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RESEARCH

The relationship between dietary phytochemical index and risk of gestational diabetes mellitus in Iran: a case–control study

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Abstract

Background The risk of developing gestational diabetes mellitus has been linked to dietary factors. This is one of the first studies that has investigated the relationship between dietary phytochemical index (DPI) and gestational diabetes mellitus (GDM). This study was conducted with the aim of investigating the relationship between DPI and GDM.

Methods This case–control study investigated 71 women without GDM and 71 women with GDM who had a singleton fetus. The average age of these two groups was 28 and 33 years, respectively, and these pregnant mothers were in the 27th week of pregnancy on average. A 168-item semi-quantitative FFQ questionnaire was used to determine food intake. Then, to check the intake status of dietary phytochemicals, DPI was calculated, then logistic regression was used in different models to evaluate the relationship between DPI and GDM.

Results After adjusting for confounding factors, participants in the highest DPI tertile had 88% less chance of developing GDM (odds ratio = 0.12; 95% confidence intervals: 0.86–0.019). The mean DPI score of the case and control groups were 31.01 ± 22.17 and 36.09 ± 8.73, respectively. The overall mean DPI score for the study was 33.59 ± 18.88.

Conclusion Women who have a higher DPI score are less likely to develop GDM, but more studies are necessary to confirm the results of the present study.

Keywords Dietary phytochemical index, Gestational diabetes mellitus, Pregnancy, Iran

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Introduction

Gestational diabetes mellitus (GDM) is a prevalent metabolic condition that occurs during pregnancy [1]. It refers to the body's inability to tolerate carbohydrates, leading to varying degrees of high blood sugar [2]. This disorder typically arises during pregnancy and is usually identified after the 24th week. According to reports in 2017, around 20.4 million women worldwide were diagnosed with GDM [2]. It is predicted that this number will rise to 30.8 million by 2045. Additionally, statistics indicate that one out of every six pregnancies globally involves GDM cases, although its prevalence varies across different populations and depends on the method of measurement [3]. The prevalence of GDM in Iran is estimated to be between 1.3 and 18.6 percent [4].

This condition can have significant complications for both the mother and the newborn. The mother's risk of developing type 2 diabetes, cardiovascular diseases, obesity, and postpartum depression increases with GDM [5]. In addition, infants born to mothers with GDM are at a higher risk of macrosomia, shoulder dystocia, birth injuries, hypoglycemia, and premature birth [5]. These babies are also more likely to experience impaired glucose tolerance (IGT) and obesity [5]. Earlier investigations have identified risk factors for GDM. These include a history of previous GDM, congenital anomalies, macrosomia, and a body mass index (BMI) greater than or equal to 25. Other potential risk factors include a history of stillbirth, abortion, premature birth, and the age of the pregnant mother [6].

As a crucial environmental factor, diet significantly contributes to managing and preventing GDM. Prior research suggests that food consumption before and during pregnancy is linked to the development of GDM [3, 7]. As an illustration, incorporating phytochemicals into your daily diet can help reduce the chances of developing abdominal obesity, prevent weight gain, lower body fat levels, improve your blood lipid profile, decrease oxidative stress levels, and provide protection against both the development of insulin resistance as well as its improvement. These beneficial effects are relevant to decreasing the risk factors associated with GDM, which were previously discussed [8]. Phytochemicals are naturally occurring bioactive compounds that are commonly found in fruits, vegetables, grains, nuts, and legumes [8]. Additionally, Gao et al. indicated that incorporating spreads rich in phytochemicals into the diet can improve maternal and fetal outcomes for individuals with GDM [9]. In another study, Li et al. found that consuming spreads that contain a significant amount of phytochemicals can help improve lipid profile and insulin resistance in women who have been diagnosed with GDM [10].

Identifying the phytochemical compounds present in either food sources or human tissue samples within a large population can be excessively costly, time-consuming, and not practical. As a result, alternative methods should be utilized to determine the levels of phytochemicals found in food products [11]. The Dietary Phytochemical Index (DPI) is a tool for assessing dietary quality, which determines the amount of daily energy intake derived from phytochemical-rich foods such as fruits, vegetables, legumes, whole grains, nuts, soy products, tea, olives, and olive oil, concerning the total energy intake [12]. This index provides an uncomplicated approach to evaluating the consumption of phytochemicals within one's daily diet. Despite some shortcomings, it can still be used for clinical purposes [13].

Since there are only a few studies available on the correlation between DPI and GDM, and these existing studies present conflicting results, this particular research was conducted to examine the association between DPI and GDM.

Methods

Study subject

This case–control study was conducted between October 2021 and March 2022 on 142 pregnant women aged 18–48 in two groups of cases and controls in order to assess the relationship between dietary phytochemical index (DPI) and gestational diabetes mellitus (GDM). The study included pregnant women who were referred to Yasuj city's medical facilities and Imam Sajjad Hospital.

The control group consisted of pregnant women with normal OGTT results at 24–28 weeks, confirming the absence of GDM [14].

The inclusion criteria for both groups were: singleton pregnancy, age 18–48 years, gestational age 24–28 weeks, no history of diabetes or GDM, no history of kidney, liver, gastrointestinal, thyroid or cardiovascular diseases, no use of medications affecting appetite or weight in the past year, no specific diet in the past year, and informed consent to participate in the study. Exclusion criteria were multiple pregnancies, abortion, preeclampsia, eclampsia, and incomplete questionnaires. From 170 initially eligible pregnant women, 28 were excluded due to: multiple pregnancies ($n=8$), incomplete questionnaires ($n=12$), and declining to participate ($n=8$).

