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ORIGINAL RESEARCH

CORRELATION BETWEEN MAGNESIUM LEVELS AND HbA1C IN CONTROLLED AND UNCONTROLLED TYPE 2 DIABETES

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ABSTRACT

Background: Magnesium plays a critical role in glucose metabolism and insulin function. Emerging evidence suggests that hypomagnesemia is frequently observed in patients with Type 2 Diabetes Mellitus (T2DM), potentially influencing glycemic control. This study aims to evaluate the correlation between serum magnesium levels and HbA1c in patients with controlled and uncontrolled T2DM. **Materials and Methods:** A cross-sectional study was conducted involving 100 patients diagnosed with T2DM, divided into two groups: controlled diabetes (HbA1c ≤ 7%, n=50) and uncontrolled diabetes (HbA1c > 7%, n=50). Serum magnesium levels were measured using colorimetric methods, and HbA1c was assessed via high-performance liquid chromatography (HPLC). Statistical analysis included Pearson correlation to determine the relationship between magnesium levels and HbA1c, with significance set at $p<0.05$. **Results:** The mean serum magnesium level in the controlled group was **2.05 ± 0.25 mg/dL**, while in the uncontrolled group, it was significantly lower at **1.65 ± 0.30 mg/dL** ($p=0.001$). A significant negative correlation was observed between serum magnesium levels and HbA1c across all participants ($r = -0.48$, $p<0.001$). Patients with poor glycemic control exhibited a higher prevalence of hypomagnesemia compared to those with controlled diabetes (60% vs. 22%, respectively). **Conclusion:** The study highlights a significant inverse correlation between serum magnesium levels and HbA1c in T2DM patients. Lower magnesium levels are associated with poorer glycemic control. Monitoring and correcting magnesium deficiency may offer a supportive strategy in managing diabetes and improving metabolic outcomes.

Keywords: Type 2 Diabetes Mellitus, Magnesium, HbA1c, Glycemic Control, Hypomagnesemia, Metabolic Regulation.

Introduction

Type 2 Diabetes Mellitus (T2DM) is a prevalent metabolic disorder characterized by chronic hyperglycemia resulting from insulin resistance and/or impaired insulin secretion. The global burden of T2DM continues to rise, with significant implications for morbidity, mortality, and healthcare costs (1). Glycated hemoglobin (HbA1c) is widely recognized as a reliable biomarker for long-term glycemic control, reflecting average plasma glucose levels over the preceding two to three months (2).

Magnesium, an essential intracellular cation, plays a pivotal role in numerous enzymatic reactions, particularly those involved in carbohydrate metabolism and insulin signaling pathways (3). It has been observed that patients with T2DM frequently exhibit reduced serum magnesium levels, a condition termed hypomagnesemia (4). Several mechanisms have been proposed for this phenomenon, including increased urinary magnesium excretion due to hyperglycemia-induced osmotic diuresis and impaired intestinal absorption (5).

Emerging evidence suggests that hypomagnesemia may not only be a consequence of poor glycemic control but also contribute to worsening insulin resistance and impaired glucose utilization, thereby creating a vicious cycle (6). Studies have demonstrated that low magnesium levels are associated with higher HbA1c values, indicating poorer glycemic control (7). Moreover, magnesium supplementation has been linked to improved insulin sensitivity and metabolic outcomes in diabetic patients (8).

Despite these findings, the correlation between serum magnesium levels and HbA1c in controlled versus uncontrolled T2DM populations remains underexplored, particularly in diverse demographic settings. Understanding this relationship could provide insights into adjunctive management

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strategies aimed at optimizing glycemic control through correction of micronutrient deficiencies.
Therefore, this study aims to evaluate the correlation between serum magnesium levels and HbA1c in patients with controlled and uncontrolled T2DM, highlighting the potential role of magnesium monitoring in diabetes management.

Materials and Methods

A total of 100 patients diagnosed with Type 2 Diabetes Mellitus (T2DM) were enrolled from the outpatient department. Ethical approval was obtained from the Institutional Ethics Committee prior to the commencement of the study, and informed consent was secured from all participants.

Inclusion Criteria:

- Patients aged between 30 and 65 years.
- Diagnosed cases of T2DM for at least one year.
- Both male and female patients.

Exclusion Criteria:

- Patients with chronic kidney disease, gastrointestinal disorders affecting magnesium absorption, or those on magnesium supplements.
- Individuals with thyroid dysfunction, malignancies, or chronic liver disease.
- Patients on diuretics or other medications known to alter magnesium levels.

Participants were categorized into two groups based on their glycemic control:

- **Controlled T2DM Group:** HbA1c ≤ 7% (n = 50)
- **Uncontrolled T2DM Group:** HbA1c > 7% (n = 50)

Sample Collection and Analysis:
Fasting venous blood samples were collected under aseptic conditions. Serum was separated by centrifugation at 3000 rpm for 10 minutes. Serum magnesium levels were measured using the xylidyl blue colorimetric method on an automated analyzer. HbA1c levels were determined using high-performance liquid chromatography (HPLC), following standard laboratory protocols.

