Impact of Magnesium Intake and Supplementation in Improving the Quality of Life in Type II Diabetes Mellitus-Patients

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Abstract

In recent years, it has been widely accepted that people tend to consume diet that has no nutritive value, leading to nutrient deficiencies of which magnesium deficiency seems to hold pole position. This deficiency is associated with various disorders of which diabetes mellitus has recently been gaining importance. Diabetes Mellitus (T2DM)is a complex, heterogeneous and polygenic metabolic disease where the body fails to utilize insulin, leading to an altered glucose homeostasis. Its pathogenesis involves complex interactions between genetic and environmental factors (Gupta, 2012). The paper focuses on assessing the usefulness of intake of magnesium rich foods and its supplementation in delaying the complications of Diabetes Mellitus and improving the quality of life of the patient. Experimental data has been collected from diabetic patients in order to analyse the levels of magnesium. Analysis was done using SPSS version 16.0. There is a positive correlation between Mg intake, suggesting that the Mg supplementation and intake can delay the development of type 2 DM and improve their quality of life.

Keywords:
Modern Food Technology, Magnesium Deficiency, Diabetes Mellitus, Magnesium Supplementation, Quality of Life

1. INTRODUCTION:

Diabetes Mellitus (T2DM) is a complex, heterogeneous and polygenic metabolic disease where the body fails to utilize insulin, leading to an altered glucose homeostasis. Its pathogenesis involves complex interactions between genetic and environmental factors (Gupta, 2012). It is a serious non-communicable disease that is rising over the years among the global population. The various risk factors attributable to the development of diabetes are obesity due to sedentary lifestyle, hypertension, smoking, etc. The non-modifiable entities are family history, genetic factors and low or high birth weight (Abate & Chandalia, 2003).

In recent years, it has been widely accepted that people tend to consume diet that has no nutritive value, leading to nutrient deficiencies of which magnesium deficiency seems to hold pole position.This deficiency is associated with various disorders of which diabetes mellitus has recently been gaining importance. This holds

credence due to the alarming prevalence of diabetes (25-39%) in people with magnesium deficiency (Hans et al., 2002).

Magnesium, an essential micronutrient is a cofactor for various enzymatic reactions. Its homeostasis is maintained by insulin and glucose and thus, in diabetes mellitus, characterized by insulin resistance and hyperglycaemia, alterations in the levels of magnesium occur. Insulin resistance also has an impact on renal magnesium handling. Magnesium deficiency also leads to oxidative stress, causing a chronic low grade inflammatory state with the elevation of inflammatory markers like HsCRP aiding in the development of macro and micro vascular complications in diabetes mellitus. Hence, hypomagnesemia can be considered both a cause as well as a consequence of diabetes mellitus (Abate & Chandalia, 2001).

This paper deals with the perception study on the impact of magnesium intake and investigates the association between magnesium intake, serum magnesium levels and insulin resistance in type 2 DM patients.

2. REVIEW OF LITERATURE:

Diabetes mellitus (type 2) one of the most common chronic diseases is a deterrent to the overall quality of life, due to its micro and macro vascular complications. In 2011 there were about 366 million people with diabetes globally and this is expected to rise to 552 million by 2030 (Abate & Chandalia, 2003).

According to World Health Organisation (WHO) criteria, the prevalence of diabetes was 5.6 per cent in the urban population compared to the 2.7 per cent in the rural population while the prevalence of diabetes according to the American Diabetes Association (ADA) criteria was 4.7 and 2.0 per cent among urban and rural areas respectively (Qatanani & Lazar, 2007).

The alleged "Asian Indian phenotype", refers to unique clinical and biochemical abnormalities which include increased insulin resistance, greater abdominl adiposity i.e., higher waist circumference despite lower body mass index, lower adiponectin and higher high sensitive C-reactive protein levels. Thus due to this phenotype and genetic factors Asian Indians more prone to diabetes and premature coronary artery disease. However, the primary driver of the epidemic of diabetes is the rapid epidemiological transition associated with changes in dietary patterns, namely the advent of the fast-food culture and decreased physical activity causing obesity, as evident from the higher prevalence of diabetes in the urban population (Pleshchitser, 1958).

