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The Association Between Fasting Blood Sugar and Index of Nutritional Quality in Adult Women

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Aim: It's unclear whether diet quality affects glycemic management. The index of nutritional quality (INQ) can examine diets both quantitatively and qualitatively (INQ). Hence, this study aimed to determine whether INQ and fasting blood sugar (FBS) are related among Iranian women.

Methods: This cross-sectional study was conducted on 360 adult Iranian women. Data were collected on the participants' general characteristics, medical history, anthropometric indices, physical activity, and dietary intake. For nutrient intake assessment, a valid food frequency questionnaire (FFQ) was used, and INQ was then calculated using the daily nutrient intake.

Results: After adjusting for age, FBS was significantly inverse associated with INQ for vitamins A (B = −0.193, $p < 0.01$), magnesium (B = −0.137, $p < 0.01$), phosphor (B = −0.175, $p < 0.01$), zinc (B = −0.113, $p < 0.01$), vitamin K (B = −0.197, $p < 0.01$), manganese (B = −0.111, $p < 0.01$) and selenium (B = −0.123, $p < 0.01$). The association between FBS and INQ for Se and Mn was disappeared after further adjustment for gender, body mass index (BMI), menopausal status, and total energy intake.

Conclusion: There was a significant inverse relationship between FBS and the INQ of vitamin A, manganese, phosphor, zinc, vitamin K, magnesium, and selenium. Prospective cohort studies should be conducted to establish a causal relationship between FBS and INQ.

Keywords: index of nutritional quality, fasting blood sugar, dietary intake, glycemic control, medical history

INTRODUCTION

Hyperglycemia is observed in about one-fifth to one-fourth of the adult population in developing countries (1). Hyperglycemia is defined as a fasting blood glucose level of more than 126 mg/dl or a random blood glucose level of more than 200 mg/dl, both of which are common among hospitalized patients (2, 3). The development of hyperglycemia is linked to an increased risk of mortality (4) and infections in hospitalized patients, according to extensive data from observational studies (5). Some studies reported that correction of hyperglycemia with insulin administration reduces hospital complications and decreases mortality in cardiac diseases (6).

Dietary components may have significant effects on the management of hyperglycemia. Recently, several indicators were introduced to evaluate the quality of the diet. For example, glycemic index (GI) is a value used to measure how much specific foods increase blood sugar levels, and foods with a low GI $<$ 50 cause a slower rise in blood glucose concentration compared to an equal carbohydrate amount from high GI foods (7). Evidence suggests that dietary management with a low GI diet improves glycemic control in diabetic patients (7, 8). Although carbohydrate is likely the most significant component of food to affect postprandial glycemia, previous research found that dietary fat and protein have a key role in the glycemic response following the ingestion of carbohydrate (9). Dietary fat can delay hyperglycemic peak responses by slowing glucose absorption (10–12) and dietary protein facilitates glucose clearance by stimulating insulin release (13–16). A decreased incidence of hyperglycemia was linked to a 'healthy traditional' dietary pattern rich in vegetables, grains, and products, fish, and shrimp. Greater consumption of fruits, juice, and alcohol, on the other hand, was linked to a higher risk of hyperglycemia (17–19). Controversial results in relation to hyperglycemia and dietary components were previously observed. For example, some studies reported that fat intake is positively associated with the prevalence of impaired fasting glucose (20, 21). While other studies did not highlight an association between total fat intake and the risk of type-2 diabetes mellitus (T2DM) (22–25).

The index of nutritional quality (INQ) score was created to assess the diet quality and comprises four components: variety, adequacy, moderation, and overall balance (26) and was used in a few studies (27–29). Previous studies in European adults have reported an inverse association between INQ and cardiovascular risk factors, including lipid biomarkers and obesity (30). The incidence of fasting blood sugar disorder was reported to decrease by 75% in men with higher scores of INQ (31). In another study, the patients in the highest tertile of INQ had fewer fasting blood sugar amounts. However, no significant correlations were observed in some studies between dietary quality indices and fasting blood sugar (29). For example, in a cross-sectional study on the correlation between diet quality and glycemic status in patients with type 2 diabetes, no significant correlations were observed between INQ and fasting blood sugar, glycosylated hemoglobin (HbA1c), insulin, and insulin resistance [28]. To the best of our knowledge, no firm association between INQ and FBS has been yet established. So, this study aimed to investigate the association between INQ and FBS in Iranian adults.

