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Original Article

The Association of Ultra-Processed Foods Intake with Prevalence of Diabetes in Adult Population, Shiraz, Southern Iran: A Cohort-Based Study

Mohsen Mohit[1], Salman Mohammadi[2], Melika Mahmoudizadeh[3], Sanaz Jamshidi[4], Najmeh Hejazi[5,6], Seyed Jalil Masoumi[5,6]*

1. Student Research Committee, Nutrition Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
2. Nutritional Health Research Center, School of Health and Nutrition, Lorestan University of Medical Sciences, Khorramabad, Iran
3. Department of Community Nutrition, School of Nutrition and Food Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
4. Department of Nutrition, School of Public Health, Iran University of Medical Sciences, Tehran, Iran
5. Department of Clinical Nutrition, School of Nutrition and Food Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
6. Nutrition Research Center, Department of Clinical Nutrition, School of Nutrition and Food Sciences, Shiraz University of Medical Sciences, Shiraz, Iran

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**Corresponding author:*
Seyed Jalil Masoumi, MD, PhD;
Department of Clinical Nutrition, School of Nutrition and Food Sciences, Shiraz University of Medical Sciences, Shiraz, Iran.
Email: masoumi7415@gmail.com
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ABSTRACT

Background: The expansion of the food industry and the rise in food processing have changed dietary habits, leading to concerns about excessive consumption. This study examined the relationship between the intake of ultra-processed foods (UPFs) and the prevalence of diabetes in an adult population in Shiraz, Southern Iran.

Methods: Data from 3,285 participants in Employee Health Cohort of the Shiraz University of Medical Sciences were collected between August 2017 and February 2020 and analyzed using logistic regression analysis. The associations, yielding odds ratios with corresponding 95% confidence intervals were determined.

Results: The relationship between higher consumption of UPFs and diabetes prevalence did not reach statistical significance. Even after adjusting for potential confounders, including age, gender, body mass index (BMI), educational level, smoking habit, intake of energy drinks, and physical activity did not reveal a significant association.

Conclusion: Our findings did not show any statistically significant association between higher consumption of UPFs and diabetes prevalence. Comprehensive judgments require further investigations with more comprehensive study designs, larger sample sizes, and other populations.

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Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder marked by a high blood glucose level caused by issues with insulin secretion, insulin action, or both (1). It is broadly divided into two groups of type 1 diabetes and type 2 diabetes mellitus (T2DM); while the global prevalence of T2DM is alarmingly high and continues to grow. This rise is fuelled by factors such as aging populations, urbanization, sedentary lifestyles, and increasing obesity rates (2, 3). According to the International Diabetes Federation (IDF), approximately 537 million adults; about 10% of the global population aged 20-79 were living with diabetes in 2021. This number is expected to climb to 643 million by 2030 and 783 million by 2045 (4). The prevalence of prediabetes among Iranian men and women was estimated to be 28.96% and 30.86%, respectively, while the prevalence of diabetes was 25.43% in men and 30.26% in women (5). The burden of diabetes is not evenly distributed and low- and middle-income countries faced higher prevalence rates, often due to limited access to healthcare and preventive measures (6).

Diabetes mellitus can lead to serious long-term complications if not properly managed. Chronic complications of DM categorized into microvascular including retinopathy, nephropathy, and neuropathy; and macrovascular such as cardiovascular disease, stroke, and peripheral artery disease (7-10). These complications significantly impact quality of life and increase mortality rate. Additionally, diabetes raises the risk of infections, delays wound healing, and contributes to other systemic health issues, underscoring the importance of comprehensive management strategies (11-13).

Emerging research has highlighted a strong link between the consumption of ultra-processed foods (UPFs) and the risk of developing T2DM (14). UPFs are industrial food products typically made with five or more ingredients, including additives, preservatives, artificial flavors, and colors; substances rarely used in home cooking. Common examples include soft drinks, packaged snacks, instant noodles, and ready-to-eat meals (15, 16). A large prospective cohort study revealed that a 10% increase in the proportion of UPFs in the diet was associated with a 15% higher risk of developing T2DM (17).

Diets high in UPFs are often loaded with refined sugars, unhealthy fats, and low in fiber, all of which can impair insulin sensitivity. These foods are also energy-dense and highly palatable, making overconsumption easy and contributing to weight gain; a major risk factor for T2DM. Furthermore, UPFs lack essential nutrients and are linked to inflammation and metabolic dysfunction, further elevating the risk of diabetes (18, 19). In this study, we aimed to investigate the relationship between UPFs consumption and the prevalence of diabetes in a large-scale Iranian population.

