients from Dakshina Kannada, Uttara Kannada, and neighbouring districts of northern Kerala, thereby providing a heterogeneous diabetic population representative of the region. Both outpatient and inpatient diabetic individuals attending the hospital during the study period were screened for eligibility.

Study Population

The study population consisted of adult patients diagnosed with type 2 diabetes mellitus according to established clinical criteria and attending the Department of General Medicine for routine evaluation or treatment during the study period. Participants were subsequently categorized into two equal groups based on the presence or absence of documented diabetic complications.

Group I: Patients with type 2 diabetes mellitus without microvascular or macrovascular complications (n = 55).

Group II: Patients with type 2 diabetes mellitus with one or more documented microvascular and/or macrovascular complications (n = 55).

Among patients with complications, 31 had macrovascular complications alone, 14 had isolated microvascular complications, and 10 had both microvascular and macrovascular complications.

Inclusion Criteria

Patients satisfying all the following criteria were included:

- Adults diagnosed with type 2 diabetes mellitus.
- Patients attending the General Medicine outpatient department or admitted to the medical wards.
- Patients with or without documented diabetic microvascular or macrovascular complications.
- Individuals willing to participate and provide informed consent.

Exclusion Criteria

Patients fulfilling any of the following criteria were excluded:

- Type 1 diabetes mellitus.
- Recent history of persistent vomiting or diarrhoea.
- Severe renal insufficiency likely to independently alter electrolyte balance.
- History of diuretic therapy during the preceding two weeks.
- Patients unwilling to participate.

Sample Size

The sample size was estimated using comparison of means based on serum magnesium concentrations reported in previous literature.[2] Assuming a standard deviation of 0.07 mmol/L in one group and 0.08 mmol/L in the other, an expected mean difference of 0.04 mmol/L, an effect size of 0.53, 80% statistical power, and a 5% level of significance, the calculated minimum sample size was 55 participants per group. Therefore, a total sample of 110 participants was included in the study. Sample size estimation was performed using nMaster software version 2.0.

Sampling Technique

Eligible participants presenting consecutively during the study period were recruited until the required sample size was achieved. This consecutive sampling approach reduced selection bias while ensuring adequate representation of patients with varying clinical characteristics.

Study Variables

The primary outcome variables included serum sodium, serum potassium, and serum magnesium concentrations. The principal independent variable was the presence or absence of diabetic complications. Additional demographic variables included age, sex, and type of diabetic complication (microvascular, macrovascular, or both).

Study Procedure

Following eligibility assessment, demographic and clinical information was recorded using a structured proforma. Patients underwent detailed clinical evaluation and review of available medical records to identify documented diabetic complications. Patients were then classified into either the complication group or the non-complication group. Venous blood samples were collected under standard aseptic precautions for biochemical analysis. Serum sodium, potassium, and magnesium concentrations were estimated using standardized laboratory procedures in the hospital's central biochemistry laboratory with routine quality-control measures. Electrolyte values were subsequently categorized as normal or abnormal according to the laboratory reference ranges used at the institution.

Data Management

All clinical and laboratory information was entered into a structured database after verification for completeness and accuracy. Data confidentiality was maintained by assigning unique identification numbers to each participant, thereby preventing disclosure of personal identifiers.

Outcome Measures

The primary outcome of the study was to determine whether serum sodium, potassium, and magnesium concentrations differed significantly between diabetic patients with established vascular complications and those without complications.

Secondary outcomes included describing the prevalence of electrolyte abnormalities in both study groups and identifying any electrolyte that demonstrated a clinically meaningful trend toward association with diabetic complications.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 29.0. Continuous variables were summarized as mean $\pm$ standard deviation, whereas categorical variables were presented as frequencies and percentages. The Independent Student's t-test was employed to compare mean electrolyte concentrations between patients with and without diabetic complications after confirming equality of variances. Categorical variables were summarized descriptively. Two-sided p-values less than 0.05 were considered statistically significant. Mean differences and corresponding 95% confidence intervals were also calculated to estimate the magnitude and precision of observed differences between study groups.

Ethical Considerations

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Institutional approval was obtained before commencement of the study. All eligible participants were informed regarding the objectives and procedures

of the study, and written informed consent was obtained before enrolment. Participant confidentiality was maintained throughout data collection, analysis, and reporting. Only anonymized data were used for statistical analysis and publication.