METHODS

This cross-sectional study was performed on 360 Iranian adult women in Tehran, Iran. The participants were selected from healthy women referring to the nutrition clinic of Shohadaye Tajrish Hospital, Tehran, Iran. The sample size was calculated using the OPENEPI software and the quantity of odds ratio (OR) acquired in a prior research [19]. The inclusion criteria were willingness to participate in the study, age between 35 and 75 years old, having no history of metabolic syndrome, not suffering from diseases affecting blood sugar, and did not use antihyperglycemic drugs. Participants with alcohol or drug addiction, have weight-related illnesses including specific psychological or neurological disorders, insulin resistance, thyroid disease, liver disease, kidney failure, infectious diseases, history of multiple sclerosis, hypertension, dialysis, and pregnant or lactating women were excluded from the study ($n = 7$). The objectives of the study were explained to the participants, and a written consent form was collected. Data on age, height, weight, and BMI were collected through face-to-face interviews and the amount of physical activity was estimated using a validated International Physical Activity Questionnaire (IPAQ).

FBS Measurement

Five ml of blood samples were collected from all participants after 10–12 hr of overnight fasting. In order to prevent glycolysis, plasma was isolated up to 1 h after sampling, and blood glucose levels were measured using glucose oxidase and photometry using the colorimetric method GOD-PAP solution (Pars Azmoun, Iran) and RA-1000 auto analyzer.

Dietary Assessment

A semi-quantitative food frequency questionnaire (FFQ) that has previously been validated in Iran was used to collect the necessary nutritional data [6]. The FFQ consisted of 147 food items with standard serving sizes commonly used by Iranians. Participants were asked to report the frequency of consumption of each food item according to its standard portion size during the last year. Final portion sizes were changed into g/day using household measures based on USDA database with minor modification for the special national foods like breads and the average. Then, the data obtained from these questionnaires were analyzed using nutritionist-IV software (version 4.1; First Databank Division; Hearst) and daily intake of energy and nutrients was calculated.

The INQ score assess variety, adequacy, moderation, and overall balance of the diet, thus it may capture different aspects of diet quality related to under- and over-nutrition (26).

The INQ analyzes foods, meals, and diets quantitatively and qualitatively and compares people's dietary intakes extracted from the FFQ with the recommended standards. It modifies the effect of total energy intake and provides accurate estimations of individual intake (32). The following nutrients were used in computing INQ: vitamin A, riboflavin, vitamin C, vitamin D, vitamin K, vitamin B6, thiamin, niacin, biotin, folate, vitamin

TABLE 1 | Characteristics of the participants with high and normal levels of fasting blood sugar.

Parameters	Normal FBS (n = 219)	High FBS (n = 134)	P
Age (y)	47.40 (± 7.4)	52.9 (± 8.7)	0.001
Height (cm)	156.292(± 5.6)	155.970(± 5.3)	0.590
Weight (kg)	69.187(± 10.8)	74.746(± 11.8)	0.000
Body mass index (BMI) (kg/m^2)	28.3012(± 4.08)	30.6590(± 4.17)	0.000
Physical activity (kcal/kg/h)	1.5646(± 1.5)	1.3769(± 1.4)	0.257
Smoking n (%)	1(0.5%)	2(1.5%)	0.56
Using alcohol n (%)	2 (0.9%)	1(0.7%)	0.68

B12, vitamin E, zinc (Zn), iron, copper, manganese (Mn), phosphor (P), manganese (Mg), and selenium (Se).

