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RESEARCH ARTICLE
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"SERUM LIPIDS AND ELECTROLYTES: A STUDY OF ASSOCIATION IN TYPE-2 DIABETICS OF UTTAR PRADESH"

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Abstract

Background: Type 2 Diabetes Mellitus (T2DM) is frequently accompanied by dyslipidemia and disturbances in electrolyte balance, both of which contribute to increased cardiovascular risk. While lipid metabolism may be linked to electrolyte abnormalities, these relationships have not been adequately explored in the Indian population, particularly with region-specific cohorts.

Objective: To evaluate the association between serum electrolytes (sodium, potassium, and chloride) and lipid profile parameters in patients with Type 2 Diabetes Mellitus.

Methods: A cross-sectional study was conducted with 128 individuals from the same age bracket (35–65 years). Laboratory tests were performed for total cholesterol, triglycerides, high-density lipoproteins (HDL-C), low-density lipoproteins (LDL-C), sodium (Na^+), potassium (K^+), and chloride (Cl^-). Group data was compared using the independent sample t-test, and Pearson's correlation coefficient was used for the correlation analysis.

Results: A high prevalence of dyslipidemia was observed, with 81.25% of patients having elevated triglycerides, 53.2% having elevated total cholesterol, 64.8% having high LDL-C, and 50.8% having low HDL-C levels. With 59.4% of the subjects having hyponatremia, the mean serum sodium level was significantly lower in the study group ($p < 0.001$) than the Biological Reference Interval for the general population. A statistically significant negative correlation was found between serum sodium levels and LDL-C levels ($p = 0.036$), suggesting that hyponatremia may be associated with dyslipidemia. Serum chloride and potassium levels did not exhibit a significant correlation with lipid parameters.

Conclusion: This study highlights the co-occurrence of electrolyte and lipid abnormalities in T2DM patients, with a notable association between hyponatremia and elevated LDL-C levels.

Keywords: T2DM, Serum Electrolytes, Sodium, Dyslipidemia, LDL-C, Hyponatremia, Cardiovascular Risk

INTRODUCTION

Diabetes mellitus (DM) is a long-term condition in which high blood sugar occurs due to insufficient insulin production, insulin resistance, or a combination of these.[1,2] It has emerged as one of the most significant public health challenges globally. A consistently high burden of Type 2 Diabetes strikes India, where 8.9% of the population was affected in 2019, significantly higher than the 7.7% reported in 2016.[3] Type 2 Diabetes Mellitus is the predominant form of diabetes, comprising over 90% of all cases. It is primarily associated with lifestyle-related risk factors, insulin resistance, and impaired pancreatic β-cell function.[4]

In addition to dysregulated glucose homeostasis, patients with T2DM often exhibit disturbances in fluid and electrolyte balance, as well as alterations in lipid metabolism.[5] Electrolytes play a vital role in maintaining fluid balance, regulating acid-base homeostasis, supporting nerve impulse transmission, facilitating muscle contraction, and contributing to blood coagulation. The proper balance of electrolytes in our bodies depends on levels of sodium, potassium, and chloride.[6] When blood sugar continues to be high, osmotic diuresis occurs, and this causes a loss of sodium, potassium, and chloride, which can complicate glycemic control and increase the risk of cardiovascular complications.[7,8]

Sodium is the principal extracellular cation, essential for maintaining fluid balance, neuromuscular function, and blood pressure regulation. In diabetes, hyperglycemia raises extracellular osmolality, causing water to shift out of cells and potentially resulting in reduced serum sodium levels. Osmotic diuresis is also responsible for losing sodium through the kidneys.[9] Insulin, along with key hormones such as aldosterone, antidiuretic hormone (ADH), and natriuretic peptides, plays a significant role in the regulation of sodium levels. Alterations in sodium homeostasis are closely linked to insulin sensitivity and metabolic pathways, and disturbances in these levels may contribute to adverse metabolic outcomes, including insulin resistance.[10] In animals, if salt (salt being sodium and chloride) is effectively reduced in food, it can block the action of lipoprotein lipase, leading to a rise in the level of plasma triglycerides even though triglyceride production in the liver continues as normal.[11]