RESULTS

A total of 110 patients with confirmed type 2 diabetes mellitus were enrolled in this hospital-based observational study. The study population was equally divided into 55 patients without diabetic complications (Group I) and 55 patients with established microvascular and/or macrovascular complications (Group II). No participant was excluded after enrolment due to incomplete biochemical evaluation.

Table 1. Baseline Demographic Characteristics of Study Participants

Variable	Without Complications (n=55)	With Complications (n=55)
Mean age (years)	58.65 ± 14.06	59.96 ± 9.50
Male	31 (56.4%)	36 (65.5%)
Female	24 (43.6%)	19 (34.5%)

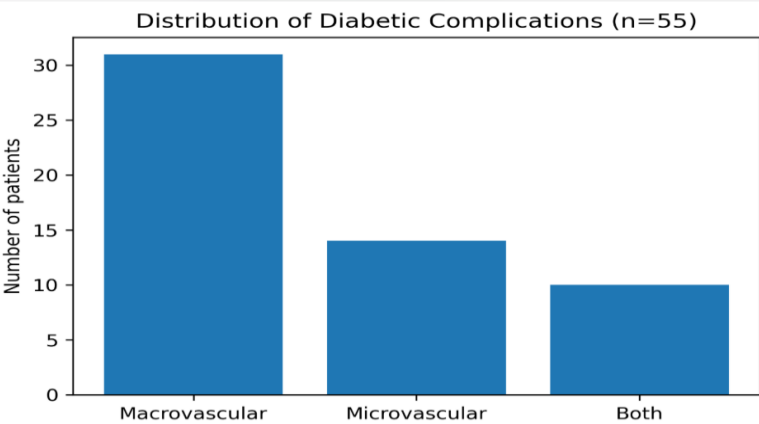
Among patients without diabetic complications, 31 (56.4%) were males and 24 (43.6%) were females. The mean age was 58.65 ± 14.06 years (range: 26–90 years). In the complication group, 36 (65.5%) were males and 19 (34.5%) were females, with a mean age of 59.96 ± 9.50 years (range: 40–75 years). Overall, males constituted the majority of the study population in both groups, indicating a slightly higher representation of men among diabetic patients attending the tertiary care centre.

Table 2. Distribution of Diabetic Complications (n = 55)

Complication Type	Number	Percentage
Macrovascular	31	56.4
Microvascular	14	25.5
Both microvascular and macrovascular	10	18.2

Among the 55 patients with diabetic complications: 31 (56.4%) had isolated macrovascular complications. 14 (25.5%) had isolated microvascular complications. 10 (18.2%) had both microvascular and macrovascular complications. Macrovascular disease therefore represented the predominant complication in the study population.

Figure 1- Distribution of Diabetic Complications

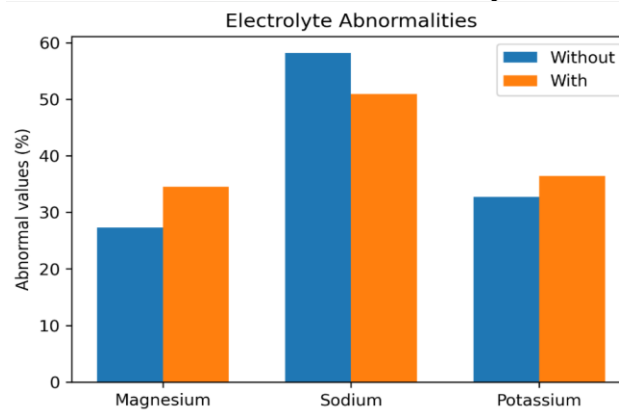


Bar chart showing the proportion of patients with isolated macrovascular complications (56.4%), isolated microvascular complications (25.5%), and combined microvascular and macrovascular complications (18.2%).