Materials and Methods

This study utilized baseline data from an ongoing cohort survey involving Iranian employees of the Shiraz University of Medical Sciences (SUMS) Health Cohort from August 2017 to February 2020. The SUMS Employees Health Cohort is part of a PERSIAN cohort study (19), which focuses on the most prevalent non-communicable diseases (NCDs) and their related factors. The inclusion criteria for the study were age between 20 and 70 years and to have Iranian nationality. Additionally, participants with abnormal energy intake (for men: less than 600 or more than 4,200 Kcal/day; for women: less than 500 or more than 3,600 kcal/day) were also excluded. A written informed consent was provided from all participants. The study received ethical approval from SUMS (No: IR.SUMS.SCHEANUT.REC.1404.017) and was performed in consistent with the Declaration of Helsinki.

Trained health care personnel measured participants' weight and height using a digital scale with 100 g accuracy (Seca808; Seca, Germany) and a stadiometer with 0.5 cm precision, respectively. For these measurements, participants were barefoot, wore light clothing, and stood upright. BMI was calculated by dividing weight (kg) by height squared (m^2). A non-extensible measuring tape was also used to measure waist circumference (WC) and hip circumference (HC) to the nearest 0.5 cm. Also, WC was divided by HC to calculate the waist-to-hip ratio (WHR). T2DM was diagnosed based on two criteria of fasting blood sugar (FBS) >26 mg/dL, and a history of taking medications for T2DM.

Dietary intakes were assessed through face-to-face interviews using a 116-item semi-quantitative food frequency questionnaire (FFQ) (20). The frequencies over periods of a day, week, month, or year were multiplied by the weight of the predefined portion sizes and converted to grams/millilitres of consumption per day. The intakes were analyzed using Nutritionist IV software version 4.0 (adapted for Iranian dishes), from which the energy and nutrient amounts of individuals' diets were derived. According to the criteria for categorizing foods in UPFs group of NOVA classification system (focuses on the level of processing) (21), all food items that underwent ultra-processing were identified and subsequently classified into one of the UPFs subgroups of breads, salty snacks, fast foods, sweetened beverages, sweets and desserts, dairy products, and other UPFs. The daily amounts of consumed foods (g) and beverages (mL) in each subgroup were determined. The overall UPFs consumption was calculated by summing the amounts from the seven subgroups. Then, it was divided to tertiles of UPFs consumption for the statistical analysis.

A general questionnaire was applied to gather information on age (years), sex (male, female), marital status (married, not married), the educational level (under diploma, diploma, bachelor's degree, master's degree, and Doctorate), and smoking history (yes, no). For the level of physical activity, participants completed the International Physical Activity Questionnaire (IPAQ) (22). Descriptive statistical analysis of continuous and categorical data was done using ANOVA. Mean±standard deviation (SD) was reported. Chi-square test (number, percentage) was demonstrated across tertiles of UPFs consumption, respectively. Logistic regression analysis was conducted to examine the odds of T2DM associated with UPFs consumption as well as its subgroups. The adjusted model accounted for confounders including sex, age, BMI, total energy intake, physical activity, and smoking. SPSS software (SPSS Inc., version 26.0, Chicago, IL, USA) was used for the statistical analyses, considering the statistical significance level as *p* value <0.05.

Table 1: Baseline characteristics of study participants.

Variable	Total (n=3285)	Tertile of UPFs			*P* value
		T1 (N=1095)	T2 (N=1095)	T3 (N=1095)	
Age (year)	40.94±6.89	42.11±6.80	40.56±6.89	40.15±6.84	<0.001 [a]
Gender, male (%)	1465 (44.6%)	393 (35.9%)	471 (43%)	601 (54.9%)	<0.001 [b]
Education level, Bachelor's degree and higher	2066 (62.9%)	686 (62.6%)	737 (67.3%)	643 (58.7%)	<0.001 [b]
Marital status, married (%)	2655 (80.8 %)	854 (78%)	891 (81.4%)	910 (83.1%)	0.008 [b]
Smoking history, yes (%)	309 (9.4%)	79 (7.2%)	92 (8.4%)	138 (12.6%)	<0.001 [b]
BMI (kg/m^2)	26.76±4.14	26.48±4.02	26.61±3.92	27.21±4.44	<0.001 [a]
WC (cm)	102.52±7.66	93.02±10.17	93.68±9.77	95.63±11.00	<0.001 [a]
HC (cm)	94.11±10.38	101.74±7.38	102.42±7.52	103.40±7.98	<0.001 [a]
WHR	0.91±0.06	0.91±0.06	0.91±0.06	0.92±0.06	<0.001 [a]
Physical activity (Met.hr/week)	119.71±93.83	111.15±90.45	110.49±87.11	137.50±100.91	<0.001 [a]
Diabetes (n)	221 (6%)	85 (7%)	71 (6.5%)	65 (6%)	0.216 [b]
FBS (mg/dL)	92.24±17.63	92.31±16.14	91.72±17.31	92.70±19.31	0.421 [a]