The INQ for each nutrient was then calculated as the ratio of the amount of nutrient consumed per 1,000 kcal per day to the recommended dietary allowance of the RDA for nutrients per 1,000 kcal (33). In cases where the RDA for specific nutrients was not defined, adequate intake (AI) values were used. Individuals whose average daily energy intake was reported to be <800 or >4,200 kcal or who did not consume more than 70 food items (>40% of items in the food frequency questionnaire) were excluded from the study.

Statistical Analysis

To compare different variables in individuals with normal and high FBS profiles, independent t-test and chi-square methods for quantitative and qualitative variables were used, respectively. A multiple linear regression method was used to investigate the association between fasting blood sugar and the INQ after adjusting for age (model 1), age, gender, BMI, menopausal status, and total energy intake (model 2). The SPSS software version 23 was used for statistical analysis and the probability level of $P <$ 0.05 was considered statistically significant.

RESULTS

The general characteristics of the participants are presented in **Table 1**. People with higher FBS (n = 134) had significantly higher age (52.9 ± 8.7 vs. 47.40 ± 7.4, P = 0.001), weight (74.74 ± 11.8 vs. 69.18 ± 10.8, P = 0.001) and BMI (30.65 ± 4.17 vs. 28.30 ± 4.08, P = 0.001) compared with the participants with normal FBS (n = 219). No significant difference was observed between the two groups regarding height, physical activity, smoking, and using alcohol.

Table 2 shows the association between dietary intake among people with normal and high levels of FBS. People with higher FBS (n = 134) had significantly higher intake of thiamin (2.51 ± 1.06 vs. 2.05 ± 0.63, P=0.015), riboflavin (2.48 ± 1.55 vs. 1.95 ± 0.82, P = 0.046), niacin (25.37 ± 8.60 vs. 22.18 ± 5.95, P = 0.051), vitamin B6 (1.93 ± 0.87 vs. 1.60 ± 0.51, P = 0.032), folate (704.06 ± 205.20 vs. 612.48 ± 194.57, P= 0.051), vitamin B12 (4.41 ± 4.43 vs. 2.96 ± 1.41, P = 0.028), biotin (33.45 ± 16.15 vs. 26.67 ± 10.55, P = 0.024), P (1,567.48 ± 1,094.6 vs. 1,217.70 ± 492.78, P = 0.047), selenium (105.31 ± 45.22 vs. 85.69 ± 26.28, P = 0.014) compared with the participants with normal FBS.

Table 3 presents the association between FBS and the INQ of nutrients. There was a significant inverse association between FBS and the INQ of vitamin A (B = −0.193, P < 0.01), Magnesium (B = −0.137, P < 0.01), P (B = −0.175, P < 0.01), zinc (B = −0.113, P < 0.01), vitamin K (B = −0.197, P < 0.01), Mn (B = −0.111, P < 0.01) and Se (B = −0.123, P < 0.01) after adjustment for age (model 1). The association between the FBS and INQ of Se and Mn were disappeared after further adjustment for gender, BMI, menopausal status, and total energy intake (Model 2).

DISCUSSION

The present study investigated the association between FBS and INQ in adult women. There was a significant difference between the INQ of vitamin A, Mg, zinc, vitamin K, Mn, and selenium with FBS after adjustments for age, gender, BMI, menopausal status, and total energy intake.

Similar to this study, some studies found that vitamin A has both antioxidant and antihyperglycemic potential and, therefore, can be considered a hypoglycemic factor (34, 35). Vitamin A can impact T2DM pathogenesis through several potential molecular mechanisms, including chelation of oxide radicals, improves insulin sensitivity, and beta-cell regeneration (36). Shidfar et al., on the other hand, discovered no correlation between FBS and vitamin A in 48 diabetes mellitus type 1 (DMTI) patients (37). Jafarirad et al. showed in another trial that vitamin A had no significant influence on lipid profiles, FBS, or liver enzymes (38). The most likely explanation for these discrepancies is that the current research employed an assessment of nutritional quality rather than the quantity of nutrients consumed (34).

