Original Article

Dietary Antioxidant Minerals (Cr, Mg, Cu, Se, Zn) in Diabetic Children and their Relationship with Fasting and Postprandial Blood Glucose

Abstract

Background: Dietary micronutrient levels can influence glucose and insulin regulation. Studies show micronutrients can have a positive effect on blood sugar control. This study aimed to investigate the relationship between blood sugar levels and dietary antioxidant minerals (Cr, Mg, Cu, Se, Zn) in children with type 1 diabetes. **Methods:** This cross-sectional study was conducted on 82 children aged 3–18 with type 1 diabetes. A three-day food record was used to collect dietary information. Fasting blood sugar and 2-hour postprandial glucose were recorded by parents. Dietary data were extracted by N4. SPSS Version 27 was used for all statistical analyses. **Results:** The average age of subjects was 10/3 ± 3/3 years. According to the comparison of intake amounts of antioxidant minerals based on age and sex with Recommended Dietary Allowance (RDA), most children reported enough intake. A significant positive relationship was observed between the intake of copper and 2 hours of blood sugar after breakfast (*P* values < 0.05). We found a significant relationship between intake of chromium, magnesium, selenium, and zinc with blood sugar levels, after adjusting for confounding variables (*P* values < 0.05). **Conclusions:** The amount of dietary antioxidant minerals in most children was within the appropriate range compared with the RDA. There is a significant relationship between dietary antioxidant minerals (chromium, magnesium, selenium, and zinc) and fasting and postprandial blood glucose after adjusting for confounding variables.

Keywords: *Antioxidant minerals, blood sugar control, children, type 1 diabetes*

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Introduction

Diabetes is a chronic disease defined by high levels of blood sugar. It occurs when the insulin is not enough produced or cannot effectively act.[1] Diabetes hyperglycemia causes long-term damage, dysfunction, and failure of various organs, especially the eyes, kidneys, nerves, heart, and blood vessels.[2] The prevalence of diabetes is increasing globally. In 2000, the estimated prevalence of diabetes for all age groups worldwide was 2.8%. This is projected to rise to 4.4% by 2030.[3] There are different types of diabetes, with the most common being type 1 diabetes and type 2 diabetes. In type 1 diabetes, the immune system mistakenly attacks beta cells.[4,5] The exact cause of this autoimmune response is not fully understood.[6,7] Type 1 diabetes is usually diagnosed in childhood or adolescence, but it can occur at any age.

Medical nutrition therapy (MNT) is a main component of diabetes management. It includes designing dietary planning individualized along with regular monitoring by the Recommended Dietary Allowance (RDA).[8-10] The goal of MNT is to sustain near-normal blood glucose levels by coordinating insulin therapy, diet, and physical activity.[11-13]

Some studies showed that a balanced diet with adequate nutrient content can reduce the glycosylated hemoglobin percentage (%HbA1c) by 0.3%–2%.[14]

Micronutrients, including vitamins and minerals, are essential micronutrients for the normal functioning of the body.[15] Minerals and rare elements are needed in many biochemical reactions, and they act as stabilizing components of enzymes and proteins and cofactors for many enzymes. The primary imbalance of trace elements in type 1 diabetes increases oxidative stress, leading to insulin resistance, and glucose metabolism disturbances. Several trace elements including chromium, magnesium, copper, selenium, and zinc play a role in various physiological functions at the

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cellular level, including those related to insulin and glucose metabolism.[16-18]

Chromium (Cr) is an essential nutrient involved in the metabolism of glucose, insulin, and blood lipids.[19] Studies have shown that chromium supplementation can have positive effects on blood sugar, insulin, cholesterol, and HbA1c levels in patients with diabetes.[20,21] Chromium increases insulin binding to cells, and insulin receptor number, and activates insulin receptor kinase leading to increased insulin sensitivity.[19]

Magnesium (Mg) is an essential element for mitochondrial function, especially for ATP production.[22] The serum level of magnesium in children with type 1 diabetes was lower than in the control group.[23] In animal studies, administration of dietary magnesium (50 mg/ml in drinking water) for 6 weeks reduced blood glucose levels, improved mitochondrial function, and reduced oxidative stress in diabetic rats.[22,24] Also, dietary Mg supplementation for patients with type 2 diabetes mellitus (T2DM) improves glucose metabolism and insulin sensitivity.[25]

Diabetes and its complications are associated with an imbalance and dysregulation of copper metabolism. It can lead to the progression of diabetes-related complications and impaired antioxidant homeostasis.[26] Impaired antioxidant activity can contribute to oxidative stress, which is a factor in the development of type 1 diabetes.[27] It is important that while copper plays a role in diabetes, excessive amounts of copper can create oxidative stress and be toxic.[27] Therefore, maintaining a balanced intake of copper is crucial for overall health.

