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Role of Micro-Mineral Consumption on the Blood Glucose Level of Type-II Diabetic Hospitalized Patients

Vanshita Sharma [1], Anindita Nandi Batabyal [2], Pratima Singh [3], Meena Kumari [4], Soumi Chakraborty [5]*

[1] Amity Institute of Food Technology (AIFT), Amity University, Noida, Uttar Pradesh, India
[2] ICMR Postdoctoral Fellow, PG Department of Home Science, Sarder Patel University, Vallabh Vidyanagar, Gujrat, India
[3] Dietitian, Sarvodaya Healthcare, Sector 8, Faridabad, Haryana, India
[4] Chief Dietitian, Sarvodaya Healthcare, Sector 8, Faridabad, Haryana, India
[5] Assistant Professor, Amity Institute of Food Technology (AIFT), Amity University, Noida, Uttar Pradesh, India
*Corresponding Author Email: soumi.chkrbrt@gmail.com

Abstract

Objective: This study investigated the role of micro-minerals (Fe, Ca, Zn, Mg) on the blood glucose level of hospitalized diabetic patients.

Methods: Structured questionnaire and biochemical profiles of the patients have been analyses using ANOVA.

Results: Ca, Fe and Mg consumption have significant effect on the Blood glucose level, excluding Zn (p= 0.159) only. Patients with normal BGL (below 120 mg/dl) reported to consume Ca (buffalo milk, amaranth, etc.); Fe (lentils, fenugreek leaves) and Mg (Kidney beans, Black dal) rich foods compared to prediabetic and diabetic patients.

Conclusion: Micro-mineral-rich foods should be included in the hospital and follow up diet of the patients.

Keywords

Micro minerals, Trace elements, Type II diabetes mellitus, Iron, Calcium, Zinc, Magnesium, Blood glucose level.

INTRODUCTION

Type II Diabetes Mellitus (T2DM) is one of the world's fastest-growing public health crises. According to the International Diabetes Federation, 463 million people (9.3% of the global population) has diabetes in 2019, a threefold rise since 2000. By then, the figure would have risen to 578 million (10.2%) by 2030, and a whopping seven hundred million (10.9%) by 2045 [1]. Global eating habits have seen a transformation in recent decades towards more unhealthier diets (high amounts of processed foods, red meat, high-fat dairy products, high-sugar foods, and pre-packaged foods), which is responsible for developing T2DM [2] [3] [4] [5] [6].

Essential micronutrients needed for the body's normal operation include minerals and trace elements. These substances are especially advantageous for bodily processes [7]. Micronutrients are recognized as essential nutrients needed in minute quantities for homeostasis, enzyme regulation, and operations [8]. Diabetes interfere with antioxidant enzymes, is linked to trace elements. Tracemetal elements (namely Zn, Mg, Fe etc) are highly associated with lipid metabolism of Diabetes patients. Calcium, magnesium, and iron are the major macro elements. On the other hand, some trace elements, such as copper, iodine, zinc, help insulin work well by activating insulin receptor sites [9] [10].

Fe is a redox-active transitional metal and a potential catalyst in a variety of cellular interactions that might result in reactive oxygen species (ROS), which contribute to tissue damage and metabolic abnormalities, which are thought to be basic reasons for the development of T2DM [11]. Low dietary mg intake has been related to the development of T2DM and metabolic syndrome [12]. Magnesium is a cofactor in the cell membrane's glucose transportation mechanisms as well as several enzymes involved in carbohydrate oxidation. It is also implicated in insulin secretion on numerous levels, binding and boosting the ability of insulin for activating tyrosine kinase. Magnesium deficiency has been linked to diabetic complications such as insulin resistance, carbohydrate intolerance, and dyslipidemia [13]. Cross-sectional studies have revealed a high calcium intake to be inversely related to body weight and adiposity, which have been proven to be risk factors for T2DM and have indirectly supported the contribution of calcium in the progression of T2DM [14]. As iron is a powerful oxidant, having high levels of oxidative stress in the body can raise the chance of developing T2DM. Numerous epidemiological investigations have identified a connection between T2DM and other insulin-resistant conditions and high body iron storage via circulating ferritin levels. As a partial antioxidant, zinc reduces the generation of ROS, which helps with diabetes mellitus as well as ageing [10].