Potassium (K^+) plays a crucial intracellular role in maintaining nerve function, muscle activity, and overall electrolyte balance. Insulin facilitates the uptake of potassium into cells; however, insulin deficiency or resistance can lead to the accumulation of potassium in the extracellular space.[12] Conversely, excessive insulin administration or increased renal potassium loss can result in hypokalemia, which may impair insulin secretion and hinder normal glucose uptake by cells.[13]

Chloride (Cl^-) is the major extracellular anion, maintaining acid-base balance and osmotic pressures. Its concentration is closely related to sodium and is mostly controlled by the same mechanisms seen in T2DM. When chloride homeostasis is disrupted, the functioning of the kidneys, acid-base balance, and the body's electrolytes can be affected.[5]

Total cholesterol, triglycerides, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol—which together form the lipid profile—are often found to be altered in T2DM. Elevated TG and LDL-C and lowered HDL-C are the usual lipid shifts seen in diabetic dyslipidemia. Such changes are strongly associated with insulin resistance and are the primary causes of faster atherosclerosis and a higher risk of heart-related problems in people with diabetes.[14] Imbalances in electrolytes can change how lipids are metabolized, either by affecting certain enzymes or changing the way cell membranes function.[15]

Even though these parameters have been thoroughly researched, the findings are sometimes not consistent. There is not much available data about Indian populations, especially studies on regional subgroups of different geographical locations.

Thus, the current study investigates the relationship between levels of serum sodium, potassium, and chloride and the lipid profile in people with T2DM. Understanding these interactions may help in identifying early metabolic markers and guiding more effective management of diabetic complications.

Materials and methods

The study involved a total of 128 Type II Diabetic patients aged between 35 and 65. The study excluded women who were pregnant, patients with renal, hepatic, or cardiac problems, as well as those currently suffering from acute vomiting, major dehydration, alcohol dependency, or taking diuretic medications. Blood samples were collected from only those patients who had given written informed consent.

Analysis of blood samples

An overnight fast was required, and samples were drawn from the antecubital vein. Blood glucose levels were measured by GOD-POD, and HbA1c levels were quantified using High-Performance Liquid Chromatography on a D-10 BIO-RAD system.

To measure the serum cholesterol, we used the CHO-POD method, and to measure the triglycerides, we used the GPO-POD method. HDL cholesterol was measured with the enzymatic immunoinhibition technique. LDL and VLDL cholesterol levels were estimated using Friedwald’s equation, and in cases of elevated triglycerides, the Martin-Hopkins method was employed for more accurate assessment.

The ISE method was used to determine the sodium, potassium, and chloride concentrations.

Statistical analysis

The data analysis was carried out in SPSS. The difference in study parameters was studied using the independent sample “t” test. The study assessed the relationships among different parameters using the Pearson correlation coefficient (r) and set a significance threshold of $P < 0.05$.

Results

The study included 128 adult participants diagnosed with Type 2 Diabetes Mellitus. Lipid levels and electrolyte concentrations were measured in the participants, and the results for each gender were checked against the standard reference ranges.

Demographic Characteristics

Gender and Age Distribution

In the study, 50 (39.1%) of the 128 participants were males and 78 (60.9%) were females, which created a ratio of males to females of 0.64:1. People involved in the study were 35 to 65 years old, with an average age of 50.79 ± 7.67 years. The average age of males and females taking part was almost the same, and their difference was not significant ($p = 0.319$, Table 1).

Glycemic Status

All participants were found to have T2DM. In our participants, fasting glucose levels ranged from 143.0 to 438.3 mg/dL (5th–95th percentile), with the median being 214 mg/dL (IQR: 169.0–305.25 mg/dL). HbA1c (%) showed a normal distribution, ranging from 6.95% to 15.47% (90th percentile). The average HbA1c in the group was 10.62 with a standard deviation of 2.53%.