Table 3. Frequency of Serum Electrolyte Abnormalities

Electrolyte	Without Complications n (%)	With Complications n (%)
Abnormal Magnesium	15 (27.3)	19 (34.5)
Abnormal Sodium	32 (58.2)	28 (50.9)
Abnormal Potassium	18 (32.7)	20 (36.4)

Electrolyte abnormalities were observed in both study groups. Among patients without complications, abnormal values were recorded in: Magnesium: 15 (27.3%), Sodium: 32 (58.2%) Potassium: 18 (32.7%). Among patients with complications, abnormal electrolyte levels were noted in: Magnesium: 19 (34.5%), Sodium: 28 (50.9%), Potassium: 20 (36.4%). Although electrolyte disturbances were common in both groups, abnormal magnesium and potassium values were proportionately more frequent in patients with diabetic complications, whereas abnormal sodium values were marginally more common among patients without complications.

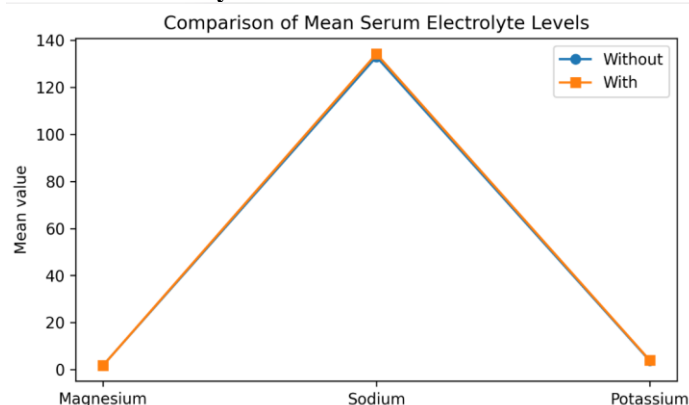
Figure 2- Electrolyte Abnormalities in Patients With and Without Complications

Clustered bar chart comparing the percentages of abnormal magnesium, sodium, and potassium levels among diabetic patients with and without vascular complications.

Table 4. Comparison of Mean Serum Electrolyte Levels

Variable	Without Complications (Mean $\pm$ SD)	With Complications (Mean $\pm$ SD)
Magnesium (mmol/L)	1.815 $\pm$ 0.389	1.784 $\pm$ 0.421
Sodium (mmol/L)	132.95 $\pm$ 8.10	134.20 $\pm$ 6.81
Potassium (mmol/L)	3.755 $\pm$ 0.583	3.993 $\pm$ 0.806

The mean serum magnesium concentration among patients without diabetic complications was 1.815 $\pm$ 0.389 mmol/L, while patients with complications demonstrated a slightly lower mean concentration of 1.784 $\pm$ 0.421 mmol/L. Similarly, the mean serum sodium concentration was 132.95 $\pm$ 8.10 mmol/L in patients without complications compared with 134.20 $\pm$ 6.81 mmol/L in patients with complications. Mean serum potassium concentration showed an increasing trend among patients with complications (3.993 $\pm$ 0.806 mmol/L) compared with those without complications (3.755 $\pm$ 0.583 mmol/L).

Figure 3- Comparison of Mean Serum Electrolyte Levels

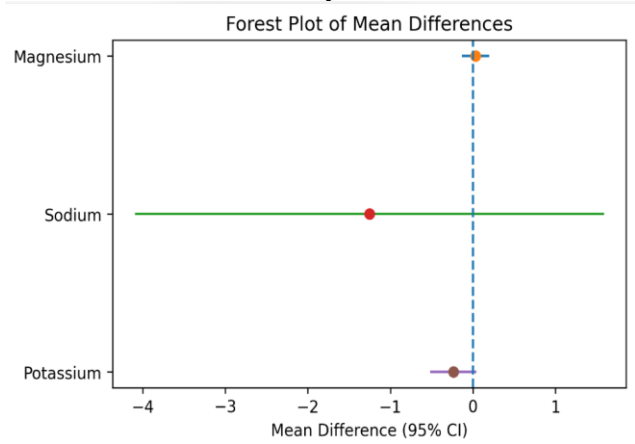
Graph displaying the mean serum concentrations of magnesium, sodium, and potassium in patients with and without diabetic complications, illustrating similar electrolyte profiles between groups.

