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ORIGINAL ARTICLE

Association Between Serum Magnesium Levels and Blood Pressure in Diabetic Patients. A Comparative Study

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ABSTRACT

Background: Magnesium is a vital intracellular cation that regulates vascular tone, insulin sensitivity, and enzymatic activity. Hypomagnesemia has been reported frequently in patients with type 2 diabetes mellitus, and it may play a role in the pathogenesis of hypertension. However, limited data are available from South Asian populations.

Objective: This study aimed to assess serum magnesium levels in diabetic patients, compare them with healthy controls, and determine their association with blood pressure.

Methods: A comparative cross-sectional study was conducted at Multan Medical and Dental College (MMDC) and Nishtar Medical University, Multan, from May 2022 to June 2023. A total of 140 participants were enrolled, including 70 patients with type 2 diabetes mellitus and 70 age- and sex-matched healthy controls. Demographic and clinical data were recorded. Blood pressure was measured using a standardized sphygmomanometer protocol. Fasting venous blood samples were collected, and serum magnesium was estimated using the colorimetric xylidyl blue method. Data were analyzed with SPSS v26 using independent t-tests and Pearson's correlation. A p value <0.05 was considered statistically significant.

Results: Serum magnesium was significantly lower in diabetic patients (1.65 ± 0.23 mg/dL) compared to controls (1.91 ± 0.21 mg/dL, $p < 0.001$). Diabetic patients also exhibited higher systolic blood pressure (143.2 ± 12.1 vs. 126.4 ± 9.5 mmHg, $p < 0.001$) and diastolic blood pressure (89.4 ± 7.1 vs. 78.6 ± 6.4 mmHg, $p < 0.001$). A significant negative correlation was observed between serum magnesium and both systolic ($r = –0.41$, $p < 0.01$) and diastolic blood pressure ($r = –0.38$, $p < 0.01$) in diabetics.

Conclusion: Hypomagnesemia is common among diabetic patients and is significantly associated with higher blood pressure. Regular monitoring and timely correction of magnesium deficiency may contribute to improved blood pressure control and reduction of cardiovascular risk in this population.

Keywords: Serum magnesium, hypertension, diabetes mellitus, hypomagnesemia, blood pressure

INTRODUCTION

Diabetes mellitus, particularly type 2 diabetes mellitus (T2DM), is one of the most prevalent metabolic disorders worldwide, characterized by chronic hyperglycemia resulting from impaired insulin secretion, insulin resistance, or both[1]. The global burden of diabetes has escalated rapidly over the past few decades, making it a major public health challenge, especially in low- and middle-income countries. In addition to microvascular complications such as retinopathy, nephropathy, and neuropathy, diabetic patients are at high risk of developing macrovascular complications, including coronary artery disease, stroke, and hypertension[2]. Among these, hypertension remains one of the most common and clinically significant comorbidities in T2DM, substantially contributing to increased morbidity and mortality. The coexistence of hypertension and diabetes markedly accelerates cardiovascular and renal complications, underscoring the importance of identifying modifiable risk factors that can influence blood pressure regulation in this population[3].

Electrolyte homeostasis plays a crucial role in maintaining normal vascular and metabolic functions. Magnesium, the second most abundant intracellular cation after potassium, is an essential element involved in over 300 enzymatic reactions in the human body[4]. It regulates diverse physiological processes, including glucose transport, insulin sensitivity, vascular smooth muscle contraction, and endothelial function. Despite its importance, magnesium has often been overlooked compared to other electrolytes such as sodium, potassium, and calcium in the context of cardiovascular and metabolic health. Emerging evidence, however, highlights its critical role in the pathogenesis of both diabetes and hypertension[5].

Hypomagnesemia is relatively common among diabetic patients and has been attributed to multiple mechanisms. Chronic hyperglycemia leads to osmotic diuresis, which promotes urinary magnesium loss[6]. Additionally, insulin resistance and the use of certain antidiabetic or antihypertensive medications may further reduce serum magnesium levels. Low magnesium status has been linked with impaired insulin signaling, worsened glycemic control, systemic inflammation, and endothelial dysfunction. Collectively, these mechanisms create a vicious cycle where magnesium deficiency not only results from diabetes but also contributes to its progression and complications[7].

