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ORIGINAL ARTICLE

Evaluation of Serum Magnesium Level in People with Type 2 Diabetes Mellitus in Sharkia Governorate

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ABSTRACT

Background: Patients with type 2 diabetes have been shown to have an elevated prevalence of hypomagnesemia. Few studies were performed on it. To our knowledge, this work has not been done in the Faculty of Medicine, Zagazig University.

Aim: To evaluate the association of serum magnesium with controlled and uncontrolled type 2 diabetes mellitus.

Subjects and methods: This case-control study was conducted on 716 patients presented at the Internal Medicine Department and outpatient clinic in Al-Ahrar Teaching Hospital, and Zagazig University Hospital on adult patients diabetic type 2, males and females, and normal people not diabetic not have other comorbidities. Magnesium was measured in all subjects.

Results: Hypomagnesemia at higher frequency in the DM uncontrolled group was 92.2%, followed by the DM control group at 24.4%, and there is no hypomagnesemia in the normal group and normal magnesium level in the normal control group

Conclusion: Hypomagnesemia had a higher frequency in the DM uncontrolled group than in the DM control group. It is linked to poor glycemic control and diabetic consequences include retinopathy, neuropathy, and nephropathy.

Keywords: Magnesium, Type 2 Diabetes Mellitus, Electrolytes.

INTRODUCTION

Among the most prevalent non-communicable illnesses because of dietary changes and lifestyle changes, diabetes mellitus (DM) affects 8.3% of adult humans worldwide and is increasing at an alarming rate. The hallmarks of DM include chronic hyperglycemia and impaired protein, lipid, and carbohydrate metabolism, which are brought on by a complete or partial insufficiency of insulin synthesis and/or action. Uncontrolled blood sugar levels can result in several debilitating disorders, including nephropathy, neuropathy, retinopathy, cardiovascular disease, stroke, and amputations of the limbs **[1].**

For a cell to operate normally, electrolytes like sodium, potassium, calcium, and magnesium are important fundamental constituents. The primary cation in human cells is magnesium, which is primarily found in the mitochondria. After sodium, potassium, and calcium, it is the body's fourth-most prevalent substance **[2].**

Magnesium (Mg), an element essential for basic biochemical activities, participates in several physiological and metabolic processes that are part of normal physiology. These processes include the transfer of potassium ions or calcium ions, the metabolism of energy, and the creation of proteins, and nucleic acids. Magnesium also has anti-inflammation, anti-oxidation, anti-spasm, vasodilation, and neuroprotection **[3].**

Mg losses in people with diabetes type 2 cause hypomagnesemia. The more typical finding is a

latent chronic magnesium deficit without change in serum total magnesium. This usually undiagnosed Mg deficiency has clinical significance since Mg is a crucial co-factor in many enzymatic reactions (more than 300 enzymatic reactions, including all the enzymes of glycolysis). Furthermore, the regulation of insulin signaling, phosphorylation of the insulin receptor kinase, insulin's post-receptor activity, and insulin's function in cellular glucose uptake are all significantly influenced by magnesium **[4].**

In comparison to diabetic individuals with normal magnesium (Mg2+) levels, hypomagnesemia in diabetes may greatly increase the risk of retinopathy, nephropathy, and foot ulcers as well as considerably contribute to a dysregulation of glycemic control. Magnesium shortage or the displacement of magnesium can increase inflammatory disorders, insulin resistance, hypertension, diabetes mellitus, and cardiovascular diseases of Mg2+ by other hazardous compounds. Additionally, these conditions also hinder DNA repair **[5].**

Due to its ability to increase insulin sensitivity, prevent diabetes, and its cardiovascular consequences, magnesium has drawn a lot of attention. It is alleged that Mg2+ intake is negatively correlated with the development of DM. It was shown that serum Mg2+ levels were adversely associated with levels of glycosylated hemoglobin (HbA1c) **[6].**

Clinical research demonstrates that hypomagnesemia in T2DM patients has decreased pancreatic-cell function and exhibits higher insulin resistance. Additionally, adding Mg2+ to the diet enhances insulin sensitivity and glucose metabolism in T2DM patients. DM is the most typical of the metabolic and endocrine disorders associated with magnesium deficiency **[7].**

PATIENTS AND METHODS

On 716 patients, this case-control research was carried out at the Internal Medicine Department, Zagazig University Hospital, and outpatient clinic in Al-Ahrar Teaching Hospital during the period from December 2022 to July 2023.

