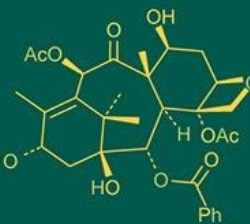
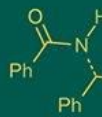
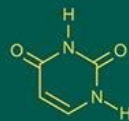
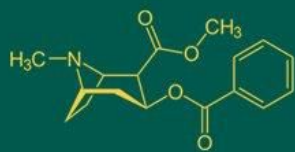


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Serum magnesium levels in diabetic patients: A comparative study at the Saint-Louis Health Center (Senegal)

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Abstract

Diabetes mellitus is a metabolic disease characterized by chronic hyperglycemia resulting from impaired insulin secretion, insulin action, or both.

A possible link between magnesium status and diabetes mellitus was first suggested in 1940. Since then, multiples studies have reported a high prevalence of hypomagnesemia in diabetic patients. However, in Senegal, data on the prevalence of hypomagnesemia in this population and its potential role in the development of complications remain scarce.

This study aimed to compare serum magnesium levels in diabetic and non-diabetic controls within a cohort of patients receiving care at the Saint-Louis Health Center. The specific objectives were to:

- Describe the epidemiological characteristics of the study population.
- Assess the prevalence of hypomagnesemia in diabetic patients compared to controls.
- Identify factors associated with hypomagnesemia in the diabetic population.

A prospective, cross-sectional, analytical case-control study was conducted with a cohort of 100 patients. Epidemiological and clinical data were collected using a standardized questionnaire, and biological data were obtained through blood samples.

Data analysis revealed that the prevalence of hypomagnesemia was significantly higher in diabetic patients (56%) compared to controls (24%). Diabetics were four times more likely to have hypomagnesemia than controls (OR = 4.03), and a significant association was observed between hypomagnesemia and disease duration ($p = 0.0031$). Furthermore, hypomagnesemia was significantly associated with the occurrence of diabetic complications, notably nephropathy ($p = 0.007$) and neuropathy ($p = 0.0073$).

In conclusion, this study highlights a higher prevalence of hypomagnesemia among diabetic patients, with a strong association with diabetic nephropathy and neuropathy. These findings support the inclusion of serum magnesium level assessment in the routine follow-up of diabetic patients to enable early detection and management of this metabolic disturbance.

Keywords: Diabetes mellitus, hypomagnesemia, magnesium, microvascular complications, nephropathy, neuropathy

Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from absolute or relative insulin deficiency. This condition arises from a combination of genetic and/or environmental factors that are often complex and multifactorial. Diabetes is now recognized as a global pandemic, with increasing morbidity and mortality [1]. According to the International Diabetes Federation (IDF), in 2017, 425 million people were living with diabetes, representing 8.8% of adults aged 20 to 79 years [2]. By 2021, the American Diabetes Association (ADA) reported 537 million adults with diabetes worldwide, corresponding to a global prevalence of 10.5%, and an estimated 4.2 million deaths attributed to diabetes or its complications. The number of people living with diabetes is projected to rise to 643 million by 2030 and 783 million by 2045 [3].

In Africa, the prevalence of diabetes is also rising steadily, with 24 million adults affected by 2021. If no significant action is taken, this figure is expected to increase exponentially,

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reaching a projected prevalence of 13.4% by 2030 [4]. Alarming, Africa has the highest proportion of undiagnosed diabetes, estimated at over 78% [5].

In Senegal, the 2021 IDF report estimated that 189,400 people aged 20 to 79 were living with diabetes, out of a total adult population of 8,036,700—representing a national prevalence of 2.4% [6]. These concerning and ever-growing figures—expected to surpass 552 million globally by 2030—continue to prompt the scientific community to explore new avenues for prevention and improved management of diabetes [6].

A possible link between magnesium levels and diabetes mellitus was first suggested as early as 1940 [7, 8]. Since then, numerous studies have demonstrated a high prevalence of hypomagnesemia in both type 1 and type 2 diabetic patients [7]. Magnesium plays a crucial role in carbohydrate metabolism, and magnesium deficiency has been associated with poor glycemic control and the development of diabetes-related complications, including both macrovascular and microvascular disorders [9, 10].

Diabetes is the most common metabolic condition linked to magnesium deficiency. Low magnesium levels are known to impair carbohydrate metabolism and reduce insulin sensitivity, particularly in individuals with type 2 diabetes [11]. The reported prevalence of hypomagnesemia varies by region—ranging from 25% to 39% in the United States [11], 13.5% to 47.7% in India [12], and around 27% in Tunisia [7]. However, in Senegal, there is a notable lack of data regarding the prevalence of hypomagnesemia among diabetic individuals and its potential role in the development of diabetes-related complications.