Micronutrient on the south Asian population with T2DM consumed less calcium (133 mg/d), magnesium (116 mg/d), zinc (1.4 mg/d), as compared to control group. However no detailed study has been reported on this area on the Indian population [15]. This study has been therefore aimed on the micro-mineral consumption of the diabetic patients of such as iron, mg, Calcium and Zn consumption and its effects on T2DM. In this study a food frequency questionnaire (FFQ) has been used to assess the monthly dietary intake of the patients [16]. A FFQ consists of a set of foods with response categories to determine the usual frequency of consumption of the foods on a monthly basis. It is usually self-administered, inexpensive to use and does not affect eating behavior [17].

MATERIAL AND METHOD

Details of Population

The study has been conducted from the middle of January until April 2023. According to a report, since the prevalence of diabetes in this city was 11.2%, we have calculated the sample size (95% confidence level, 5% error) and it was found to be 100 patients [18].

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria of the patients are mentioned in Figure 1. Patients in this study who were 30 to 70 years old, of either gender, had to meet the following requirements in order to participate: (1) Patients with any of the diabetes-related problems. (2) Known case of type II DM visiting the hospital for routine follow-up. (3) Diabetic patients who have been diagnosed with T2DM by a medical professional. (4) Patients with at least one HbA1c, FBL, RBL, or blood glucose charting record that was readily accessible.

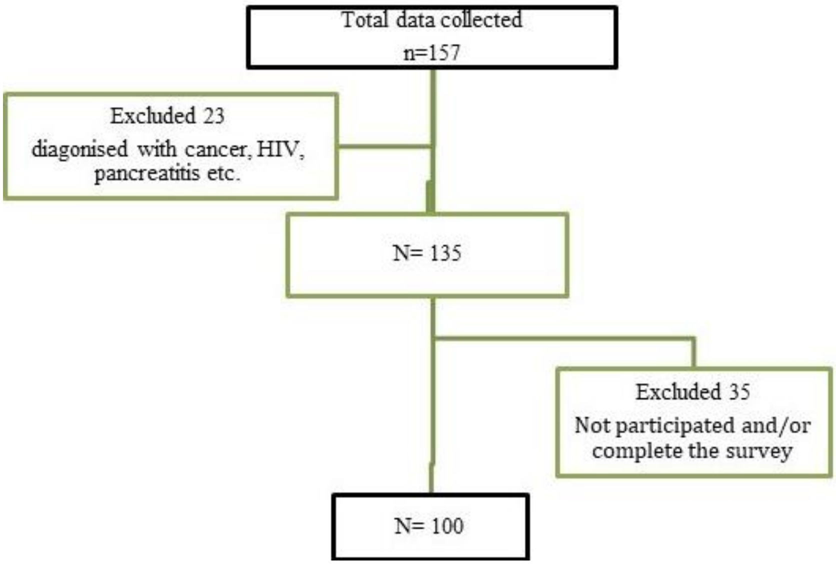

Figure 1. Details of population with inclusion and exclusion criteria

Exclusion standards included: (1) has been given a medical diagnosis, such as cancer and or acute or chronic Pancreatitis, coma (2) Those whose questionnaire were not filled (3) Those who have objected to participated in the study. For this study, there were no gender limitations. After receiving verbal consent, all patients were included. The controls were selected from the same cohort as the subjects without T2DM.

Details of Questionnaire

A handwritten semi-structured questionnaire was created to collect patient data. The basic goal of an FFQ is "A questionnaire in which an individual is given a list of foods and is required to indicate how frequently each is consumed in general terms, such as x number of times a day/ week/month, etc." Usually, the foods selected are chosen so for a specific purpose and may not be an extensive diet assessment [19]. It included two sections:

Section A. Pertaining to name, age, gender, weight, occupation, exercise, complications, etc.

Section B. Diet-related questionnaire.

The pretesting of the questionnaire was conducted and updated in response to the population's comprehension and needs. There were two sections to the investigation. The first stage involved interviewing T2DM patient respondents to collect data, and the second stage involved data analysis and the identification of three sources of each mineral—calcium, iron, magnesium, and zinc—that were high, medium, and low—from the food sources listed in the questionnaire.