Data were presented as mean±SD for quantitative variables and number (percentage) for qualitative variables. [a]The *p* value obtained by one-way ANOVA. [b]The *p* value obtained by Chi-square. The significant level was 0.05. Abbreviations: BMI: Body mass index; WC: Waist circumference; HC: Hip circumference; WHR: Waist to hip ratio; FBS: Fasting blood sugar, UPFs: Ultra-processed foods.

Table 2: Baseline dietary intake of the study participants across tertiles of ultra-processed foods (UPFs) consumption.

Variable	Total (n=3285)	Tertile of UPFs			*P* value
		T1 (N=1095)	T2 (N=1095)	T3 (N=1095)	
UPFs consumption (Kcal/day)	376.67±289.63	141.85±49.38	306.47±54.41	681.70±305.24	<0.001
Bread (g/day)	9.21±13.78	4.31±5.07	8.60±10.42	14.71±19.51	<0.001
Salty snacks (g/day)	2.81±5.90	1.09±1.96	2.66±4.58	4.68±8.56	<0.001
Fast foods (g/day)	14.53±22.10	6.68±7.39	12.90±13.41	24.02±32.83	<0.001
Sweetened beverages (mL/day)	63.66±94.62	27.81± 6.33	50.52±56.74	112.65±135.92	<0.001
Sweets and desserts (g/day)	25.07±23.65	12.68±8.94	23.88±15.72	38.65±31.82	<0.001
Dairy products (g/day)	62.75±80.81	16.41±13.80	43.71±28.94	128.14±108.54	<0.001
Other UPFs (g/day)	1.84±4.15	0.87±1.61	1.58±2.86	3.08±6.10	<0.001
Total energy intake (kcal/day)	2173.54±726.59	1826.44±512.77	2129.59±690.17	2564.29±755.14	<0.001
Protein consumption (g/day)	74.29±26.19	62.24±18.61	72.85±25.08	87.78±27.47	<0.001
Carbohydrate consumption (g/day)	344.22±129.49	293.36±95.42	338.16±133.47	401.14±132.42	<0.001
Total fat consumption (g/day)	60.80±22.77	49.37±16.74	59.15±18.25	73.95±25.25	<0.001
Dietary cholesterol (mg/day)	268.84±33.64	229.14±108.79	261.08±110.76	316.31±160.04	<0.001
Saturated fatty acids (mg/day)	17.59±6.87	14.38±5.09	17.20±5.68	21.18±7.75	<0.001
Mono unsaturated fatty acids (mg/day)	18.39±8.16	14.91±6.31	17.80±6.75	22.47±9.29	<0.001
Poly unsaturated fatty acids (mg/day)	16.73±7.48	14.14±6.25	16.38±6.68	19.66±8.29	<0.001
Vitamin B6 (mg/day)	1.68±0.57	1.42±0.47	1.64±0.49	1.97±0.61	<0.001
Vitamin B12 (µg/day)	4.52±4.53	3.54±2.93	4.39±3.39	5.64±6.27	<0.001
Vitamin C (mg/day)	185.57±93.44	163.34±84.47	181.71±86.72	211.67±101.80	<0.001
Vitamin E (mg/day)	4.66±3.06	7.86±3.55	9.34±4.33	11.82±6.07	<0.001
Zinc (mg/day)	7.99±2.76	6.68±2.09	7.83±2.28	9.46±3.06	<0.001

Data were presented as mean±SD for quantitative variables. The *p* value obtained by one-way ANOVA. The significant level was 0.05. Abbreviations: BMI: Body mass index; WC: Waist circumference; HC: Hip circumference; WHR: Waist to hip ratio; FBS: Fasting blood sugar.