Adult patients with type 2 diabetes, males and females normal people not diabetic and not have other comorbidities (healthy people not diabetic no other chronic disease), and age >18 years old were included in the study.

Subjects with pregnancy and lactation, patients with metabolic acidosis, chronic renal failure, a history of myocardial infarction within the preceding six months, severe sickness needing mechanical ventilation, signs of malignancy, type 1 diabetes mellitus, sepsis, and other conditions, malabsorption, or chronic diarrhea (diarrhea lasting longer than 4 weeks), causes of hypomagnesemia (diarrhea, Loop diuretics. etc), patients on anti-hypertensive medications or history of Mg supplement, patients on dialysis, critically ill patients, and recent use of dietary supplements were excluded from the study

Patients were grouped into three groups: healthy individuals without diabetes and other comorbidities (200 cases), and diabetic patients with type 2 DM (n=516) divided into sub-groups: diabetic controlled (258 cases) and diabetic uncontrolled (258 cases).

All studied persons were subjected to full history taking, presence of other comorbidities such as hypertension, smoking and hyperlipidemia and detection of complications: retinopathy, peripheral neuropathy, nephropathy, full general and local examinations, standard laboratory tests like complete blood count, serum creatinine level, lipid profile, fasting blood sugar (FBS), 2-hour postprandial blood sugar, glycated hemoglobin **(HbA1c),** liver function tests (SGPT, SGOT), albumin/creatinine ratio**,** and serum Mg (using a spectrophotometer) were done.

Diabetic nephropathy (DN) was diagnosed based on the presence of macroalbuminuria or microalbuminuria. Microalbuminuria was defined as an Albumin creatinine ratio (ACR) between 30 and 300 mg/g. Macroalbuminuria was defined as an ACR >300 mg/g. Diabetic retinopathy (DR) was diagnosed based on fundus examination. Diabetic neuropathy was diagnosed based on the presence of clinical features such as tingling, and numbness. Peripheral nerve assessment, monofilament test, vibration test, touch, pain, and deep reflexes **[6].**

Magnesium has been measured using the colorimetric end-point method by Cobas 6000 (Roche, Mannheim, Germany). Hypomagnesaemia is considered if its level is below 1.48 (Hypomagnesaemia is an electrolyte disturbance caused by a low serum magnesium level (less than 1.46 mg/dL) in the blood (8). The HbA1c level was calculated using the remaining 2.5 mL, which was placed in an EDTA test tube. ELISpot is an enzyme-linked immunosorbent test. (ELISA) test was used to determine HbA1c. The biological reference range for serum MG is 1.7–2.7 mg/Dl. Serum magnesium levels ≤1.8 mg/dL are considered hypomagnesemic **[8].**

Ethical considerations

Written informed consent was obtained from all participants. The study was approved by the Ethics Committee (IRB# 9496-19-4-2022) Faculty of Medicine, Al-Ahrar Teaching Hospital, Zagazig and Zagazig University Hospital. There are sufficient safeguards to protect participants' confidentiality and privacy. The study protocol conformed to the Helsinki Declaration, the ethical norm of the World Medical Association for human testing.

Statistical analysis

Recorded data were analyzed using the statistical package for social sciences, version 23.0 (SPSS Inc., Chicago, Illinois, USA). The following tests were used: independent-samples t-test, Mann Whitney U test, one-way analysis of variance (ANOVA), multivariate logistic regression analysis, chi-square test, Fisher's exact test, Tukey's test, and Pearson's correlation coefficient (r) test.

RESULTS

There was a statistically significant difference between the three groups according to demographic data about gender, BMI, SBP and DBP, HTN, smoking, neuropathy, nephropathy, and retinopathy, (Table 1).

There was a statistically significant difference between three groups according to PLT, SGOT (u/L), SGPT (u/L), Creatinine (mg/dl), INR, FBG*, 2hr PP (mg/dL), HbA1C, Albumin/creatinine ratio, Total cholesterol mg /dl, LDL (mg/dl), HDL (mg/dl) & Triglyceride (mg/dl) (Table 2).

Serum Mg level has a higher mean value in the normal Group was 1.97±0.07, followed by the DM control group at 1.94±0.19, and the lowest value in the DM uncontrolled Group was 1.48±0.22, (Table 3).

Hypomagnesemia's higher frequency in the DM uncontrolled group was 92.2%, followed by the DM control group at 24.4%, and they don't have hypomagnesemia in the Normal Group (Table 4).