Type 2 Diabetes Mellitus, a metabolic disease characterized by hyperglycaemia, insulin resistance is caused due to various factors. Among them, obesity is fast becoming one of the leading causes of insulin resistance. Insulin resistance refers to the diminished ability of cells to respond to the action of insulin in transporting glucose from the bloodstream into muscle and other tissues.Obesity occurs due to sedentary lifestyle and reduced physical activity, complicated by the consumption of micronutrient deficient diet. (IL 6 is a cytokine that closely relates obesity to insulin resistance. Plasma IL-6 concentrations more reliably predict the development of T2DM as it impairs insulin signaling by causing down-regulation of IRS and up-regulation of SOCS-3. Adipose tissue IL-6 expression accounts for 30% of systemic IL-6 but circulating IL-6 concentrations are positively correlated with obesity, impaired glucose tolerance, and insulin resistance. Hence, peripheral administration of IL-6 induces hyperlipidemia, hyperglycemia, and insulin resistance in rodents and humans (Qatanani & Lazar, 2007).

In addition to obesity, hypertension, smoking and alcohol, genetics etc. also cause insulin resistance.

- Hypertension causes stimulation of growth factors, increased cellular Ca2+ accumulation, decreased Na+K+ ATPase activity leading to insulin resistance.
- Alcohol and smoking- retard the absorption of magnesium aggravating insulin resistance (Fawcett, Haxby, & Male, 1999).
- The gene for the membrane glycoprotein PC-1 is considered to be a candidate for insulin resistance, since this protein has been shown to inhibit tyrosine kinase activity of the insulin receptor in cultured fibroblasts (Saris et al., 2000).

Apart from this, dietary insufficiencies, namely magnesium deficiency is more commonly linked to insulin resistance because it causes an impairment in the insulin signalling pathway, aggravating the insulin resistance state and also brings about a state of oxidative stress, leading to chronic inflammation with the elevation of inflammatory markers like HsCRP (Walker, 1985).

2.1 MAGNESIUM:

Mg is the fourth most abundant cation in the body and the second-most predominant component in the intracellular compartment next to potassium. It is an important regulator of various cellular processes, co-factor for more than 300 essential metabolic reactions, including the ones that produce or use the Mg-ATP complex, some of which are,

- Synthesis of nucleic acids and proteins,
- energy metabolism and production,
- cell cycle progression ,
- cytoskeletal function,
- maintenance of membrane integrity and stability
- ion homeostasis (Belin & He, 2007).

Mg2+ is also required by all enzymes involved in the phosphoryl group transfer reactions such as protein kinases and phosphatases (e.g. ATPases) (Belin & He, 2007) (Saris et al., 2000).
In our body, the total Mg2+ pool is localized to three compartments:
1. Bone (65%),
2. Intra-cellular soft tissues such as muscles (34%), and
3. Extra-cellular compartment (1%)

Extracellular Mg2+ constitutes only 0.3% of total body Mg2+ ,out of which 70-80% o exists in the biologically active ionized (free) form, while the remainder is bound to circulating proteins (e.g. albumin) (20-30%) or complexed to anions(e.g. phosphate, citrate, bicarbonate) (1-2%). Most of the intracellular magnesium is located within the mitochondria because magnesium binds strongly with ATP. In general, the more metabolically active the cell is, the higher its magnesium content.
Plasma levels of magnesium in healthy people are found to be remarkable constant, with an average of 1.7–2.4 mg/dl (0.7–1.0 mmol/l). Clinically Hypomagnesaemia may be defined as serum Mg concentration <1.6 mg/dl (Laurant & Touyz, 2000).

Until now, the function of magnesium in biological processes was largely ignored to the point where it was relegated as the 'forgotten' ion. Recently, there has been an explosion of interest in the physiological and therapeutic properties of this essential element.
It is been discovered that magnesium is involved in several processes, including hormone receptor binding and gating of calcium channels, transmembrane ion flux, regulation of adenylate cyclase, muscle contraction and neuronal activity, control of vascular tone, cardiac excitability and neurotransmitter release. It increases the body's ability to utilize calcium, phosphorus, sodium, potassium, vitamins C, E and B complex (Kirschmann, 1996).

2.2 DIETARY SOURCES OF MAGNESIUM:

The alimentary source of Mg include milky products, whole grains, cereals, legumes, vegetables (especially broccoli, squash and green leafy vegetables), nuts and seeds, crude barn (especially almonds, sesame seeds, hazelnuts, Watermelon seeds), dry beans, peas, lentils and products derived from soy. All varieties of crude barn i.e. crude rice, crude wheat, crude oat barn are good sources of Mg2+. Other sources include meats, poultries and fishes etc.