The sample size was calculated using OpenEpi calculator version 3, based on a previous study by Abshirini et al. [15], using standard deviation = 19, $\alpha=0.05$, $\beta=0.2$, and $d=9$, which determined a minimum requirement of 71 subjects per group. The formula used was:

$$n = 2(Z1 - \alpha/2 + Z1 - \beta)^2 \times s^2/d^2$$

Based on this calculation, a final sample of 142 participants (71 cases and 71 controls) was included in the analysis.

Demographic factors and anthropometric assessments

The participants answered generic questions about their chronological age, their pre-pregnancy weight, how many kids they had, their educational status, and their level of income (very low, lower middle, medium, or high) [16]. By inquiring about revenue, Participants were classified according to their income levels. Participants were then separated into four groups: extremely low, lower medium, medium, and high. Illiterate, primary school, junior high school, diploma, and bachelor's were the several levels of education.

Pre-pregnancy weight was collected through self-report. Current weight was measured by researchers using a digital scale (Seca, Germany) with 100g precision, with participants wearing light clothing and no shoes [17]. Height was measured using a non-elastic tape measure with 0.1 cm precision [18]. Pre-pregnancy BMI was then calculated by dividing self-reported pre-pregnancy weight in kilograms by height in meters squared. The International Physical Activity Questionnaire (IPAQ) was used to estimate how much physical activity they do in their routine [19]. To categorize individuals' amounts of exercise into low, moderate, and vigorous the metabolic equivalent was calculated. Consequently, if the sum of moderate and vigorous physical activities, along with walking over the past week, is below 600 Met-Min/Week, it indicates a low level of physical activity. A value of at least 600 Met-Min/Week signifies moderate intensity while achieving a minimum of 3000 Met-Min/Week indicates a vigorous level of physical activity.

Dietary assessment and DPI calculation

Dietary assessments using the validated 168-item semi-quantitative FFQ were conducted at the time of GDM screening (24–28 weeks of gestation) [20]. The FFQ captured dietary intake over the previous year, including the pre-pregnancy period. Trained dietitians conducted an in-person meeting with participants who filled out the survey. Participants in the FFQ provided information about the type of food they consumed on every day, every week, every month, or yearly basis throughout the previous year. Interviewers utilized a manual that provided a visual representation of the amount of food to improve the veracity of their dietary assessments. Following the completion of the Food frequency questionnaire, each day's consumption was calculated from how often one consumed every kind of food. Using calibrated kitchen tools including spoons, bowls, and ladles, employees guided the individuals as they estimated the amount of food. After that, portion sizes were changed to grams. Utilizing Nutritionist IV software (First Databank; Hearst, San Bruno, CA, USA), the calorie and nutrient intakes were computed based on the US Department of Agriculture dietary composition adapted for Iranian foods. Almost all of the participant list's foods were coded, and those that weren't were coded to a related item. The McCarty approach [21] was used to determine the DPI, using this equation: DPI = [daily energy obtained from foods rich in phytochemicals (kcal). Total daily energy intake (kcal)) × 100]. To determine DPI, the phytochemical-rich foods included fruits, vegetables, legumes, whole grains, nuts, soy products, seeds, and olive oil. Due to their poor phytochemical concentration, potatoes, pickled vegetables, and powdered vegetables were excluded from the computations. In addition, due to their high phytochemical content, natural fruit juices were categorized into the fruit group, whereas tomato sauces and vegetable juices were categorized into the vegetable group, and as a result, they were taken into account when calculating DPI. After computing the DPI scores, the participants were divided into tertiles, with the top tertile representing the subjects with the highest DPI values.

Statistical analysis

The data from the semi-quantitative food frequency questionnaire (FFQ) was first analyzed by entering it into the Nutrition4 software [22], and the coded data was then entered into the SPSS 20 software (version 20.0, SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was used to evaluate the normality of the data distribution. Data are presented as mean ± standard deviation (SD) for continuous variables with normal distribution and as median (interquartile range) for variables with non-normal distribution. The comparison of the quantitative characteristics of the population in the case and control groups was done through the independent samples t-test. Statistical tests such as chi-square, independent t, Mann–Whitney, one-way analysis of variance (ANOVA), and Kruskal–Wallis were utilized. To further investigate this matter and to determine the nature of the relationship—specifically, whether a significant linear relationship exists—the Spearman test was employed.

Since energy intake is an important confounder in nutritional studies, energy adjustment was performed using the residual method. DPI values were regressed on total energy intake, and the residuals were added to the predicted DPI for the mean energy intake of the study population. Multiple models of logistic regression were used to evaluate the relationship between DPI and GDM risk: Model 1 adjusted for pre-pregnancy BMI and age groups; Model 2 further adjusted for gestational week, physical activity level, family history of diabetes, smoking status of mothers, smoking status of first-degree relatives, income, maternal education level, and maternal occupation. The DPI score range was separated into tertiles, with the first tertile being ≤ 29.25, the second being more than 29.25 to 37.12, and the third being ≥ 37.12. P-trend was calculated by assigning the median value to each tertile and modeling this value as a continuous variable in logistic regression models. *P*-values less than 0.05 were considered statistically significant.

Results

Subject's characteristics

In this case–control study, 142 pregnant women (71 pregnant women without GDM and 71 pregnant women with GDM) were analyzed. The average pre-pregnancy body mass index, age, and week of pregnancy, as well as pre-pregnancy weight in the case group, were higher than the control group, and except for the pre-pregnancy weight ($p=0.096$), the other variables mentioned in the two control groups and cases had a significant difference ($P>0.001$). Also, the amount of physical activity in the control group was higher than the case group, which was statistically significant ($P>0.001$) (Table 1). The comparison of demographic characteristics in both case and control groups showed that the case and control groups were homogeneous in terms of supplement use during pregnancy ($p=0.664$), but they were not homogeneous in terms of other variables ($p<0.05$) (Table 2.).

