

Association of Serum Magnesium and Calcium with Glycemic Control and Lipid Profile in Type 2 Diabetes Mellitus: A Cross-Sectional Study

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Abstract

Background: Mineral metabolism is essential for the regulation of glucose and lipid metabolism in patients with type 2 diabetes mellitus. Alterations in serum magnesium and calcium may influence insulin secretion, insulin sensitivity, and cardiovascular risk. The objective is to evaluate the association of serum magnesium and calcium levels with glycemic indices and lipid profile in patients with T2DM. **Material and Methods:** A cross-sectional study was conducted on 130 individuals diagnosed with T2DM attending Teerthanker Mahaveer Medical College and Hospital, a tertiary care hospital in North India. Biochemical parameters, including fasting plasma glucose, HbA1c, lipid profile, serum magnesium, and serum calcium, were measured using standardized methods. Pearson correlation analysis was used to determine the association between mineral levels and metabolic parameters. A p-value <0.05 was considered statistically significant. **Results:** Serum magnesium showed significant negative correlations with HbA1c ($r = -0.44$, $p < 0.001$), fasting glucose ($r = -0.41$, $p < 0.001$), triglycerides ($r = -0.56$, $p < 0.001$), LDL-C ($r = -0.46$, $p < 0.001$), and VLDL-C ($r = -0.56$, $p < 0.001$), while HDL-C showed a positive correlation ($r = 0.22$, $p = 0.011$). Serum calcium demonstrated positive correlations with HbA1c ($r = 0.59$, $p < 0.001$), fasting glucose ($r = 0.50$, $p < 0.001$), total cholesterol ($r = 0.74$, $p < 0.001$), triglycerides ($r = 0.64$, $p < 0.001$), LDL-C ($r = 0.53$, $p < 0.001$), and VLDL-C ($r = 0.64$, $p < 0.001$), and a negative correlation with HDL-C ($r = -0.30$, $p = 0.001$). **Conclusion:** Disturbances in magnesium and calcium metabolism are significantly associated with glycemic control and lipid abnormalities in T2DM. Monitoring serum mineral levels may help identify metabolic risk and improve diabetes management.

Keywords: Magnesium, T2DM, Dyslipidemia, HbA1C, Lipid profile, Calcium.

Received: 03 April 2026

Revised: 20 April 2026

Accepted: 05 May 2026

Published: 19 May 2026

INTRODUCTION

Diabetes mellitus is regarded as one of the commonest metabolic disorders worldwide. The main characteristic of T2DM is chronic hyperglycemia resulting from impaired cellular uptake of blood sugar.^[1] The main pathology for this is due to defects in beta cells of the pancreas that lead to impaired insulin secretion, insulin action, or both.^[2,3] Long-standing hyperglycemic state leads to disturbances in the metabolic pathways of carbohydrate, lipids, and protein. Eventually, this leads to the development of various microvascular and macrovascular complications by affecting blood vessels.^[4,5] According to research, it has been found that globally, 90% of diabetes cases are mainly due to T2DM.^[6] The rising prevalence of obesity, sedentary lifestyles, and aging populations has significantly contributed to the increasing burden of T2DM, particularly in developing countries.^[7] Magnesium is a vital intracellular cation for almost 300 enzymatic reactions in our body. This also includes those biochemical reactions that are mainly related to glucose metabolism and insulin signaling pathways.^[8,9] Insufficient levels of magnesium in our body are linked with insulin resistance, poor glycemic control, and cardiovascular risk, especially in type two diabetic patients.^[10,11] Transport of glucose and insulin receptor activity is chiefly controlled by magnesium. Deficiency of magnesium may impair

insulin-mediated glucose uptake.^[12] Calcium also plays a vital role in insulin secretion from pancreatic beta cells and intracellular signaling pathways.^[13,14] Altered calcium homeostasis may influence insulin secretion and metabolic regulation.^[15,16] According to previous research, the association between elevated calcium levels and dyslipidemia as well as insulin resistance has been reported.^[17-19] Despite growing evidence linking mineral metabolism with metabolic abnormalities, data from the Indian population remain limited. Therefore, the present study aimed to evaluate the association between serum magnesium and calcium levels with glycemic indices and lipid profile in patients with T2DM.