There was a statistically significant positive correlation between serum Mg with age (yrs), duration of DM (years), neuropathy, SBP (mmHg), creatinine (mg/dl), INR and triglyceride (mg/dl), with p-value ($p<0.05$); while, a statistically significant negative correlation between serum Mg with Hb (gm), FBG*, 2hr PP (mg/dL), albumin/creatinine ratio & HDL (mg/dl) (Table 5).

There was a statistically significant positive correlation between serum Mg with HDL (mg/dl), with p-value ($p<0.05$); While, a statistically significant negative correlation between serum Mg with Creatinine (mg/dl), HbA1C, Neuropathy, 2hr PP (mg/dL), FBG*, LDL (mg/dl), SBP (mmHg), Albumin/creatinine ratio, Total cholesterol mg /dl, DBP (mmHg), HTN, Age (yrs), Nephropathy, Retinopathy, Hb (gm), Smoking, Triglyceride (mg/dl), PLT(s/UL), SGPT (u/L) & BMI [wt/(ht)^2] (Table 6).

Age (yrs), BMI [wt/(ht)^2], SBP, DBP (mmHg), Creatinine (mg/dl), 2hr PP (mg/dL), HbA1C, Albumin/creatinine ratio, Total cholesterol mg /dl, LDL (mg/dl), HDL (mg/dl), Triglyceride (mg/dl) & Serum Mg, have a significant of most important influencing factors in the Type 2 Diabetes Mellitus (Table 7).

Table (1): Comparison between groups according to baseline data.

Demographic data	Normal Group (n=200)	DM Control Group (n=258)	DM Uncontrolled Group (n=258)	Test value	p-value	Multiple Comparison		
						P1	P2	P3
Age (yrs) Mean±SD Range	50.8±12.2 19-76	51.90±11.9 21-77	52.51±10.11 21-70	1.285	0.277	0.381	0.217	0.362
Gender Female Male	118 (59.0%) 82 (41.0%)	137 (53.1%) 121 (46.9%)	184 (71.3%) 74 (28.7%)	18.674	<0.001**	0.2438	<0.001**	<0.001**
BMI [wt/(ht)^2] Mean±SD Range	29.80±1.59 26-33	29.66±2.22 25-36	32.08±3.02 25-39	79.773	<0.001**	0.569	<0.001**	<0.001**
HTN No	200 (100.0%)	215 (83.3%)	130 (50.4%)	164.098	<0.001**	<0.001*	<0.001**	<0.001**

Yes	0 (0.0%)	43 (16.7%)	128 (49.6%)			*		
Smoking								
No	200 (100.0%)	239 (92.6%)	225 (87.2%)	27.373	<0.001**	<0.001**	<0.001**	0.041*
Yes	0 (0.0%)	19 (7.4%)	33 (12.8%)					
Neuropathy								
No	200 (100.0%)	247 (95.7%)	54 (20.9%)	462.665	<0.001**	0.008*	<0.001**	<0.001**
Yes	0 (0.0%)	11 (4.3%)	204 (79.1%)					
Nephropathy								
No	200 (100.0%)	252 (97.7%)	151 (58.5%)	200.745	<0.001**	0.079	<0.001**	<0.001**
Yes	0 (0.0%)	6 (2.3%)	107 (41.5%)					
Retinopathy								
No	200 (100.0%)	252 (97.7%)	144 (55.8%)	217.907	<0.001**	0.079	<0.001**	<0.001**
Yes	0 (0.0%)	6 (2.3%)	114 (44.2%)					
SBP (mmHg)								
Mean±SD	114.70±11.9	118.36±14.5	131.22±19.0	72.780	<0.001**	0.004*	<0.001**	<0.001**
Range	90-130	90-160	90-160					
DBP (mmHg)								
Mean±SD	75.25±8.30	77.21±7.14	81.34±8.11	36.987	<0.001**	0.007*	<0.001**	<0.001**

P1: Significant level between Normal Group versus DM control. P2: Significant level between Normal DM versus DM Uncontrolled group, P3: Significant level between DM control group versus DM Uncontrolled group

Table (2): Comparison between groups according to laboratory data.