Objectives

This study was therefore designed to conduct a comparative analysis of serum magnesium levels in diabetic patients and non-diabetic controls within a cohort of individuals followed at the Saint-Louis Health Center. The specific objectives were:

- To describe the epidemiological characteristics of the study population.
- To evaluate the prevalence of hypomagnesemia in diabetic patients compared to controls.
- To analyze the factors associated with hypomagnesemia in diabetic patients.

Materials and Methods

Study Design and Period

This was a prospective, cross-sectional, case-control study conducted over a 4-month period from September 1 to December 31, 2023. Patient recruitment was carried out in the Internal Medicine Department of the Saint-Louis Health Center, based on predefined inclusion and exclusion criteria. Radiological data were obtained from the Radiology Department, and biological analyses were performed at the Health Center's laboratory.

Study Population

The study population consisted of type 2 diabetic patients and non-diabetic controls, either hospitalized or seen in outpatient consultations at the health center.

Inclusion Criteria

We included all individuals:

- Diagnosed with type 2 diabetes mellitus.
- Aged 35 years and older.
- Who were either hospitalized or received outpatient consultation.
- For each diabetic patient, a control matched by age and sex was selected, with prior informed consent confirmed by signing a consent form.

Exclusion Criteria

The following were excluded from the study:

- Patients who refused to participate.
- Patients with type 1 diabetes mellitus.
- Type 2 diabetic patients under 35 years of age.
- Patients receiving magnesium supplementation.
- Patients under treatment or presenting with conditions that may alter serum magnesium levels, such as:
 - a) Digestive diseases.
 - b) Thyroid disorders.
 - c) Chronic alcoholism.
 - d) Pregnancy and breastfeeding.

Sample Size

- A total of 100 participants were included in the study:
- 50 type 2 diabetic patients.
- 50 age- and sex-matched controls.
- All participants were selected based on the inclusion and exclusion criteria.

Ethical Considerations

All participants provided free and informed consent, confirmed by signing the consent form prior to inclusion in the study.

Variables Studied

Epidemiological Data

- Age
- Sex
- **Lifestyle factors:** Sedentary behavior, smoking
- **Personal medical history:** Stroke, hypertension

Clinical Data

- Reason for consultation
- Body Mass Index (BMI)
- Monofilament test for peripheral neuropathy

Paraclinical Data

Biological Parameters

- Fasting blood glucose
- Glycated hemoglobin (HbA1c)
- Serum magnesium (magnesemia)
- Lipid profile
- Serum creatinine
- 24-hour urine microalbuminuria

Sample Collection

- **Dry tube:** For magnesium, lipid profile, and creatinine.
- **Fluorinated tube:** For fasting blood glucose.
- **EDTA tube:** For HbA1c.
- **24-hour urine:** Patients were instructed on proper collection procedures for microalbuminuria measurement.

Radiological Parameters

- Electrocardiogram (ECG) analysis included.
- ST-segment elevation or depression, and mirror images.
- Pathological Q waves (necrosis).
- Rhythm disorders (e.g., atrial fibrillation, flutter).
- Signs of atrial or ventricular hypertrophy.

Statistical Analysis

Data were initially collected using SPSS software, then analyzed using RStudio version 2023.09.1

- Quantitative variables were expressed as means, standard deviations, and variances.
- Qualitative variables were described using frequencies and percentages.
- For comparison of proportions.

- Chi-square test was used when assumptions were met.
- Fisher's exact test was used when assumptions were not met.
- For comparison of means.
- Student's t-test was used for normally distributed data
- Mann-Whitney U test was used for non-parametric data.

Results

Socio-demographic Characteristics

- Mean age of participants: 56.39 ± 12.06 years, with a range from 35 to 80 years.
- Sex ratio (M/F): 0.7.
- The most represented age group was 60 to 70 years (44%), as shown in Figure 1.

