Association of Serum Magnesium Levels with Homeostatic Model Assessment of Insulin Resistance in Patients with Type 2 Diabetes Mellitus on Metformin or Pioglitazone

by Sony Wibisono

Submission date: 30-Aug-2020 12:46PM (UTC+0800)
Submission ID: 1376166345
File name: naskah.pdf (574.9K)
Word count: 3951
Character count: 19835

ASIAN JOURNAL OF PHARMACEUTICAL AND CLINICAL RESEARCH

NNOVARE ACADEMIC SCIENCES
Knowledge to Innovation

Vol 12, Issue 6, 2019

Online - 2455-3891
Print - 0974-2441

Research Article

ASSOCIATION OF SERUM MAGNESIUM LEVELS WITH HOMEOSTATIC MODEL ASSESSMENT OF INSULIN RESISTANCE IN PATIENTS WITH TYPE 2 DIABETES MELLITUS ON METFORMIN OR PIOGLITAZONE

HUWAINAN NISA NASUTION[1,2], SONY WIBISONO MUDJANARKO[1], DWI APRILAWATI[3], AGUNG PRANOTO[1]

[1]Department of Internal Medicine, Airlangga University, Indonesia. [2]Department of Internal Medicine, Muhammadiyah University of North Sumatera, Indonesia. [3]Department of Public Health and Preventive Medicine, Airlangga University, Indonesia.
Email: huwainannisa@gmail.com

Received: 14 March 2019, Revised and Accepted: 19 April 2019

ABSTRACT

Objective: The aim of this study is to analyze the association between serum magnesium (Mg) level with insulin resistance in patients with type 2 diabetes mellitus (DM) who had taken metformin or pioglitazone. In a hypomagnesemic state, there is a decrease in the phosphorylation of insulin receptor which leads to an increase in insulin resistance.

Methods: The inclusion criteria were patients of type 2 DM who had already used metformin or pioglitazone with a body mass index of <30 kg/m^2. An examination of Mg nutrient intake on the patients was carried out with a validated food frequency questionnaire of nutrient intake for the past 3 days by a nutritionist. Fasting plasma glucose was analyzed using *Roche/Hitachi Cobas C System*. Fasting insulin was analyzed using the *Elecsys and Cobas E Immunoassay Analyzers*. Serum Mg level was analyzed using *Roche/Hitachi Cobas C 311/501 System.*

Results: The study involved 41 subjects of patients with type 2 DM. The mean of Mg nutrient intake was still low with an average of 207.2±90.5 mg/d. The mean value of serum Mg levels was 0.83±0.07 mmol/l. The mean of homeostatic model assessment of insulin resistance (HOMA-IR) was 4.82±5.66. The lower level of the serum Mg had a significant correlation with HOMA-IR.

Conclusion: The nutrient intake containing Mg is lower than the recommendation. There is a significant negative correlation between the Mg level and HOMA-IR on type 2 DM on metformin or pioglitazone.

Keywords: Serum magnesium levels, Insulin resistance, Homeostatic model assessment of insulin resistance, Type 2 diabetes mellitus.

 DOI: http://dx.doi.org/10.22159/ajpcr.2019.v12i6.33061

INTRODUCTION

Death due to type 2 diabetes mellitus (DM) increased in line with a number of patients with type 2 DM. The data indicate that every 10 s, there is a death of a person due to the complications of type 2 DM worldwide [1]. One of the causes of increasing complication in type 2 DM is hypomagnesemia [2,3]. Hypomagnesemia is known to be associated with an increase in insulin resistance in type 2 DM resulting in the accelerated progression of the disease causing the risk of complications in type 2 DM [4,5].

The prevalence of hypomagnesemia in patients with type 2 DM varies between 13.5 and 47.7% [4]. In Indonesia, there have been no data on the prevalence or incidence of hypomagnesemia in type 2 DM. Hypomagnesemia has its contribution to the worsening of glycemic control, and if it is not controlled, it can lead to complications of type 2 DM in certain periods of time [6-10]. Additional data related indicate that hypomagnesemia is associated with the incidence of retinopathy, nephropathy, and diabetic feet as the complications of type 2 DM [7,9,10].