CBC	Normal Group (n=200)	DM Control Group (n=258)	DM Uncontrolled Group (n=258)	Test value	p-value	Multiple Comparison		
						P1	P2	P3
Hb (gm)								
Mean±SD	12.22±0.99	12.38±1.19	12.53±1.25	F:4.031	0.058	0.126	0.163	0.300
Range	10.5-14	9-15	9-15					
TLC (s/UL)								
Mean±SD	6.83±1.69	7.56±4.21	7.21±4.18	H:2.232	0.108	0.243	0.344	0.552
Range	4.3-9.4	4-42	4.2-42					
PLT(s/UL)								
Mean±SD	230.5±68.9	262.6±72.3	268.90±71.3	H:18.234	<0.001**	<0.001**	<0.001**	0.584
Range	157-376	128-435	114-435					
SGOT (u/L)								
Mean±SD	23.02±10.5	27.09±13.6	29.12±12.93	H:8.122	<0.001**	0.020*	<0.001**	0.175
Range	12-43	12-85	10-82					
SGPT (u/L)								
Mean±SD	24.69±10.8	28.33±10.5	28.85±12.89	H:4.830	0.008*	0.022*	0.007*	0.870
Range	12-45	12-54	11-64					
Creatinine (mg/dl)								
Mean±SD	0.64±0.16	0.73±0.18	0.97±0.28	H:105.20	<0.001**	0.002*	<0.001**	<0.001**
Range	0.3-a1	0.3-a1.2	0.3-a1.7					
INR								
Mean±SD	1.04±0.05	1.04±0.05	1.03±0.04	F:3.793	0.023*	0.973	0.018*	0.026*
Range	1-1.12	1-1.2	1-1.12					
FBG*								
Mean±SD	93.87±7.97	106.09±21.44	179.50±48.73	H:373.74	<0.001**	0.008*	<0.001**	<0.001**

Range	82-109	79-210	79-270					
2hr PP (mg/dL)								
Mean±SD	119.93±10.49	139.43±40.64	304.91±119.64	H:328.42	<0.001**	0.108	<0.001**	<0.001**
Range	100-136	99-345	99-497					
HbA1C								
Mean±SD	5.29±0.40	6.02±0.63	9.23±2.36	F:841.735	<0.001**	<0.001**	<0.001**	<0.001**
Range	4.8-6.1	4.8-7.9	4.8-14.2					
Albumin / creatinine ratio								
Mean±SD	15.32±4.46	18.79±7.60	42.22±31.23	H:103.34	<0.001**	0.336	<0.001**	<0.001**
Range	10-26	8-39	8-119					
Total cholesterol mg /dl								
Mean±SD	185.63±8.78	184.84±10.7	239.82±35.38	F:487.712	<0.001**	0.398	<0.001**	<0.001**
Range	170.2-199.4	158-208	169-302					
LDL (mg/dl)								
Mean±SD	90.34±7.89	91.38±9.17	148.03±33.1	F:606.128	<0.001**	0.983	<0.001**	<0.001**
Range	77-105	70-105	77-200					
HDL (mg/dl)								
Mean±SD	65.38±6.16	59.21±6.88	52.25±6.51	F:229.116	<0.001**	<0.001**	<0.001**	<0.001**
Range	55-77	45-71	44-70					
Triglyceride (mg/dl)								
Mean±SD	149.54±31	171.70±37	198.32±47.8	F:84.826	<0.001**	<0.001**	<0.001**	<0.001**
Range	100-200	111-280	116-310					

P1: Significant level between Normal Group versus DM control, P2: Significant level between Normal DM versus DM Uncontrolled group , P3: Significant level between DM control group versus DM Uncontrolled group

Table (3): Comparison between groups according to serum Mg.

Serum Mg	Normal Group (n=200)	DM Control Group (n=258)	DM Uncontrolled Group (n=258)	Test value	p-value	Multiple Comparison		
						P1	P2	P3
Mean±SD	1.97±0.07	1.94±0.19	1.48±0.22	581.921	<0.001**	0.034*	<0.001**	<0.001**
Range	1.9-2.1	1.3-2.4	1-1.9					

P1: Significant level between Normal Group versus DM control , P2: Significant level between Normal DM versus DM Uncontrolled group, P3: Significant level between DM control group versus DM Uncontrolled group

Table (4): Comparison between groups according to level of serum Mg.

Level of Serum Mg	Normal Group (n=200)	DM Control Group (n=258)	DM Uncontrolled Group (n=258)	Test value	p-value	Multiple Comparison		
						P1	P2	P3
Normomagnesemia	200 (100.0%)	195 (75.6%)	20 (7.8%)	444.863	<0.001**	<0.001**	<0.001**	<0.001**
Hypomagnesemia	0 (0.0%)	63 (24.4%)	238 (92.2%)					

P1: Significant level between Normal Group versus DM control, P2: Significant level between Normal DM versus DM Uncontrolled group, P3: Significant level between DM control group versus DM Uncontrolled group

Table (5): Correlation between serum Mg with different parameters among DM control group, using Spearman's rank correlation coefficient (rs).