In line with this study, some studies reported the beneficial effects of Mg on glycemic control in individuals with T2DM (39–42). While, other studies showed no significant effects of Mg on T2DM (39, 40). The improvement in the glycemic control indicators after Mg therapy could be explained by different mechanisms, including the influence of Mg on insulin receptor activity through enhanced tyrosine kinase phosphorylation (43, 44). There was the possibility that Mg could help facilitate the translocation of glucose transporter number 4 (GLUT 4) to the cell membrane caused by the activation of tyrosine–kinase in the presence of Mg (45).

Regarding the association of FBS and dietary phosphorus, Fang et al. reported that the serum level of phosphate in the type 2 diabetic group was significantly lower than that in the control group (46). Besides, Duan et al. demonstrated that higher urinary phosphorus excretion was associated with decreased risk of T2DM (47). However, other research found that phosphorus had no significant influence on T2DM (48). For instance, one research discovered that diabetic rats also had increased plasma phosphorus amounts (49). The reason for the difference in results may be related to the study population and some of which were performed on animals (49). Phosphorus concentration

TABLE 2 | Dietary intakes among people with normal and high levels of fasting blood sugar.

Parameters	Normal FBS	High FBS	P
Total energy intake (Kcal/d)	2,473.36 (± 703.65)	2,869.39 (± 997.91)	0.039
Protein (gr/d)	75.67 (± 27.52)	92.10 (± 46.31)	0.45
Carbohydrate (gr/d)	365.51 (± 96.05)	420.47 (± 133.72)	0.34
Fat (gr/d)	84.86 (± 36.46)	96.91 (± 44.66)	0.191
Cholesterol (mg/dl)	216.19 (± 110.84)	254.93 (± 137.90)	0.170
Saturated fatty acids (mg/dl)	25.64 (± 11.97)	31.124 (± 21.40)	0.137
Mono unsaturated fatty acids (mg/dl)	29.292413 (± 14.26)	31.097204 (± 12.94)	0.576
Poly unsaturated fatty acids (mg/dl)	19.653896 (± 10.29)	19.293867 (± 7.65)	0.871
PFA3 (mg/dl)	1.241493 (± 0.64)	1.259295 (± 0.514)	0.899
PFA6 (mg/dl)	6.074097 (± 8.48)	5.141801 (± 6.17)	0.608
Sodium (IU/L)	5,115.400291 (± 2302.7)	5,934.210146 (± 2656.7)	0.150
Potassium (IU/L)	3,652.394859 (± 1477.40)	4,298.316661 (± 1958.69)	0.096
Vitamin A (IU/L)	505.368241 (± 288.28)	444.731172 (± 209.94)	0.277
Beta-carotene (IU/L)	2,924.71 (± 1354.95)	3,212.54 (± 2216.34)	0.464
Alpha-carot (IU/L)	438.97 (± 376.75)	595.76 (± 691.5)	0.183
Lutein (IU/L)	1,573.75 (± 904.35)	1,541.09 (± 742.75)	0.869
Beta-cryptoxanthin (IU/L)	322.25 (± 201.73)	284.90 (± 163.59)	0.400
Lycopene (IU/L)	7,173.65 (± 4313.99)	7,843.467731(± 4,733.68)	0.519
Vitamin C (IU/L)	138.61 (± 138.61)	156.78 (± 156.78)	0.401
Vitamin E (IU/L)	17.96 (± 14.43)	17.546 (± 9.76)	0.892
Alpha-tocopherol (IU/L)	11.841 (± 9.40)	11.48 (± 6.70)	0.858
Thiamin (IU/L)	2.05 (± 0.637)	2.51(± 1.06)	0.015
Riboflavin (IU/L)	1.957 (± 0.829)	2.48 (± 1.55)	0.046
Niacin (IU/L)	22.188 (± 5.95)	25.37 (± 8.60)	0.051
Vitamin B6 (IU/L)	1.60 (± 0.51)	1.93 (± 0.87)	0.032
Folate (IU/L)	612.48 (± 194.57)	704.06 (± 205.20)	0.051
Folate (IU/L)	755.47 (± 237.27)	856.65 (± 301.00)	0.098
Vitamin B12 (IU/L)	2.96 (± 1.41)	4.41 (± 4.43)	0.028
Biotin (IU/L)	26.67 (± 10.55)	33.45(± 16.15)	0.024
Pantothenic (IU/L)	4.71 (± 1.81)	5.61 (± 3.00)	0.092
Vitamin K (IU/L)	127.47 (± 56.87)	118.18 (± 51.52)	0.455
Phosphor (IU/L)	1,567.48 (± 1,094.6)	1,217.70 (± 492.78)	0.047
Magnesium (IU/L)	401.01 (± 169.82)	344.61 (± 131.99)	0.099
Zinc (IU/L)	11.77 (± 6.19)	10.54 (± 5.73)	0.372
Copper (IU/L)	1.79 (± 0.51)	1.97 (± 0.64)	0.167
Manganese (IU/L)	6.06 (± 2.93)	5.18 (± 1.80)	0.091
Selenium (IU/L)	105.31 (± 45.22)	85.69 (± 26.28)	0.014
Iron (mg/dl)	2,956.16 (± 1,620.08)	3,584.31 (± 1,980.78)	0.126
Chromium (IU/L)	014 (± 0.047)	026 (± 0.104)	0.442
Fiber-t (mg/dl)	27.41 (± 10.74)	30.073 (± 11.58)	0.302
Fiber-s (mg/dl)	1.02 (± 4.29)	1.07 (± 0.92)	0.768
Fiber-is (mg/dl)	11.53 (± 6.62)	5.59 (± 4.29)	0.484
Crude-fiber (mg/dl)	11.128 (± 6.82)	11.53 (± 6.62)	0.797
Sugar-t (mg/dl)	128.49 (± 46.73)	150.25 (± 70.52)	0.096
Glucose (mg/dl)	20.30 (± 8.10)	22.096 (± 9.33)	0.369
Gal (mg/dl)	2.69 (± 2.42)	5.09 (± 10.66)	0.114
Fructose (mg/dl)	25.98 (± 10.26)	27.67 (± 11.62)	0.499
Sucrose (mg/dl)	46.40 (± 21.12)	50.49 (± 29.76)	0.471
Lactose (mg/dl)	10.13 (± 7.12)	17.21 (± 28.84)	0.088
Maltose (mg/dl)	2.73 (± 1.23)	3.11 (± 1.68)	0.235
Caffeine (mg/dl)	161.00 (± 94.46)	200.91 (± 117.54)	0.095