Table 1. Demographic Details of the Population

Demographic characteristics	PreDiabetes (*n* =35)	Diabetes (*n* =46)	Control (*n*=19)
Age (years), mean (sd)	40-80	40-80	40-80
Sex Male gender, *n* (%)	48.5% (17)	52.1% (24)	63.1% (12)
Female gender *n* (%)	51.4% (18)	47.82% (22)	36.8% (7)

Demographic characteristics	PreDiabetes (*n* =35)	Diabetes (*n* =46)	Control (*n*=19)
Smoker *n* (%)	8.57% (3)	21.7% (10)	26.31% (5)
Alcohol *n* (%)	14.2% (5)	23.91% (11)	21.05% (4)
Blood Glucose level	122.62	170.45	493.64
HbA_{1c} (mmol/mol), mean (sd)	1.80	2.25	0.82
Calcium consumption (mg/month), mean (sd)	5509.15	4335.70	6253.05
Fe consumption (mg/month), mean (sd)	69.91	62.17	73.504
Mg consumption (mg/month), mean (sd)	1854.93	1683.44	1920.55
Zn consumption (mg/month), mean (sd)	38.62	37.45	41.38

Dietary Assessment Methodology

Dietary intake was recorded for food items generally consumed each day, week, or month in order to calculate individual total monthly consumption. Every food item mentioned during the interview was counted as one intake of the pertinent item on the Food frequency questionnaire, and each intake was summarized in frequencies and intervals (day/week/month) throughout the interview. Questions containing options like Regularly, Frequently, Rarely, Never were interpreted as 4,2,1,0 days a month. Options like 1 time a month and rarely were clubbed to form a meaningful interpretation. Each mineral source was identified based on the amount consumed in the standard exchange of the food items and the amounts were calculated from the IFCT 2017 [21].

Biochemical Parameters of Patients

The data provided from the hospital dated from January to April 2023.

Statistical Analysis

Continuous data are expressed as mean ± SEM except where specified. Differences in continuous variables were compared using Student's t tests (two groups) or one-way ANOVA (three or more groups, where subgroups were compared using Dunnet post hoc test. The Social Science Methodological kit (SPSS-v.27 available at https://www.ibm.com/support/pages/downloading-ibm-spss-statistics-27 accessed on 3 April 2023) was used to analyze the data. This software has been used to calculate the mean ± standard deviation, and frequencies and percentages. Pre-diabetes and control group has been decided based on a previous report[21]. Significance was measured at 0.05%.

RESULTS AND DISCUSSION

Effect of Calcium Consumption

The demographic details of the population have been mentioned in Table1 and Figure 2.

Figure 2. Demographic data of the population

Table 1. Patient characteristics

ANOVA study affirms that the Ca consumption has significant effects (p= 0.002 and F= 6.95) on maintaining the blood glucose level (in the range of 70-140 mg/dl) in non-diabetic patients, compared to pre-diabetic (140-200 mg/dl) and diabetic (>200 mg/dl) groups.

In this cohort, diabetic patients have been seen to consume low Ca rich sources such as almond (228 mg/100 g), rajma/kidney beans (126 mg/100 g), curd (82 mg/100 g) etc. It is also noted that patients consuming high Ca rich foods such as dairy products (mostly buffalo and cow milk), leafy green vegetables, meals fortified with calcium, and Ca supplements have lower blood glucose levels. Similar findings have also been reported and found that higher dietary calcium intake is associated with a decreased risk of T2D development [22]. Another study has reported that among the several calcium-rich foods (kimchi, anchovies, tofu, radish leaves, soy, and sea mustard) in the Korean diet, only yogurt has reduced the risk of T2DM. This has been further concluded by the authors that this Ca consumption and BGL are entirely depends on their ethnicity, since this Ca consumption showed beneficial effects on few of the Australian, Dutch, Japanese, United States and Spanish population. In addition, the few populations of Australian and Japanese are also showed no such association with BGL [23].