Dietary intakes

In Table 3, the amount of daily intake of different nutrients, including macronutrients, as well as food groups and micronutrients that played a role in calculating dietary phytochemicals is presented. The comparison of these nutrients in the case and control groups showed that both groups were homogeneous in terms of intake of energy, fat, protein, carbohydrates, calcium, whole grains, soy, tea, potassium, and magnesium ($p<0.05$). But the statistical difference is significant in the daily intake of phosphorus ($P=0.033$), calcium ($P=0.035$), legumes ($P<0.001$), fruit ($P<0.001$), nuts ($P=0.037$) and olives and its products ($P<0.001$) (Table 3).

Table 1 Comparing the averages of quantitative demographic characteristics between the case and control groups

Variable	group	Mean ± SD	*P*-value*
Pre-pregnancy Body Mass index (kg.m^2)	control	28.37 ± 4.005	0.008
	case	29.18 ± 4.85	
Age (year)	control	28.88 ± 5.83	< 0.001
	case	32.06 ± 5.39	
Pre-pregnancy weight(kg)	control	63.49 ± 11.30	0.096
	case	66.31 ± 11.72	
Pregnancy week	control	26.14 ± 7.051	0.004
	case	29.08 ± 4.71	
Number of births	control	1.36 ± 1.18	0.968
	case	1.38 ± 1.48	
Number of abortions	control	0.34 ± 0.77	0.330
	case	0.44 ± 0.74	
Physical activity (Met-Min/Week)	control	936.53 ± 1109.09	0.008
	case	518.97 ± 1110.87	

* The comparison of the quantitative characteristics of the population in the case and control groups was done through the independent samples t-test

DPI score and demographic characteristics

Table 4 shows the mean and standard deviation of the qualitative variables of the participants in the study. The range of DPI score was divided into tertiles, in the range of less equal to 25.29 (first tertile), more than 25.29 to 37.12 (second tertile), and more equal to 37.12 (third tertile). The findings showed differences that the age range ($P=0.024$) was significant among the DPI score tertiles and the DPI score tertiles had a direct and significant relationship with the literacy level of pregnant women ($P=0.044$; $r=0.235$), but between other qualitative demographic characteristics and DPI tertiles No significant difference was found ($p>0.05$) (Table 4).

The results of the comparison of quantitative demographic characteristics showed that the average difference in physical activity among the tertiles of the DPI score was significant ($p=0.016$), but there was no significant difference between age, current weight, pre-pregnancy weight, pre-pregnancy body mass index, the number of births, and the number of abortions with the tertiles of the DPI score ($p>0.05$) (Table 5).

DPI score and food group intake

Table 4 shows the daily intake of different food groups used in DPI calculation, including fruits, vegetables, legumes, whole grains, nuts, olive and its products, tea, and soy products among DPI tertiles. results showed that the intake of vegetables ($P<0.001$) and legumes ($P<0.001$) was significantly higher in tertiles with a higher DPI score. Still, there was not a significant association between the average intake of energy, protein, fat, whole grains, nuts, and tea and the tertiles of the DPI score ($p>0.05$) (Table 6).

DPI score and risk of GDM

The odds ratio of the association between the DPI score tertiles with the risk of GDM is shown in Table 4. Since energy intake is an important confounder in nutritional studies, to reduce the effect of this confounder in this study, adjusted energy DPI was used for regression calculations. All models' findings showed a significant relationship between the increase in DPI score and the decrease in the chance of GDM in the third tertile compared to the first tertile. So, the chance of developing GDM in the third tertile compared to the first is 0.218 times in the crude model, 0.260 times in the adjusted model based on age and pre-pregnancy body mass index, and 0.213 times in the adjusted model based on age, pre-pregnancy body mass index, pregnancy week, physical activity level, Family history of diabetes, income, education level of the pregnant woman, and occupation of the pregnant woman. In all models, with increasing DPI score, the chance of developing GDM decreased. However, this

Table 2 Comparison of qualitative demographic characteristics between case and control groups

Variable		(71 individuals) Cases (percentage) Number	(71 individuals) controls (percentage) number	*P*-value
Family history of diabetes	Yes	25(35%)	1(1.4%)	< 0.001*
	No	46(64.4%)	70(98.6%)	
Age range	< 30	16(22.4%)	32(44.8%)	0.005*
	> 30	55(77.6%)	39(55.2%)	
Supplement usage during pregnancy	Yes	57(79.8%)	59(82.6%)	0.664
	No	14(20.2%)	12(17.4%)	
Body mass index	Underweight or normal weight (≤ 18.5–24.9)	11(15.4%)	20(28%)	0.006**
	Overweight (25–29.9)	29(40.6%)	35(49%)	
	Obesity (≥ 30)	31(43.4%)	16(22.4%)	
Physical activity	Low	55(77%)	36(50.4%)	0.001**
	Moderate	13(18.2%)	30(42%)	
	Vigorous	3(4.2%)	5(7%)	
Income	Below 3 million tomans every month	36(50.4%)	61(85.4%)	< 0.001**
	Between 3 to 7 million tomans every month	24(33.6%)	8(11.2%)	
	Over 7 million tomans every month	10(14%)	2(2.8%)	
Educational level of pregnant woman	Illiterate	7(9.8%)	5(7%)	< 0.001**
	Primary school	9(12.6%)	33(46.2%)	
	High school	17(28.9%)	14(20.2%)	
	Diploma	18(25.2%)	15(21%)	
	Bachelor	20(28%)	4(5.6%)	
Pregnant woman occupation	Housemaker	58(81.69%)	68(95.77%)	0.008*
	Employee	13(18.30%)	3(4.22%)	

* The comparison of the qualitative characteristics of the population in the case and control groups has been done through the chi square test