Physiological magnesium (Mg) has an important role in carbohydrate metabolism. It is as a cofactor of glucose transport mechanism in membrane cells and various enzymatic reactions to carbohydrate oxidation [11]. The existence of hypomagnesemia can affect the insulin sensitivity [3,12]. The role of Mg in the insulin sensitivity is situated on the autophosphorylation of the β-subunit insulin receptor. The crystalline structure of the insulin receptor tyrosine kinase shows the presence of two Mg ions that bind to the domain of tyrosine kinase [12]. In a hypomagnesemic state, there is a decrease in the phosphorylation of the insulin receptor which leads to an increase in insulin resistance.

In this study, the association of serum Mg level and homeostatic model assessment of insulin resistance (HOMA-IR) in patients with type 2 DM on metformin or pioglitazone is analyzed. Author's also studied the profile of Mg nutrient intake in patients with type 2 DM. According to the author's knowledge, no comprehensive work was dedicated to analyze this association in patient with type 2 DM on metformin or pioglitazone treatment. It is highly expected that this study can provide some information to prevent the worse condition of patients with type 2 DM since Mg serum level is contributing to the insulin resistance in patients with type 2 DM.

METHODS

This study is an observational analytic study with cross-sectional design conducted at Private Practice of Internists of Metabolic and Diabetes Endocrinology Consultants in Surabaya, Indonesia. The study was approved by the Committee of the Health Research Ethics of the Faculty of Medicine, Airlangga University, Surabaya. The inclusion criteria were patients with type 2 DM, more than 18 years, use of metformin ≥750 mg/d for at least 3 weeks or pioglitazone ≥15 mg/d for at least 4 weeks, and the body mass index (BMI) <30 kg/m^2. The exclusion criteria included impaired renal function with serum creatinine >106.08 µmol/l for women and >132.6 µmol/l for men, pregnant or lactating women, acute infections or inflammation, gastrointestinal and chronic liver diseases, history of drinking alcohol or smoking, taking proton-pump inhibitors, diuretics, aminoglycoside drugs, amphotericin B, vitamin and mineral supplementation, steroids, and history of getting therapy of cetuximab, erlotinib, cisplatin, carboplatin, cyclosporine, or tacrolimus.

An examination of nutritional intake containing Mg was carried out through validated food frequency questionnaires based on recall and record of nutrition intake for the past 3 days by nutritionists, and then, the examinations of the fasting plasma glucose, fasting insulin, and serum Mg levels after fasting 10–12 h were done. Fasting plasma glucose was analyzed using *Roche/Hitachi Cobas C System*. Fasting insulin was analyzed using the *Elecsys and Cobas E Immunoassay Analyzers*. Serum Mg level was analyzed using *Roche/Hitachi Cobas C 311/501 System*. HOMA-IR was calculated using the formula [13]:

HOMA-IR = {fasting insulin [mIU/l] × (fasting plasma glucose [mmol/l]/22.5)}

All data were analyzed using SPSS version 20.0 software. Bivariate analysis of correlations among the variables was performed by Pearson test or Rank Spearman test. Multivariate analysis was performed by multiple logistic regression. The results were presented in correlation coefficient (r value), and the significant p<0.05 and confidence interval was 95%.

RESULTS

The study involved 41 subjects of patients with type 2 DM who had met the inclusion and exclusion criteria. The characteristics of subjects are shown in Table 1 and Figs. 1 and 2. The mean of serum Mg levels was 0.83±0.07 mmol/l. The mean Mg nutrient intake was 207.2±90.5 mg/d. Unfortunately, not all study subjects were willing to be examined. Six of them refused to conduct the nutritional examination. The mean of HOMA-IR was 4.82±5.66.

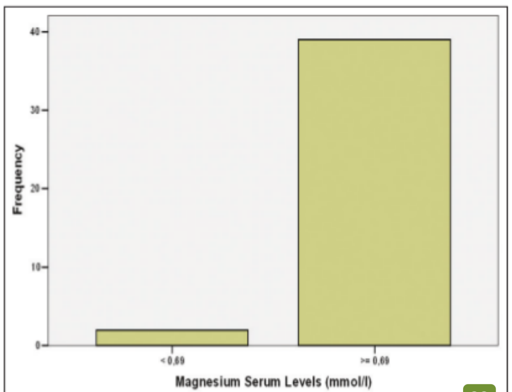

Fig. 1: Graph of serum magnesium levels. Sample size=41, serum magnesium levels <0.69 mmol/l=4.9%, serum magnesium levels ≥0.69 mmol/l=95.1%