Selenium is a trace element that is involved in an antioxidant defense that may play a role in preventing diabetes complications. Selenium is essential for glutathione peroxidase (GPx) enzyme activity. Diabetes causes an increased oxidative burden due to the production of reactive oxygen species. GPx is an important cellular defense against free radicals.[28]

Zinc (Zn) plays a crucial role in the function and biosynthesis of insulin, as well as in insulin sensitivity in target tissues.[29] Zn may play a role in the regulation of insulin receptor-initiated signal transudation mechanism and insulin receptor synthesis.[30] Zinc deficiency may be associated with poor blood sugar control in individuals with diabetes. Copper and zinc are the main trace elements that work as ion cofactors in proteins, hormones, and receptors and also as cofactors in numerous enzymatic reactions. They are structural ions of superoxide dismutase and reduce oxidative stress by induction of metallothionein synthesis.[31]

Based on the results, it seems the limited information on the relationship between the intake of certain micronutrients (chromium, magnesium, copper, selenium, and zinc) and blood sugar levels in Iranian children with type 1 diabetes. The purpose of this study was to investigate the association between blood sugar levels and dietary antioxidant minerals (Cr, Mg, Cu, Se, Zn) in Iranian children with type 1 diabetes.

Methods

Study population

This cross-sectional study was conducted on 92 children aged 3–18 with type 1 diabetes referred to the outpatient diabetes clinic in Isfahan City, Iran. They were selected by random sampling method and using G.power software (considering the 10% dropout of study participants). Recruited subjects were assessed by different approaches, including anthropometric, dietary, and biochemical.

The parents also were asked about the children's health status, such as the duration of the illness, the amount of insulin units received, and the use of medicine or supplements.

Inclusion criteria

Parents' consent for children's participation in the study, aged 3–18 years and suffering from type 1 diabetes. Absence of liver diseases, hyperthyroidism, and proteinuria.

Exclusion criteria

Incomplete recording of food information for 3 days, and blood sugar recording table.

Anthropometric measurement

Children's weight was measured using a digital scale (Seca, Hamburg, Germany), in light clothes and without shoes, with a precision of 0.1 kg. The height of the participants was assessed using a Seca stadiometer, with a precision of 0.1 cm. Body mass index (BMI) was calculated as weight (kg)/height (m^2).

Socio-economic status assessment

To evaluate the family's economic status based on the number of available household items, parents were asked which of the following nine types of items they have: sofa, hand-woven carpet, refrigerator, freezer, washing machine, dishwasher, microwave, computer, personal car, and personal home.[32] The categorization of economic status based on the number of items is as follows:

- Weak economic status: Having less than or equal to three items.
- Moderate economic status: Having 4–6 of these items.
- Good economic status: Having 7–9 of these items.[32]

Parents' education was measured through questions and classified according to unlearned, sub-diploma, diploma, Bachelor's degree, and above.

Dietary assessment

A three-day food record (two weekdays and one weekend day) was used to collect dietary information. Parents reported food and beverages consumed on an accurate scale. Home measurements were used for accurate estimating. The data about the intake of calories, macronutrients, and micronutrients were extracted by Nutritionist IV software. The intake of dietary antioxidant minerals (magnesium, zinc, copper, selenium, and chromium) was compared with the RDA according to the age and gender of children.[33]

Blood sugar monitoring

The children's parents checked the blood sugar level four times a day using a self-testing blood sugar test device. The measurements were taken in the form of fasting 2 hours after breakfast, lunch, and dinner. The parents received training on using the device and accurately performing the blood sugar tests. This training was given to parents based on the latest instructions presented in review studies that aimed to identify the steps of the self-monitoring of blood glucose (SMBG) method for children with type 1 diabetes. The goal of SMBG is to collect accurate information about blood glucose levels at different times so that more consistent glucose levels can be maintained with more precise diets.[34] Capillary plasma glucose target before meals in children and adolescents with type 1 diabetes is 90–130 mg/dL.[35] For most people with type 1 diabetes, a postprandial capillary plasma glucose level of <180 mg/dL is considered normal.[36]

Statistical analyses

In this study, SPSS 27 was used for all statistical analyses. Data were reported as mean ± standard deviation (SD) for continuous variables and number (percentage) for categorical variables. Determining the relationship between intake of antioxidant minerals and blood sugar level was done with Pearson's correlation test and a detailed investigation of the relationship between blood sugar level and intake of antioxidant minerals was done with linear regression test and adjustment of confounding variables and appropriate modeling. P values < 0.05 were considered as significant statistically.