No significant differences were found in the mean FPG and HbA1c levels between male and female participants ($p = 0.887$ for FPG and $p = 0.917$ for HbA1c, Table 1).

Variables	Male Subjects (n = 50)	Female Subjects (n = 78)	p-value
Age (years) (Mean ± SD)	51.64 ± 7.72	50.24 ± 7.64	0.319
Fasting Plasma Glucose (mg/dl) (Median, IQR)	218.5 (171.25 – 304.0)	213.0 (165.0 – 309.75)	0.887
HbA1c (%) (Mean ± SD)	10.65 ± 2.52	10.60 ± 2.56	0.917

Table 1: Gender-wise Comparison of Age and Glycemic Indices in Study Participants with Type-2 Diabetes Mellitus

Serum Lipid Profile

Triglycerides (TG)

Among all the participants, only 24 (18.75%) had serum TGs within the normal range. The rest of the subjects showed borderline-high or high triglyceride levels. TG levels followed a normal distribution, with 90% confidence interval (based on the fifth to ninety-fifth percentiles) ranging from 94.45 and 396.15 mg/dL, and the mean was 224.0 ± 85.92 mg/dL (after removing outliers).

Total Cholesterol

Out of the participants, 46.8% (60 individuals) had total cholesterol levels that were desirable, while 26.6% each had slightly higher levels or high cholesterol. The mean total cholesterol was 204.34 mg/dL. After outlier removal, the distribution was symmetrical, with values falling within a 90% confidence interval- from 101.6 to 326.8 mg/dl derived from the 5th to 95th percentiles.

HDL Cholesterol

Among female participants, 70.1% had HDL-C levels below 50 mg/dl, whereas 52% of male participants also exhibited HDL-C concentrations under this threshold. The average HDL-c level was 40.13 ± 12.50 mg/dl. A confidence interval encompassing the central 90% of the data (5th–95th percentiles), extended from 17.35 to 61.55 mg/dL.

LDL Cholesterol

Only 35.2% (n = 45) of participants had LDL cholesterol levels below 100 mg/dl, while 64.8% (n = 83) had elevated levels above this threshold. The mean LDL-C concentration was 121.45 ± 49.09 mg/dl. The estimated confidence interval, based on the 5th to 95th percentiles, ranged from 46.9 to 217.0 mg/dl.

VLDL Cholesterol

VLDL-c levels followed a normal distribution, with a mean of 43.89 ± 15.77 mg/dL. The values fell within a confidence interval derived from the 5th to 95th percentiles, ranging from 19.0 to 73.55 mg/dl.

Frequency distribution of Lipid Abnormalities and Chi-Square Analysis

A frequency-based analysis was performed to identify the most altered lipid parameters among the study participants. As shown in Table 2, hypertriglyceridemia and low HDL-c levels were the most frequently observed abnormalities.

Lipid Parameter	Normal	Borderline/High or Low n (%)	Total (N=128)	p-value
Triglyceride	18.75% (24)	81.25% (104)	128	0.515
Total Cholesterol	46.88% (60)	53.12% (68)	128	0.866
HDL-c	28.9% (37)	71.1% (91)	128	0.882
LDL-c	35.2% (45)	64.8% (83)	128	0.967

Table 2: Frequency Distribution of Lipid Abnormalities Among Study Participants

Comparison with Population Means

When compared to established population reference values, patients with Type 2 Diabetes Mellitus exhibited significantly higher levels of total cholesterol, triglycerides, and LDL-c, while their HDL-c levels were significantly lower ($p < 0.001$, Table 2).