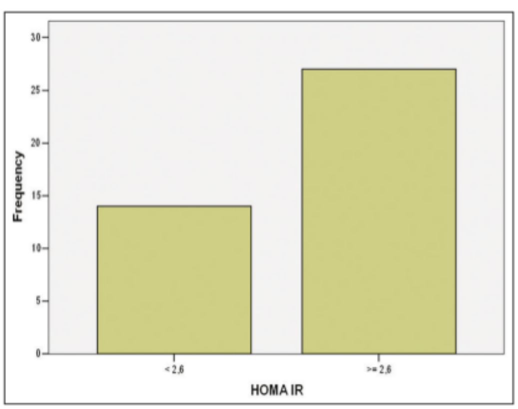

Fig. 2: Graph of serum magnesium levels. Sample size=41, homeostatic model assessment of insulin resistance (HOMA-IR) <2.6=34.1%, HOMA-IR ≥2.6=65.9%

Bivariate analysis using with Rank Spearman test related to the factors that influence HOMA-IR. Serum Mg levels and using insulin had a significant negative association with HOMA-IR. These data are shown in Table 2. Multivariate analysis was continued using multiple logistic regression with HOMA-IR which was categorized into HOMA-IR <2.6 and HOMA IR ≥2.6. Table 3 indicates the results of multivariate analysis describing that only serum Mg levels were significantly negatively associated with HOMA IR with p=0.024 and odds ratio 0.004 (0.000–0.489). The equation for multiple logistic regression is y = −5.55x + 12.113. Fig. 3 shows a graph of correlation of serum Mg level and HOMA-IR.

Table 1: Characteristics of the study participants

Characteristics	n=41
Female, n (%)	30 (73.2%)
Age (years), mean±SD	60.3±11.5
Duration of type 2 diabetes mellitus (years), mean±SD	11.8±10.11
Dyslipidemia, n (%)	25 (65.9)
Use of statin, n (%)	27 (65.9)
Use of antihypertensive, n (%)	5 (12.2)
Use of insulin, n (%)	13 (31.7)
BMI (kg/m2), mean±SD	25.4±2.8
Fasting plasma glucose (mmol/l), mean±SD	7.31±2.27
Postprandial plasma glucose (mmol/l), mean±SD	10.26±4.35
HbA1c (%), mean±SD	7.44±1.57
Fasting insulin (mIU/l), mean±SD	14.04±11.71
HOMA IR, mean±SD	4.82±5.66
Total cholesterol (mmol/l), mean±SD	4.33±0.98
Triglyceride (mmol/l), mean±SD	1.44±0.59
LDL (mmol/l), mean±SD	2.48±0.88
HDL (mmol/l), mean±SD	1.23±0.39
Serum creatinine (μmol/l), mean±SD	69.83±15.91
eGFR (ml/min), mean±SD	86.8±17.62
Serum magnesium (mmol/l), mean±SD	0.83±0.07
Magnesium intake (mg/d), mean±SD	207.2±90.5

Sample size=41, BMI: Body mass index, eGFR: Estimated glomerular filtration rate, HbA1c: Glycated hemoglobin, HDL: High-density lipoprotein, HOMA-IR: Homeostatic model assessment of insulin resistance, LDL: Low-density lipoprotein, SD: Standard deviation

Table 2: Bivariate analysis of factors influencing HOMA-IR

Independent variable	r value	p-value
Age of patient	0.222	0.162
BMI	0.136	0.398
Dyslipidemia	−0.146	0.363
Serum magnesium	−0.375	0.016
Use of statin	−0.146	0.363
Use of antihypertensive	−0.085	0.597
Use of insulin	0.346	0.027

Sample size=41, BMI: Body mass index, r: Correlation coefficient, HOMA-IR: Homeostatic model assessment of insulin resistance

Table 3: Multivariate analysis of factors influencing HOMA-IR

Factor	p-value	OR	95% CI	
			Min	Max
Use of insulin	0.206	0.321	0.055	1.867
Serum magnesium	0.024	0.004	0.000	0.489
Dependent variable	HOMA IR			

Sample size=41, CI: Confidence interval, HOMA-IR: Homeostatic model assessment of insulin resistance, Min: Minimal, Max: Maximal, OR: Odds ratio