DM Control Group	Serum Mg	
	r-value	p-value
Age (yrs)	0.329	<0.001**
BMI [wt/(ht)^2]	-0.094	0.131
Duration of DM (years)	0.372	<0.001**
HTN	0.102	0.103
Smoking	0.055	0.382
Neuropathy	0.212	<0.001**
Nephropathy	0.046	0.463
Retinopathy	0.046	0.463
SBP (mmHg)	0.143	0.022*
DBP (mmHg)	0.040	0.523
Hb (gm)	-0.162	0.009*
TLC (s/UL)	0.008	0.899
PLT(s/UL)	-0.018	0.769
SGOT (u/L)	0.021	0.737
SGPT (u/L)	-0.010	0.868
Creatinine (mg/dl)	0.294	<0.001**
INR	0.298	<0.001**
FBG*	-0.518	<0.001**
2hr PP (mg/dL)	-0.555	<0.001**
HbA1C	-0.094	0.131
Albumin / creatinine ratio	-0.172	0.006*
Total cholesterol mg /dl	-0.015	0.811
LDL (mg/dl)	0.034	0.592
HDL (mg/dl)	-0.265	<0.001**
Triglyceride (mg/dl)	0.195	0.002*

Table (61): Correlation between serum Mg with different parameters among DM uncontrolled group, using Spearman's rank correlation coefficient (rs).

DM Uncontrolled Group	Serum Mg	
	r-value	p-value
Age (yrs)	-0.379	<0.001**
BMI [wt/(ht)^2]	-0.152	0.014*
Duration of DM (years)	0.061	0.328
HTN	-0.451	<0.001**
Smoking	-0.242	<0.001**
SBP (mmHg)	-0.511	<0.001**
DBP (mmHg)	-0.455	<0.001**
Hb (gm)	-0.348	<0.001**
TLC (s/UL)	0.032	0.605
PLT(s/UL)	-0.200	<0.001**
SGOT (u/L)	-0.105	0.091
SGPT (u/L)	-0.174	0.005*
Creatinine (mg/dl)	-0.737	<0.001**

INR	0.075	0.229
FBG*	-0.574	<0.001**
2hr PP (mg/dL)	-0.597	<0.001**
HbA1C	-0.684	<0.001**
Albumin / creatinine ratio	-0.504	<0.001**
Total cholesterol mg /dl	-0.500	<0.001**
LDL (mg/dl)	-0.567	<0.001**
HDL (mg/dl)	0.493	<0.001**
Triglyceride (mg/dl)	-0.226	<0.001**

Table (7): Multivariate binary logistic regression analysis of most important influencing factors in the Type 2 Diabetes Mellitus.

Factors	□	Odds Ratio			p-value
		OR	Lower	Upper	
Gender	0.175	1.879	1.682	2.096	0.305
Age (yrs)	0.534	2.046	1.585	2.636	<0.001**
BMI [wt/(ht)^2]	0.170	1.574	1.499	1.652	<0.001**
HTN	0.156	0.572	0.231	1.419	0.856
Smoking	0.193	5.467	2.491	14.839	0.867
Neuropathy	1.030	1.611	1.491	1.740	0.863
Nephropathy	1.030	0.768	0.151	1.769	0.867
Retinopathy	0.597	3.059	1.793	5.217	0.867
SBP (mmHg)	1.329	7.792	2.897	15.041	0.044*
DBP (mmHg)	0.222	2.343	1.752	3.134	0.003*
Hb (gm)	0.678	7.251	3.834	20.365	0.241
TLC (s/UL)	0.216	1.747	1.565	1.949	0.112
PLT(s/UL)	0.198	1.902	1.474	2.451	0.296
SGOT (u/L)	0.244	1.464	1.395	1.537	0.171
SGPT (u/L)	1.308	0.531	0.214	1.320	0.159
Creatinine (mg/dl)	1.308	5.084	2.316	13.800	<0.001**
INR	0.759	1.499	1.387	1.618	0.227
FBG*	1.687	0.715	0.141	1.645	0.124
2hr PP (mg/dL)	0.282	2.845	1.668	4.851	0.032*
HbA1C	0.860	7.246	2.694	13.988	<0.001**
Albumin / creatinine ratio	0.274	2.179	1.629	2.915	0.007*
Total cholesterol mg /dl	0.251	6.743	3.565	18.940	0.006*
LDL (mg/dl)	0.311	1.624	1.454	1.813	0.006*
HDL (mg/dl)	1.661	1.769	1.371	2.280	0.008*
Triglyceride (mg/dl)	1.661	1.362	1.297	1.430	0.005*
Serum Mg	0.963	0.494	0.200	1.228	<0.001**

DISCUSSION

According to our results, there was a substantial difference in demographic data about gender, and BMI, with a p-value between the three groups (p<0.05).