Analyte	Indian Population Mean (mg/dl)	Study Group Mean (mg/dl)	p-value
Triglyceride	162±106.7	224.0±85.92	<0.001
Total Cholesterol	176.7±42.1	204.34±58.58	<0.001
HDL-Cholesterol	43.2±11.7	40.13±12.50	0.007
LDL-Cholesterol	110.5±34.0	121.45±49.09	0.013

Table 3: Comparison of lipid profile with the Indian population mean

Serum Electrolyte Status

Sodium

Hyponatremia emerged as the most common sodium imbalance, affecting 59.4% (n = 76) of the study participants, while cases of hypernatremia were rare. Serum sodium levels followed a normal distribution, with a mean of 133.15 ± 5.81 mEq/L. The confidence interval, based on 5th to 95th percentiles, ranged from 121.53 to 142.17 mEq/L. When compared to the reported mean serum sodium level in healthy individuals (140 mEq/L), the mean value in this cohort was significantly lower ($p < 0.001$; Table 3).

Potassium

The serum potassium levels in 88.3% of participants were within the clinically accepted normal range (3.5–5.5 mEq/L). The mean potassium concentration was 4.46 ± 0.66 mEq/L. A confidence interval estimated from the 5th to 95th percentile spanned from 3.46 to 5.71 mEq/L. When compared to the healthy reference population, individuals with Type 2 Diabetes Mellitus exhibited significantly higher serum potassium levels ($p < 0.007$, Table 3).

Chloride

Hypochloremia (defined as serum chloride <98 mEq/L) was observed in 23.4% of the study population. The mean serum chloride concentration was 100.33 ± 5.09 mEq/L. A confidence interval calculated from the 5th to 95th percentiles extended from 90.6 to 109.0 mEq/L. This mean value was significantly lower than the reported mean for the healthy reference population (102.5 mEq/L; $p < 0.001$) (Table 3).

Analyte	Healthy Population Mean	Study Population Mean & SD	p-value
Sodium (mEq/L)	140.0±3.5	133.51±5.81	<0.001
Potassium (mEq/L)	4.3±0.4	4.46±0.66	0.007
Chloride (mEq/L)	102.0±3.0	100.33±5.09	<0.001

Table 4: Comparison of serum Electrolytes with Healthy population mean

Frequency distribution of Electrolyte Abnormalities among Study participants

A consolidated summary showing the number and percentage of participants falling into clinically defined categories for sodium, potassium, and chloride levels.

Parameter	Normal n (%)	Hyponatremia / Hypokalemia / Hypochloremia	Hypernatremia / Hyperkalemia / Hyperchloremia	Borderline n (%)	Total (N=128)	p-value
Sodium (Na^+)	38 (29.7%)	76 (59.4%)	3 (2.3%)	11 (8.6%)	128	0.866
Potassium (K^+)	113 (88.3%)	3 (2.3%)	12 (9.4%)	0 (0.0%)	128	0.882
Chloride (Cl^-)	90 (70.3%)	30 (23.4%)	8 (6.3%)	0 (0.0%)	128	0.967

Table 5: Frequency distribution of Electrolyte Abnormalities among Study participants

Correlation Analysis

Correlation analysis between lipid parameters and serum electrolytes revealed a significant inverse relationship between:

- **Sodium and LDL-C** ($r = -0.186^*$, $p < 0.05$) (Table 6)

No statistically significant correlations were observed between serum potassium and chloride levels with any of the components of the lipid profile.