Results

Table 1 shows that baseline characteristics such as age, gender, educational level, marital status, smoking habits, physical activity, BMI, waist and hip circumference, and WHR to be significantly different across tertiles of UPF intake (all $p<0.05$), except for FBS, which illustrated no significant difference. Table 2 indicates that both UPF consumption and total energy intake varied significantly across UPF tertiles. Intakes of various dietary components; including protein, carbohydrates, cholesterol, different types of fatty acids, and several vitamins and minerals; also differed significantly with UPF intake (all $p<0.001$).

Table 3 shows that the association between increased UPFs consumption and diabetes prevalence was not statistically significant. In model 2, which was adjusted for variables such as age, gender, BMI, educational level, smoking habits, energy intake, and physical activity, the association remained non-significant. Table 4 presents a detailed analysis of the association between various subgroups of UPF

Table 3: Association between ultra-processed foods (UPFs) intake and diabetes.

Diabetes	UPFs consumption				
	T1 (N=1095)	T2 (N=1095)	*P* value	T3 (N=1095)	*P* value
Crude	Ref.	0.82 (0.59, 1.14)	0.245	0.75 (0.53, 1.04)	0.092
Model 1	Ref.	0.90 (0.64, 1.26)	0.565	0.82 (0.58, 1.16)	0.279
Model 2	Ref.	0.92 (0.65, 1.30)	0.650	0.85 (0.58, 1.24)	0.422

Adjusted odds ratios and 95% confidence intervals for diabetes across tertiles of ultra-processed food. Model 1: Adjusted for age, gender, BMI, education, and smoking. Model 2: Additionally, adjusted for energy intake, and physical activity. Ref: Reference.

Table 4: Associations between ultra-processed foods (UPFs) intake subgroups and diabetes.

Diabetes	Subgroup				
	Bread				
	T1 (N=1095)	T2 (N=1095)	*P* value	T3 (N=1095)	*P* value
Crude	Ref.	0.81 (0.59, 1.12)	0.220	0.66 (0.47, 0.93)	0.018
Model 1	Ref.	0.88 (0.63, 1.23)	0.480	0.76 (0.54, 1.09)	0.142
Model 2	Ref.	0.89 (0.64, 1.23)	0.490	0.78 (0.54, 1.11)	0.174
Salty snacks					
Crude	Ref.	0.80 (0.58, 1.11)	0.190	0.67 (0.48, 0.94)	0.023
Model 1	Ref.	0.88 (0.63, 1.24)	0.486	0.80 (0.56, 1.15)	0.240
Model 2	Ref.	0.89 (0.63, 1.24)	0.493	0.82 (0.57, 1.18)	0.295
Fast foods					
Crude	Ref.	0.97 (0.70, 1.33)	0.871	0.67 (0.47, 0.94)	0.024
Model 1	Ref.	1.05 (0.76, 1.46)	0.751	0.79 (0.54, 1.14)	0.210
Model 2	Ref.	1.06 (0.76, 1.47)	0.726	0.81 (0.55, 1.17)	0.267
Sweetened beverages					
Crude	Ref.	0.56 (0.40, 0.78)	<0.001	0.58 (0.41, 0.80)	<0.001
Model 1	Ref.	0.57 (0.40, 0.80)	0.001	0.68 (0.47, 0.97)	0.036
Model 2	Ref.	0.57 (0.40, 0.81)	0.002	0.69 (0.48, 1.00)	0.054
Sweets and desserts					
Crude	Ref.	0.70 (0.50, 0.98)	0.043	0.80 (0.58, 1.11)	0.187
Model 1	Ref.	0.72 (0.51, 1.02)	0.071	0.83 (0.60, 1.16)	0.296
Model 2	Ref.	0.74 (052, 1.04)	0.087	0.87 (0.61, 1.24)	0.448
Dairy products					
Crude	Ref.	0.95 (0.68, 1.33)	0.799	0.94 (0.67, 1.31)	0.734
Model 1	Ref.	1.06 (0.76, 1.50)	0.707	0.98 (0.70, 1.39)	0.942
Model 2	Ref.	1.08 (0.77, 1.52)	0.642	1.01 (0.71, 1.44)	0.927
Other UPFs					
Crude	Ref.	0.81 (0.58, 1.12)	0.215	0.72 (0.52, 1.01)	0.064
Model 1	Ref.	0.87 (0.62, 1.21)	0.414	0.90 (0.63, 1.27)	0.548
Model 2	Ref.	0.87 (0.62, 1.22)	0.431	0.92 (0.65, 1.32)	0.928

Adjusted odds ratios and 95% confidence intervals for diabetes across tertiles of ultra-processed food subgroups. Model 1: Adjusted for age, gender, BMI, education, and smoking. Model 2: Additionally, adjusted for energy intake, and physical activity, Ref: Reference.

consumption and the prevalence of diabetes among the study population. The findings indicated that, in the adjusted model 2, there was no significant association when comparing the third tertile of UPF consumption to the first tertile suggesting that higher consumption levels of these foods were not correlated with an increased prevalence of diabetes in the assessed subgroups.