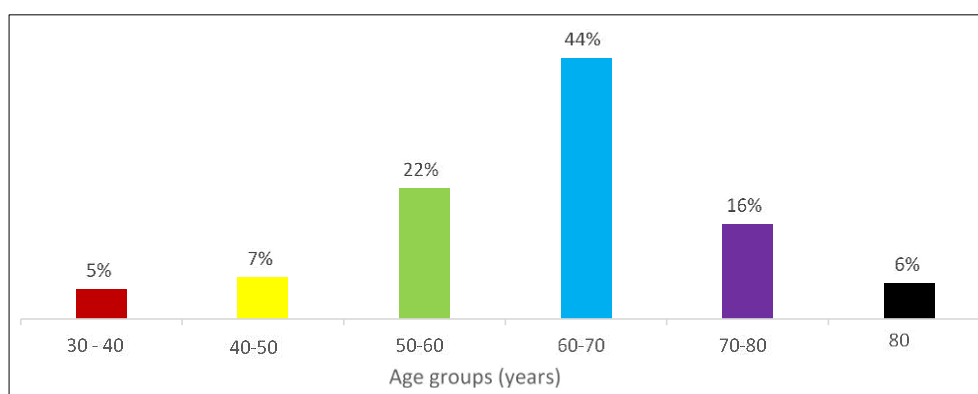


Fig 1: Age distribution of the study population

Socio-professional status

The most common occupational category was housewives (28%), followed by retirees (22%). The detailed breakdown of occupational status is presented in Table 1.

Table 1: Distribution of patients by occupation

Occupation	Percentage n (%)
Housewives	28 (28)
Fishermen	18 (18)
Employees	10 (10)
Growers	10 (10)
Merchants	7 (7)
Retirees	22 (22)
Teachers	5 (5)
Total	100 (100)

Comorbidities

Tobacco use

In our study, 21% of the participants were smokers. Tobacco use was slightly more prevalent among diabetics (24%) than among controls (18%), as presented in Table 2.

Table 2: Distribution of smoking patients among the study population

Tobacco consumption	Diabetes n (%)	Controls n (%)	Total n (%)
Yes	12 (24)	9 (18)	21 (21)
No	38 (76)	41 (82)	79 (79)
Total	50 (100)	50 (100)	100 (100)

Sedentary lifestyle

A sedentary lifestyle was reported in 56% of participants: 60% among diabetics and 52% among controls, as shown in Table 3.

Table 3: Distribution of sedentary lifestyle in the study population

Sedentary lifestyle	Diabetes n (%)	Controls n (%)	Total n (%)
Yes	30 (60)	26 (52)	56 (56)
No	20 (40)	24 (48)	44 (44)
Total	50 (100)	50 (100)	100 (100)

High Blood Pressure (HBP)

The overall prevalence of high blood pressure (HBP) was 38%. It was significantly more common among diabetics (56%) compared to controls (20%), as seen in Table 4.

Table 4: Distribution of hypertension in the study population

HTA n (%)	Diabetes n (%)	Controls n (%)	Total n (%)
Oui	28 (56)	10 (20)	38 (38)
Non	22 (44)	40 (80)	62 (62)
Total	50 (100)	50 (100)	100 (100)

Clinical data

Chief of complain

The most common presenting symptoms were headaches (30%), paresthesia (20%), muscle cramps (10%), and asthenia (8%), as detailed in Table 5.

Table 5: Distribution of symptoms in the study population

Symptoms	Percentage
Headaches	30
Asthenia	8
Muscle cramps	10
Dizziness	5
Paresthesia/Tingling/Talalgia	20
Palpitations	4
Headache/muscle cramps	13
Dizziness/Headache	10
Total	100

Paraclinical data**Biology**

Table 6 presents the mean values of key biological parameters. Significant differences were

observed between diabetics and controls in magnesium levels, HDL, triglycerides, creatinine, and fasting blood glucose ($p < 0.05$).

Table 6: Comparison of biological parameters between diabetics and controls

Parameters	Control (Means SD)	Diabetic (Means SD)	P- value
Magnesium (mg/L)	19,5 ± 2,15	17,98 ± 2,03	0,003
Calcium (mg/L)	90,47 ± 7,81	89,76 ± 10,12	0,77
HDL (g/L)	0,52 ± 0,13	0,67 ± 0,09	0,02
LDL (g/L)	1,39 ± 0,36	1,40 ± 0,42	0,93
Total Cholesterol (g/L)	2,00 ± 0,836	2,16 ± 0,58	0,23
Triglycerides (g/L)	0,43 ± 0,32	2,71 ± 0,11	0,023
Creatinine (mg/L)	11,04 ± 2,84	13,10 ± 4,75	0,043
blood glucose (g/L)	0,99±0,22	1,63± 0.79	0,007

Prevalence of Hypomagnesemia: Overall, 40% of participants presented with hypomagnesemia. It was more

frequent in diabetics (56%) compared to controls (24%), as shown in Table 7.