Table 5. Independent Student's t-test Comparing Serum Electrolyte Levels

Electrolyte	Mean Difference	t-value	p-value	Interpretation
Magnesium	0.031	0.400	0.690	Not significant
Sodium	-1.255	-0.880	0.381	Not significant
Potassium	-0.238	-1.776	0.079	Borderline, not significant

Independent Student's t-test was performed to compare mean electrolyte concentrations between the two study groups. No statistically significant difference was observed in: Serum magnesium (p = 0.690), Serum sodium (p = 0.381). Serum potassium demonstrated a borderline increase among patients with diabetic complications (p = 0.079), although the association did not reach the predefined level of statistical significance. These findings suggest that while electrolyte disturbances are common in patients with type 2 diabetes mellitus, serum sodium, potassium, and magnesium levels alone may not reliably distinguish patients with established vascular complications within the present study population.

Figure 4. Forest plot of mean differences in serum electrolyte levels.



Forest plot depicting mean differences and corresponding 95% confidence intervals for serum magnesium, sodium, and potassium levels between diabetic patients with and without vascular complications, demonstrating no statistically significant differences.

DISCUSSION

In the present study, electrolyte abnormalities were frequently observed in both diabetic patients with and without vascular complications. Although patients with complications demonstrated a greater proportion of abnormal magnesium and potassium levels, whereas sodium abnormalities were marginally more frequent among those without complications, none of these differences reached statistical significance. These findings suggest that electrolyte imbalance is a common metabolic abnormality in diabetes mellitus irrespective of complication status and may be influenced by multiple factors including glycaemic control, duration of diabetes, renal function, medication use, dietary intake, and hydration status.

Magnesium

Magnesium is an essential intracellular cation involved in glucose transport, insulin receptor activation, ATP metabolism, and numerous enzymatic reactions regulating carbohydrate metabolism. Magnesium deficiency has been implicated in impaired insulin secretion, increased insulin resistance, endothelial dysfunction, oxidative stress, and chronic low-grade inflammation, all of which contribute to the development of diabetic vascular complications. In the present study, the mean serum magnesium concentration was marginally lower among patients with diabetic complications (1.784 ± 0.4207 mmol/L) compared with patients without complications (1.815 ± 0.3885 mmol/L). Furthermore, abnormal magnesium levels were observed more frequently in the

complication group (34.5%) than in the non-complication group (27.3%). However, these differences were not statistically significant ($p = 0.690$).

These observations are partially consistent with the study conducted by Pham et al., who reported that hypomagnesaemia is highly prevalent among patients with T2DM and is associated with poor glycaemic control and insulin resistance. Similarly, Guo et al. demonstrated significantly lower serum magnesium concentrations among diabetic patients with peripheral neuropathy, suggesting that magnesium deficiency may contribute to microvascular damage through oxidative stress and endothelial dysfunction. Likewise, Wang et al. observed that reduced magnesium concentrations were associated with increased prevalence of macrovascular disease among Chinese patients with diabetes.

In contrast, the present study failed to demonstrate a statistically significant association between magnesium levels and diabetic complications. Similar findings have been reported in few observational studies where the relationship disappeared after adjustment for confounding variables such as renal function, duration of diabetes, hypertension, and medication use. [11,12,13]

Sodium

Sodium homeostasis is frequently disturbed in diabetes mellitus owing to hyperglycaemia-induced osmotic shifts, osmotic diuresis, dehydration, and impaired renal concentrating ability. Hyponatraemia is among the most commonly encountered electrolyte abnormalities in hospitalized diabetic patients and has been associated with increased morbidity, prolonged hospitalization, and mortality.

In the present study, the mean serum sodium concentration was slightly higher among patients with diabetic complications (134.20 ± 6.808 mmol/L) compared with patients without complications (132.95 ± 8.095 mmol/L), although the difference was not statistically significant ($p = 0.381$). Interestingly, abnormal sodium levels were more common in the non-complication group (58.2%) than among patients with complications (50.9%).

These findings differ from several previous investigations. Katz [14] first described dilutional hyponatraemia associated with severe hyperglycaemia due to osmotic movement of intracellular water into the extracellular compartment. Later studies have consistently demonstrated lower sodium concentrations in patients with poorly controlled diabetes. Wang et al. [10] reported that serum sodium abnormalities were independently associated with macrovascular disease among patients with diabetes. The discrepancy between the present findings and earlier studies may be attributed to differences in patient characteristics, severity of hyperglycaemia, hydration status, use of

antihypertensive medications, renal function, and the heterogeneous nature of diabetic complications included in the study. Additionally, the present study evaluated a relatively stable outpatient and inpatient diabetic population rather than critically ill individuals, which may explain the absence of a significant association.