In harmony with our findings, **Manonmani et al. [9]** enrolled age differences between the study group of 50 clinically diagnosed type 2 DM patients (25 men and 25 women) and the control group of 50 healthy people (25 men and 25 women) were not statistically significant. However, there was a BMI difference that was statistically different between the study group and the control group.

In the same context as our results, **Radha et al. [10]** enrolled 106 uncontrolled diabetic patients and 100 controlled diabetes patients with 100 non-diabetic subjects as controls and

observed that age was significantly higher in the uncontrolled diabetic group.

Obesity is currently recognized as the most important modifiable risk factor for prediabetes and type 2 diabetes. Depending on the quantity, distribution, timing, and duration of excess weight gain, obesity may eventually lead to a variety of symptoms associated with metabolic syndrome and cardiovascular disease **[11]**. Notably, in addition to how a growing body mass index (BMI) affects the chance of developing type 2 diabetes, a separate positive correlation between central/visceral obesity and T2DM has also been well demonstrated **[12].**

The current study revealed that there was a statistically significant difference between the DM control group and the DM uncontrolled group according to the duration of DM "years". Statistics show that there was a statistically significant difference between the three groups with regard to smoking and HTN risk variables.

In agreement with our study, **Paladiya et al. [13]** enlisted 300 individuals with a confirmed diagnosis of type 2 DM and were divided into diabetic patients and non-diabetic patients in their study, and they discovered a substantial difference between the two groups as regards HTN while smoking was non -significant. HTN incidence was higher in the DM group.

Raoufi et al. [14] studied 117 patients who already had type 2 diabetes, of which 93 (79.5%) had it poorly controlled and 24 (20.5%) had it under control. They discovered that people with well-controlled diabetes and those with poorly controlled diabetes did not have significantly different diabetes durations DM ($p = 0.77$). This variation may result from various populations and sample sizes.

According to statistics, there was a statistically significant difference between the groups in the current study regarding neuropathy, nephropathy, and retinopathy, with a p-value ($p<0.001$).

In agreement with our study, **Odegaard et al. [15]** found that neuropathy, nephropathy, and retinopathy differences between the three groups were statistically significant. Diabetes that is not well controlled is related to several disorders, such as metabolic, cellular, and blood disturbances that can cause oxidative stress and vascular complications like nephropathy, retinopathy, and neuropathy. Increased blood glucose levels caused oxidative stress to be generated, which in turn damaged different organs, vascular endothelium, and hematological and immunological factors.

According to our findings, there was a statistically significant difference between the three groups regarding SBP (mmHg) and DBP (mmHg).

Similarly to our results, **Yossef et al. [16]** conducted a cross-sectional case-control study on 90 patients over the age of 35 and they were split into two groups as follows: 70 participants with type 2 diabetes for at least five years (24 men and 46 women) and 20 participants (seven men and 13 women) and found that SBP and DBP were considerably higher in the diabetic in comparison to the control group.

Wongrith et al. [17] reported that both groups (controlled and uncontrolled DM patients) were able to control blood pressure under criteria that SBP<140 mmHg, and DBP <90 mmHg during one year of monitoring. The average SBP showed the majority in well-controlled (138± 7.53 mmHg), while DBP showed completely controlled in both groups (77.22±5.08 mmHg). Most of all in controlled pressure group can control target blood pressure, while about half of the uncontrolled pressure group can control blood pressure.

There was statistically significant difference between the three groups according to PLT, SGOT (u/L), SGPT (u/L), Creatinine (mg/dl), INR, FBG, 2hr PP (mg/dL), HbA1C, Albumin/creatinine ratio, Total cholesterol mg /dl, LDL (mg/dl), HDL (mg/dl) & Triglyceride (mg/dl), with p-value ($p<0.05$).

