Journal of Umm Al-Qura University for Medical Sciences

Journal homepage: https://uqu.edu.sa/en/mj

Research Article

Dietary Intake and Physical Activity are Associated with Type 2 Diabetes Mellitus Among Saudi Adults From Makkah: A Case-control Study

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ARTICLE INFO

Received: 02/07/2023
Revised: 25/07/2023
Accepted: 03/09/2023

Keywords:
Dietary habits,
Physical activity,
Dietary Intake, T2DM,
Diabetes, Saudi Arabia

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ABSTRACT

Background: Diabetes mellitus (DM) is a global public health problem. The treatment of type 2 diabetes mellitus (T2DM) is a combination of medications and lifestyle changes. The study aims to assess behavioral risk factors (dietary patterns and physical activity) and their association with T2DM among Saudi adults from Makkah.

Methods: A retrospective case-control study was conducted from December 2020 to February 2021. Data was obtained via online interviews with T2DM (cases) and without T2DM participants (controls) in Makkah, Saudi Arabia. Dietary habits were assessed by a Saudi FFQ. Habitual physical activity was assessed by the International Physical Activity Questionnaire-Short Form.

Results: Out of 273 participants, n=94 (34.4%) were in the case group and 179 (65.6%) in the control group. The prevalence of obesity was significantly higher among cases (51.6%) compared to controls (29.4%). The number of meals and consumption of cooked rice were positively associated with the prevalence of T2DM. The consumption frequency of the following foods was lower among T2DM patients: sausage, cold meats, salami, vegetable oil, restaurant consumption, cooked pasta, additive sugar, sweet biscuits, cakes, salty pies and potato chips. T2DM patients performed more low-intensity physical activity compared to controls.

Conclusion: Obesity, number of meals and high rice consumption were associated with T2DM. These factors may be used in preventive and treatment measures, indicating the importance of lifestyle behaviors in T2DM.

INTRODUCTION

Diabetes mellitus (DM) is a significant issue in international public health. The International Diabetes Federation estimated that the prevalence of the global diabetic population aged 20 to 79 years is 463 million, rising to 700 million by 2045 (International Diabetes Federation, 2021). Saudi Arabia ranks second highest in the Middle East and is seventh globally for diabetes prevalence. Saudi Arabia's annual cost of treating patients with DM is around $9.6 billion. Each Saudi diabetic is expected to cost the government around $800 per month (Abdulaziz Al Dawish et al., 2016; Midhet et al., 2010). The World Health Organization (WHO) reported that diabetes is a significant cause of blindness, kidney failure, heart attacks, stroke, and amputation of the lower limbs. Thus, identifying the factors associated with T2DM is essential in prevention and treatment (World Health Organization, 2018).

Irreversible factors that may increase T2DM are age, genetics, race, and ethnicity. On the other hand, reversible factors, including diet, physical activity, and smoking, have been reported as the leading causes of the increase in T2DM (Aljulifi, 2021; Neuenschwander et al., 2019; Sami et al., 2017; Zhang et al., 2020).

Significant associations between physical inactivity and T2DM have been observed in numerous cross-sectional, prospective, and retrospective studies (Neuenschwander et al., 2019). Physical activity plays a significant role in preventing T2DM in at-risk subjects and managing T2DM patients. Physical activity benefits go beyond the insulin resistance framework and help improve T2DM risk related to glycemic control and protection of the pancreatic ß-cells function (Kanaley et al., 2022; Neuenschwander et al., 2019). Even in the absence of weight changes, many positive effects of physical activity on health status can be obtained, such as controlling lipids, blood pressure, T2DM-related comorbidities,

Doi: https://doi.org/10.54940/ms94614842

cardiovascular risk, and mortality, while enhancing the quality of life (Neuenschwander et al., 2019; Sami et al., 2017). Several prospective studies showed that particularly among those who have reported being physically inactive, being overweight and obese was associated with a significantly increased risk of diabetes. In contrast, a lower risk of diabetes within all body mass index categories was related to high physical activity levels (Hjerkind et al., 2017).

Several potential biological pathways for the protective effect of physical activity on T2DM have been suggested. Physical activity improves abnormal glucose levels when caused by insulin resistance (Charokopou et al., 2016; Yang et al., 2019). Moreover, physical activity is likely to be most beneficial in preventing the progression of T2DM during the initial stages before insulin therapy is needed (Neuenschwander et al., 2019; Sami et al., 2017)It appears that physical activity's protective mechanism synergizes with insulin. Previous studies highlight the importance of studying physical activity in T2DM.

Healthy nutritional practices are essential for preventing T2DM and reducing the risk of T2DM development and metabolic effects, consequently enhancing the quality of life. The U.S. Department of Agriculture defines a healthy diet as “the eating pattern that provides enough of each essential nutrient from nutrient-dense foods containing a variety of foods from all the primary food groups and focuses on balancing calories consumed with calories expended to help you achieve and sustain a healthy weight. This eating pattern limits the intake of solid fats, sugar, salt (sodium), and alcohol (US Department of Agriculture, 2019).