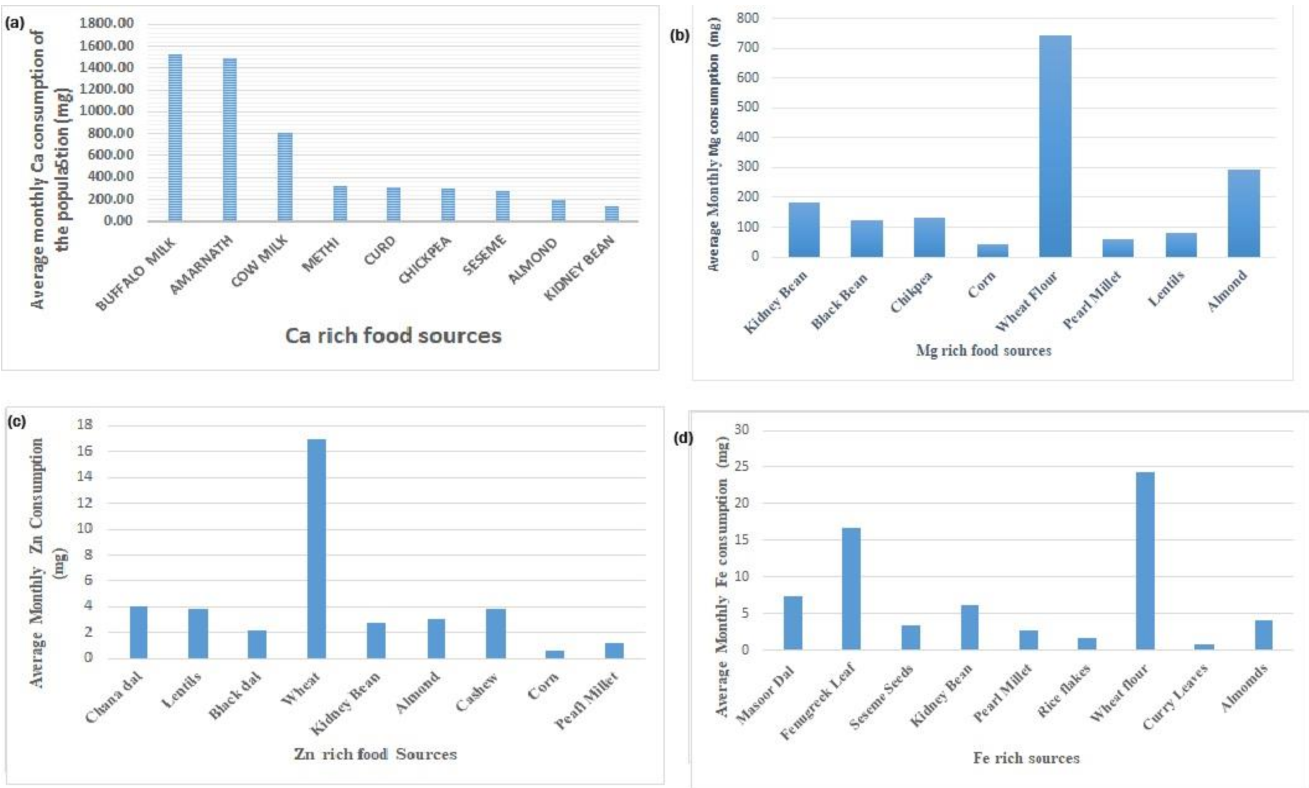

Figure 3. Average monthly consumption of (a) Ca-rich food sources (b) mg-rich food sources (c) Zn-rich food sources (d) Fe-rich food sources

The major Ca rich food sources consumed by the population have been presented in Figure 3. In our study, the non-diabetic patients reported their Ca intake from buffalo milk followed by the high consumption of green leafy vegetables such as Amaranth and fenugreek leaves etc, which could have a lowering effect on BGL of the patients. These fenugreek and amaranth have a positive effect on lowering BGL [24] [25]. From different studies it has been clearly indicated that type of Ca rich food sources is very important rather than the Ca intake of the individual. Since few Ca rich sources are high in sugar and fat (such as buffalo milk) which could increase the BGL in the patients [26].

Table 2. Dunnet Table of Statistical Analysis

Dependent Variable			Mean Difference	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
Ca	Diabetes	control	-1917.35*	547.95	0.00	-3134.79	-699.91	
	Pre-diabetes	control	-743.89	575.47	0.31	-2022.47	534.67	
Fe	Diabetes	control	-11.32*	3.80	0.01	-19.76	-2.89	
	Pre-diabetes	control	-3.58	3.99	0.55	-12.44	5.27	

Dependent Variable			Mean Difference	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
Mg	Diabetes	control	-237.10*	102.63	0.04	-465.13	-9.08	
	Pre-diabetes	control	-65.61	107.78	0.75	-305.09	173.86	
Zn	Diabetes	control	-3.94	2.03	0.09	-8.45	0.57	
	Pre-diabetes	control	-2.76	2.13	0.31	-7.50	1.96	

*. The mean difference is significant at the 0.05 level.
a. Dunnett t-tests treat one group as a control, and compare all other groups against it.