Electrolyte	Lipid Parameter	Correlation (r)	p-value	N
Sodium (Na)	Triglyceride	-0.126	0.158	128
	Total Choleserol	-0.170	0.054	128
	High Density Lipoprotein-Cholesterol	0.049	0.586	128
	Low Density Lipoprotein-Cholesterol	-0.186*	0.036	128
	Very low-density lipoprotein-cholesterol	-0.111	0.772	128
Potassium (K)	Triglyceride	-0.026	0.772	128
	Total Cholesterol	0.067	0.455	128
	High Density Lipoprotein-Cholesterol	0.013	0.888	128
	Low Density Lipoprotein-Cholesterol	0.080	0.367	128
	Very low-density lipoprotein-cholesterol	-0.008	0.931	128
Chloride (Cl)	Triglyceride	-0.122	0.171	128
	Total Cholesterol	0.002	0.981	128
	High Density Lipoprotein-Cholesterol	0.027	0.766	128
	Low Density Lipoprotein-Cholesterol	0.043	0.630	128
	Very low-density lipoprotein-cholesterol	-0.151	0.088	128

Table 6: Inter-relationship of lipid profile with electrolytes

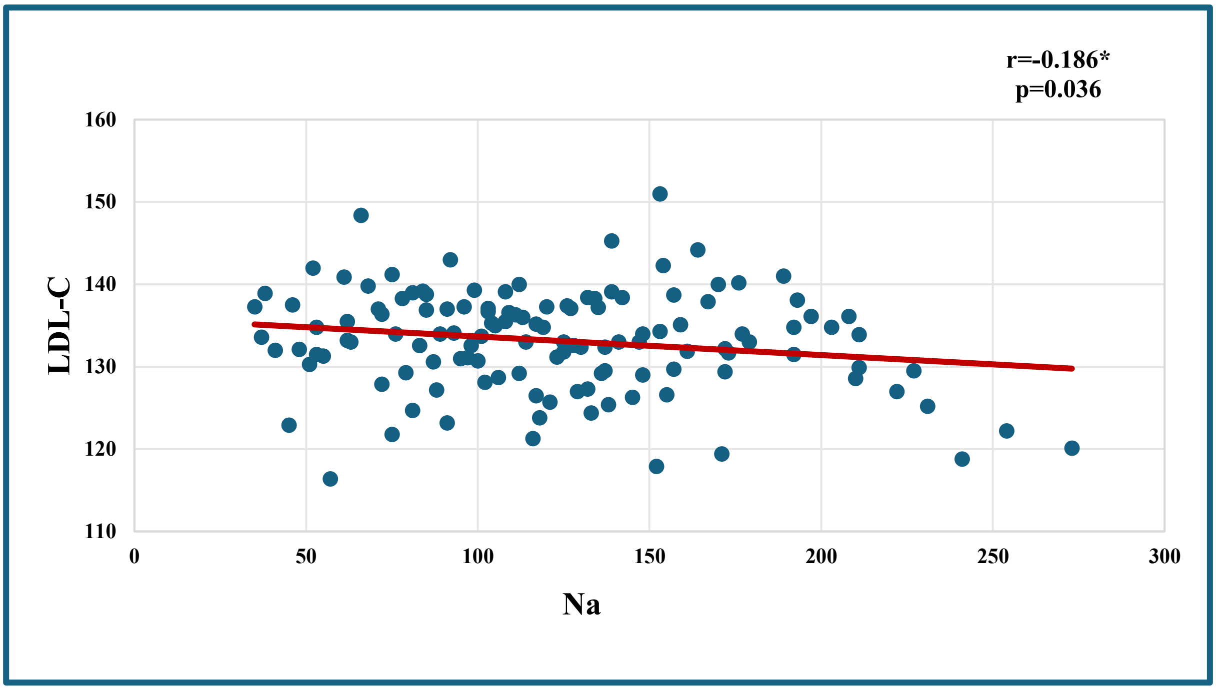

Figure 1: Scatter diagrams of the correlation of Na with LDL-C

DISCUSSION AND CONCLUSION

Type 2 Diabetes Mellitus (T2DM) remains a major health concern globally, characterized by chronic hyperglycemia resulting from insulin resistance or inadequate insulin secretion.[16] As a result, metabolism of carbohydrates, proteins, and lipids is frequently disrupted, causing microvascular and macrovascular complications affecting various organs like the kidneys, eyes, nerves, and heart.[17]