Table 7: Prevalence of hypomagnesemia in diabetics and controls

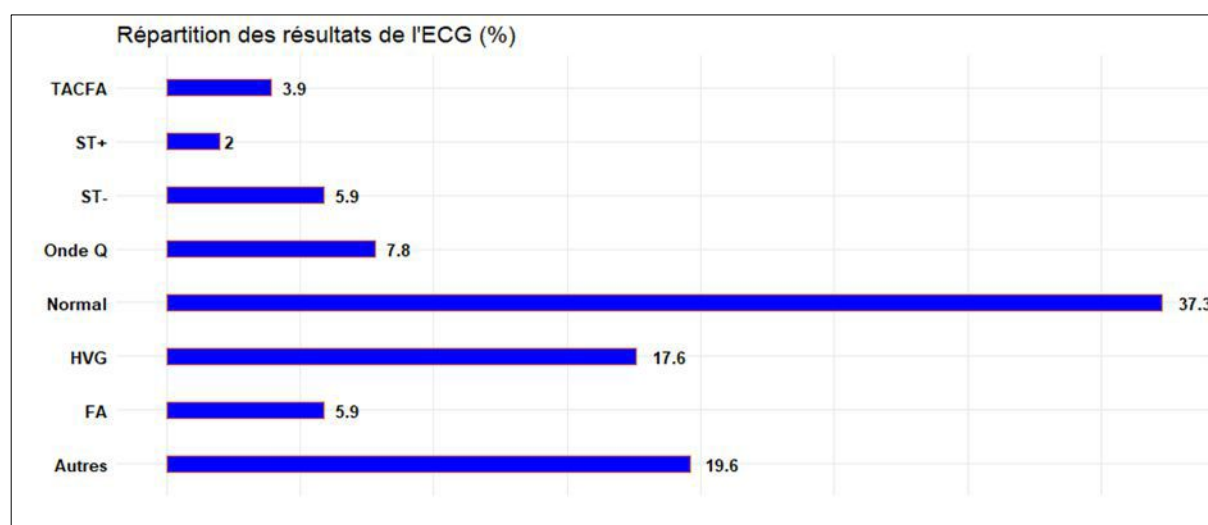
Magnesiumemia	Diabetic n (%)	Control n (%)	Total
Hypomagnesemia	28 (56)	12 (24)	40 (40)
Normal	22 (44)	38 (76)	60 (60)
Total	50 (100)	50 (100)	100(100)

Electroencephalogram (ECG)

The most common abnormalities on ECG were:

- Left Ventricular Hypertrophy (LVH): 17.6%

- Rhythm disturbances: 9.8%
- Necrotic Q waves: 7.8%

**Fig 2:** Distribution of ECG abnormalities**Bivariate analysis**

The following factors were significantly associated with hypomagnesemia:

- Duration of diabetes ($p = 0.0031$)

- Hypercholesterolemia ($p = 0.0024$)
- Hypertriglyceridemia ($p = 0.05$)
- Diabetic nephropathy ($p = 0.007$)
- Diabetic neuropathy ($p = 0.0073$)

Discussion

Socio-demographic data

Age

The mean age of the study population was 56.39 years, ranging from 35 to 80 years. The most represented age group was 60–70 years (44%). These results are comparable to those reported by Dembélé *et al.* [13], who found a mean age of 58.72 years. Similar findings were noted by Zahra *et al.* [14] and Loukil *et al.* [15], who reported mean ages of 56 and 60.4 years, respectively, with standard deviations of 7.9 and 7.5. A multicenter study by Diop *et al.* [16] conducted in Africa also showed a similar trend, with a mean age of 53.2 years. This relatively high average age may be explained by the predominance of type 2 diabetics in our sample.

Sex-ratio

A female predominance was noted in both the diabetic and control groups, in line with findings from Dembélé *et al.* [13] (sex ratio = 0.79) and Barry *et al.* [17] (sex ratios of 0.60 and 0.58). This could be attributed to greater healthcare-seeking behavior among women, and their higher rates of sedentary lifestyle, which may contribute to obesity and insulin resistance.

Socio-professional status

Housewives were the most represented group (28%), followed by retirees (22%). Similar trends were observed in studies by Dembélé *et al.* [13] (44.2%), Nasser *et al.* [18] (46.5%), and Doumbia *et al.* [19] (45%), reinforcing the link between socio-professional inactivity and chronic conditions like diabetes.

Clinical data

Headache was the most common reason for consultation (39%), followed by vertigo (16%), asthenia (14%), and muscle cramps (14%). These symptoms, although non-specific, are frequently associated with magnesium deficiency [20], even though they are not pathognomonic and can be absent in some cases [21].