Table 3. ANOVA Table of Analysis

ANOVA						
		Sum of Squares	Degree of freedom	Mean Square	F	Sig.
Ca	Between Groups	59759462.467	2	29879731.23	6.950	0.002
	Within Groups	417008749.447	97	4299059.27		
	Total	476768211.914	99			
Fe	Between Groups	2220.360	2	1110.18	5.384	0.006
	Within Groups	20002.568	97	206.21		
	Total	22222.927	99			
Mg	Between Groups	1011943.566	2	505971.78	3.355	0.039
	Within Groups	14629059.458	97	150815.04		
	Total	15641003.024	99			
Zn	Between Groups	214.657	2	107.32	1.878	0.159
	Within Groups	5487.624	96	57.16		
	Total	5702.281	98			

In line with our findings, few researchers have concluded that US adults having dietary Ca below the RDA were associated with increased risk of T2DM in all population and women, while higher ratio of Ca to Mg was associated with increased risk of T2DM in all population [27]. It has been found that low Calcium level is 3.17 times more prevalent in diabetic group as compared to the non- diabetic group [28]. A systematic Review and Meta-Analysis conclude that vitamin D and calcium insufficiency may negatively influence glycemia while combined supplementation with both nutrients may be beneficial in optimizing glucose metabolism [29]. It is reported that calcium helps to control the release of insulin so alterations in calcium levels can have a negative effect on beta cell function which hinders normal Insulin release [30].

Effect of Fe Consumption

Dunnet post hoc ANOVA test (Table 2 and 3) shows that iron has a significant effect (p=0.006; F=5.384) on elevating the blood glucose levels which resulted in the significant difference in the BGL level of diabetic, prediabetic and normal population. It was observed that the patients preferred some specific foods like lentil (7.06 mg/100 g), fenugreek (5.69 mg/100 g), kidney beans (6.13 mg/100 g), almonds (4.59 mg/100 g) in their diet on a regular basis [31].

In contrary, recent epidemiological and experimental research shown potential pathways by which iron metabolism influences type 2 diabetes. Excess iron can attack pancreatic b cells via elevated oxidative stress, resulting in beta cell apoptosis and a reduction in glucose-induced insulin secretion [31] [32]. Second, excessive iron interferes with glucose use in tissues of muscles, resulting in a shift from glucose to fatty acid oxidation and a decrease in insulin-induced glucose transport in adipocytes, which may hinder insulin action and result in increased insulin resistance [32]. A recent study on patterns and trends of diet quality of the US type 2 diabetes has reported that medians of usual intakes of dietary iron as well as supplements, declined significantly from 2003 to 2020 [33].

Effect of Mg Consumption

In the present study we observed lower dietary intake of calcium rich foods in diabetic patients ANOVA test (Table 3) have shown a significant effect (p=0.039) on maintaining the blood glucose levels. In this study the sources for accessing high magnesium consumption are as follows: Amaranth leaves (194 mg/100 g), Black gram (173 mg/100 g), kidney bean (173mg/100 g). Soriano-Pérez et al., (2022) also affirmsMg^{2+} supplementation has been proposed to help T2DM patients because of glucose control and Mg^{2+} homeostasis measures have an inverse relationship. The randomized controlled trials (RCTs) looking at Mg^{2+} supplementation in T2DM patients found that the Mg^{2+} intervention resulted in lower fasting glucose levels. Although there were no discernible changes in the levels of glycated hemoglobin (HbA1c), the authors speculated that Mg^{2+} supplementation for 4 to 48 weeks may be useful in lowering blood glucose levels [34].

Magnesium is a cofactor necessary for the transport of blood sugar into the cell and for the metabolism of carbohydrates. It contributes to insulin's cellular action. Diabetes is a potential consequence of low magnesium consumption. They have shown that combined magnesium and zinc supplementation for 12 weeks had beneficial effects on FPG, insulin and inflammatory markers [35] [10]. Magnesium is one of the crucial cofactors in the enzymatic processes that require adenosine triphosphate and kinase, and therefore it plays an important role in glucose metabolic pathways [36]. Deficiency in magnesium hinders cellular defenses against oxidation damage, resulting in a lower resistance to the oxidative stress generated by diabetes, accelerating the progression of diabetes-related problems [10].