Many dietary patterns differ based on gender, ethnicity, and geographical region. In Middle Eastern populations, information on dietary patterns and the risk of T2DM is limited. Due to the unique characteristics of their dietary intakes and the high prevalence of T2DM, assessment of dietary patterns concerning T2DM is particularly important for Middle Eastern populations. Findings from the Western population cannot be easily extrapolated to non-Western nations due to differences in food items and combinations (Zaroudi et al., 2016). Saudi Arabia has unique dietary options that are occasionally consumed, such as dates, pastries, sweets, kabsa (a dish made with rice and meat), and high-fat and carbohydrate choices. Some studies have focused on dietary patterns that promote the increase of T2DM in Saudi Arabia. Since foods such as kabsa, French fries, and baked products are widespread in Saudi Arabia, the study found that they were the most critical determinants of T2DM in the Saudi Arabian population (Midhet et al., 2010). Collectively, several dietary patterns and food items in Saudi Arabia may increase the risk of T2DM; therefore, it is highly important to study the association between dietary intake and T2DM in Saudis.

The WHO, 2018 estimated that the leading global causes of morbidity and mortality in the Kingdom of Saudi Arabia would be due to non-communicable diseases, including T2DM. Few studies assessed the associations between physical activity and dietary intake to T2DM (Ardisson Korat et al., 2014; Fareed et al., 2017). However, Saudi Arabia lacks population-based epidemiological studies assessing the risk factors of T2DM (World Health Organization, 2018). Thus, it is necessary to conduct some updated studies that focus on diabetic risks.

This study aims to fill these gaps by focusing on behavioural risk factors (dietary patterns and physical activity) and their association with T2DM among Makkah adults. The aims of this study are 1) to compare the prevalence of common foods in the Saudi diet between cases (participants with T2DM) and controls (without T2DM). 2) to compare physical activity between cases and controls. To the best of our knowledge, this is the first study to address these associations in Makkah, Saudi Arabia.

MATERIALS AND METHODS

Participants

A retrospective case-control study from December 2020 to February 2021. Data was obtained via phone interviews with individuals newly diagnosed with T2DM (cases) and without T2DM participants (controls). Medical records (fasting blood sugar level or random blood sugar) and contact numbers of eligible cases and controls were searched for the most recent laboratory test results in the laboratory department of Al-Salam Hospital and AlBeshry clinics in Makkah, KSA). The study was approved by The Biomedical Research Ethics Committee, Umm Al-Qura University (Approval No. HAPO-02-K-012-2022-11-1262).

Cases: This study tried to obtain the same number of cases and controls as previously reported (Zaroudi et al., 2016). A random selection of n=94 patients (females=59, and males=35) (19 - 70 years old) who were already diagnosed with T2DM was recruited from the diabetic clinic of Al-Salam Hospital and AlBeshry clinic. Data on the most recent random or fasting blood glucose level readings were extracted from medical records for all potential participants. The researchers excluded A1C because most patients did not have results. This may be due to COVID-19 restrictions at that time. The information on comorbidity was collected from patients’ files.

Controls: comprised (179) normoglycemic subjects randomly selected from the patient laboratory test and matched for residential location. We excluded control subjects who reported having diabetes, prediabetes, cardiovascular disease (myocardial infarction, angina pectoris, coronary artery surgery, stroke), or cancer because a diagnosis of these diseases may affect diet and physical activity or affect reporting of them. The researchers excluded prediabetes patients based on the diagnosis reported in the files.

Data Collection and Questionnaire

Two researchers and two trained interviewers conducted interviews via phone calls in Arabic. Participants gave their oral consent before the interview started. The purpose of the study and the proposed use of the findings were explained to the participants. The online questionnaire was created using SurveyHero. All these procedures were conducted remotely due to restrictions on Coronavirus disease (COVID-19).

The questionnaire was available in Arabic and English. The translation process was previously conducted (Faleh, 2019). Before starting the study, the questionnaire was initially administered to 10 bilingual subjects, who completed both the Arabic and English versions to determine the test-retest reliability. All information was consistent and independent of the version administered. The questionnaire included demographic information (age, gender, education, marital status, etc.), diabetic information (diabetic onset and management), dietary habits, and physical activity. Dietary habits were assessed by a Food Frequency Questionnaire (FFQ) derived from a developed Saudi food frequency questionnaire (Faleh, 2019). Researchers KG (PhD in nutrition) and EN (PhD in nutrition and also, a consultant registered dietitian are experts in the clinical nutrition field and have modified the questionnaire for this study by including only 22 questions that represent the main food items. This modification was conducted to enhance participants' responses and reduce the burden of questionnaire filling. The questions asked about the number of meals and regularity of snacks, food items used in snacks, sugar, soft drinks, dairy products, fruits, vegetables, meat, and chicken, carbohydrate items and fat intake. Food intake was assessed for the past month, and the score of food was divided into three categories to simplify the reporting of results (no consumption, moderate consumption (1-3 portions a week), and high consumption (4 portions a week or more)). Habitual physical activity was assessed using the International Physical Activity Questionnaire-Short Form (IPAQ-SF)(Lee et al., 2011). The scoring of the IPAQ-SF was conducted using the IPAQ-SF guideline(Lee et al., 2011). IPAQ-SF reports four activity intensity levels: vigorous, moderate, walking, and sitting.