This came in line with **Yossef et al. [16]** who found that FBS, PPBS, HbA1c, creatinine level, Alb/Cr ratio, cholesterol, and TG were all noticeably increased in the diabetic group compared to the control group.

Additionally, **Manonmani et al. [9]** found that fasting blood sugar (FBS), PPBS, and lipid profile were noticeably higher in the diabetic group when compared to the control group.

We found that serum Mg level had a higher mean value in Normal Group was 1.97±0.07, followed by DM control group 1.94±0.19, and the lowest value in the DM Uncontrolled Group was 1.48±0.22, with a p-value ($p<0.001$). Hypomagnesemia's higher frequency in the DM uncontrolled group was 92.2%, followed by the DM control group 24.4%, and no hypomagnesemia in the normal Group, with a p-value ($p<0.001$).

This came in consistency with **Khanna et al. [18]** who found that serum magnesium levels in diabetics and controls were found to be considerably different. The average serum magnesium levels were 1.87mg/dL and

2.13mg/dL for both cases and controls, respectively. Hypomagnesemia was 35 times more likely to occur in cases (< 1.80 mg/dL) than controls with p<0.001.

Our present study correlated with other studies that also found low magnesium when levels of type 2 diabetic patients are compared to those of healthy controls **[19, 20, 21]**.

Also, in a study done by **Wahid et al. [22]** 34% of patients of type 2 diabetes mellitus had hypomagnesemia. **Walti et al. [23]** a study carried out in Zurich, Switzerland, found that the prevalence of hypomagnesemia among type 2 diabetics was 37.6% compared to 10.9% in non-diabetic controls.

The study conducted by **Winzer et al. [24]** emphasized that in patients Hypomagnesemia was more frequent in people with type 2 diabetes, Mg absorption is inhibited and its excretion through the kidneys is increased by insulin resistance and insufficiency. Low Mg levels further reduce insulin sensitivity, which affects how its receptors work. The study conducted by **Liotta et al. [25]** discovered that the worst functional results, were intracerebral hemorrhage, hematoma expansion, and low Mg levels. Additionally, Mg plays a substantial part in the clotting processes leading to the idea that hypomagnesemia may contribute to the rupture of cerebral aneurysms.

The current study showed a statistically significant positive correlation between serum Mg with age (yrs), duration of DM (years), neuropathy, SBP (mmHg), Creatinine (mg/dl), INR and Triglyceride (mg/dl), While serum Mg had a statistically significant negative association with Hb (gm), FBG*, 2hr PP (mg/dL), Albumin/creatinine ratio & HDL (mg/dl), with p-value (p<0.05). among the DM control group.

A prior study that supported our findings found that hypomagnesemia is linked to low levels of high-density lipoprotein, as well as increased triglyceride, very low-density lipoprotein, and low-density lipoprotein concentrations. While insulin-induced magnesium entry is restricted in cases of insulin resistance, free magnesium can enter the cell more readily **[26]**. Diabetes complications may also be attributed to magnesium's effects on the functioning of cell membrane ATPase and consequently on the metabolism of intracellular sodium, calcium, and potassium. Chronic hypomagnesemia raises the likelihood of macro and microvascular consequences of diabetes (such as neuropathy) **[27].**

Low magnesium levels increase platelet aggregation and vascular complications, which in turn promote endothelial cell failure and thrombogenesis. The inhibition of it has been demonstrated that thromboxane A2 and magnesium inhibit the formation of the IIb-IIa receptor complex, which prevents platelet activation. Magnesium's impact on intracellular ATPase activity and, in turn, cell membrane Ca^{2+}, Na^{+}, and K^{+} Diabetes problems may also be influenced by metabolism. Chronic hypomagnesemia raises the risk of DM macro- and microvascular complications **[28]**.

Studies by **Lecube et al. [29]** and **Dasgupta et al. [30]** on diabetes and hypomagnesemia found significant negative correlations between Mg and fasting plasma glucose. In another study by **Rao et al. [31]** the mean value of FBS, PPBS, and HbA1C was higher among the group with serum Mg <1.7 mg/dL. In controlling insulin action, insulin-mediated glucose absorption, and vascular tone, intracellular magnesium is essential **[32]**. Diabetes patients' insulin resistance worsens as a result of impaired lowered intracellular Mg concentrations, tyrosine-kinase activity, and insulin action with post-receptor dysfunction **[33]**.