Effect of Zn Consumption

Dunnet post hoc ANOVA test (Table 2 and 3) have not shown any significant effect ($p=0.159$; $F=1.878$) on elevating or maintaining the blood glucose levels. Zinc is also involved in insulin synthesis, storage, and secretion [37]. However, few studies have demonstrated that zinc deficiency can affect glycemic control [37] [38] [39]. It has been recently discovered that individuals with lower zinc contents in their plasma had poorer glycemic management, as measured by the proportion of glycated hemoglobin [40]. The recognized association between zinc and the metabolism of glucose is ascribed to the nutrient's participation in the crystallization and signaling of insulin. Physiologically, zinc is plentiful in the pancreas and is particularly concentrated in the insulin secretory vesicles of beta cells, where it serves to stabilize and reduce the susceptibility of insulin to oxidative damage [41].

LIMITATIONS

There are various limitations to this study, the first and foremost being small population size. Impact of different diseases and medication on consumption of various food groups and their absorption were not considered during the conduction of the study. As the majority of the population were vegetarian so the effect of non-vegetarian food sources was not included. No special biochemical tests were conducted to assess the serum levels of micronutrients.

CONCLUSION

This study inevitably concluded that micronutrient consumption has a significant effect on the blood glucose level of the patients. This approach of correcting micronutrient deficiency could be one of the preventive strategies for developing diabetes. In addition, consumption of high Ca, Fe and Mg rich foods should be encouraged to stop developing diabetes from prediabetes condition. However, over consumption of any one or all micronutrients has detrimental side effects on the onset and progression of T2DM.

Conflicts of Interest and Source of Funding

There is no conflict of interest to declare. The authors did not receive support from any organization for the submitted work.

Ethical Approval of Studies and Participant Informed Consent

Ethical approval was not required for this study.

Population details

This hospital-based cross-sectional study was conducted on in-patients at Sarvodaya Hospital and Research Centre, Faridabad, India.

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REFERENCE

[1] Saeedi P, Petersohn I, Salpea P, Malanda B, Karuranga S, Unwin N, Colagiuri S, Guariguata L, Motala AA, Ogurtsova K, Shaw JE. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas. Diabetes research and clinical practice. 2019;157:107843.

[2] Cena H, Calder PC. Defining a healthy diet: evidence for the role of contemporary dietary patterns in health and disease. Nutrients. 2020;12(2):334.

[3] Fallah Z, Darand M, Salehi-Abargouei A, Mirzaei M, Ferns GA, Khayyatzadeh SS. The association between dietary habits and metabolic syndrome: findings from the Shahedieh-cohort study. BMC Nutrition. 2022;8(1):1-2.

[4] Stewart NR, Heiston EM, Miller SL, Ballantyne AC, Cheema US, Spaeth AM, Kokkinos P, Malin SK. Role of Blood Pressure Responses to Exercise and Vascular Insulin Sensitivity with Nocturnal Blood Pressure Dipping in Metabolic Syndrome. Journal of Vascular Research. 2022;59(3):151-62.

[5] Bolla E, Tentolouris N, Sfikakis PP, Tektonidou MG. Metabolic syndrome in antiphospholipid syndrome versus rheumatoid arthritis and diabetes mellitus: Association with arterial thrombosis, cardiovascular risk biomarkers, physical activity, and coronary atherosclerotic plaques. Frontiers in Immunology. 2023; 9(13):1077166.

[6] Huang JH, Li RH, Huang SL, Sia HK, Chen YL, Tang FC.

Lifestyle factors and metabolic syndrome among workers: The role of interactions between smoking and alcohol to nutrition and exercise. International journal of environmental research and public health. 2015;12(12):15967-78.

[7] Al-Fartusie FS, Mohssan SN. Essential trace elements and their vital roles in human body. Indian J Adv Chem Sci. 2017; 1,5(3):127-36.

[8] Kashiv Y, Austin JR, Lai B, Rose V, Vogt S, El-Muayed M. Imaging trace element distributions in single organelles and subcellular features. Scientific reports. 2016 25;6(1):21437.

[9] Wolide AD, Zawdie B, Alemayehu T, Tadesse S. Association of trace metal elements with lipid profiles in type 2 diabetes mellitus patients: a cross sectional study. BMC endocrine disorders. 2017;17:1-7.