Discussion

In present cross-sectional study, although BMI, WC, HC, and WHR increased across tertiles of UPF consumption, no remarkable difference was found according to diabetes prevalence and FBS level. In addition, based on adjusted models, no association was found between UPFs and subgroups intake with diabetes rate. Based on our literature review, a recent systematic review and meta-analysis revealed that an elevated consumption of UPFs could notably increase the risk of developing T2DM. However, it should be mentioned that data were obtained from a total of five studies, which included one cross-sectional study and four cohort studies and none of them were conducted among Iranian population (23).

Also, a meta-analysis represented a positive correlation between both moderate and high intake of UPFs and the prevalence of diabetes. Notably, high consumption was associated with a greater risk of diabetes compared to low or moderate intake. The stratified analyses based on consumption frequency revealed a dose-response relationship, indicating that the risk of diabetes increased with the number of consumption occasions per week, as well as across different quartiles and quintiles of intake. Furthermore, the analysis concerning follow-up duration revealed that studies extending beyond 10 years denoted to higher risk levels for both moderate and high consumption of UPFs (24).

Due to the cross-sectional design of our study, we were unable to investigate the incidence of diabetes, which might account for our non-significant findings. Another study evaluating pre-diabetes and T2DM patients demonstrated a positive, non-linear correlation between the overall consumption of UPFs and the likelihood of pre-diabetes among Iranian adults. However, in line with our findings there was no significant link between UPFs consumption and the risk of T2DM (25). In addition, an investigation in UK indicated a diet rich UPFs to be linked with a significant increase in the risk of T2DM (26).

The production of UPFs involves various stages, such as breaking down of whole foods into smaller components, making chemical alterations, incorporating various cosmetic additives, and utilizing advanced packaging techniques. Each of these stages can significantly contribute to the risk of developing diabetes (15). A meta-analysis revealed that bisphenol, a prevalent substance in plastic packaging, was linked to a 28% increase in diabetes risk (27). Also, non-nutritive compounds generated during industrial food processing, including advanced glycation end products and acrylamide, had the potential to elevate insulin resistance (28, 29).

Additionally, UPFs typically exhibited a high energy density coupled with a low nutrient density and low fiber. These foods often contain significant amounts of added sugars, which can contribute to an energy imbalance and obesity, both of which are recognized as risk factors for the onset of T2DM (30-32). Although, numerous studies, primarily carried out within Western populations, a study in the Middle East, Iran, by Amirian *et al.* illuminated no notable correlation between the consumption of the UPFs and the risk of developing T2DM, even after categorizing UPF consumption into quartiles (33).

It should be noted that NOVA food classification is a qualitative system and the classification of UPFs varies significantly between countries, for instance the processing degree of pizza. In Iran, the UPFs may be less processed compared to those in other regions, which could explain the lack of association found in our study. This study is among limited population-based studies conducted in Iran that explored the relationship between the UPFs consumption and diabetes prevalence. On the other hand, we conducted various subgroups of UPFs to capture any probable association between components of UPFs and diabetes. However, since the design of our study was cross-sectional, reverse causation should also be considered as a potential limitation. Individuals diagnosed with diabetes may change their dietary habits such as decreasing or increasing their intake of UPFs following their diagnosis. Such behavioral changes could influence the observed associations in the present study. Moreover, a frequent limitation was the reliance on a FFQ to assess typical dietary intake. Furthermore, the FFQ could not provide comprehensive details regarding the differentiation between industrial and non-industrial food items. Nonetheless, the lack of dietary assessment tools was specifically tailored to evaluate food processing remained a prevalent limitation in the current research.

Conclusion

Our results provided no remarkable association between UPFs and prevalence of diabetes. Since diabetic patients were a vulnerable population, future researches could explore this area attentively.

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Authors' Contribution

The study was initially conceptualized and designed by MM, SM, and SJM. Data analysis was conducted by MM and SM utilizing statistical methods. The first draft of the manuscript was authored by MM, SM, SJ, and MMZ, with NH and SJM contributing to its revision. All authors participated in the review process and provided approval for the final version of the manuscript.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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