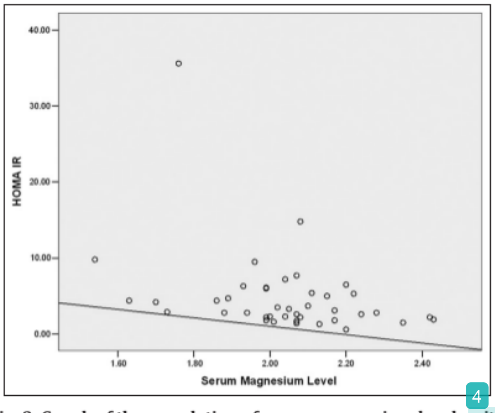

Fig. 3: Graph of the correlation of serum magnesium levels with homeostatic model assessment of insulin resistance. Sample size =41, correlation coefficient −0.375

DISCUSSION

Characteristics of subjects were dominated by women. It is different from previous studies in India of Chutia and Lynrah (2015) and Gupta *et al.* (2014), in which men were dominant. This study is in line with the data in Indonesia taken from Indonesian Ministry of Health 2014, indicating that diabetics were indeed dominated by women [8,14,15]. This difference in results can be due to different characteristics between India and Indonesia. The most dominant age group was 46–60 years (46.3%). A different thing was shown by Gupta *et al.* (2014) in India, in which the age group of 34–45 years was dominated [8]. The study is in line with the report of Indonesian Ministry of Health 2014 showing the dominance of the 45–64 years age group [15]. Similar data were shown by Nguyen *et al.* (2012) in 144 type 2 DM patients in New Orleans showed the incidence of type 2 DM increased with age in both different races and genders [16]. These data support the result of this study that the incidence of type 2 DM increased with age. The mean of BMI in this study was 25.4±2.8 kg/m^2. It has been noticed that obesity itself is a confounding factor for insulin resistance [17]. Arafat *et al.* (2014) indicated that there was a significant difference between the presence of type 2 DM in obese subjects compares to non-obese one regardless age, race, and gender [18]. It was the underlying reason why obesity in this study was excluded. The mean of Mg nutrient intake in this study was 207.2±90.5 mg/d. It was much lower than recommended one [19].Some different things were shown in the study of 97 patients with type 2 DM and 100 healthy non-diabetic subjects in Switzerland. The results indicated that the mean of Mg nutrient intake in diabetic men and men in the control group was 423.2±103.1 mg/d and 421.1±111.0 mg/d, while the mean of Mg nutrient intake in diabetic women and women in the control group was 419.1±109.7 mg/d and 383.5±109.7 mg/d. The results of the study indicated that there was no difference in Mg nutrient intake in diabetics and non-diabetics subjects and the average of intake in both groups in Switzerland was in accordance with the recommendations [20]. Other studies, Schmidt *et al.* (1994) in the United States, used the food records for 3 days in 50 patients with type 2 DM. It showed that the averages of Mg nutrient intake in men were 336.8 mg/d and in women 216.5 mg/d [21]. These different results show that there were some differences in patterns of eating habits related to food containing Mg. Food items that were often consumed in Switzerland were cereal products with 23% of food containing Mg, while in the United States, cereal consumption was estimated at 17–18% of food containing Mg [20, 21]. In this study, there were limitations so food containing Mg which was often consumed cannot be recorded.

The mean of serum Mg levels in this study was 0.83±0.07 mmol/l. The same result was shown by Tarigan *et al.* (2015) in Jakarta that the serum Mg levels <0.69 mmol/l were 13.2% and ≥0.69 mmol/l were 86.8% that dominated with the normomagnesemia group [22]. The different results were shown in the previous studies in India by Gupta *et al.* (2014) and Chutia and Lynrah (2015) that the mean of serum Mg levels was 0.49 mmol/l and 0.60 mmol/l [8,14]. Both studies showed lower serum Mg levels in the subjects than those of this study and Tarigan *et al.* (2015) [22]. This was related to Mg nutrient intake which is different from those in Indonesia. The diet in the previous study, Gupta *et al.* (2014) in western India and Chutia and Lynrah (2015) in northern India, shows that diets tended to be based on fruits, snacks, sweet foods, vegetables, whole grains, wheat, and rice [23]. These food ingredients were containing high glucose. Plummer (2017) states that there has been a change in diet in India over the past 25 years. Consumption of meat and animal products increased, while consumption of grains and wheat decreased. The average consumption of sugar and fatty food also increased. This was the cause of higher glycemic control in India which will eventually lead to lower serum Mg levels than in Indonesia [24].