MATERIALS AND METHODS

Study Design: A hospital-based cross-sectional study.

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DOI:
10.21276/amit.2026.v13.i2.669

How to cite this article: Manisha, Ali S, Haria J, Kiran PU. Association of Serum Magnesium and Calcium with Glycemic Control and Lipid Profile in Type 2 Diabetes Mellitus: A Cross-Sectional Study. Acta Med Int. 2026;13(2):172-177.

Study Setting: Department of Biochemistry, Teerthanker Mahaveer Medical College and Hospital, a tertiary care Medical college hospital in Moradabad, North India.

Ethical Approval: The study was approved by the Institutional Ethics Committee (Approval No: TMU/IEC/2024-25/PG/002). Written informed consent was obtained from all participants.

Sample Size: Calculated using the correlation coefficient formula with expected $r = 0.3$, power 80%, $\alpha 0.05$. The minimum required sample was 110; 130 participants were included.

Study Population: A total of 130 patients diagnosed with type 2 diabetes mellitus in the age group of 40–70 years were included for this study.

Inclusion Criteria:

- Diagnosed cases of T2DM according to ADA criteria
- Age 40–70 years
- Willing to provide informed consent

Exclusion Criteria:

- Chronic kidney disease
- Patients receiving calcium or magnesium supplementation
- Acute myocardial infarction
- Alcohol abuse

Sample Collection: Fasting venous blood samples were collected and centrifuged at 3000 rpm for serum separation.

Biochemical Analysis:

HbA1c – High-performance liquid chromatography (HPLC)

Plasma glucose – Hexokinase method

Serum magnesium – Calmagite colorimetric method

Serum calcium – Arsenazo III method

Total cholesterol – Enzymatic method

Triglycerides – Enzymatic colorimetric assay

HDL-C – Direct enzymatic method

Statistical Analysis: Data were collected and compiled in Excel sheets. Data analyzed using SPSS version 20. Statistical analysis included Student's t-test, one-sample t-test, and the Pearson correlation coefficient. A p-value <0.05 was considered statistically significant.

RESULTS

This study consisted of a total of 130 T2DM cases. The mean age of participants was approximately 51 years. Among the study subjects, there were 76 female and 54 male diabetic patients. A significant negative correlation was found between serum magnesium levels and glycemic indices and atherogenic lipid profile parameters. Serum calcium levels showed significant positive correlations with HbA1c, fasting glucose, total cholesterol, triglycerides, LDL-C, and VLDL-C, while HDL-C showed a negative association. These findings suggest that disturbances in mineral metabolism may contribute to poor glycemic control and dyslipidemia in patients with T2DM.

Table 1: Demographic and Biochemical Characteristics of Studied Subjects and Reference-Based Comparison

Variables	Study population Mean± SD	Population Mean	p-value	t-value
Age (years)	51.78 ± 8.57			
Sex (M/F)	54/76			
HbA1c (%)	9.69 ± 1.99	5.7	<0.001	24.6
Glucose (mg/dL)	265.56 ± 76.25	76.25	<0.001	30.4
Triglyceride (mg/dL)	199.15 ± 87.68	125	<0.001	10.4
HDL-C (mg/dL)	43.88 ± 7.88	50	<0.001	9.5
Total Cholesterol (mg/dL)	237.64 ± 44.26	200	<0.001	10.4
LDL-C (mg/dL)	154.13 ± 44.37	100	<0.001	14.9
VLDL-C (mg/dL)	39.63 ± 17.99	30	<0.001	6.6
Calcium (mg/dL)	8.11 ± 0.96	9.5	<0.001	17.7
Magnesium (mg/dL)	1.74 ± 0.48	2.1	<0.001	9.2

According to the results shown in [Table 1], the mean age of the study subjects was (51.78 ± 8.57) years. On comparison between the biochemical parameters in the study population

with those of the population, a statistically significant difference was seen with a p-value of <0.001 .