TABLE 3 | The association between the index of nutritional quality (INQ) of the nutrients and FBS.

INQ	Model 1[a]		Model 2[a]	
	B	*P*-value	B	*P*-value
Vitamin A (IU/L)	−0.193	<0.01	−0.227	<0.01
Mg (IU/L)	−0.137	<0.01	−0.153	<0.01
P (IU/L)	−0.175	<0.01	−0.236	<0.01
Zn (IU/L)	−0.113	0.02	−0.192	<0.01
Copper (IU/L)	−0.018	0.72	0.088	0.16
Mn (IU/L)	−0.111	0.02	0.057	0.37
Se (IU/L)	−0.123	<0.01	−0.097	0.12
E (IU/L)	−0.017	0.71	0.020	0.74
B1 (IU/L)	−0.032	0.50	−0.057	0.36
B2 (IU/L)	0.072	0.13	0.064	0.31
B3 (IU/L)	0.003	0.94	0.049	0.43
B6 (IU/L)	0.051	0.28	0.033	0.60
B9 (IU/L)	0.027	0.57	0.047	0.45
B12 (IU/L)	0.020	0.67	0.038	0.54
B5 (IU/L)	0.058	0.22	0.132	0.05
Biotin (IU/L)	−0.016	0.73	−0.010	0.87
Vitamin C (IU/L)	0.051	0.28	0.055	0.38
Vitamin D (IU/L)	0.037	0.43	−0.005	0.93
Vitamin K (IU/L)	−0.197	<0.01	−0.165	<0.01

[a]*First model adjusted for age and the second model adjusted for age, gender, BMI, menopausal status, and total energy intake.*

is a determining factor in regulating the metabolism and rate of oxygen consumption. In diabetes, the highest oxygen consumption is associated with the lowest concentration of phosphorus (50).