The mean of HOMA-IR shown in this study was 4.82. Different results were shown by Chutia and Lynrah (2015) in 38 patients with type 2 DM with an average of 4.05 [14]. Similar HOMA-IR mean values were shown in Gupta *et al.* (2014) in 50 patients with type 2 DM with overweight with the mean value of 5.7. The results of this previous study were different from this study because the subjects in Gupta *et al.* (2014) had the mean glycated hemoglobin (HbA1c) 8.2% that higher than our study with the mean HbA1c of 7.44% [8]. The same was shown by Chutia and Lynrah (2015) with the mean fasting plasma glucose 10.82 mmol/l that higher than our study with the mean fasting plasma glucose 7.31 mmol/l [14]. If fasting plasma glucose was relatively high, it could be assumed that HbA1c in Chutia and Lynrah (2015) study was also higher than our study [25,26]. This higher characteristic of HbA1c could be causing higher HOMA-IR than our study. The second reason was that in this study, the subjects before being recruited in this study had used metformin or pioglitazone so that the HOMA-IR could be lower. This was because metformin or pioglitazone had a function to reduce insulin resistance [27-29].

In this study, the serum Mg levels had a significant negative relationship to the HOMA-IR with r=0.375 and p=0.024. It is similar to Gupta *et al.* (2014) with r=0.6; p<0.0001 and Chutia and Lynrah (2015) with r=0.518; p<0.001 [8,14]. The lower value of a correlation in the previous study could be caused by several things. First, it could be caused by a different study design. Second, the study subjects of the case group in Gupta *et al.* (2014) were overweight patients who could be the confounding factor that increased the insulin resistance [8]. Third, subjects in this study had already used metformin or pioglitazone. Fourth, there were still some confounding factors in this study that could not be controlled such as diet, physical activities, and dyslipidemia. These are the things that are believed to underlie the differences in the correlation values of the previous studies and this study.

Limitations and weaknesses of this study, there were still some confounding variables that cannot be controlled such as diet, physical activity, and dyslipidemia. Kartono *et al.* (2017) found that increased physical exercise enhanced insulin sensitivity [30]. Second, there was no overall antidiabetic drug equation. Third, in the inclusion criteria, BMI <30 kg/m^2 which aims to exclude obesity is carried out according to the World Health Organization criteria of 2004 not according to the Asia-Pacific criteria.

CONCLUSION

It can conclude that the intake of nutrients containing Mg is much lower than that of the recommended one. The results indicated that there was a significant negative relationship between serum Mg level and HOMA-IR on type 2 DM on metformin of pioglitazone. It means that the serum Mg level is an important thing to consider in patients with type 2 diabetes.

ACKNOWLEDGMENT

Huwainan Nisa Nasution, Sony Wibisono Mudjanarko, and Dwi Aprilawati carried out the experiment. Huwainan Nisa Nasution wrote the manuscript with support from Sony Wibisono Mudjanarko, Dwi Aprilawati, and Agung Pranoto. Sony Wibisono Mudjanarko and Dwi Aprilawati helped supervise the project.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