Water with high mineral content or "hard" water, is also a source of magnesium. Grains,beans ,nuts also contain phytanic acid which prevents the absorption of magnesium and other minerals. It has been estimated that refining and processing of food causes a substantial loss of magnesium. For example, refining of rice to polished rice causes a loss of 83 % of the original Mg2+content. Thus, modern food technology partially explains why a significant segment of the population has an intake of magnesium below recommended dietary amounts predisposing them to a chronic, latent magnesium deficiency (Marier, 1985).

Epidemiological and multi-centric studies have registered an inverse relationship between the ingestion of Mg 2+ rich food and the risk of diabetes. In the Iowa Women's Healthy Study, a cohort of postmenopausal women showed a significant reduction in the relative risk of diabetes in women with increased intake of whole grains and other foods which are good sources of Mg. The Framingham Offspring Study notified a reduction in the metabolic risk factors for the development of diabetes, associated to the whole grains intake. Other cohort studies carried out with men and women have also verified an inverse association between Mg2+ intake and the risk of type 2 DM. Hence, there is a positive correlation between insulin sensitivity and Mg intake, suggesting that the Mg supplementation can delay the development of type 2 DM.

2.3 HOMEOSTASIS OF MAGNESIUM:

The homeostasis of Mg2+ depends on the amount ingested, efficacy of the intestine to absorb and the capacity of the kidney to excrete (Walker, 1985). The homeostatic regulation of Mg is increased by the action of parathormone (PTH), calcitonin, vitamin D, glucagon, antidiuretic hormone, aldosterone and sexual steroids. Beyond these, insulin is involved in the transport of Mg through the cellular membrane intra-cellularly. A normal person may requires approximately 300 mg of magnesium per day.

Several drugs, particularly diuretics, thiazides, cisplatin, gentamycin and cyclosporin cause magnesium loss in urine by inhibiting magnesium re-absorption in the kidneys. Lipid-lowering drug treatment in type-2 diabetic patients has recently been added to that list (H ardwick, Jones, Brautbar, & Lee, 1991).

2.4 MAGNESIUM DEFICIENCY:

Magnesium deficit can be categorized into two types: magnesium deficiency and magnesium depletion. Dietary amounts of magnesium are taken marginally in our population and little alteration in magnesium intake may increase the prevalence of magnesium deficiency. Magnesium depletion may be due to dis-regulation of factors controlling magnesium homeostasis: intestinal hypo-absorption of magnesium, reduced uptake and mobilization of bone magnesium, sometimes urinary leakage, hyper-adrenoglucocorticism by decreased adaptability to stress, insulin resistance and adrenergic hypo-receptivity.

Magnesium deficiency in old age results from various pathologies and treatment to elderly persons, i.e. diabetes mellitus and use of hyper-magnesuric diuretics. Osmoticdiuresis caused by glycosuria (as in diabetes mellitus), mannitol and urea results in urinary magnesium wasting. It has been suggested that aging, stress and various disease states may increase magnesium requirement. Magnesium deficiency co-exists with electrolyte abnormalities, particularly hypokalemia and to a lesser extent, hyponatremia or hypocalcaemia.

Patients with hypo-magnesemia can present with cardiovascular alterations, such as ischemic cardiac insufficiency, vascular complications of DM and hypertension. Neurological, hormonal, renal, gastro-intestinal and muscular dysfunction have also been associated to hypo-magnesemia. There were speculations about a possible relation between Mg deficiency and climatic variations, contributing to the increase in deaths due to cardiovascular disease and diabetes. High temperatures would increase sweat loss and consequently, among the minerals, Mg would be the most affected, because the losses would not be compensated by the diet and water intake. Hence, in our country there is an increasing risk of diabetes (Hans et al., 2002).

2.5 MAGNESIUM AND INSULIN:

Plasma Mg and $[Mg^{2+}]_i$ concentrations are tightly regulated by several factors . Among them, insulin is an important modulator of the cellular content of Mg, as it causes the shift of Mg from extracellular to intracellular spaces. It also regulates $[Mg^{2+}]_i$ concentration by stimulating the plasma membrane adenosine triphosphate (ATPase) pump and erythrocyte Mg uptake. Insulin starts its action by binding to specific cell surface receptors on target tissues.