In terms of the association between of FBS and Zn, a negative association was found between serum Zn with FBS. Low Zn levels were reported to be associated with poor glycemic control and poor glycemic control is a strong predictor of Zn deficiency (51). Another study reported that there is no definite cause-and-effectrelationship between Zn and the level of FBS (52). The reduced concentration of Zn in T2DM was indicated by Saharia and Goswami (53), which was in line with the present study. Al-Maroof and Al-Sharbatti (54) also reported that Zn levels were lower in diabetic patients compared to the controls, and a strong negative relationship was found between glycosylated hemoglobin levels of diabetic patients with their serum Zn levels. Zn has an important role in the utilization of glucose by muscle and fat cells (55). Zn acts as a cofactor for intracellular enzymes involved in protein, lipid, and glucose metabolism (55). Zinc is required for the stability of insulin hexamers and the hormone's pancreatic storage (56).

Similar with the results of the present study, high circulating levels of vitamin K were reported to be related to a lower risk of the high amount of FBS (57). Some studies found a lower risk for diabetes mellitus in people with higher vitamin K intakes (58, 59). Rees et al. (60) in a systematic review of studies that evaluated the association of vitamin K deficiency with T2DM concluded that there is no evidence of an effect of vitamin K and a higher level of FBS. The differences in the obtained results can be related to the study population since some studies have been done on diabetics and some others on healthy people. Vitamin K has been shown to reduce insulin resistance by inhibiting inflammation. Vitamin K may inhibit the generation of IL-6 (Interleukin 6) in lipopolysaccharide-induced inflammatory models (61, 62). Moreover, high plasma Vitamin K concentrations were associated with decreased concentrations of inflammatory markers TNF-α (Tumor necrosis factor alpha) and IL-6 (63). In a study that assessed the status of fat-soluble vitamins in patients with chronic pancreatitis, the results indicated that the serum concentrations of fat-soluble vitamins were decreased in these patients (64).

Tan et al. revealed that pregnant women with impaired glucose tolerance (IGT) or gestational diabetes mellitus (GDM) had lower blood selenium levels and discovered an inverse association between FBS and serum selenium levels (65), which was in line with the present study. However, the evidence for a link between selenium and GDM is inconsistent, with other research finding no correlation between selenium concentration and FBS level (66, 67).

Moreover, a higher intake of manganese was frequently reported to be associated with a lower level of FBS (68–70). However, another study found that both low and high levels of plasma manganese were associated with higher levels of FBS (71). Manganese plays significant roles in multiple physiological functions, including glucose and lipid metabolism, insulin production, and insulin secretion. Manganese deficiency leads to impaired glucose tolerance and increased risk of metabolic syndrome through impaired glucose and lipid metabolism (72, 73).

To the best of our knowledge, few studies investigated the association between FBS and the quality of diet. The strengths of the present study were its acceptable sample size and using the index of nutritional quality. However, the results may be affected by some limitations. This study was a cross-sectional study, which could not explain the causal relationship. Future prospective studies should be performed to establish a causal relationship between FBS and the INQ in adult women. Moreover, this study was performed on young women and cannot be generalized to the public. In addition, the semi-quantitative FFQ is not the best indicator to know the amount of micronutrients that are being ingested and, probably, it would be more indicated to carry out an intake analysis with double weighing in future studies.

The present study provides the first evidence for an association between FBS and the INQ in adult women. According to the findings of the study, there was a significant inverse association between FBS and the INQ of vitamin A, Mg, P, zinc, vitamin K, Mn, and Se. Prospective cohort studies should be performed to establish a causal relationship between FBS and INQ in adult women.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by IR.SBMU.nnftri.Rec.1400.049. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

FA, MG, SD, GM, MA, HS, AA, MM, and SD designed the study, involved in the data collection, analysis, and drafting of the manuscript. SD and FV were involved in the design of the study, analysis of the data, and critically reviewed the manuscript. All authors read and approved the final manuscript.

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