** The comparison of the qualitative characteristics of the population in the case and control groups has been done through the Mann–Whitney U test

Table 3 Comparison of nutrient intake between case and control groups

variable	Control (*N* = 71) Mean ± SD	Case (*N* = 71) Mean ± SD	*P*-value*
Energy (Kcal/d)	2613.76 ± 844.88	2796.30 ± 610.52	0.142
Fat (g/d)	97.92 ± 49.35	107.92 ± 39.18	0.184
Protein (g/d)	85.27 ± 30.57	81.36 ± 17.74	0.354
Carbohydrate (g/d)	369.023 ± 120.72	393.71 ± 81.91	0.156
Legume (g/d)	54.82 ± 24.23	20.47 ± 12.04	< 0.001
Fruits (g/d)	365.86 ± 168.92	174.33 ± 86.72	< 0.001
Vegetables (g/d)	323.01 ± 86.09	320.63 ± 125.22	0.998
Whole grain (mg/d)	10.57 ± 11.11	7.58 ± 18.64	0.033
Nuts (g/d)	60.22 ± 53.63	44.30 ± 44.46	0.037
Olive (g/d)	16.01 ± 16.42	3.48 ± 7.19	< 0.001
Soy (g/d)	1.92 ± 2.28	1.58 ± 1.10	0.258
Tea (g/d)	315.98 ± 316.72	311.64 ± 235	0.926
Calcium (mg/d)	1085/77 ± 490/6	945/28 ± 261/82	0/035
Potassium (mg/d)	4092/61 ± 1325	4050/92 ± 998/29	0/833
Phosphorus (mg/d)	1674 ± 657/18	1444/81 ± 613/13	0/033
Magnesium (mg/d)	335/78 ± 135/84	321/23 ± 82/47	0/841
DPI	36.09 ± 8.73	31.01 ± 22.17	< 0.001

* The comparison of the quantitative characteristics of the population in the case and control groups was done through the independent samples t-test

trend was not statistically significant (P-trend > 0.05) (Table 7).

Discussion

The present investigation is a case–control study that aims to determine a correlation between DPI and the probability of developing GDM. The findings demonstrated an inverse relationship between dietary phytochemical consumption and the odds of developing GDM. The results from all models showed a significant correlation between rising DPI scores and reducing GDM risk in the third tertile compared to the first tertile. After adjusting for several confounding factors, the association remained substantial. The findings of the study indicate a statistically significant increase in the consumption of vegetables and legumes among the tertiles with a higher DPI score. However, there was no significant difference observed in the mean intake of energy, protein, fat, whole grains, nuts, and tea about the phytochemical index score of the diet.

The current investigation reports on the mean dietary phytochemical index scores of the case and control groups, which were 31.01 ± 22.17 and 36.09 ± 8.73,

Table 4 Comparison of qualitative demographic characteristics between DPI score tertiles

		total number of participants in the study (142 individuals)			*P*-value*
		$T_1(N=47)$	$T_2(N=48)$	$T_3(N=47)$	
DPI index score range		29.25	29.25–37.12	37.12 <	
Family history of diabetes	yes	7(14.56%)	5(10.4%)	6(12.72%)	0.507
	no	40(85.44%)	43(89.44%)	41(87.28%)	
Age range	< 30	10(21.2%)	22(45.76%)	14(29.68%)	0.024
	> 30	37(76.96%)	26(54.08%)	33(70.32%)	
Supplement usage during pregnancy	yes	35(74.2%)	38(79.04%)	35(74.2%)	0.632
	no	12(25.8%)	10(20.96%)	12(25.8%)	
Body mass index	Underweight or normal weight (≤ 18.5–24.9)	12(25.8%)	12(24.96%)	9(12.08%)	0.428
	Overweight (25–29.9)	17(36.04)	21(43.68%)	24(50.88%)	
	Obesity (≥ 30)	18(38.16%)	15(31.2)	14(29.68%)	
Physical activity	low	31(65.72%)	25(52%)	32(67.84%)	0.148
	moderate	15(31.8%)	20(41.6%)	13(27.56%)	
	vigorous	1(2.12%)	2(4.16%)	2(4.24%)	
Income	Below 3 million tomans every month	32(67.84%)	38(79.04%)	29(61.48%)	0.470
	Between 3 to 7 million tomans every month	10(12.26%)	8(16.64%)	13(27.56%)	
	Over 7 million tomans every month	5(10.6%)	2(4.16%)	5(10.6%)	
Educational level of pregnant woman	illiterate	3(6.36%)	3(6.24%)	6(12.72%)	0.044** *r*=0.235
	Primary school	7(14.84%)	14(29.12%)	21(44.52%)	
	High school	14(29.68%)	9(18.72%)	8(16.96%)	
	diploma	15(31.8%)	13(27.04%)	5(10.6%)	
	bachelor	8(16.96%)	9(18.72%)	7(14.84%)	
Pregnant woman occupation	housemaker	42(89.04%)	44(91.52%)	41(86.92)	0.752
	Employee	5(10.96%)	4(8.48%)	6(13.08%)	

* The comparison of the qualitative characteristics of the population in the case and control groups has been done through the chi square test