The relationship between magnesium and blood pressure regulation is biologically plausible. Magnesium acts as a natural calcium antagonist in vascular smooth muscle cells, promoting relaxation and vasodilation[8]. It also modulates the renin–angiotensin–aldosterone system (RAAS), reduces sympathetic nervous system activity, and improves endothelial nitric oxide release—all of which contribute to blood pressure regulation. Consequently, reduced magnesium availability is thought to increase vascular resistance and arterial stiffness, leading to elevated blood pressure. Several observational studies and meta-analyses have suggested that lower serum magnesium is independently associated with higher systolic and diastolic blood pressure in both diabetic and non-diabetic populations[9,10].

Despite these findings, the relationship between serum magnesium and blood pressure in diabetic patients is not fully established, particularly in South Asian populations where dietary magnesium intake is often insufficient, and the prevalence of both diabetes and hypertension is rising at alarming rates[11]. Moreover, cultural dietary habits, high carbohydrate consumption, limited intake of magnesium-rich foods, and genetic predispositions may influence the magnesium–blood pressure relationship differently compared to Western populations. Understanding this association in local populations is essential for developing cost-effective preventive strategies aimed at reducing cardiovascular risk in diabetic patients[12].

Therefore, this study was designed to evaluate serum magnesium levels in diabetic patients and investigate their association with blood pressure, comparing the results with

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healthy, age- and sex-matched controls. By highlighting the role of magnesium in blood pressure regulation among diabetic patients, this research may provide valuable insights into the potential benefits of monitoring and correcting magnesium deficiency as part of integrated diabetes and hypertension management strategies[13].

MATERIALS AND METHODS

Study Design and Setting: This comparative cross-sectional study was conducted jointly at the Department of Medicine and Department of Biochemistry, Multan Medical and Dental College (MMDC), Multan, and Nishtar Medical University, Multan. The study duration extended over a period of fourteen months, from May 2022 to June 2023. Both institutions are recognized tertiary care centers catering to a large and diverse patient population, which ensured the availability of suitable participants and enhanced the reliability of the findings.

Study Population and Sample Size: A total of 140 individuals were enrolled in the study through non-probability consecutive sampling. The study participants were divided into two groups. Group A consisted of 70 patients with type 2 diabetes mellitus who fulfilled the inclusion criteria, while Group B included 70 age- and sex-matched apparently healthy adults serving as the control group. The sample size was chosen to provide sufficient statistical power to detect differences in serum magnesium levels and blood pressure between diabetic patients and healthy controls.

Inclusion and Exclusion Criteria: The inclusion criteria comprised adults aged between 30 and 65 years. In the diabetic group, patients with a confirmed diagnosis of type 2 diabetes mellitus according to the American Diabetes Association (ADA) criteria were included. The control group consisted of healthy individuals without a history of diabetes, hypertension, renal, or cardiovascular disease. Exclusion criteria were carefully applied to minimize confounding factors. Patients with chronic kidney disease, chronic liver disease, thyroid dysfunction, or malabsorption syndromes were excluded. Pregnant and lactating women were not included, and individuals using magnesium supplements, diuretics, or medications that could alter magnesium metabolism were also excluded. Furthermore, patients with recent acute illness or hospitalization within the preceding three months were excluded from the study.

Data Collection Procedure: All participants provided written informed consent before enrollment. A structured proforma was used to collect demographic data, medical history, duration of diabetes, and medication details. Clinical examination included assessment of height, weight, and body mass index (BMI). Blood pressure was measured using a mercury sphygmomanometer with participants seated comfortably after a 10-minute rest period. Two readings were taken five minutes apart, and the mean of both readings was used to minimize observer variability. Venous blood samples were collected under aseptic conditions after an overnight fast. The blood samples were centrifuged, and serum was separated for laboratory analysis. Serum magnesium levels were determined using the colorimetric xylidyl blue method on a semi-automated analyzer, while fasting blood glucose levels were assessed to verify the diabetic status of participants.

Ethical Considerations: Ethical approval for the study was obtained from the Institutional Review Boards of Multan Medical and Dental College and Nishtar Medical University. Confidentiality of participants was strictly maintained, and data were anonymized for analysis. All participants were informed about the objectives of the study, and results were communicated to them. Those with abnormal findings were referred for appropriate clinical management.