Results

Table 1 shows the average quantitative data such as age, anthropometric measurements, disease duration, fasting and 2-hour blood sugar levels, and dietary antioxidant mineral (chromium, magnesium, copper, selenium, and zinc) intake. The mean age of children was 10/3 ± 3/3 years. The mean BMI for age (Z score) in the participating children was −0.54 ± 1.48.

Table 2 shows the number (percentage) of qualitative variables such as gender, parents' education level, and economic status. The number of girls was more than the boys. The education level of the parents was mostly diploma and the economic status of the parents was in the average range.

Table 3 shows the dietary intake of antioxidant minerals according to RDA in diabetic children. The comparison of intake amounts of antioxidant minerals based on age and sex with RDA shows that most children reported enough intake and, selenium and chromium were adequately received in all children.[33]

Table 4 shows the relationship between dietary antioxidant minerals (chromium, magnesium, copper, selenium, and zinc) with blood sugar levels. A significant positive relationship was observed between the intake of copper and 2 hours of blood sugar after breakfast (P values < 0.05). However, no significant relationship was reported between the other minerals with blood sugar levels (P values > 0.05).

As shown in Table 5, linear regression revealed a significant relationship between copper consumption and 2 hours of blood sugar after breakfast in the crude model (model 1) (P values < 0.05). After adjusting the variables of age, sex, BMI, disease duration, education, and economic status, in model 2 there was a significant relationship between the intake of chromium, magnesium, selenium, and zinc with 2 hours of blood sugar after lunch

Table 1: General characteristics (quantitative variables) of diabetic children (n=82)

Variables	Number	Minimum	Maximum	Mean±SD
Age (year)	82	3.0	16.0	10.3±3.3
BMI for age (Z score)	82	3.62-	4.10	0.54±1.48-
Duration of disease (months)	82	0.2	108.0	24.3±30.4
Fasting blood sugar (mg/dL)	82	75.33	386.33	184.6±72.39
Blood sugar 2 hours after breakfast (mg/dL)	82	84.67	528.33	227.0±102.65
Blood sugar 2 hours after lunch (mg/dL)	82	70.67	549.67	231.1±96.90
Blood sugar 2 hours after dinner (mg/dL)	82	88.33	570.67	244.8±120.33
Magnesium (mg)	82	113.2	424.9	235.8±71.0
Zinc (mg)	82	4.2	15.7	8.7±2.4
Copper (mg)	82	0.4	6.1	1.1±0.8
Selenium (µg)	82	41.3	199.0	84.8±28.3
Chromium (µg)	82	102.3	947.0	337.9±152.3

and dinner (*P* values < 0.05). Furthermore, a significant relationship was observed between copper consumption and 2 hours of blood sugar after breakfast and dinner in the adjusted model (*P* values < 0.05).

Discussion

This article aims to investigate the relationship between blood sugar levels and dietary antioxidant minerals (Cr, Mg, Cu, Se, and Zn) in Iranian children with type 1 diabetes. The results showed that in the adjusted model, intake of chromium, magnesium, selenium, and zinc has a significant relationship with 2 hours of blood sugar after lunch and dinner. Also, the results showed a significant positive relationship between the intake of copper with increasing the 2 hours of blood sugar after breakfast. Previous studies have shown the effect of confounding variables,[37-40] so it is suggested to do future research on the effect of these variables.