[10] Dubey P, Thakur V, Chattopadhyay M. Role of minerals and trace elements in diabetes and insulin resistance. Nutrients. 2020; 23;12(6):1864

[11] Jung DH, Hong KW, Park B, Lee YJ. Dietary iron to total energy intake ratio and type 2 diabetes incidence in a longitudinal 12-year analysis of the Korean Genome and Epidemiology Cohort Study. European Journal of Nutrition. 2021 Dec;60(8):4453-61.

[12] Pelczyńska M, Moszak M, Bogdański P. The role of magnesium in the pathogenesis of metabolic disorders. Nutrients. 2022;20;14(9):1714.

[13] Masood N, Baloch GH, Ghori RA, Memon IA, Memon MA, Memon MS. Serum zinc and magnesium in type-2 diabetic patients. J Coll Physicians Surg Pak. 2009 1;19(8):483-6.

[14] Nikooyeh B, Neyestani TR, Farvid M, Alavi-Majd H, Houshiarrad A, Kalayi A, Shariatzadeh N, Gharavi AA, Heravifard S, Tayebinejad N, Salekzamani S. Daily consumption of vitamin D–or vitamin D+ calcium–fortified yogurt drink improved glycemic control in patients with type 2 diabetes: a randomized clinical trial. The American journal of clinical nutrition. 2011 ;1;93(4):764-71.

[15] Shah M, Vasandani C, Adams-Huet B, Garg A. Comparison of nutrient intakes in South Asians with type 2 diabetes mellitus and controls living in the United States. Diabetes research and clinical practice. 2018;138:47-56.

[16] Sauvageot N, Alkerwi AA, Albert A, Guillaume M. Use of food frequency questionnaire to assess relationships between dietary habits and cardiovascular risk factors in NESCAV study: validation with biomarkers. Nutrition journal. 2013 Dec;12:1-1.

[17] Petersen KS, Smith JM, Clifton PM, Keogh JB. Dietary intake in adults with type 1 and type 2 diabetes: validation of the Dietary Questionnaire for Epidemiological Studies version 2 FFQ against a 3-d weighed food record and 24-h urinalysis. British Journal of Nutrition. 2015 Dec;114(12):2056-63.

[18] Misra A, Pandey RM, Rama Devi J, Sharma R, Vikram NK, Khanna N. High prevalence of diabetes, obesity and dyslipidaemia in urban slum population in northern India. International journal of obesity. 2001;25(11):1722-9.

[19] Rothenberg E, Strandhagen E, Samuelsson J, Ahlner F, Rydberg Sterner T, Skoog I, Lundberg CE. Relative Validity of a Short 15-Item Food Frequency Questionnaire Measuring Dietary Quality, by the Diet History Method. Nutrients. 2021 ;24;13(11):3754.

[20] Longvah, T., Ananthan, R., Bhaskarachary, K., &Venkaiah, K. (2017). Indian Food Compostion Tables. *National Institute of Nutrition*, 505.

[21] Bansal N. Prediabetes diagnosis and treatment: A review. World journal of diabetes. 2015 3;6(2):296.

[22] Kim KN, Oh SY, Hong YC. Associations of serum calcium levels and dietary calcium intake with incident type 2 diabetes over 10 years: the Korean Genome and Epidemiology Study (KoGES). Diabetology & metabolic syndrome. 2018;10:1-7.

[23] Jeon J, Jang J, Park K. Effects of consuming calcium-rich foods on the incidence of type 2 diabetes mellitus. Nutrients 2018; 11: 31.

[24] Baliga M, Palatty PL, Adnan M, Naik TS, Kamble PS, George T, D'souza JJ. Anti-Diabetic effects of leaves of Trigonella foenum-graecum L.(Fenugreek): Leads from preclinical studies. Journal of Food Chemistry & Nanotechnology, 2017; 29;3(2):67-71.

[25] Girija K, Lakshman K, Udaya C, Sachi GS, Divya T. Anti–diabetic and anti–cholesterolemic activity of methanol extracts of three species of Amaranthus. Asian Pacific journal of tropical biomedicine. 2011 1(2):133-8.

[26] Villegas R, Gao YT, Dai Q, Yang G, Cai H, Li H, Zheng W, Shu XO. Dietary calcium and magnesium intakes and the risk of type 2 diabetes: the Shanghai Women's Health Study. The American journal of clinical nutrition. 2009;89(4):1059-67.