Statistical Analysis: Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables such as serum magnesium, systolic blood pressure, and diastolic blood pressure were expressed as mean ± standard deviation (SD). Group comparisons between diabetic patients and healthy controls were conducted using independent sample t-tests. The association between serum magnesium levels and blood pressure was explored using Pearson's correlation coefficient. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Baseline Characteristics: A total of 140 participants were included in this study, comprising 70 patients with type 2 diabetes mellitus (Group A) and 70 healthy controls (Group B). Both groups were comparable in terms of age and gender distribution. The mean age of diabetic patients was 52.4 ± 8.1 years, while that of controls was 50.9 ± 7.6 years ($p = 0.28$). The proportion of males and females was also similar across groups (male:female ratio 1.2:1 in diabetics vs. 1.1:1 in controls). However, the mean body mass index (BMI) was significantly higher in the diabetic group compared with the control group (28.3 ± 3.5 vs. 25.9 ± 3.1 kg/m², $p < 0.01$) (Table 1).

Table 1: Baseline characteristics of study participants

Parameter	Diabetic Patients (n = 70)	Controls (n = 70)	p-value
Age (years)	52.4 ± 8.1	50.9 ± 7.6	0.28
Male : Female ratio	1.2 : 1	1.1 : 1	NS
BMI (kg/m²)	28.3 ± 3.5	25.9 ± 3.1	<0.01

(NS: Not significant)

Serum Magnesium Levels: Serum magnesium levels were significantly lower among diabetic patients compared to healthy controls. The mean serum magnesium in the diabetic group was 1.65 ± 0.23 mg/dL, while in the control group it was 1.91 ± 0.21 mg/dL, with the difference being statistically significant ($p < 0.001$) (Table 2).

Blood Pressure Levels: Systolic and diastolic blood pressure readings were both significantly higher in diabetic patients than in controls. The mean systolic blood pressure in diabetics was 143.2 ± 12.1 mmHg compared to 126.4 ± 9.5 mmHg in controls ($p < 0.001$). Similarly, mean diastolic blood pressure was higher in the diabetic group (89.4 ± 7.1 mmHg vs. 78.6 ± 6.4 mmHg, $p < 0.001$) (Table 2).

Table 2: Comparison of serum magnesium and blood pressure between groups

Parameter	Diabetic Patients (n = 70)	Controls (n = 70)	p-value
Serum Magnesium (mg/dL)	1.65 ± 0.23	1.91 ± 0.21	<0.001
Systolic BP (mmHg)	143.2 ± 12.1	126.4 ± 9.5	<0.001
Diastolic BP (mmHg)	89.4 ± 7.1	78.6 ± 6.4	<0.001

Correlation Between Serum Magnesium and Blood Pressure: Pearson's correlation analysis demonstrated a significant negative correlation between serum magnesium levels and blood pressure among diabetic patients. Serum magnesium showed a moderate inverse correlation with systolic blood pressure ($r = –0.41$, $p < 0.01$) and with diastolic blood pressure ($r = –0.38$, $p < 0.01$). This indicates that lower magnesium levels were associated with higher blood pressure values in diabetic patients. In contrast, no significant correlation was observed between serum magnesium and blood pressure in the control group (Table 3).

Table 3: Correlation between serum magnesium and blood pressure in diabetic patients

Parameter	Correlation coefficient (r)	p-value
Serum Mg vs. Systolic BP	–0.41	<0.01
Serum Mg vs. Diastolic BP	–0.38	<0.01

In summary, the study demonstrated that diabetic patients had significantly lower serum magnesium levels and higher blood pressure compared to healthy individuals. Furthermore, within the diabetic group, magnesium deficiency was negatively associated with both systolic and diastolic blood pressure, highlighting the potential role of hypomagnesemia in the pathogenesis of hypertension in diabetes.

DISCUSSION

The present study investigated the association between serum magnesium levels and blood pressure in diabetic patients compared to healthy controls[11]. The findings demonstrated that serum magnesium levels were significantly lower among diabetic individuals, while both systolic and diastolic blood pressure values were higher than those observed in the control group. Moreover, a significant negative correlation was observed between serum magnesium and blood pressure in diabetic patients, suggesting that hypomagnesemia may play an important role in the development or exacerbation of hypertension in this population[12,13].