Table 2: Comparison of Biochemical parameters between male and female subjects using the unpaired t- test

Variables	Male (54)	Female (n=76)	p-value
Age (years)	52.96 ± 9.17	50.93 ± 8.08	0.185
HbA1c (%)	9.45 ± 2.13	9.87 ± 1.88	0.242
Glucose (mg/dL)	250.39 ± 71.74	276.34 ± 77.98	0.056
Triglyceride (mg/Ll)	194.06 ± 85.71	202.76 ± 89.45	0.579
HDL-C (mg/dL)	43.98 ± 7.77	43.8 ± 8.01	0.899
Total Cholesterol (mg/dL)	233.33 ± 46.57	240.7 ± 42.59	0.352
LDL-C (mg/dL)	150.54 ± 45.12	156.68 ± 43.94	0.44
VLDL-C (mg/dL)	38.81 ± 17.14	40.21 ± 18.67	0.664
Calcium (mg/dL)	7.96 ± 0.97	8.22 ± 0.94	0.135
Magnesium (mg/dL)	1.81 ± 0.49	1.69 ± 0.48	0.186

Data from [Table 2] indicates that the average age for male participants was (52.96 ± 9.17) years, while for female participants it was (50.93 ± 8.08) years. The age variation between these two cohorts was not considered statistically

significant, with a (p-value of 0.185). The HbA1c level for males was (9.45 ± 2.13%), while the mean for females was higher (9.87 ± 1.88%), though it was not statistically significant (p = 0.242). The mean glucose level for men was

(250.39 ± 71.74) mg/dL, while for women it was (276.34 ± 77.98) mg/dL. On comparison, it was found that the levels were lower in males and the difference was not statistically significant (p = 0.056). Males had a triglyceride level of (194.06 ± 85.71) mg/dL, while females had a level of (202.76 ± 89.45) mg/dL. The two groups did not differ significantly from one another (p = 0.579). HDL-C: For men, it was (43.98 ± 7.77) mg/dL, while for women, it was (43.8 ± 8.01) mg/dL. The values were nearly identical, and hence the statistical difference was not significant (p = 0.899). The recorded values of cholesterol for males and females were (233.33 ± 46.57) mg/dL and (240.7 ± 42.59) mg/dL, respectively. There was no statistically significant change (p = 0.352). Males had an LDL level of (150.54 ± 45.12) mg/dL, while females had (156.68 ± 43.94) mg/dL. The two groups did not differ significantly (p = 0.44). VLDL values for males were (38.81 ± 17.14) mg/dL, while in women it was (40.21 ± 18.67) mg/dL. This difference was again not statistically significant (p = 0.664). Serum calcium levels in men were (7.96 ± 0.97) mg/dL, while those in women were (8.22 ± 0.94) mg/dL. (p = 0.135). The change was not statistically significant. Magnesium levels were (1.81 ± 0.49) mg/dL for men and (1.69 ± 0.48) mg/dL for women. The groups did not differ statistically significantly (p = 0.186).