** Spearman correlation

Table 5 Comparison of qualitative demographic characteristics between DPI score tertiles

		total number of participants in the study (142 individuals)			*P*- value*
		$T_1(N=47)$	$T_2(N=48)$	$T_3(N=47)$	
DPI index score range	range	< 29.25	29.25–37.12	37.12 <	
	Mean ± SD	18.02 ± 6.94	33.73 ± 2.04	48.87 ± 18.35	
Age(year)	mean ± SD	32.02 ± 6.19	29.60 ± 5.56	30.04 ± 5.64	0.091
Current weight (kg)	mean ± SD	74.88 ± 14.82	71.67 ± 10.66	71.14 ± 11.91	0.254
Pre-pregnancy weight(kg)	mean ± SD	67.26 ± 13.66	64.32 ± 9.66	63.49 ± 11.46	0.220
Pre-pregnancy body mass index(kg.m^2)	mean ± SD	29.18 ± 5.2	27.87 ± 4.02	27.94 ± 3.94	0.239
Number of births	mean ± SD	1.36 ± 1.18	1.38 ± 1.49	1.35 ± 1.26	0.935
Number of abortions	mean ± SD	0.53 ± 0.8	0.31 ± 0.19	0.37 ± 0.74	0.197
Physical activity (Met-Min/Week)	mean ± SD	361.18 ± 599.83	962.30 ± 1297.31	925.95 ± 1476.84	0.016

* One-way ANOVA test

respectively. The overall mean dietary phytochemical index score for the study was 33.59 ± 18.88. Similar to our research, Firouzabadi et al. and Delshad Aghdam et al. reported the mean and standard deviation of the DPI score as 33.7 ± 24.7 and 34.6 ± 10.4, respectively [23, 24]. However, in other studies, the mean and standard deviation of the DPI score were lower than in our study [25, 26]. The mean and standard deviation of the DPI score

Table 6 Comparison of energy and nutrients intake between DPI score tertiles

		Total number of participants in the study (142 individuals)			
		T_1($N=47$)	T_2($N=48$)	T_3($N=47$)	*P*-value*
DPI score range		< 29.25	29.25–37.12	> 37.12	
Energy	mean ± SD	2693.24 ± 865.61	2839.29 ± 735.20	2598.93 ± 606.34	0.142
Protein	mean ± SD	88.09 ± 32.41	84.77 ± 20.28	77.48 ± 21.10	0.118
Carbohydrate	mean ± SD	384.06 ± 124.41	406.78 ± 101.97	356.47 ± 80.73	0.035
Fat	mean ± SD	99.46 ± 52.21	105.91 ± 60.82	104.44 ± 40.33	0.580
Fruit	mean ± SD	295.31 ± 356.66	264.37 ± 216.53	428.27 ± 297.52	< 0.001
Vegetable	mean ± SD	261.25 ± 115.63	347.60 ± 74.85	348.98 ± 102.74	< 0.001
Legumes	mean ± SD	24.92 ± 23.56	42.70 ± 21.24	47.41 ± 27.78	< 0.001
Whole grain	mean ± SD	9.37 ± 23.33	7.49 ± 7.92	10.20 ± 10.77	0.049
Nuts	mean ± SD	39.80 ± 43.66	50.21 ± 41.99	66.87 ± 59.32	0.076
Olive	mean ± SD	2.72 ± 5.38	14.68 ± 15.13	12.42 ± 16.59	< 0.001
Tea	mean ± SD	123.83 ± 154.89	294.34 ± 138.36	523.47 ± 335.38	0.773
Soy	mean ± SD	1.63 ± 1.81	1.59 ± 1.27	1.97 ± 2.23	< 0.001

* One-way ANOVA

Table 7 Effect of DPI on the chance of GDM using logistic regression model

	total number of participants in the study (142 individuals)			
	T_1 ($N=47$)	T_2 ($N=48$)	T_3 ($N=47$)	P-trend**
DPI score range	< 29.25	29.25–37.12	> 37.12	
Crude model	reference	0.716 (0.306–1.677)*	0.21(0.087–0.545)*	0.457
Model 1	reference	0.66(0.271–1.604)*	0.26(0.1–0.675)*	0.323
Model 2	reference	0.739(0.187–2.914)*	0.12(0.019–0.862)*	0.675

Model 1: Adjusted for pre-pregnancy body mass index and age groups

Model 2: Adjusted based on the model of 1 + weeks of pregnancy, physical activity level, family history of diabetes, income, education level of the pregnant woman, occupation of the pregnant woman

* Data are presented as OR (95% CI)

** P–trend was calculated by assigning the median value to each tertile and modelling this value as a continuous variable in logistic regression models

in Qureshi et al. were reported to be higher than in the current research [27]. Because diet-related indicators, such as DPI, rely on various variables, including data collection methods, socioeconomic status, culture, and the geographic location of each area, variations in these variables may affect the findings of various research studies.

The results of our study demonstrate that the risk of GDM is 79% lower in the third tertile than in the first tertile in the crude model, 74% lower in the adjusted model based on age and pre-pregnancy body mass index, and 88% lower in the adjusted model based on age, pre-pregnancy body mass index, week of pregnancy, level of physical activity, income and education level of the pregnant mother, and occupation of the pregnant mother. Our investigation findings align with prior research, such as the 16-week intervention conducted by Lee et al. on a sample of 222 individuals. This study demonstrated that the intake of phytochemicals enhances insulin resistance and lipid indices among women diagnosed with GDM [10]. In addition, another intervention in China demonstrated that phytosterol consumption during pregnancy enhances glucose metabolism and reduces neonatal complications in women with GDM [9]. The findings of a prospective cohort study conducted in Iran suggest that a diet rich in phytochemicals could offer protective benefits against insulin resistance [28]. Additionally, a case study conducted by Shahidi Abshirini et al. discovered that a higher DPI score was associated with a lower risk of developing prediabetes [29].