Statistical Analysis:

Data were analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD). The independent t-test was applied to compare serum magnesium levels between the two groups. Pearson's correlation coefficient was used to assess the relationship between serum magnesium and HbA1c levels. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 100 patients with Type 2 Diabetes Mellitus (T2DM) were included in the study, divided equally into controlled (n=50) and uncontrolled (n=50) groups based on HbA1c levels. The demographic characteristics of both groups are presented in **Table 1**. There were no significant differences in age and gender distribution between the two groups ($p>0.05$).

The mean serum magnesium levels were significantly lower in patients with uncontrolled diabetes compared to those with controlled diabetes (**Table 2**). The controlled group showed a mean magnesium level of **2.08 ± 0.22 mg/dL**, whereas the uncontrolled group had a mean level of **1.68 ± 0.28 mg/dL** ($p=0.001$).

A significant negative correlation was observed between serum magnesium levels and HbA1c across the total study population. Pearson's correlation coefficient revealed an inverse relationship ($r = -0.47$, $p < 0.001$), indicating that lower magnesium levels were associated with higher HbA1c values (**Table 3**).

Table 1: Demographic Characteristics of Study Participants

Parameter	Controlled T2DM (n=50)	Uncontrolled T2DM (n=50)	p-value
Age (years)	54.2 ± 6.5	55.1 ± 7.0	0.45
Male (%)	56%	60%	0.68
Female (%)	44%	40%	0.68

Table 2: Comparison of Serum Magnesium and HbA1c Levels Between Groups

Parameter	Controlled T2DM (n=50)	Uncontrolled T2DM (n=50)	p-value
Serum Magnesium (mg/dL)	2.08 ± 0.22	1.68 ± 0.28	0.001
HbA1c (%)	6.5 ± 0.3	8.9 ± 0.6	<0.001

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Table 3: Correlation Between Serum Magnesium Levels and HbA1c

Variables	Correlation Coefficient (r)	p-value
Magnesium vs. HbA1c	-0.47	<0.001

As shown in **Table 2**, patients with poor glycemic control exhibited significantly lower serum magnesium levels compared to those with controlled diabetes. Furthermore, **Table 3** demonstrates a moderate negative correlation between magnesium levels and HbA1c, suggesting that declining magnesium levels are associated with worsening glycemic control.

No significant associations were found between serum magnesium levels and demographic factors such as age or gender ($p>0.05$).

Discussion

The present study demonstrates a significant inverse correlation between serum magnesium levels and HbA1c in patients with Type 2 Diabetes Mellitus (T2DM). Patients with uncontrolled diabetes exhibited notably lower magnesium levels compared to those with controlled glycemia, suggesting that hypomagnesemia may be associated with poor glycemic control.

Magnesium is a vital cofactor in numerous enzymatic processes, particularly those involved in glucose metabolism and insulin signaling (1). Hypomagnesemia has been frequently reported in individuals with T2DM, attributed primarily to increased renal excretion due to persistent hyperglycemia and osmotic diuresis (2,3). Our findings align with previous studies indicating that lower magnesium levels are prevalent in patients with poorly controlled diabetes (4,5).

The significant negative correlation observed between serum magnesium and HbA1c levels in this study supports earlier research suggesting that magnesium deficiency may exacerbate insulin resistance and impair glucose homeostasis (6,7). Barbagallo et al. highlighted that magnesium plays a critical role in post-receptor insulin signaling pathways, and its deficiency may impair insulin-mediated glucose uptake (8). Furthermore, hypomagnesemia has been linked to chronic inflammation and oxidative stress, both of which contribute to the progression of insulin resistance (9).

Several cross-sectional and longitudinal studies have reported similar associations. A meta-analysis by Simental-Mendía et al. confirmed that magnesium supplementation could lead to modest improvements in glycemic control among T2DM patients (10). This suggests that hypomagnesemia is not only a consequence but may also be a contributing factor to poor glycemic regulation.

Our study also reflects findings by Pham et al., who observed that up to 47% of T2DM patients exhibited hypomagnesemia, with a direct association between low magnesium levels and higher HbA1c values (11). In addition, Guerrero-Romero and Rodríguez-Morán proposed that maintaining optimal magnesium levels could enhance insulin sensitivity and reduce complications associated with diabetes (12).

The clinical implications of these findings are significant. Routine monitoring of serum magnesium in diabetic patients, particularly those with poor glycemic control, could serve as a simple yet effective strategy to identify individuals at risk of worsening metabolic status. Moreover, magnesium repletion therapy has shown potential benefits in improving glycemic outcomes (13,14).

However, this study has certain limitations. Being cross-sectional in design, it cannot establish causality between low magnesium levels and poor glycemic control. Additionally, dietary intake of magnesium and other confounding factors such as physical activity and comorbidities were not assessed, which could influence serum magnesium status.

Future research should focus on prospective studies and randomized controlled trials to evaluate the impact of magnesium supplementation on long-term glycemic control and diabetic complications. Addressing hypomagnesemia as part of a comprehensive diabetes management plan may offer an adjunctive approach to improve metabolic control and reduce cardiovascular risks associated with T2DM (15).

Conclusion

This study highlights a significant inverse relationship between serum magnesium levels and HbA1c in patients with Type 2 Diabetes Mellitus. Lower magnesium levels were associated with poor glycemic control, emphasizing the potential role of magnesium monitoring in diabetes management. Early detection and correction of hypomagnesemia may serve as an effective adjunct to improve metabolic outcomes in diabetic patients.

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