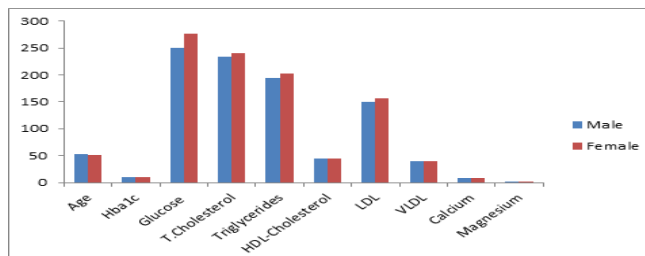


Figure 1: Comparison of Biochemical Parameters between Male and Female Subjects

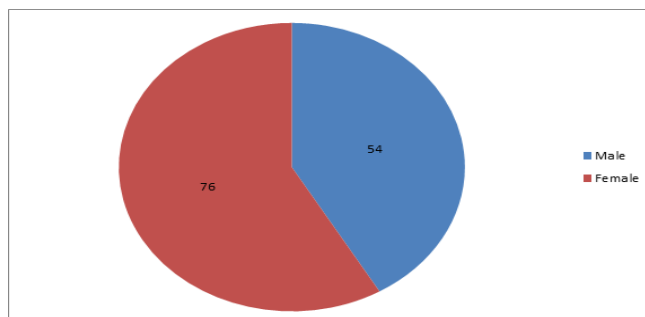


Figure 2: Distribution of study population between male and female groups.

Table 3: Pearson's correlation between glycemic indices, lipid profiles, and serum magnesium.

Variables	With Magnesium	
	r-value	p-value
HbA1c (%)	-0.44	<0.001
Glucose (mg/dL)	-0.41	<0.001
Triglyceride (mg/dL)	-0.56	<0.001
HDL-C (mg/dL)	0.22	0.011
Total Cholesterol (mg/dL)	-0.65	<0.001
LDL-C (mg/dL)	-0.46	<0.001
VLDL-C (mg/dL)	-0.56	<0.001

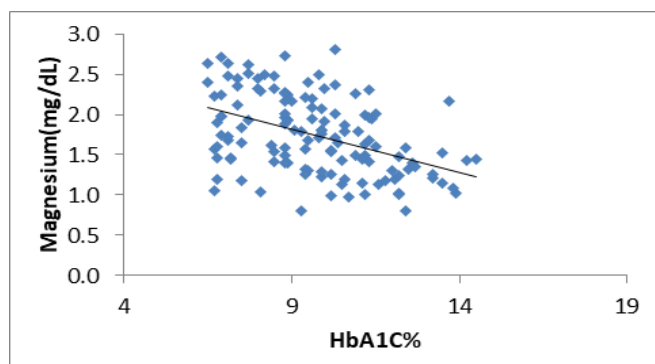


Figure 3: Correlation between Magnesium and HbA1C.

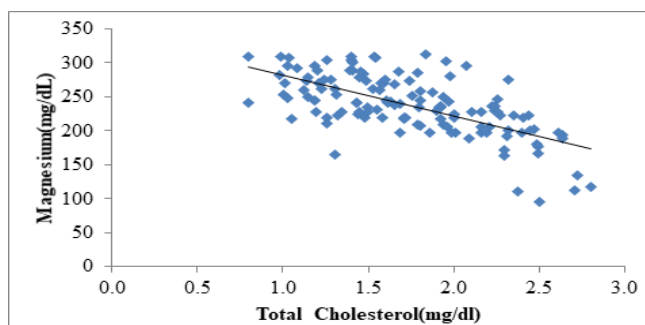


Figure 5: Correlation between Magnesium and Total Cholesterol.

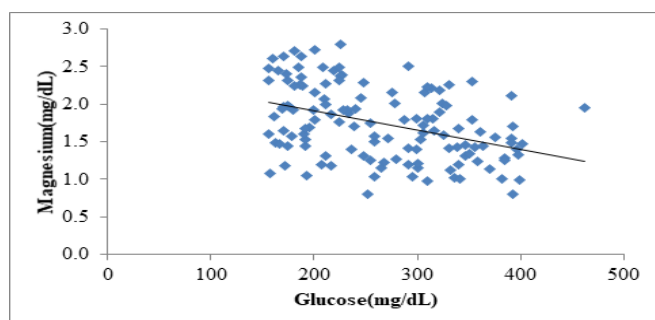


Figure 4: Correlation between Magnesium and glucose.