Potassium

Potassium plays an essential role in maintaining membrane excitability, cardiac conduction, skeletal muscle function, and insulin-mediated glucose uptake. Both hypokalaemia and hyperkalaemia have been associated with increased cardiovascular mortality among diabetic patients. Insulin deficiency, diabetic nephropathy, metabolic acidosis, and medications such as renin-angiotensin-aldosterone system inhibitors may all influence serum potassium levels.

The current study demonstrated that the mean serum potassium concentration was higher among patients with diabetic complications (3.993 ± 0.8060 mmol/L) than among patients without complications (3.755 ± 0.5830 mmol/L). Likewise, abnormal potassium levels were observed more frequently in the complication group (36.4%) compared with the non-complication group (32.7%). Although the difference did not reach statistical significance, the p -value (0.079) indicated a borderline association.

This observation is clinically important because several previous studies have demonstrated a U-shaped relationship between serum potassium concentration and mortality. Collins et al. [15] reported that both low and high potassium levels were independently associated with increased all-cause mortality among patients with diabetes, chronic kidney disease, and heart failure. Similarly, Krogager et al. [16] demonstrated that even modest deviations in serum potassium concentration were associated with increased short-term mortality in patients with hypertension and diabetes.

Despite the absence of statistically significant associations, the high prevalence of electrolyte abnormalities observed in both study groups underscores the importance of routine electrolyte monitoring in patients with T2DM. Early identification and correction of electrolyte disturbances may improve metabolic stability, reduce cardiovascular risk, optimize insulin responsiveness, and potentially delay progression of diabetic complications. Regular assessment of serum electrolytes should therefore be considered an integral component of comprehensive diabetes management, particularly in patients with long-standing disease, poor glycaemic control, nephropathy, or cardiovascular comorbidities.

Overall, the findings of the present study contribute to the growing body of evidence indicating that electrolyte disturbances are common among patients with T2DM.

Although serum sodium, potassium, and magnesium levels were not independently associated with vascular complications in this cohort, the observed trends particularly for potassium highlight the need for adequately powered multicentric prospective studies incorporating measures of glycaemic control, renal function, inflammatory biomarkers, and duration of diabetes to better define the prognostic role of electrolyte homeostasis in the development and progression of diabetic complications.

Limitations of the Study

The study was conducted at a single tertiary care centre with a relatively modest sample size, which may limit the generalizability of the findings. The cross-sectional observational design precluded assessment of causal relationships between electrolyte abnormalities and diabetic complications. Important factors such as glycaemic control (HbA1c), duration of diabetes, renal function parameters, dietary intake, and concurrent medications, which may influence serum electrolyte levels, were not evaluated in detail. Therefore, the findings should be interpreted with these limitations in mind.

Future Recommendations

Future multicentre prospective studies involving larger and more diverse populations are recommended to validate the present findings. Further research should incorporate glycaemic control parameters, renal function tests, duration of diabetes, medication history, and inflammatory biomarkers to better understand the relationship between electrolyte disturbances and the development of diabetic microvascular and macrovascular complications. Longitudinal studies are also warranted to evaluate whether routine monitoring and correction of electrolyte abnormalities can improve clinical outcomes and reduce the progression of diabetic vascular complications.

Strengths of the Study

The present study provides a comprehensive evaluation of serum sodium, potassium, and magnesium levels in patients with type 2 diabetes mellitus by comparing individuals with and without established microvascular and macrovascular complications. The inclusion of equal numbers of participants in both groups, standardized laboratory assessment of serum electrolytes, and the evaluation of both microvascular and macrovascular complications strengthen the reliability of the findings. The study also contributes valuable regional data on electrolyte abnormalities among Indian patients with type 2 diabetes mellitus, where limited evidence is currently available.

CONCLUSION

In this study, diabetic subjects were divided into equal groups of 55, totaling 110 samples. The serum electrolyte values were evaluated and the statistical analysis suggested that electrolyte imbalance may be influenced by multiple other factors rather than complications alone. Even though statistical significance was not achieved, a considerable proportion of patients had abnormal electrolyte levels, highlighting the need for routine monitoring. However, potassium values showed a borderline tendency to achieve significance but needs further evaluation in a larger sample size to be clinically relevant. Early detection and correction of electrolyte imbalances may help improve overall metabolic control and possibly prevent complications. Further large-scale, controlled studies are required to establish a definitive association.