The two key pathological elements of GDM, dysfunctional pancreatic beta cells, and chronic insulin resistance during pregnancy, are the main causes of GDM in the majority of cases [30]. Research has indicated that phytochemicals, particularly polyphenols, can enhance insulin secretion and regulate blood glucose levels through the inhibition of glucose absorption via the SGLT-1 transporter as well as by protecting beta cells against glucotoxicity [21, 28]. Genistein is a phytochemical in the isoflavone category that is mainly found in soy and its products. Genistein suppresses the secretion of insulin in beta cells and pancreatic islets at physiologically feasible doses (≤5 μmol/L), according to earlier research, with a substantial activation of the cAMP/PKA cascade [31]. Apart from the acute effect on insulin secretion, research has demonstrated that extended consumption of phytochemicals enhances the secretory potential of pancreatic beta cells [31]. In general, dietary phytochemicals have an anti-diabetic impact by acting as a beta-cell growth factor and enhancing insulin production [32]. Pro-inflammatory cytokines have recently been shown to have other functions, including the ability to prevent the release of insulin from beta cells, which may contribute to the physiopathology of GDM [33]. According to several studies, consuming phytochemicals may improve insulin secretion by lowering the levels of pro-inflammatory cytokines [33, 34].

The process of insulin signaling involves the binding of insulin to the receptor, leading to the activation of IRS. This activation, in turn, triggers the activation of PI3K, resulting in the activation of AKT2. Ultimately, this cascade of events results in the translocation of GLUT4 to the cell surface [30]. Several factors can lead to the deactivation of this pathway, consequently disrupting insulin signaling. In particular, proinflammatory cytokines are one such factor [30]. The study conducted by Kim et al. analyzed a sample size of 18,699 participants and observed that there was a negative correlation between the levels of inflammatory markers and a high score on the DPI [33]. Furthermore, previous epidemiological investigations and clinical experiments have demonstrated the capacity of dietary phytochemicals to reduce the concentrations of pro-inflammatory cytokines [34–36]. Therefore, a high intake of dietary phytochemicals may protect cells by preventing the activity of pro-inflammatory enzymes and thus contribute to improved insulin signaling [37]. Adiponectin is one of the activators of the insulin signaling pathway that triggers the activation of IRS through the induction of AMPK [30]. Prior research has indicated that numerous phytochemicals can enhance insulin sensitivity by elevating adiponectin levels or increasing adiponectin signaling, ultimately leading to an improvement in insulin resistance [38, 39]. The translocation of GLUT4 to the plasma membrane is a crucial step in insulin signaling that facilitates the transportation and utilization of glucose [40]. In general, insulin-induced glucose uptake is diminished by 54% in GDM in comparison to a pregnancy without complications. As opposed to this, insulin receptor frequency and number are often unaffected [41, 42]. Previous studies have demonstrated that certain phytochemicals can increase the quantity of GLUT4 and facilitate the translocation of GLUT4 to the cellular membrane [28, 43].

According to previous research, actinobacteria, firmicutes, and proteobacteria are all positively correlated with GDM. In contrast, butyrate-producing bifidobacteria have a negative association with GDM [44]. The results of in vivo investigations [45, 46] support the in vitro findings that phytochemicals can improve bifidobacteria and reduce proteobacteria, while also demonstrating that firmicutes can be decreased when phytochemicals are consumed [47]. According to research conducted on human subjects, the intake of phytochemicals has been linked to a decrease in Firmicutes and an increase in Bifidobacteria [48, 49]. Therefore, by modifying the gut flora, phytochemical ingestion may lower the risk of developing GDM.

This study represents one of the first studies in Iran examining the association between DPI and GDM. A 168-item semi-quantitative food frequency questionnaire that considers consumption over the previous year was used in the present study. More confounding variables were analyzed and adjusted in our investigation than in previous, comparable studies, such as energy intake, which is another point worth mentioning. This research has certain limitations, including the fact that it was conducted during the COVID-19 epidemic and a period of declining pregnant healthcare attendance. Due to the fear of contracting the disease and being in the environment, the expectant mothers who cooperated with the interviewer had a limited amount of time to answer questions. The limited sample size was the most significant limitation of the study. The use of a semi-quantitative food frequency questionnaire to assess food intake is an additional limitation of the present study. Due to people's dependence on their memories, responding to this question may result in inaccurate measurements. Another limitation of this research is the absence of assessments of the study participants' pre-pregnancy body composition, fasting blood sugar levels, insulin levels, glycosylated hemoglobin, insulin levels, pro-inflammatory cytokine levels, or lipid profiles.

Conclusion

Women who have a higher DPI score are less likely to develop GDM, but more studies are necessary to confirm the results of the present study. Further randomized clinical trials and large-scale prospective cohorts are needed to validate these current findings using dietary data with low measurement errors.

Abbreviations

GDM	Gestational diabetes mellitus
IGT	Glucose tolerance
BMI	Body mass index
DPI	Dietary Phytochemical Index
IPAQ	International physical activity questionnaire
FFQ	Food frequency questionnaire

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Authors' contributions
T.B: Conception and design, Acquisition of data M.A.Z: Drafting the manuscript M.R.J: Drafting the manuscript D.S: Drafting the manuscript A.Z: Acquisition of data Z.M: Analysis and interpretation of data M.R: Visualization A.P: Conception and design, Revising manuscript for intellectual Content.