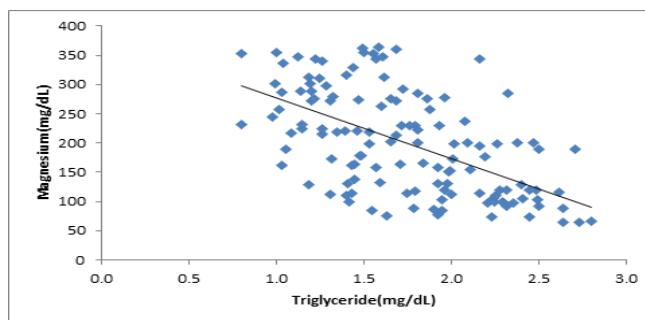


Figure 6: Correlation between Magnesium and Triglyceride.

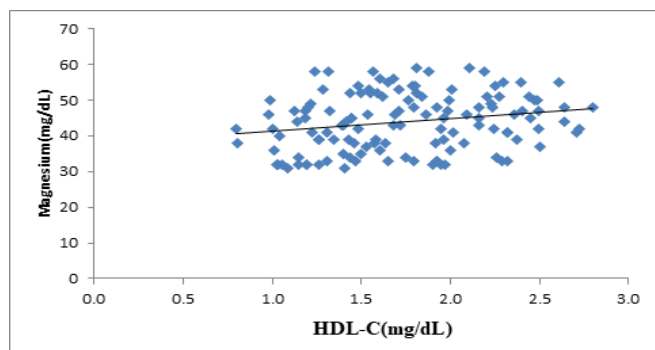


Figure 7: Correlation between Magnesium and HDL-C.

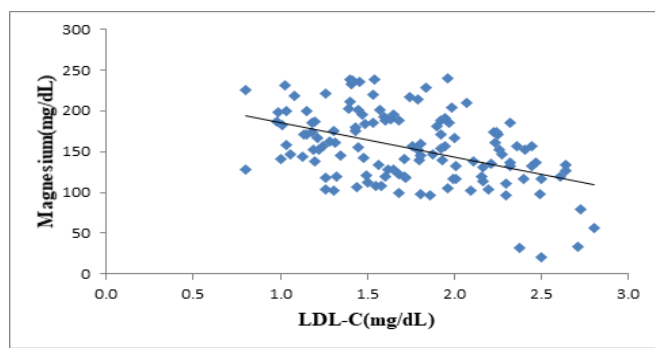


Figure 8: Correlation between Magnesium and LDL-C.

According to the results shown in [Table 3], the correlation study revealed a strong unfavorable relationship ($r = -0.44$) between serum magnesium and HbA1c levels. The current study's fasting blood glucose and serum magnesium levels revealed $r = -0.41$ and a p-value of < 0.001 . This implies that magnesium levels and glucose levels were significantly correlated negatively. A substantial inverse relationship was

observed between serum magnesium and total cholesterol ($r = -0.65$, $p < 0.001$), indicating that as magnesium levels decline; total cholesterol concentrations tend to rise significantly. Triglyceride levels and serum magnesium exhibited a significant negative connection ($r = -0.56$, $p < 0.001$), suggesting that higher triglyceride concentrations are linked to lower magnesium levels. Serum magnesium and HDL-C showed a weak but statistically significant positive correlation ($r = 0.22$, $p = 0.011$). This suggests that elevated HDL cholesterol levels are linked to elevated magnesium levels. Serum magnesium and LDL levels showed a strong negative connection ($r = -0.46$), which was statistically significant ($p < 0.001$), according to the analysis. This result implies that lower LDL values in the study population are linked to increased serum magnesium levels. These findings indicate a comparatively substantial negative correlation ($r = -0.56$) between serum magnesium and VLDL levels that is statistically significant ($p < 0.001$).

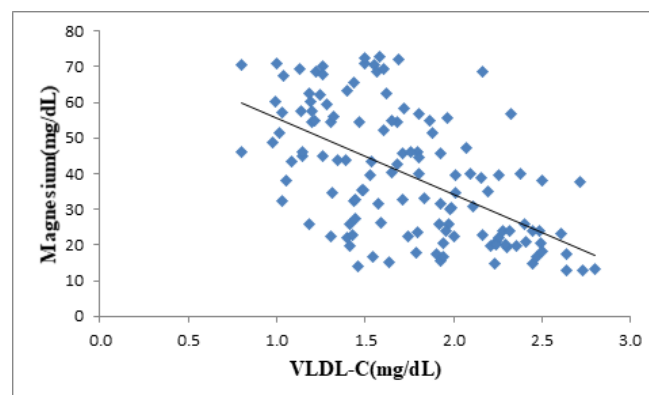


Figure 9: Correlation between Magnesium and VLDL-C.