This study investigated serum lipid profiles and electrolyte levels among 128 patients with T2DM. Among the study participants, T2DM was predominantly observed in females (60.9%) when compared to males (39.1%). The likelihood of developing the condition increases with age, consistent with findings from other studies attributing this to insulin resistance, β-cell dysfunction, and reduced physical activity in older adults.[18]

A significant finding was the universal presence of dyslipidemia among study participants, with combined hypertriglyceridemia and low HDL-C being the most prevalent pattern as shown in Table 2. This result is consistent with other studies describing the same dyslipidemic patterns in people with high blood sugar.[19]

Electrolyte disturbances were prominent in the present cohort study, with a considerable proportion of subjects exhibiting hyponatremia as summarized in Table 5. A statistically significant inverse correlation was observed between serum sodium and LDL-C levels (p=0.036), as presented in Table 6, suggesting that reduced sodium concentrations may influence lipid metabolism and contribute to elevated LDL-C or dyslipidemia. These findings are consistent with previous literature implicating hyperglycemia-induced osmotic shifts and resultant diuresis in the disruption of sodium homeostasis.[20] The potential mechanisms linking hyponatremia to altered lipid profiles may involve insulin resistance, impaired hepatic LDL receptor function, and disruption in lipid transport pathways.[21]

In this study, hypochloremia was present in 23.4% of T2DM participants (Table 5), though no significant correlation was found with lipid parameters (Table 6). Low chloride levels in diabetes may result from osmotic diuresis due to hyperglycemia or early renal dysfunction. While not directly associated with dyslipidemia in this cohort, altered chloride levels could still reflect underlying metabolic changes in T2DM. Similar findings were reported by Siddiqui and Choudhary (2019), who observed significantly reduced serum chloride levels in type 2 diabetic patients compared to healthy controls.[22]

Potassium levels, although slightly elevated on average, did not show statistically significant associations with lipid parameters in this study (Table 6). Hyperkalemia was observed in 9.4% participants, while 2.3% had hypokalemia as shown in Table 5. Factors causing potassium imbalance in T2DM include insulin's activity and potassium loss from the kidneys, but the relationship between these and lipid changes has not yet been fully established by research.[23] In comparison with the study conducted by Arkajit Dasgupta et al., serum potassium levels in both studies showed no significant correlation with lipid parameters. However, while their study reported lower potassium levels, our T2DM participants had significantly higher potassium concentrations compared to healthy references.[24] This difference may be explained biochemically by insulin resistance, a hallmark of T2DM, which impairs the activity of Na^+/K^+-ATPase pumps in cell membranes. Reduced insulin action decreases cellular uptake of potassium, leading to relatively higher extracellular potassium levels. Additionally, chronic hyperglycemia and resulting osmotic stress may alter renal handling of potassium, further contributing to elevated serum levels in these individuals. This difference could also potentially be attributed to variations in dietary potassium intake, renal function, or use of antihypertensive medications such as ACE inhibitors or ARBs, all of which can influence serum potassium levels in diabetic individuals.[25]

In conclusion, the study indicates that patients with Type 2 Diabetes Mellitus commonly exhibit disturbances in both electrolyte and lipid profiles. A statistically significant association was identified between hyponatremia and elevated LDL-C levels. These findings suggest that electrolyte monitoring, particularly of serum sodium, may offer additional insights into the cardiovascular risk stratification in T2DM. Further studies are needed to better understand the links between these electrolyte changes and diabetes, as well as to determine whether improved management of these electrolytes improves care for diabetic patients.

LIMITATIONS

1. Cross-Sectional Design: Although the study identifies a relationship between serum electrolytes and lipid profile in patients with T2DM, the cross-sectional nature of the study limits the ability to determine the directionality or causality of these associations.
2. The sample is isolated to West Uttar Pradesh, so its findings may be less useful in other situations.
3. Changes in Electrolytes and Lipids: The research does not record long-term alterations in electrolyte and lipid levels.

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