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Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
Participants were informed about the research objectives and methodology before they enrolled in the study, and their consent to participate was obtained through a formal written consent form. The investigation was conducted following the principles of the Helsinki Declaration, and this study complies with those standards, and the investigation methodology was authorized by the Ethics Board of Lorestan University of Medical Sciences (IR.LUMS.REC.1400.092).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Kakalar SG, Sohrabi M, Amiri P, Mazahri M. GDM prevalence in 301 pregnant women in nikkhah cilinc_urmia. J Med Sci Stud. 2019;29(9):687–97.
2. Zito G, Della Corte L, Giampaolino P, Terzic M, Terzic S, Di Guardo F, et al. Gestational diabetes mellitus: prevention, diagnosis and treatment. A fresh look to a busy corner. J Neonatal Perinatal Med. 2020;13(4):529–41.
3. Bahar A, Akha O, Bordbar M, Abediankenari S, Mohammadpoor R, Ehsani Z, et al. Anti-Inflammatory Markers IL-10 and IL-35 Role in Developing Gestational Diabetes Mellitus. Journal of Clinical & Diagnostic Research. 2020;14(8).
4. Bahadori F, Sahebazzamani Z, Zarei L, Valizade N. The relationship between vitamin D and gestational diabetes. Tehran Univ Med J. 2018;76(9):608–13.
5. Johns EC, Denison FC, Norman JE, Reynolds RM. Gestational diabetes mellitus: mechanisms, treatment, and complications. Trends Endocrinol Metab. 2018;29(11):743–54.
6. Lee KW, Ching SM, Ramachandran V, Yee A, Hoo FK, Chia YC, et al. Prevalence and risk factors of gestational diabetes mellitus in Asia: a systematic review and meta-analysis. BMC Pregnancy Childbirth. 2018;18:1–20.
7. Looman M, Schoenaker DA, Soedamah-Muthu SS, Geelen A, Feskens EJ, Mishra GD. Pre-pregnancy dietary carbohydrate quantity and quality, and risk of developing gestational diabetes: the Australian Longitudinal Study on Women's Health. Br J Nutr. 2018;120(4):435–44.
8. Jaworsky K, DeVillez P, Basu A. The role of phytochemicals and plant-based diets in gestational diabetes: evidence from clinical trials. Int J Environ Res Public Health. 2023;20(5):4188.
9. Gao F, Wang G, Wang L, Guo N. Phytosterol nutritional supplement improves pregnancy and neonatal complications of gestational diabetes mellitus in a double-blind and placebo-controlled clinical study. Food Funct. 2017;8(1):424–8.
10. Li Q, Xing B. A phytosterol-enriched spread improves lipid profile and insulin resistance of women with gestational diabetes mellitus: a randomized, placebo-controlled double-blind clinical trial. Diabetes Technol Ther. 2016;18(8):499–504.
11. Mofrad MD, Siassi F, Guilani B, Bellissimo N, Azadbakht L. Association of dietary phytochemical index and mental health in women: a cross-sectional study. Br J Nutr. 2019;121(9):1049–56.
12. Hamedi-Shahraki S, Jowshan M-R, Zolghadrpour M-A, Amirkhizi F, Asghari S. Dietary phytochemical index is favorably associated with oxidative stress status and cardiovascular risk factors in adults with obesity. Sci Rep. 2023;13(1):7035.
13. Vincent HK, Bourguignon CM, Taylor AG. Relationship of the dietary phytochemical index to weight gain, oxidative stress and inflammation in overweight young adults. J Hum Nutr Diet. 2010;23(1):20–9.
14. Carpenter MW, Coustan DR. Criteria for screening tests for gestational diabetes. Am J Obstet Gynecol. 1982;144(7):768–73.
15. Abshirini M, Bagheri F, Mahaki B, Siassi F, Koohdani F, Safabakhsh M, et al. The dietary acid load is higher in subjects with prediabetes who are at greater risk of diabetes: a case–control study. Diabetol Metab Syndr. 2019;11:1–8.
16. Shakeri M, Jafarirad S, Amani R, Cheraghian B, Najafian M. A longitudinal study on the relationship between mother's personality trait and eating behaviors, food intake, maternal weight gain during pregnancy and neonatal birth weight. Nutr J. 2020;19(1):1–10.
17. Jowshan M-R, Rafraf M, Hashemi A-H, Hajjarzadeh S, Asghari-Jafarabadi M, Asghari S. Association between healthy eating index-2015 scores and metabolic syndrome among Iranian women: a cross-sectional study. BMC Womens Health. 2024;24(1):30.
18. Zolghadrpour M-A, Jowshan M-R, Seyedmahalleh MH, Imani H, Karimpour F, Asghari S. Consumption of a new developed synbiotic yogurt improves oxidative stress status in adults with metabolic syndrome: a randomized controlled clinical trial. Sci Rep. 2024;14(1):20333.
19. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381–95.
20. Mirmiran P, Esfahani FH, Mehrabi Y, Hedayati M, Azizi F. Reliability and relative validity of an FFQ for nutrients in the Tehran lipid and glucose study. Public Health Nutr. 2010;13(5):654–62.
21. Bahadoran Z, Golzarand M, Mirmiran P, Saadati N, Azizi F. The association of dietary phytochemical index and cardiometabolic risk factors in adults: Tehran lipid and glucose study. J Hum Nutr Diet. 2013;26:145–53.
22. Ayoubi SS, Yaghoubi Z, Pahlavani N, Philippou E, MalekAhmadi M, Esmaily H, et al. Developed and validated food frequency questionnaires in Iran: a systematic literature review. J Res Med Sci. 2021;26(1):50.
23. DelshadAghdam S, Siassi F, NasliEsfahani E, Qorbani M, Rajab A, Sajjadpour Z, et al. Dietary phytochemical index associated with cardiovascular risk factor in patients with type 1 diabetes mellitus. BMC Cardiovasc Disord. 2021;21(1):293.
24. Firouzabadi FD, Jayedi A, Asgari E, Farazi M, Noruzi Z, Djafarian K, et al. The association of dietary phytochemical index with metabolic syndrome in adults. Clin Nutr Res. 2021;10(2):161.
25. Golzarand M, Bahadoran Z, Mirmiran P, Sadeghian-Sharif S, Azizi F. Dietary phytochemical index is inversely associated with the occurrence of hypertension in adults: a 3-year follow-up (the Tehran Lipid and Glucose Study). Eur J Clin Nutr. 2015;69(3):392–8.
26. Bahadoran Z, Mirmiran P, Delshad H, Azizi F. White rice consumption is a risk factor for metabolic syndrome in Tehrani adults: a prospective approach in Tehran Lipid and Glucose Study. Archives of Iranian medicine. 2014;17(6):0-.
27. Ghoreishy SM, Aminianfar A, Benisi-Kohansal S, Azadbakht L, Esmaillzadeh A. Association between dietary phytochemical index and breast cancer: a case–control study. Breast Cancer. 2021;28:1283–91.
28. Bahadoran Z, Mirmiran P, Tohidi M, Azizi F. Dietary phytochemical index and the risk of insulin resistance and β-cell dysfunction: a prospective approach in Tehran lipid and glucose study. Int J Food Sci Nutr. 2015;66(8):950–5.
29. Abshirini M, Mahaki B, Bagheri F, Siassi F, Koohdani F, Sotoudeh G. Higher intake of phytochemical-rich foods is inversely related to prediabetes: a case-control study. Int J Prevent Med. 2018;9:64.