Table 4: Correlation of serum calcium with glycemic indices and lipid profile.

Variables	With Calcium	
	r-value	p-value
HbA1c (%)	0.59	<0.001
Glucose (mg/dL)	0.50	<0.001
Triglyceride (mg/dL)	0.74	<0.001
HDL-C (mg/dL)	0.64	<0.001
Total Cholesterol (mg/dL)	-0.30	0.001
LDL-C (mg/dL)	0.53	<0.001
VLDL-C (mg/dL)	0.64	<0.001

According to the results obtained in [Table 4], a strong positive association was identified between serum calcium and markers of glycemic control, with significant correlations observed for both fasting blood glucose and HbA1C levels. This suggests that elevated calcium levels were linked to poorer glucose regulation. Furthermore, a highly significant positive relationship was found between serum calcium and total cholesterol, alongside a moderate to strong positive connection with triglycerides ($r = 0.64$, $p < 0.001$). Calcium also shared a statistically significant positive correlation with LDL. In contrast, a notable inverse relationship was recorded with HDL-C, indicating that higher calcium levels were related to lower concentrations of High-Density Lipoprotein. There was a statistically significant, moderate to strong positive connection between

serum calcium and VLDL ($r = 0.64$, $p < 0.001$) in this study.

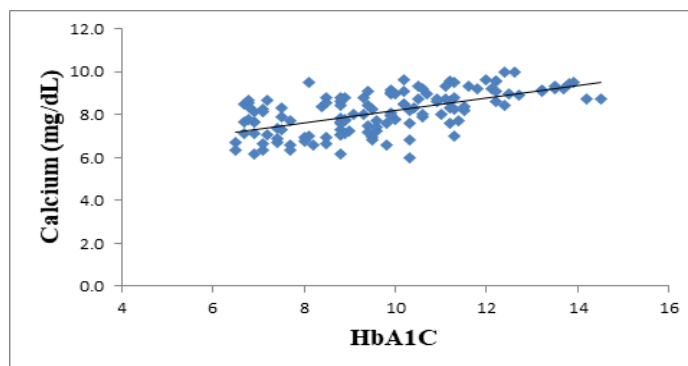


Figure 10: Correlation between calcium and HbA1C.

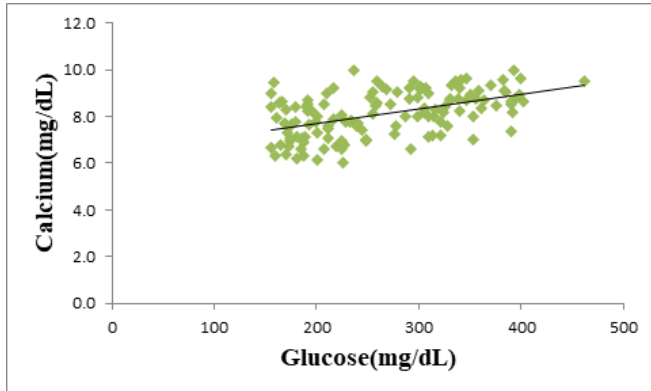


Figure 11: Correlation between calcium and Glucose.