Table 2: General characteristics (qualitative variables) of diabetic children (*n*=82)

Variables	Characteristics	Frequency	Percentage
Sex of participants	Girl	49	59.8
	Boy	33	40.2
Level of parental education	Unlearned	3	3.7
	Sub-diploma	17	20.7
	Diploma	39	47.6
	Bachelor's degree and above	23	28.0
Economic status of parents[1]	Weak	31	37.8
	Moderate	41	50.0
	Good	10	12.2

[1]Economic status was evaluated based on owning a house, personal car, handwoven carpet, side-by-side refrigerator, computer, dishwasher washing machine, microwave, and sofa. Scores of 0 to 3 were classified as low economic status, 4 to 6 were classified as moderate, and 7 to 9 were classified as good economic status

Table 3: Dietary intake of antioxidant minerals according to RDA in diabetic children (*n*=82)

Variables		Number	Percentage
Magnesium	≥RDA	46	56.1
	<RDA	36	43.9
Zinc	≥RDA	58	70.7
	<RDA	24	29.3
Copper	≥RDA	67	81.7
	<RDA	15	18.3
Selenium	≥RDA	82	100
	<RDA	0	0
Chrome	≥RDA	82	100
	<RDA	0	0

Recommended dietary allowance (RDA) is considered based on age[33]. The data is presented as the number of people (percentage)

Micronutrients, including trace elements, play an essential role in maintaining health status. However, information about their dietary intake and the role of dietary antioxidant micronutrients in controlling blood sugar in children with type 1 diabetes is lacking.[41] Our findings showed that the amount of dietary antioxidant minerals in most children was within the appropriate range compared to the RDA. Against our findings, Giorgini *et al*.[42] showed in a cohort study that included 60 participants with type 1 diabetes showed that dietary intake of selenium was low in adult patients with type 1 diabetes, and moderate in zinc, copper, and magnesium. Some studies have shown that a low-carbohydrate diet has a positive relationship with a decrease in the intake of vitamins and minerals,[43] which can be one of the main reasons for insufficient intake of antioxidant minerals in diabetic patients.

Many studies have shown positive correlations between reduced levels of serum minerals and poor glycemic control in type 1 diabetes patients. Lin CC HY review indicated that blood levels of trace elements (especially magnesium and zinc) were lower in type 1 diabetic patients and were even lower in type 1 diabetes patients with poor glycemic control.[44] In our study, a significant relationship between magnesium and zinc consumption with blood sugar level was observed after adjusting for confounding variables. Wang X's study showed that zinc supplementation improves blood sugar control in both diabetic and prediabetes patients. Zinc supplementation reduces blood glucose concentration and increases insulin sensitivity Magnesium intake plays a vital role in preventing diabetes and its complications. Several randomized controlled trials have been conducted to assess the effects of zinc supplementation on glycemic control, and the results of meta-analyses of these trials have shown that zinc supplementation can significantly reduce

Table 4: Associations between intake of dietary antioxidant minerals with blood sugar levels in diabetic children (*n*=82)

Mineral	[1]FBS (mg/dL)		2 hours after breakfast (mg/dL)		2 hours after lunch (mg/dL)		2 hours after dinner (mg/dL)	
	[2]*r*	[3]*P*	*r*	*P*	*r*	*P*	*r*	*P*
Magnesium (mg)	−0.092	0.410	−0.039	0.728	−0.034	0.761	−0.049	0.662
zinc (mg)	0.053	0.635	0.032	0.773	−0.007	0.948	−0.028	0.802
copper (mg)	0.074	0.510	0.218*	0.049	0.087	0.439	0.162	0.147
Selenium (µg)	0.035	0.758	−0.002	0.983	0.083	0.459	0.031	0.781
Chrome (µg)	0.123	0.271	0.143	0.198	0.134	0.230	0.086	0.440

[1]FBS (fasting blood sugar). [2]Correlation coefficient. [3]*P*-values were obtained from a correlation test. *P*<0.05 were considered as significant

Table 5: Multivariable-adjusted linear regression between dietary antioxidant minerals with blood sugar levels in diabetic children (*n*=82)