2.6 HYPOMAGNESEMIA, INSULIN RESISTANCE IN DIABETES:

It is believed that in diabetes, osmotic diuresis clearly accounts for a portion of the magnesium loss and glycosuria impairs renal tubular re-absorption of magnesium from the glomerular filtrate resulting in hypo-magnesemia. Hence Magnesium deficiency has been interlinked with insulin resistance, carbohydrate intolerance, accelerated atherosclerosis, dyslipidemia and hypertension. The renal magnesium handling may be modulated by glucose and insulin even in non-diabetic individuals, where the administration of insulin with or without glucose increases urinary magnesium excretion rates. A rise in the urinary magnesium excretion rates in diabetic patients with increasing insulin dosage has been reported despite maintenance of serum levels, suggesting the effect of insulin on renal magnesium handling (Hans et al., 2002).

The Recommended Daily Allowance (RDA) for magnesium for individuals varies with age. For women and men aged 19 to 30 are 310 mg/day and 400 mg/day, respectively (Marier, 1985). The RDA for women aged 31 and older is 320 mg/day; for men, it's 420 mg/day. As those affected do not consume the fully-recommended daily allowance for magnesium, hence dietary magnesium intake also an adverse factor in its deficiency. Glycemic control in patients with type-2diabetes, however, may not correct low magnesium concentrations, suggesting that other factors may regulate magnesium levels in diabetic patients.

The existence of a close relationship between metabolic control and impaired magnesium balance was confirmed by Fujii *et al.,* who observed that a marked depletion in plasma and erythrocyte magnesium levels was particularly evident in diabetic patients with advanced retinopathy and poor diabetic control. This relationship between magnesium and glucose metabolism is supported by a recent epidemiological study showing that deficient magnesium intake is a risk factor for the development of type-2 diabetes independent of age, body mass index, alcohol intake and family history of diabetes.

Thus, Magnesium, through its emerging importance in metabolic functions is increasingly recognized as an important dietary nutrient.

In summary, taken together, intracellular Mg2+ deficiency results in enhanced oxidative stress and reduced antioxidant defense, which promotes inflammation, lipid oxidation, insulin resistance, pancreatic-cell dysfunction, vascular remodeling, and atherosclerosis. Thus it is evident to study the effect of magnesium deficient diet on DM patients.

3. OBJECTIVE:

1. To study the socio-demographic factors that affect DM and non-DM individuals .
2. To study the environmental factors that affect DM and non-DM individuals .
3. To study the food habits in DM and non DM individuals
4. To study the effect of Magnesium supplementation on DM individuals.
5. To study the impact of complications on DM individuals.
6. To compare magnesium levels in DM individuals on Mg supplementation and complications with healthy controls and evaluate their usefulness as a contributing factor in the development of various complications.

4. **METHODOLOGY**:

4.1 STUDY DESIGN: Descriptive and case control study

4.2 STUDY CENTRE: Department of Diabetology

4.3 STUDY POPULATION:

Cases for perception study:
194 individuals with type 2 diabetes mellitus.
Controls:
180 healthy individuals
Cases for observation study:
30 individuals with type 2 diabetes mellitus on Mg supplementation.
30 individuals with type 2 diabetes mellitus and complication
Exclusion criteria: individuals on insulin therapy, antacids, renal disorder, lipid lowering drugs, hypo-albuminemia
Controls:
30 healthy age and sex matched individuals.

5. **DATA COLLECTION PROCEDURES AND INSTRUMENTS USED**:

Data collection for perception study was primary data, collected through questionnaire. Data for observation study is done using standardized proforma by the principal investigator .All the biochemical analyses will be performed using automated (alpha-IMMUCHEM)and semi-automated(MERCK) clinical chemical analyzer.

6. DATA ANALYSIS AND INTERPRETATION:

6.1 PERCEPTION STUDY:

Application of statistical tool using SPSS package:
Chi – square test – χ^2

It is one of the most important non parametric tests. χ^2 is a Greek word 'Chi'. It was first used by Karl Pearson in 1990. χ^2 describe the magnitude of the discrepancy between theory and observation defined as:-

$$\chi^2 = \frac{(O-E)^2}{E}$$

Where O is the Observed frequency
E is the Expected frequency

$$E = \frac{(RT \times CT)}{N}$$

Where RT = Row total for the row containing the cell.
CT = Column total for the column containing the cell
N = Total number of observations

The calculated value of χ^2 is compared with the table value for the given degrees of freedom at a certain level of significance (Say 5%). If the calculated value is greater than table value, the difference is considered significant, on the other hand, if calculated value is lesser, the difference is not considered significant.