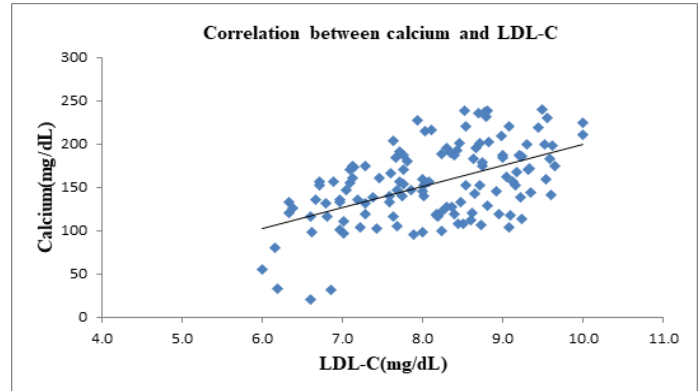


Figure 15: Correlation between calcium and LDL-C

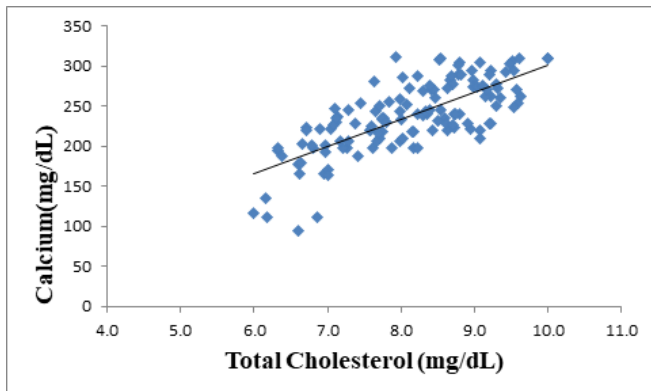


Figure 12: Correlation between Calcium and Cholesterol

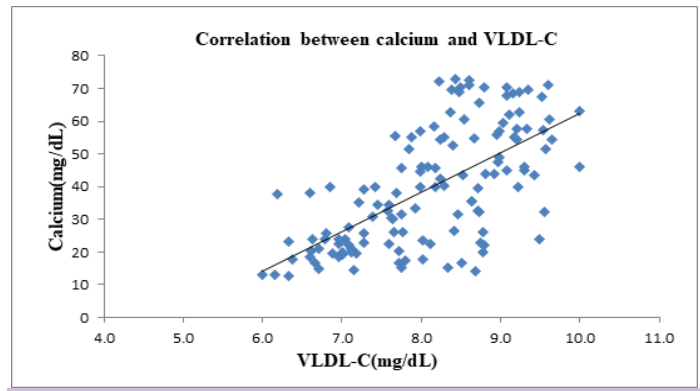


Figure 16: Correlation between calcium and VLDL-C

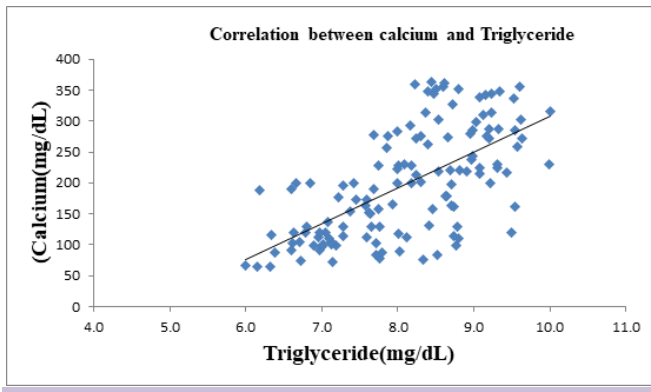


Figure 13: Correlation between calcium and Triglyceride

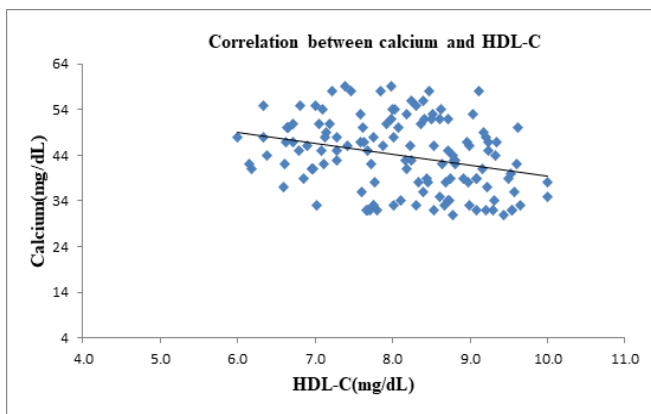


Figure 14: Correlation between calcium and HDL-C

DISCUSSION

According to the present study, a significant association was found between magnesium, calcium and other metabolic parameters in T2DM. Magnesium deficiency has been reported in several studies in poorly controlled diabetic patients. It is also considered an important factor influencing insulin resistance and glycemic control.^[2,10,20] Magnesium plays a pivotal role in insulin receptor activity and glucose transport mechanisms. It is also important for post-receptor signaling pathways, and reduced magnesium levels may impair insulin-mediated glucose uptake, leading to hyperglycemia.^[12,21] Reduced magnesium levels may impair insulin signaling and contribute to insulin resistance.

The observed negative correlation between serum magnesium and glycemic indices such as HbA1C and fasting glucose in the present study is consistent with previous reports reporting that hypomagnesemia contributes to insulin resistance and impaired glycemic control.^[10,22] Furthermore, the inverse relationship between magnesium and lipid parameters, including triglycerides, LDL-C, and VLDL-C, suggests that magnesium deficiency may contribute to diabetic dyslipidemia.^[4,23] Similar outcomes have been described in earlier studies, highlighting the role of magnesium in lipid metabolism and cardiovascular risk reduction.^[11,20] Magnesium is known to influence lipid metabolism by regulating enzymes involved in lipid synthesis and transport.

In contrast, serum calcium levels showed a positive correlation with glycemic and atherogenic lipid parameters. These findings are in agreement with studies suggesting that elevated calcium levels may promote insulin resistance and adverse lipid