Funding

The authors received no financial support for this study.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

Data are available from the corresponding author on reasonable request.

Acknowledgements

The authors sincerely acknowledge the Department of General Medicine, K.S. Hegde Medical Academy, and Justice K.S. Hegde Charitable Hospital, Nitte (Deemed to be University), Mangaluru, Karnataka, for providing the necessary facilities and support to conduct this study. The authors are also grateful to all the participants who voluntarily consented to take part in the study.

Author Contributions

Uthra Krishnan contributed to the study conception and design, data collection, data analysis, interpretation of results, and preparation of the initial manuscript. **Dr. Supriya P. S.** contributed to the study design, supervision of data collection, critical revision of the manuscript, and interpretation of the findings. **Dr. Chethan Subramanya** conceptualized and supervised the study, contributed to the study methodology, data interpretation, critical review of the manuscript, and approved the final version for publication. All authors read and approved the final manuscript.

REFERENCES

1. International Diabetes Federation. **IDF Diabetes Atlas**. 10th ed. Brussels, Belgium: International Diabetes Federation; 2021.

2. Sun H, Saeedi P, Karuranga S, Pinkepank M, Ogurtsova K, Duncan BB, et al. IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. *Diabetes Res Clin Pract.* 2022;183:109119.
3. American Diabetes Association Professional Practice Committee. Classification and diagnosis of diabetes: Standards of Care in Diabetes 2025. *Diabetes Care.* 2025;48(Suppl 1):S20–S38.
4. American Diabetes Association Professional Practice Committee. Comprehensive medical evaluation and assessment of comorbidities: Standards of Care in Diabetes 2025. *Diabetes Care.* 2025;48(Suppl 1):S52–S71.
5. Forbes JM, Cooper ME. Mechanisms of diabetic complications. *Physiol Rev.* 2013;93(1):137–188.
6. Brownlee M. The pathobiology of diabetic complications: A unifying mechanism. *Nature.* 2005;414:813–820.
7. DeFronzo RA, Goldberg M, Agus ZS. The effects of glucose and insulin on renal electrolyte transport. *J Clin Invest.* 1976;58(1):83–90.
8. Pham PC, Pham PM, Pham SV, Miller JM, Pham PT. Hypomagnesemia in patients with type 2 diabetes. *Clin J Am Soc Nephrol.* 2007;2(2):366–373.
9. Guo W, Zhou Q, Jia Y, Xu J. Cluster and factor analysis of elements in serum and urine of diabetic patients with peripheral neuropathy and healthy people. *Biol Trace Elem Res.* 2020;194(1):48–57.
10. Wang S, Hou X, Liu Y, Lu H, Wei L, Bao Y, et al. Serum electrolyte levels in relation to macrovascular complications in Chinese patients with diabetes mellitus. *Cardiovasc Diabetol.* 2013;12:146.
11. Barbagallo M, Dominguez LJ. Magnesium and type 2 diabetes. *World J Diabetes.* 2015;6(10):1152–1157.
12. Gröber U, Schmidt J, Kisters K. Magnesium in prevention and therapy. *Nutrients.* 2015;7(9):8199–8226.
13. Gommers LMM, Hoenderop JGJ, Bindels RJM, de Baaij JHF. Hypomagnesemia in type 2 diabetes: A vicious circle? *Diabetes.* 2016;65(1):3–13.
14. Katz MA. Hyperglycemia-induced hyponatremia Calculation of expected serum sodium depression. *N Engl J Med.* 1973;289(16):843–844.
15. Collins AJ, Pitt B, Reaven N, Funk S, McGaughey K, Wilson D, et al. Association of serum potassium with all-cause mortality in patients with and without heart failure, chronic kidney disease, and/or diabetes. *Am J Nephrol.* 2017;46(3):213–221.
16. Krogager ML, Torp-Pedersen C, Mortensen RN, Køber L, Gislason GH, Sogaard P, et al. Short-term mortality risk of serum potassium levels in hypertension: A retrospective analysis of nationwide registry data. *Eur Heart J.* 2017;38(2):104–112.