The observed reduction in serum magnesium among diabetics can be explained by multiple mechanisms. Chronic hyperglycemia leads to osmotic diuresis, resulting in increased urinary excretion of magnesium[14]. Furthermore, insulin resistance impairs magnesium uptake into cells, reducing its availability for enzymatic and metabolic processes. Low magnesium levels are also known to worsen insulin resistance, thus creating a bidirectional relationship between hypomagnesemia and diabetes progression. Previous studies have similarly reported a higher prevalence of hypomagnesemia among diabetic patients compared to healthy individuals, supporting the findings of this study[15].

The significant association between magnesium deficiency and elevated blood pressure noted in this study is consistent with established physiological mechanisms. Magnesium acts as a natural calcium channel blocker in vascular smooth muscle cells, promoting relaxation and vasodilation[16]. Deficiency of magnesium leads to increased vascular resistance and heightened sympathetic nervous system activity, both of which contribute to raised blood pressure. In addition, low magnesium levels impair endothelial function and reduce nitric oxide bioavailability, further exacerbating vascular dysfunction. Previous studies have confirmed that magnesium deficiency is associated with hypertension in both diabetic and non-diabetic populations, reinforcing the clinical relevance of our results[17,18].

Interestingly, the negative correlation between serum magnesium and both systolic and diastolic blood pressure was significant in the diabetic group but not in healthy controls. This suggests that the interplay between magnesium and blood pressure regulation may be more critical in the presence of diabetes-related metabolic disturbances[19]. It also implies that magnesium deficiency may exacerbate the risk of hypertension particularly in those already predisposed due to insulin resistance and hyperglycemia. This observation has important clinical implications, as identifying and correcting magnesium deficiency in diabetic patients may serve as a simple and cost-effective strategy to support blood pressure management and reduce cardiovascular risk[20,21].

The results of this study are comparable with previous research from different populations, which reported that dietary magnesium intake and serum magnesium levels were inversely associated with hypertension[22]. Furthermore, interventional studies have suggested that magnesium supplementation improves vascular reactivity and modestly lowers blood pressure, particularly in individuals with metabolic disorders. These findings highlight the potential role of magnesium supplementation as an adjunctive therapy in diabetes management. However, further randomized controlled trials are needed to establish a causal relationship and to determine optimal supplementation strategies[23].

This study has several strengths, including a well-defined comparative design, use of standardized protocols for blood pressure measurement, and analysis of a reasonably sized sample from two tertiary care hospitals[24]. However, certain limitations should be acknowledged. Being cross-sectional in nature, causality between hypomagnesemia and hypertension cannot be inferred. Dietary magnesium intake and urinary magnesium excretion were not assessed, which could have provided additional insights. Furthermore, the study was limited to patients from two centers in Multan, and results may not be generalizable to the broader population. Despite these limitations, the findings provide valuable evidence for the association between magnesium and blood pressure in diabetic patients within the local population[25].

CONCLUSION

This study demonstrated that serum magnesium levels are significantly reduced in diabetic patients compared to healthy individuals, and that hypomagnesemia is strongly associated with elevated systolic and diastolic blood pressure in this group. The findings suggest that magnesium deficiency may contribute to hypertension in diabetic patients and highlight the importance of monitoring serum magnesium as part of routine clinical assessment. Early recognition and correction of hypomagnesemia, through dietary modification or supplementation, may represent an effective adjunctive approach in the comprehensive management of diabetes and hypertension. Future longitudinal and interventional studies are recommended to further clarify the causal role of magnesium and to explore its therapeutic potential in reducing cardiovascular risk in diabetic populations.

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Conflicts of Interest: The authors declare that there are no conflicts of interest regarding this study.

Ethical Approval: Ethical approval was obtained from the Institutional Review Boards of Multan Medical and Dental College (MMDC), Multan, and Nishtar Medical University, Multan. Written informed consent was obtained from all participants prior to inclusion in the study.

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Authors' Contributions:

- **ZHQ**: Study conception, design, data interpretation, manuscript drafting.
- **AJ**: Data collection, analysis, literature review.
- **AHM**: Laboratory work, biochemical analysis, data entry.
- **FF**: Clinical evaluation, patient recruitment, results interpretation.
- **BF**: Statistical analysis, tables preparation, manuscript editing.
- **EHS**: Supervision, critical review, and final approval of the manuscript.

All authors have read and approved the final version of the manuscript.

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