profiles.^[17,24] Calcium-mediated intracellular signaling pathways may influence pancreatic beta-cell function and vascular smooth muscle activity, thereby contributing to metabolic disturbances.^[13,25] Previous studies have also demonstrated a relationship between higher calcium levels and increased risk of metabolic syndrome and dyslipidemia, potentially contributing to metabolic disturbances.^[15,16,19] The negative association between calcium and HDL-cholesterol observed in this study further supports the role of calcium imbalance in adverse lipid profile; these findings are in agreement with earlier research indicating that altered calcium metabolism may contribute to cardiovascular risk factors in patients with type two diabetes mellitus.^[17,24] The stronger correlations observed for calcium compared to magnesium suggest a potentially more pronounced role of calcium dysregulation in metabolic abnormalities.

Overall, the findings of the present study support the hypothesis that disturbances in magnesium and calcium metabolism may play a significant role in the pathogenesis of metabolic abnormalities in diabetes mellitus. Monitoring these minerals may provide additional insight into metabolic control and help in early identification of patients at higher risk of complications.

Limitations: Cross-sectional design limits causal inference. Lack of dietary and medication data. No assessment of ionized calcium or intracellular magnesium. Potential residual confounding.

CONCLUSION

The study demonstrates that serum magnesium and calcium levels are significantly associated with glycemic control and lipid profile in patients with type 2 diabetes mellitus. Reduced magnesium levels were associated with poor glycemic control and dyslipidemia. Calcium levels showed a positive correlation with glycemic indices and most lipid profile parameters except HDL cholesterol. This suggests a potential association of calcium with worsening metabolic status. Monitoring mineral status may help identify patients at higher metabolic risk and may improve clinical management strategies in diabetes. Lower serum magnesium levels and disturbances in calcium homeostasis were observed to correlate with adverse lipid parameters. These findings suggest the importance of routine monitoring of micronutrient status along with the lipid profile in diabetic patients. Early identification and correction of these imbalances may contribute to improved metabolic control and reduced cardiovascular risk. Routine evaluation of serum magnesium and calcium, along with lipid profile and glycemic indices, may aid in early identification of high-risk individuals. Further prospective studies are necessary to clarify the causal relationship between mineral metabolism and diabetic complications.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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