30. Plows JF, Stanley JL, Baker PN, Reynolds CM, Vickers MH. The pathophysiology of gestational diabetes mellitus. Int J Mol Sci. 2018;19(11):3342.
31. Aryaeian N, Sedehi SK, Arablou T. Polyphenols and their effects on diabetes management: a review. Med J Islam Repub Iran. 2017;31:134.
32. Park HJ, Yang J-Y, Ambati S, Della-Fera MA, Hausman DB, Rayalam S, et al. Combined effects of genistein, quercetin, and resveratrol in human and 3T3-L1 adipocytes. J Med Food. 2008;11(4):773–83.
33. Kim C, Park K. Association between phytochemical index and inflammation in Korean adults. Antioxidants. 2022;11(2):348.
34. Mazidi M, Katsiki N, George ES, Banach M. Tomato and lycopene consumption is inversely associated with total and cause-specific mortality: a population-based cohort study, on behalf of the International Lipid Expert Panel (ILEP). Br J Nutr. 2020;124(12):1303–10.
35. Roager HM, Vogt JK, Kristensen M, Hansen LBS, Ibrügger S, Mærkedahl RB, et al. Whole grain-rich diet reduces body weight and systemic low-grade inflammation without inducing major changes of the gut microbiome: a randomised cross-over trial. Gut. 2019;68(1):83–93.
36. Yu Z, Malik VS, Keum N, Hu FB, Giovannucci EL, Stampfer MJ, et al. Associations between nut consumption and inflammatory biomarkers. Am J Clin Nutr. 2016;104(3):722–8.
37. Ruiz-Castell M, Le Coroller G, Landrier J-F, Kerkour D, Weber B, Fagherazzi G, et al. Micronutrients and markers of oxidative stress and inflammation related to cardiometabolic Health: results from the EHES-LUX study. Nutrients. 2020;13(1):5.
38. Atazadegan MA, Bagherniya M, Fakheran O, Sathyapalan T, Sahebkar A. The effect of herbal medicine and natural bioactive compounds on plasma adiponectin: A clinical review. Natural Products and Human Diseases: Pharmacology, Molecular Targets, and Therapeutic Benefits. 2021:37–57.
39. Peter EL, Nagendrappa PB, Hilonga S, Tuyiringire N, Ashuro E, Kaligirwa A, et al. Pharmacological reflection of plants traditionally used to manage diabetes mellitus in Tanzania. J Ethnopharmacol. 2021;269:113715.
40. Rosenzweig T, Sampson SR. Activation of insulin signaling by botanical products. Int J Mol Sci. 2021;22(8):4193.
41. Yuen L, Wong VW. Gestational diabetes mellitus: challenges for different ethnic groups. World J Diabetes. 2015;6(8):1024.
42. Alesi S, Ghelani D, Rassie K, Mousa A. Metabolomic biomarkers in gestational diabetes mellitus: a review of the evidence. Int J Mol Sci. 2021;22(11):5512.
43. Bu Kang B, Huang Chiang B. A novel phenolic formulation for treating hepatic and peripheral insulin resistance by regulating GLUT4-mediated glucose uptake. J Tradit Complement Med. 2022;12(2):195–205.
44. Kunasegaran T, Balasubramaniam VR, Arasoo VJT, Palanisamy UD, Ramadas A. The modulation of gut microbiota composition in the pathophysiology of gestational diabetes mellitus: a systematic review. Biology. 2021;10(10):1027.
45. Neyrinck AM, Sánchez CR, Rodriguez J, Cani PD, Bindels LB, Delzenne NM. Prebiotic effect of berberine and curcumin is associated with the improvement of obesity in mice. Nutrients. 2021;13(5):1436.
46. Cao H, Li C, Lei L, Wang X, Liu S, Liu Q, et al. Stachyose improves the effects of berberine on glucose metabolism by regulating intestinal microbiota and short-chain fatty acids in spontaneous type 2 diabetic KKAy mice. Front Pharmacol. 2020;11:578943.
47. Rossi MdSC, Stedefeldt E, da Cunha DT, de Rosso VV. Food safety knowledge, optimistic bias and risk perception among food handlers in institutional food services. Food control. 2017;73:681–8.
48. Sorrenti V, Ali S, Mancin L, Davinelli S, Paoli A, Scapagnini G. Cocoa polyphenols and gut microbiota interplay: bioavailability, prebiotic effect, and impact on human health. Nutrients. 2020;12(7):1908.
49. Wiese M, Bashmakov Y, Chalyk N, Nielsen DS, Krych Ł, Kot W, et al. Prebiotic effect of lycopene and dark chocolate on gut microbiome with systemic changes in liver metabolism, skeletal muscles and skin in moderately obese persons. BioMed Res Int. 2019;2019:4625279.

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