Comorbidities

Sedentarism

Overall, 56% of participants were sedentary (60% of diabetics and 52% of controls), consistent with Diouf *et al.* [1], who reported 63% and 53%, respectively. However, in our context, many housewives might not be entirely inactive, which may limit the interpretation of this data.

Tobacco use

Tobacco consumption was reported by 21% of participants, with 24% among diabetics and 18% among controls. This relatively low prevalence—consistent with Diouf *et al.* [1] (9%)—may reflect the socio-cultural and religious context in Senegal, and the predominance of women in the sample.

Hypertension

The prevalence of hypertension was 38% overall, affecting 56% of diabetics and 20% of controls. These findings are consistent with data from a 2010 Saint-Louis survey by Mbaye *et al.* [22], which reported 46% in the general population and 73% in diabetics. Hypertension is a common comorbidity in diabetics, affecting 20% to 60% of this population [23]. It may result from metabolic disorders, such

as obesity, or from renal and vascular complications related to diabetes [24].

Paraclinical data

Biological parameters

Hypomagnesemia was present in 40% of the study population, affecting 56% of diabetics and 24% of controls—a statistically significant difference ($\chi^2 = 10.667$; $p = 0.00109$). Diabetics had four times higher odds of hypomagnesemia (OR = 4.03). Similar findings were reported by Dharam *et al.* [12], and Wälti *et al.* [25], with prevalence of 30.6% and 37.6%, respectively. Safi *et al.* [26] found a lower prevalence of 20.66% in the general population.

In Wälti *et al.*'s study [12], hypomagnesemia prevalence was 37.6% in diabetics and 10.9% in controls, with significantly lower magnesium concentrations in diabetics (0.77 ± 0.08 mmol/L vs. 0.83 ± 0.07 mmol/L; $p < 0.001$). Similarly, Manonmani M *et al.* [27] found significantly lower serum magnesium levels in diabetics (1.61 ± 0.37 mg/dL) than in controls (2.10 ± 0.21 mg/dL; $p < 0.0001$).

This relationship is well-documented in the literature, suggesting that hypomagnesemia in diabetics may result from both reduced intake and increased urinary losses, possibly reflecting renal dysfunction. Magnesium plays a crucial role in insulin action and glucose metabolism, and its deficiency may exacerbate insulin resistance [28]. Some studies have suggested that magnesium supplementation may help prevent or manage type 2 diabetes.

Hypomagnesemia and duration and diabetes

The duration of diabetes was significantly longer in patients with hypomagnesemia (5.04 years) than in those without (2.8 years; $p = 0.0031$), consistent with the idea that hypomagnesemia worsens with disease progression [12].

Neuropathy

A statistically significant association was found between hypomagnesemia and diabetic neuropathy ($\chi^2 = 7.259$; $p = 0.0073$). Diabetic patients with hypomagnesemia were 6.33 times more likely to develop neuropathy. This is consistent with findings by Dharam *et al.* [12], who also reported a significant link between the two. Other studies have shown that magnesium supplementation may improve nerve conduction in these patients [29].

Nephropathy

A strong association was also found between hypomagnesemia and diabetic nephropathy ($\chi^2 = 7.259$; $p = 0.007$), with hypomagnesemic diabetics having a sixfold increased risk. Odusan *et al.* [30] found significantly lower magnesium levels in diabetics with microalbuminuria and proteinuria. However, the literature is not unanimous on this association, as some studies did not find a significant link [17].

Other complications

No significant association was found between hypomagnesemia and diabetic microangiopathy, echoing results from certain other studies.

Limitations

- This study has several limitations:
- The small sample size reduced the statistical power of some analyses.

- The limited technical resources restricted the diagnosis of certain neurological complications.
- The cross-sectional design did not allow for assessment of temporal relationships or progression, limiting causal inference. A longitudinal study would be more appropriate to confirm these findings and explore their implications.

Conclusion

Magnesium is a vital ion involved in numerous cellular processes, including energy metabolism, protein synthesis, and insulin function. This study found a high prevalence of hypomagnesemia among type 2 diabetics compared to controls, with significant associations with neuropathy and nephropathy. These findings suggest the potential value of routine magnesium monitoring in diabetic patients. Early detection and correction of magnesium deficiency could serve as an effective strategy for preventing complications.

Conflict of interest

The authors declare no conflict of interest.

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Authors contributions

All authors contributed to the conception, design, data collection, analysis, and manuscript preparation. All authors read and approved the final version of the manuscript.

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