Exposure	Model	[1]FBS			2 hours after breakfast			2 hours after lunch			2 hours after dinner		
		R	Adjusted R^2	**P*	*R*	Adjusted R^2	*P*	*R*	Adjusted R^2	*P*	*R*	Adjusted R^2	*P*
Chrome	*1	0.123	0.003	0.271	0.143	0.008	0.198	0.134	0.006	0.230	0.086	-0.005	0.440
	*2	0.357	0.058	0.105	0.352	0.053	0.118	0.402	0.094	0.035*	0.468	0.157	*0.004
Magnesium	1	0.092	−0.004	0.410	0.039	−0.011	0.728	0.034	−0.011	0.761	0.049	−0.010	0.662
	2	0.378	0.074	0.066	0.345	0.049	0.135	0.403	0.096	0.034*	0.479	0.167	0.003*
Copper	1	0.074	−0.007	0.510	0.218	0.036	0.049*	0.087	−0.005	0.439	0.162	0.014	0.147
	2	0.358	0.059	0.103	0.396	0.090	*0.041	0.406	0.098	0.545	0.229	−0.010	0.031*
Selenium	1	0.035	−0.011	0.758	0.002	−0.012	0.983	0.083	−0.006	0.459	0.031	−0.012	0.781
	2	0.351	0.053	0.121	0.335	0.041	0.164	0.398	0.091	0.039*	0.469	0.157	0.004*
Zinc	1	0.053	−0.010	0.635	0.032	−0.011	0.773	0.007	−0.012	0.948	0.028	−0.012	0.802
	2	0.352	0.053	0.118	0.336	0.042	0.162	0.397	0.090	0.040*	0.471	0.159	0.004*

Model *1: Crude. Model *2: Adjusted for age, sex, BMI, disease duration, education, and economic status. [1]FBS (fasting blood sugar). **P*-values obtained from linear regression test. *$P<0.05$ were considered as significant

key glycemic indicators, particularly fasting glucose, in subjects with diabetes.[45,46]

In this study, also a positive correlation was observed between copper intake and blood sugar 2 hours after breakfast. These findings are in according to the results of Basu'study that found an increase in HbA1c levels due to high copper consumption in nondiabetic subjects with poor glycemic control.[41] Increased inflammation operated by dietary factors, such as copper, can damage insulin signaling.[47] Too much copper can create oxidative stress, which is a factor in the initiation and progression of T2DM.[27] However, in some studies, copper supplementation has reduced glucose levels in diabetic rats.[48] Currently, data regarding dietary intake and blood concentrations of copper and glucose are contradictory. Therefore, more clinical trials should be conducted in this field.

Similar to other minerals, selenium and chromium also showed a significant relationship with blood sugar levels after adjusting for confounding variables. There are different results on the effect of selenium on blood sugar control. In a systematic review and meta-analysis of randomized controlled trials, selenium supplementation was found to decrease insulin secretion as measured by the HOMA-beta homeostasis model and increase insulin sensitivity. However, Mahdavi *et al*.[49] showed that selenium supplementation did not significantly improve fasting blood glucose, insulin, HOMA-IR, and HbA1c indices. In contrast, in the study by Santos *et al*.,[50] individuals with low selenium intakes (≤45 µg/day) showed high concentrations of glycated hemoglobin (HbA1c) and a prevalence of disturbances.

Balk in a systematic review indicated chromium supplementation significantly improved glycemia among patients with diabetes.[51] However, it has been reported that supplemental, dietary chromium did not affect serum insulin and glucose concentrations.[52] Also, in another study, the effect of fermented food supplements containing chromium and zinc on metabolic control in patients with type 2 diabetes was investigated but no relevant changes in glycated hemoglobin, fructosamine, fasting blood glucose, or lipid parameters.[53] Therefore, it seems that the relationship between dietary antioxidant minerals and blood sugar levels in diabetic children needs more detailed studies.

The strengths of this study include: first, evaluating the relationship between the intake of dietary antioxidant minerals (chromium, magnesium, copper, selenium, and zinc) with fasting and blood sugar levels after eating in children with type 1 diabetes. Second, the use of a three-day food record helps reduce the possibility of memory errors in reporting food intake. However, some limitations should be considered; it seems that increasing the volume of studied samples moderates the effect of confounding variables and reduces the error rate of self-reporting blood sugar.

Conclusions

We found that the amount of dietary antioxidant minerals in most children was within the appropriate range compared to the dietary reference intakes and there is a significant relationship between dietary antioxidant minerals (chromium, magnesium, selenium, and zinc) and fasting and postprandial blood glucose after adjusting for confounding variables.

Ethical Approval and Consent to Participate

This study was approved by the Iran National Committee for Ethics in Biomedical Research under the document code IR.IAU.SRB. REC.1401.270. The subject of the study, the objectives of the research, and the method of its implementation were fully explained to all the eligible people by the authors, and then they were asked to sign a written consent form if they were willing to cooperate. For under 18 years old, all the procedures of the study were fully informed to their parents and consent form was signed by them.

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Conflicts of interest

There are no conflicts of interest.

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