In the present study, there was a statistically significant positive correlation between serum Mg and HDL (mg/dl), with a p-value (p<0.05). While a statistically significant negative correlation between serum Mg with creatinine (mg/dl), HbA1C, Neuropathy, 2hr PP (mg/dL), FBG*, LDL (mg/dl), SBP (mmHg), Albumin/creatinine ratio, Total cholesterol mg /dl, DBP (mmHg), HTN, Age (yrs), Nephropathy, Retinopathy, Hb (gm), Smoking, Triglyceride (mg/dl), PLT(s/UL), SGPT (u/L) & BMI [wt/(ht)^2], among DM uncontrolled group.

In the same line with our findings, **Yossef et al. [16]** showed that serum Mg levels were statistically significant in the negative direction with FBS, 2-h PPBS, and HbA1c (P=0.0001), which agrees with the conclusions of two investigations showing hypomagnesemia was linked to inadequate glycemic control **[6, 30]**.

Siddique et al. [34] discovered that hypomagnesemia is linked to higher HbA1c levels. Also, The serum magnesium level and HbA1c level have a strong inverse relationship. Meanwhile, **Navarrete-Cortes et al. [35]** showed that in diabetic patients with normomagnesemia, using magnesium supplements does not improve insulin sensitivity or HbA1c.

Regarding Mg and lipid profile, **Yossef et al. [16]** demonstrated a serum Mg has a statistically significant negative correlation with serum cholesterol and triglycerides **[36, 37]**, but disagreed with others **[38, 39]**. Patients with

microvascular diabetes complications have a high prevalence of hypomagnesemia **Yossef et al. [16]** study, as 51 (98%) of 52 patients with nephropathy, 20 (95.2%) of 21 patients with retinopathy, 16 (76.1%) of 21 patients with neuropathy, and 20 (95.2%) of 21 Hypomagnesemia was present in retinopathy patients.

This is supported by **Dasgupta et al. [30]** who discovered that hypomagnesemia was connected to retinopathy, nephropathy, and foot ulcers, and **Xu et al. [40]** who came to the conclusion that the decline in blood Mg level or the increase in urine Mg level was not influenced by diabetic nephropathy, retinopathy, or peripheral neuropathy sequelae. Additionally, decreased intestinal absorption brought on by diabetic autonomic neuropathy may contribute to low Mg levels.

According to studies, People with diabetic peripheral neuropathy have reduced intracellular Mg levels. and supplementation improves nerve conduction **[41, 42]**.

Yossef et al. (16) found no significant difference in serum Mg levels between patients with and without nephropathy, but find a statistically significant negative link between serum Mg level and serum creatinine level and albumin/creatinine ratio). Other studies that demonstrated a significant reduction in serum ionized Mg in diabetes patients with microalbuminuria or clinical proteinuria compared to the normoalbuminuria group support this **[6, 43, 44]**.

Also, **Pham et al.** found that lower serum Mg levels in type 2 diabetes patients have been found to have more rapid decreases in renal function, and a subsequent investigation established a strong negative association between serum Mg and estimated glomerular filtration rate **[45, 16]**. Other researchers came to the same conclusion and discovered there was a negative relationship between microalbuminuria and serum magnesium, indicating that hypomagnesemia may be a new indicator of end-stage renal disease in people with type 2 diabetic nephropathy. **[40]**.

Baihui *et al.* found that low serum magnesium levels and microalbuminuria are related in their study of Chinese diabetic patients **[40].** The association between HbA1C and albuminuria and the severity of retinopathy can be accounted for by the similar process of tissue damage brought on by DM. Due to HbA1C's unique affinity for oxygen, tissue becomes anoxic, which aids in the emergence of both micro- and macroangiopathy. In **Kumar et al. [47]** they also discovered a negative connection between serum magnesium levels and urine ACR.

Finally we found that Age (yrs), BMI [wt/(ht)^2], SBP, DBP (mmHg), Creatinine (mg/dl), 2hr PP (mg/dL), HbA1C, Albumin / creatinine ratio, Total cholesterol mg /dl, LDL (mg/dl), HDL (mg/dl), Triglyceride (mg/dl) & Serum Mg, have a significant of most important influencing factors in the Type 2 Diabetes Mellitus. **Ghattaura *et al.* [48]** reported strongest association between BMI with T2DM.

CONCLUSION

Patients with diabetes frequently have hypomagnesemia in comparison to the DM control group, the DM uncontrolled group exhibited a greater frequency of hypomagnesemia. It is linked to poor glycemic control and diabetic consequences include retinopathy, neuropathy, and nephropathy.

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