[27] Shah IU, Sameen A, Manzoor MF, Ahmed Z, Gao J, Farooq U, Siddiqi SM, Siddique R, Habib A, Sun C, Siddeeg A. Association of dietary calcium, magnesium, and vitamin D with type 2 diabetes among US adults: National health and nutrition examination survey 2007–2014—A cross-sectional study. Food science & nutrition. 2021;9(3):1480-90.

[28] Chudhary HR, Amin A, Malik MH, Hafeez MM, Rana MA, Malik A. Risk assessment of non-conventional contributory factors in onset of diabetes mellitus type II. Biological and Clinical Sciences Research Journal. 2020 Dec 12;2020(1).

[29] Pittas AG, Lau J, Hu FB, Dawson-Hughes B. The role of vitamin D and calcium in type 2 diabetes. A systematic review and meta-analysis. The Journal of Clinical Endocrinology & Metabolism. 2007;92(6):2017-29.

[30] Osmani D, Haseena S. A possible correlation between low serum vitamin-D levels and type 2 diabetes mellitus. International Journal of Advanced Biochemistry Research. 2020;4:06-11.

[31] Jung CH, Son JW, Kang S, Kim WJ, Kim HS, Kim HS, Seo M, Shin HJ, Lee SS, Jeong SJ, Cho Y. Diabetes fact sheets in Korea, 2020: an appraisal of current status. Diabetes & metabolism journal. 2021 Jan 13;45(1):1-0.

[32] Díaz-López A, Iglesias-Vázquez L, Pallejà-Millán M, Rey Reñones C, Flores Mateo G, Arija V. Association between iron status and incident type 2 diabetes: a population-based cohort study. Nutrients. 2020;12(11):3249.

[33] Cooksey RC, Jouihan HA, Ajioka RS, Hazel MW, Jones DL, Kushner JP, McClain DA. Oxidative stress, β-cell apoptosis, and decreased insulin secretory capacity in mouse models of hemochromatosis. Endocrinology. 2004;145(11):5305-12.

[34] Soriano-Pérez L, Aranda-Rivera AK, Cruz-Gregorio A, Pedraza-Chaverri J. Magnesium and Type 2 Diabetes Mellitus: clinical and molecular mechanisms. Health Sciences Review. 2022;21:100043.

[35] Hamedifard Z, Farrokhian A, Reiner Ž, Bahmani F, Asemi Z, Ghotbi M, Taghizadeh M. The effects of combined magnesium and zinc supplementation on metabolic status in patients with type 2 diabetes mellitus and coronary heart disease. Lipids in Health and Disease. 2020;19(1):1-9.

[36] Barbagallo M, Dominguez LJ. Magnesium metabolism in type 2 diabetes mellitus, metabolic syndrome and insulin resistance. Archives of biochemistry and biophysics. 2007;458(1):40-7.

[37] Saha-Roy S, Pal S, Bera S, Choudhury KM, Bhattacharya A, Sen G, Gupta S. Status of serum magnesium, zinc & copper in patients suffering from type-2 diabetes mellitus. Journal of Drug Delivery and Therapeutics. 2014;4(1):70-2.

[38] Capdor J, Foster M, Petocz P, Samman S. Zinc and glycemic control: a meta-analysis of randomised placebo controlled supplementation trials in humans. Journal of Trace Elements in Medicine and Biology. 2013;27(2):137-42.

[39] Saharia GK, Goswami RK. Evaluation of serum zinc status and glycated hemoglobin of type 2 diabetes mellitus patients in a tertiary care hospital of assam. Journal of laboratory physicians. 2013;5(01):30-3.

[40] Da Silva Bandeira V, Pires LV, Hashimoto LL, de Alencar LL, Almondes KG, Lottenberg SA, Cozzolino SM. Association of reduced zinc status with poor glycemic control in individuals with type 2 diabetes mellitus. Journal of Trace Elements in Medicine and Biology. 2017 Dec 1;44:132-6.

[41] Fernández-Cao JC, Warthon-Medina M, Moran VH, Arija V, Doepking C, Lowe NM. Dietary zinc intake and whole blood zinc concentration in subjects with type 2 diabetes versus healthy subjects: A systematic review, meta-analysis and meta-regression. Journal of Trace Elements in Medicine and Biology. 2018 Sep 1;49:241-51.