REFERENCES

1. Bergman M. Pathophysiology of prediabetes and treatment implications for the prevention of Type 2 diabetes mellitus. Endocrine 2013;43:504-13.
2. Gröber U, Schmidt J, Kisters K. Magnesium in prevention and therapy. Nutrients 2015;7:8199-226.
3. Chhabra S, Chhabra S, Ramessur K, Chhabra N. Hypomagnesemia and its implications in Type 2 diabetes mellitus a review article. Webmedcentral Diabetes 2013;4:1-11. Available from: https://www.webmedcentral.com/wmcpdf/Article_WMC004005.pdf. [Last accessed on 2017 Jun 14].
4. Günther T. The biochemical function of mg^{2+} in insulin secretion, insulin signal transduction and insulin resistance. Magnes Res 2010;23:5-18.
5. Ghose B, Ide S. Hypomagnesemia and Type 2 diabetes mellitus: A review of literature. Austin J Nutr Food Sci 2014;2:1025.
6. Sales CH, Pedrosa LF, Lima JG, Lemos TM, Colli C. Influence of magnesium status and magnesium intake on the blood glucose control in patients with Type 2 diabetes. Clin Nutr 2011;30:359-64.
7. Dasgupta A, Sarma D, Saikia UK. Hypomagnesemia in Type 2 diabetes mellitus. Indian J Endocrinol Metab 2012;16:1000-3.
8. Gupta NK, Sharma S, Kaushik GG, Gupta B. Association between index of insulin sensitivity/resistance and serum magnesium levels in overweight diabetic subjects. Indian J Clin Pract 2014;24:932-7.
9. Sadiq F, Nawaz MR. Hypomagnesemia in patients with Type 2 diabetes. Pak J Med Sci 2014;8:983-5.
10. Rao P, Shariff MG. Serum magnesium levels in Type 2 diabetic patients with microalbuminuria and normoalbuminuria. Int J Sci Study 2015;3:11-4.
11. Hans CP, Sialy R, Bansal DD. Magnesium deficiency and diabetes mellitus. Curr Sci 2002;83:1456-63.
12. Gommers LM, Hoenderop JG, Bindels RJ, De Baaji JH. Hypomagnesemia in Type 2 diabetes: A vicious circle? Diabetes 2016;65:3-13.
13. Bonora E, Formentini G, Calcaterra F, Lombardi S, Marini F, Zenari L, *et al.* HOMA-estimated insulin resistance is an independent predictor of cardiovascular disease in Type 2 diabetic subjects: Prospective data from the verona diabetes complications study. Diabetes Care 2002;25:1135-41.
14. Chutia H, Lynrah KG. Association of serum magnesium deficiency with insulin resistance in Type 2 diabetes mellitus. J Lab Physicians 2015;7:75-8.
15. Infodatin (Indonesian Ministry of Health Database and Information). Current Situation and Analysis of Diabetes 2014. Situasi dan Analisis Diabetes 2014. Indonesian. Jakarta: Indonesian Ministry of Health; 2014. Available from: http://www.depkes.go.id/resources/download/pusdatin/infodatin/infodatin-diabetes.pdf. [Last accessed on 2019 Jan 23].
16. Nguyen QM, Xu JH, Chen W, Srinivasan SR, Berenson GS. Correlates of age onset of Type 2 diabetes among relatively young black and white adults in a community: The bogalusa heart study. Diabetes Care 2012;35:1341-6.
17. Thevenod F. Pathophysiology of diabetes mellitus Type 2: Roles of obesity, insulin resistance and β-cell dysfunction. Front Diabetes 2008;19:1-18.
18. Arafat MA, Salam A, Arafat O. The association of Type 2 diabetes with obesity and other factors: In multinational community. Int J Pharm Pharm Sci 2014;6:257-60.
19. Government of Canada. Canada: Food Sources of Magnesium Canadian Nutrient File; 2015. Available from: http://www.hc-sc.gc.ca/fn-an/nutrition/fiche-nutri-data/index-eng.php. [Last accessed on 2017 Jun 13].
20. Wälti MK, Zimmermann MB, Spinas GA, Jacob S, Hurrell RF. Dietary magnesium intake in Type 2 diabetes. Eur J Clin Nutr 2002;56:409-14.
21. Schmidt LE, Arfken CL, Heins JM. Evaluation of nutrient intake in subjects with non-insulin-dependent diabetes mellitus. J Am Diet Assoc 1994;94:773-4.
22. Tarigan TJ, Marbun MB, Harimurti K. Korelasi kadar magnesium serum dengan albuminuria pada pasien diabetes mellitus tipe 2. eJ Kedokt Indones 2015;3:115-9.
23. Green R, Milner J, Joy EJ, Agrawal S, Dangour AD. Dietary patterns in india: A systematic review. Br J Nutr 2016;116:142-8.
24. Plummer L. 50 years of Food in India: Changing Eating Habits of a Rapidly Changing Nation (of Foodies)! India: The Better India; 2017. Available from: https://www.thebetterindia.com/98604/india-eating-habits-food-50-years-culture. [Last accessed on 2019 Feb 13].
25. Monnier L, Colette C. Contributions of fasting and postprandial glucose to hemoglobin A1c. Endocr Pract 2006;12 Suppl 1:42-6.
26. Monnier L, Colette C, Owens D. Postprandial and basal glucose in Type 2 diabetes: Assessment and respective impacts. Diabetes Technol Ther 2011;13 Suppl 1:S25-32.
27. Ou HY, Cheng JT, Yu EH, Wu TJ. Metformin increases insulin sensitivity and plasma beta-endorphin in human subjects. Horm Metab Res 2006;38:106-11.
28. Rajagopalan S, Dutta P, Hota D, Bhansali A, Srinivasan A, Chakrabarti A, *et al.* Effect of low dose pioglitazone on glycemic control and insulin resistance in Type 2 diabetes: A randomized, double blind, clinical trial. Diabetes Res Clin Pract 2015;109:e32-5.
29. Jain R, Jain P, Jain P. A review on treatment and prevention of diabetes mellitus. Int J Curr Pharm Res 2016;8:16-8.
30. Kartono AF, Irawati D, Setiawan AA, Syafutra H, Sumaryada T. The effects of physical exercise on the insulin-dependent diabetes mellitus subjects using the modified minimal model. Int J Pharm Pharm Sci 2017;9:179-86.