Characteristics		Diabetic N=194	Non Diabetic N=180	Total [374]	Chi Square Test Value
Age group	<40	5	7	12	10.474
	40-50	20	27	47	
	50-60	92	78	170	
	60-70	72	62	134	
	70-80	5	6	11	
Residence	Urban	35	49	84	4.52
	Rural	159	131	290	
Income Group	<5000	114	77	191	12.196
	5001-30000	61	67	128	
	>30000	19	36	55	
Educational Status	Illiterate	139	111	250	7.54
	Basic	17	21	38	
	U.G.	30	29	59	
	P.G.	8	19	27	
Marital Status	Married	180	168	348	0.978
	Single	7	6	13	
	Others	7	6	13	
Water	Treated Water	187	175	367	1.866
	Hard Water	7	5	7	

Table-1 : Socio-demographic characteristics and environmental related factors affecting DM and non-DM individuals.

Eating Habits		Diabetic N=194	Non Diabetic N=180	Total [374]	Chi Square Test Value
Frequency of eating Dairy products	Everyday	6	15	21	20.107
	Two Days Once	12	32	44	
	Once a Week	69	62	131	
	Once a Month	107	71	178	
Frequency of eating green Leafy Vegetables	Everyday	32	25	57	10.142
	Two Days Once	45	69	114	
	Once a Week	92	68	160	
	Once a Month	25	18	43	
Taking Nuts after a meal	Yes	39	57	96	6.544
	No	155	123	279	

Table-2: Diabetic people and their food habits.

Among the statistical methods of analysis, chi square methods is used for the study. The association between diabetic and its independent variable was examined by chi-square test analysis.

The mean age of the DM patients was 60 years old (range from 35-80). Five (1.3%) were <40 years old and five (1.3%) were 70-80 years old. Majority of the study group were 50- 60 years old. Two hundred and ninety (77.5%) of the women came from rural and eighty four (22.5%) came from urban. Out of 374 patients 250 (66.8%) illiterate, 38(10.8%) basic education, 59 (15.8%), U.G., and 27(7.2%) were P.G. One hundred and ninety seven (52.7%) women were house wife and 140 (37.4%) were of working group. Three hundred and forty eight women (93%) were married. The mean monthly income of the women was 338.28 (range from 70 – 1000).

6.2 OBSERVATION STUDY:

The study was conducted on the 30 cases of Diabetes Mellitus on Mg supplementation, 30 cases of Diabetes Mellitus with complications from the 190 DM and 30 age and sex matched healthy controls from 184 non-DM individuals. Diabetic patients on diuretics, statin therapy were excluded.

Statistical analysis performed using SPSS package

a) Spearman's rank correlation used for uni-variate analysis.
b) The groups are compared using analysis of variance & t test.
c) p-value of <0.05 is considered significant

Variable	Group	N	Mean	Std. Deviation	P-Value
Serum Mg2+	Case-1	30	2.59	0.97	<0.001
	Case-2	30	1.71	0.38	
	Control	30	2.39	0.51	
	Total	90	2.23	0.74	
Urine Mg 2+	Case-1	30	0.18	0.19	<0.001
	Case-2	30	0.06	0.06	
	Control	30	0.60	0.89	
	Total	90	0.28	0.57	

TABLE 6:

Serum magnesium levels were found to be significantly higher among case 1 than case 2 when compared to controls. Mean levels in case 1=2.59 mg/dl, case 2=1.71 mg/dl, controls=2.39 mg/dl ($p<0.001$) .Urine magnesium levels were low when compared to controls. Mean levels in case 1=0.18 mg/dl, case 2 =0.06 mg/dl, controls = 0.60 mg/dl.
($p<0.001$)

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DISCUSSION:

The presence of diabetes was assessed based on socio-demographic characteristics of the study subjects. Age, residence, occupation, income family, marital status and educational status were taken as study variables to see the outcome of dependent variable. There was a statistical significant association between all categories of socio demographic variables and diabetes with chi-square test analysis (table 1).

One of the major contributory factors in developing countries is consumption of plant based food containing sufficient magnesium. The current study tried to assess different dietary risk factors for diabetes. Drinking hard water, eating green leafy vegetables and taking nuts after meal showed a statistical significance difference with diabetes on chi-square test analysis but none of them showed a statistical significant difference with diabetes on multivariate analysis which may be due to difference in eating habit between diabetic and non-diabetic group.

Alterations in the metabolism of trace elements like magnesium have been associated with the pathogenesis of diabetes mellitus. Several studies have supported the fact that intra-cellular magnesium deficiency plays an important role in the development of insulin resistance, glucose tolerance, oxidative stress and inflammation leading to micro and macro vascular complications. This study is a case control study with 30 cases of Diabetes Mellitus on Mg supplementation, 30 cases of diabetes mellitus with complications and 30 healthy age and sex matched individuals.($p< 0.903$)

The mean serum level of Mg^{2+}in case 1 was 2.59 ,case 2 was 1.71 and controls was 2.39 ,($p<0.001$).Our study supports several other studies like *Arunthati Dasgupta ,Dipti Sarma ,Umakaimal Saikia:Hypomagnesemia in type 2 diabetes Mellitus* (Dasgupta, Sarma, & Saikia, 2012) which showed serum hypo-magnesemia among diabetes mellitus patients. Serum magnesium is significant between Case 1 and case 2 .But when complications set in, serum magnesium levels are drastically reduced in case 2. Controls have high level of Mg 2+ because of their insulin sensitivity. *The Phuong-chi t Pham :Hypomagnesemia in patients with type 2 diabetes* (Pham, Pham, Pham, Miller, & Pham, 2007*)* study supports this. An inverse correlation between plasma concentration of magnesium and glucose was found in *Mather HM et al. Diurnal profiles of plasma magnesium and blood glucose* (Mather et al., 1982) *in diabetes study*. Similarly, an inverse correlation between serum magnesium levels and duration of diabetes was found in *Ewald U, Gebre-Medhin M,Tuvemo T Hypomagnesemia in diabetes children* (Ewald, GEBRE-MEDHIN, & Tuvemo, 1983).

In our study, urine magnesium levels were found to be significantly lower in case 1 and case 2 with the mean of 0.18 and 0.06 respectively when compared to the controls with a mean of 0.60. ($p<0.001$).Thereby, the hypomagnesuric state is caused due to reduced insulin resistance and deficient magnesium in the diets of patients with type 2 diabetes. Insulin resistance may exacerbate renal wasting because of its magnesuric effect, acting on both the Thick ascending limb and Distal convoluted tubule, which is stated in "*Phuong-chi t Pham :Hypomagnesemia in patients with type 2 diabetes* ''study (Takaya et al., 2004). According to the study *"Chinyerel N.A et al "Serum and Urine Levels of Chromium and Magnesium in Type 2 Diabetics in Calabar*" (Chinyere, Opara, Henrieta, & Nathaniel, 2005) the Food Frequency Questionnaire was used to assess the Mg2+ intake in diabetic subjects. This showed a significant dietary Mg2+ restriction among case 2 population. In

presence of reduced dietary intake, the re-absorption by the kidneys is increased and thus limits Mg2+ loss in urine. This serves as a cause of reduced urinary Mg2+ excretion, as the renal re-absorption of Mg2+ is inverse to the gastric intake.

There was a significant correlation between blood sugar and serum Mg 2+ levels .This association is supported with results from several studies like *Chetan P. Hans, R.sialy ,Devi D. Bansal:Magnesium deficiency and Diabetes mellitus (Hans et al., 2002)*

7. CONCLUSIONS:

Diabetics is a global public health problem affecting both developing and developed countries with major consequences for human health as well as social and economic development. Food rich in Mg are dairy products, green leafy vegetables, nuts, which when consumed reduces the chance of acquiring diabetes and also reduces the consequences of diabetes.

The Serum Mg2+ levels were found to be significantly reduced among case 2 and can be attributed to the Insulin Resistance and prevalence of complications due to DM. Urine Mg2+ is reduced due to insulin resistance and dietary magnesium deficiency in Case 2.

Serum Mg2+levels were assayed and found to be higher in controls because of insulin sensitivity. Serum Magnesium levels in case 2 individuals were found to be significantly lower since complications had set in .This may be attributed to Insulin Resistance and deficient dietary magnesium intake among the case 2 individuals. The Insulin resistance among cases accounts for increased magnesium absorption in the tubules, causing decreased urinary Magnesium levels when compared with the controls.

Among the parameters constituting diabetes mellitus, serum Mg 2+ and urine Mg2+ were found to be significant. Since serum Mg2+ is higher in case 1 individuals intracellular Mg2+ content should not be affected. In case 2 individuals serum Mg 2+ is reduced because insulin resistance is present with complications. In clinical practice, patients who are at risk for Diabetes mellitus could be screened for Mg2+ status. An abnormal Mg2+ state, if detected, should be treated by Mg2+ supplementation and increase in a Mg2+ rich diet. Also, such patients should be advised on lifestyle modifications such as physical activity, which improves insulin sensitivity and thus, the efficacy of Mg2+.

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