Association of Serum Magnesium Levels with Homeostatic Model Assessment of Insulin Resistance in Patients with Type 2 Diabetes Mellitus on Metformin or Pioglitazone

ORIGINALITY REPORT

18%	4%	18%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	"Minutes of the 44th Genral Assembly of the European Association for the Study of Diabetes", Diabetologia, 2009 Publication	2%
2	"Abstracts of the IDF Congress in Paris 2003", Diabetologia, 2003 Publication	1%
3	R F Hurrell. "Dietary magnesium intake in type 2 diabetes", European Journal of Clinical Nutrition, 05/08/2002 Publication	1%
4	A. Ghadge, S. Harke, S. Khadke, A. Diwan, M. Pankaj, O. Kulkarni, P. Ranjekar, A. Harsulkar, A. Kuvalekar. "Effects of Commonly Used Antidiabetic Drugs on Antioxidant Enzymes and Liver Function Test Markers in Type 2 Diabetes Mellitus Subjects – Pilot Study", Experimental and Clinical Endocrinology & Diabetes, 2015 Publication	1%

5	Lisanne M.M. Gommers, Joost G.J. Hoenderop, René J.M. Bindels, Jeroen H.F. de Baaij. "Hypomagnesemia in Type 2 Diabetes: A Vicious Circle?", Diabetes, 2015 Publication	1%
6	Joanna Suliburska, Paweł Bogdański, Danuta Pupek-Musialik, Zbigniew Krejpcio. "Dietary Intake and Serum and Hair Concentrations of Minerals and their Relationship with Serum Lipids and Glucose Levels in Hypertensive and Obese Patients with Insulin Resistance", Biological Trace Element Research, 2010 Publication	1%
7	"Abstracts of the EASD, Stockholm 2010", Diabetologia, 2010 Publication	1%
8	Vincent Wai-Sun Wong. "Genetic polymorphisms of adiponectin and tumor necrosis factor-alpha and nonalcoholic fatty liver disease in Chinese people", Journal of Gastroenterology and Hepatology, 06/2008 Publication	1%
9	"38th EASD Annual Meeting of the European Association for the Study of Diabetes", Diabetologia, 2016 Publication	1%
10	Park, H.Y.. "Correlation Between Insulin	

Resistance and Intracranial Atherosclerosis in Patients With Ischemic Stroke Without Diabetes", Journal of Stroke and Cerebrovascular Diseases, 200811/12
Publication

1%

11 Jie Wei, Chao Zeng, Xiao-xiao Li, Qian-yi Gong, Guang-hua Lei, Tu-bao Yang. "Association among dietary magnesium, serum magnesium, and diabetes: a cross-sectional study in middle-aged and older adults", Journal of Health, Population and Nutrition, 2016
Publication

1%

12 Pushpa Bharati, Uma N. Kulkarni. "Nutritional sufficiency of traditional meal patterns", Elsevier BV, 2020
Publication

1%

13 Wiebe Boorsma, Marieke B. Snijder, Giel Nijpels, Caterina Guidone et al. "Body Composition, Insulin Sensitivity, and Cardiovascular Disease Profile in Healthy Europeans", Obesity, 2008
Publication

1%

14 FangFang, Hongyan Li, Tingting Qin, Min Li, Shiping Ma. "Thymol improves high-fat diet-induced cognitive deficits in mice via ameliorating brain insulin resistance and upregulating NRF2/HO-1 pathway", Metabolic

<1%

Brain Disease, 2016

Publication

---

15 S. S. Schwartz. "Glycemic Control and Weight Reduction Without Causing Hypoglycemia: The Case for Continued Safe Aggressive Care of Patients With Type 2 Diabetes Mellitus and Avoidance of Therapeutic Inertia", Mayo Clinic Proceedings, 12/01/2010 <1%

Publication

---

16 Kırım, Sinan, Sakir Ozgur Keskek, Adil Karaca, Gulay Ortoğlu, and Tayyibe Saler. "Low serum magnesium levels can be one of the causes of diabetic foot ulcers", Pakistan Journal of Medical Sciences, 1969. <1%

Publication

---

17 Geeta Shamnani, Shekhawat S. Bhartiy, Rekha Jiwane, Vani Gupta, Narsingh Verma, Dileep Verma. "Correlation of Serum Magnesium with Insulin Resistance in North Indian Adult Population", Current Diabetes Reviews, 2020 <1%

Publication

---

18 Wen-Ko Chiou, Jawl-Shan Hwang, Kuang-Hung Hsu, Jen-Der Lin. "Diabetes Mellitus Increased Mortality Rates More in Gender-Specific than in Nongender-Specific Cancer Patients: A Retrospective Study of 149,491 Patients", Experimental Diabetes Research, 2012 <1%

Publication

19	Gravely-Witte, S.. "Cardiologists' charting varied by risk factor, and was often discordant with patient report", Journal of Clinical Epidemiology, 200810 Publication	<1 %
20	T Kharitonova, M Thoren, N Ahmed, J M Wardlaw, R von Kummer, L Thomassen, N Wahlgren. "Disappearing hyperdense middle cerebral artery sign in ischaemic stroke patients treated with intravenous thrombolysis: clinical course and prognostic significance", Journal of Neurology, Neurosurgery & Psychiatry, 2009 Publication	<1 %
21	Rosnani Pangaribuan, Jürgen G Erhardt, Veronika Scherbaum, Hans K Biesalski. "Vitamin A capsule distribution to control vitamin A deficiency in Indonesia: effect of supplementation in pre-school children and compliance with the programme", Public Health Nutrition, 2007 Publication	<1 %
22	M. Rodriguez-Moran, F. Guerrero-Romero. "Oral Magnesium Supplementation Improves Insulin Sensitivity and Metabolic Control in Type 2 Diabetic Subjects: A randomized double-blind controlled trial", Diabetes Care, 2003 Publication	<1 %

23	Abhijit A. Ghadge, Abhay M. Harsulkar, Arundhati G. Diwan, Aniket A. Kuvalekar. "Gender dependent differences in lipid metabolism in individuals with type 2 diabetes mellitus", Journal of Diabetes & Metabolic Disorders, 2020 Publication	<1%
24	Mohammad Reza Parvizi, Mohsen Parviz, Seyed Mohammad Tavangar, Nepton Soltani et al. "Protective effect of magnesium on renal function in STZ-induced diabetic rats", Journal of Diabetes & Metabolic Disorders, 2014 Publication	<1%
25	Mikaela Sjöstrand, Nayyar Iqbal, Jane Lu, Boaz Hirshberg. "Saxagliptin improves glycemic control by modulating postprandial glucagon and C-peptide levels in Chinese patients with type 2 diabetes", Diabetes Research and Clinical Practice, 2014 Publication	<1%
26	Amalia Gastaldelli, Kenneth Cusi. "From NASH to diabetes and from diabetes to NASH: Mechanisms and treatment options", JHEP Reports, 2019 Publication	<1%
27	Alireza Esteghamati, Omid Khalilzadeh, Mehrshad Abbasi, Manouchehr Nakhjavani,	<1%

Leila Novin, Abdul Reza Esteghamati. "HOMA-Estimated Insulin Resistance Is Associated with Hypertension in Iranian Diabetic and Non-Diabetic Subjects", Clinical and Experimental Hypertension, 2009
Publication

---

28 Hsiao-Chun Cheng, Christina M. Ulane, Robert E. Burke. "Clinical progression in Parkinson disease and the neurobiology of axons", Annals of Neurology, 2010 <1%
Publication

---

29 Fernando Martinez. "Association of a Mineralocorticoid Receptor Gene Polymorphism With Hypertension in a Spanish Population", American Journal of Hypertension, 03/26/2009 <1%
Publication

---

30 Ki Eun Kim, Ju Sun Heo, Sol Han, Seul-Ki Kwon, Soo-Yeon Kim, Jung Hyun Kim, Kwang-Hyun Baek, Youn Ho Sheen. "Blood concentrations of lipopolysaccharide-binding protein, high-sensitivity C-reactive protein, tumor necrosis factor-α, and Interleukin-6 in relation to insulin resistance in young adolescents", Clinica Chimica Acta, 2018 <1%
Publication

---

31 T. Forst. "IRIS II study: the IRIS II score-assessment of a new clinical algorithm for the <1%

classification of insulin resistance in patients with Type 2 diabetes", Diabetic Medicine, 10/2004

Publication

Exclude quotes	Off	Exclude matches	< 10 words
Exclude bibliography	On		