The weight and height of the participants were self-reported by participants. Body mass index (BMI) was calculated: body weight (kg)/ (height (m))^2. Using their BMI, patients were classified according to the WHO classification into underweight (<18.5), normal (18.5 - 24.99), overweight (25- 29.99), and obese (30 and above)(WHO, 2010).

Statistical analysis

Data was analyzed using (SPSS) (IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp). All variables were coded and checked before analysis. Continuous data were presented as means and standard deviation (SD). Categorical data were presented as percentages and frequency. Chi-square was used to compare qualitative variables (case and control groups). The student's t-test was used to compare BMI, random blood sugar (RBS), and fasting blood sugar (FBS) values between case and control groups. A p-value of less than 0.05 and a confidence interval of 95% were considered significant.

RESULTS

Sociodemographic profile and medical history

A total of 273 participants were included, n= 94 (34.4%) were included in the case group and 179 (65.6%) in the control group. The number of men was higher in the case group than in the control group (37.2% vs. 16.2%), while the number of women was higher in the control group than in the case group (83.8% vs 62.8%). The socio-demographic data are presented in Tables 1A, 1B.

Medical characteristics of the participants

Table 2 demonstrates the health status of the participants. The prevalence of obesity was higher among the case group (51.6%). In comparison, the prevalence of normal weight and overweight were higher among the control group (35.0% and 30.5%, respectively) with significant differences (p<0.0001). The mean score of BMI was higher among the case group (32.03 vs 26.94, p<0.0001) than the control group. The mean score of random (205.74 vs 123.52, p<0.0001) and fasting blood sugar (157.75 vs 89.63, p<0.0001) was higher among cases than controls.

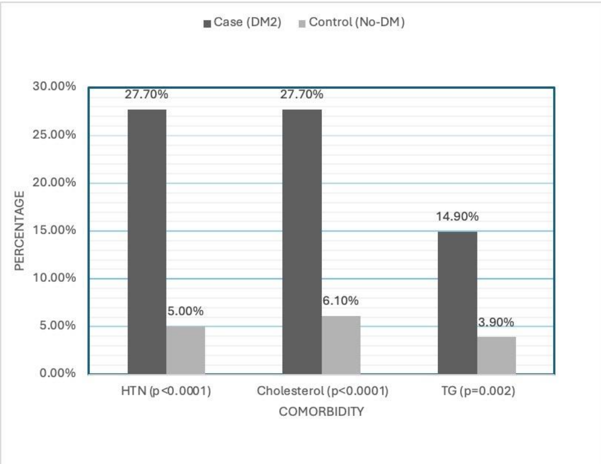

Figure 1: *Prevalence of comorbidities among cases and controls: DM2; Type 2 Diabetes Mellitus, HTN; hypertension, No-DM: Does not have diabetes, TG; triglyceride.*

As shown below in (Figure 1) we noticed that there were significant differences between the groups (cases and controls) regarding comorbidity prevalence, where the prevalence of hypertension (HTN) (27.7% vs 5.0%, p<0.0001), cholesterol (27.7% vs. 6.1%, p<0.0001), and triglyceride (TG) (14.9% vs 3.9%, p=0.002) were higher in the case group than the control group.

Table 1A: *Sociodemographic profile of the participants.*

Variable		Cases (n=94)	Controls (n=179)	Total (n=273)
Sex	Female	59	150	209
		62.8%	83.8%	76.6%
	Male	35	29	64
		37.2%	16.2%	23.4%
Age (Y)	18-29	7	56	63
		7.4%	31.3%	23.1%
	30-39	11	59	70
		11.7%	33.0%	25.6%
	40-50	31	41	72
		33.0%	22.9%	26.4%
	51-64	40	21	61
		42.6%	11.7%	22.3%
	65 and more	5	2	7
		5.3%	1.1%	2.6%
Pregnancy	No	59	150	208
		100.0%	100.0%	100.0%
Breastfeed-ing	Yes	0	1	1
		0.0%	.7%	.5%
	No	59	149	208
		100.0%	99.3%	99.5%
Resident	Makkah	94	179	273
		100.0%	100.0%	100.0%
Nationality	Saudi	84	168	252
		89.4%	93.9%	92.3%
	Non-Saudi	10	11	21
		10.6%	6.1%	7.7%
Marital status	Single	10	56	66
		10.6%	31.3%	24.2%
	Engaged	71	105	176
		75.5%	58.7%	64.5%
	Married	8	7	15
		8.5%	3.9%	5.5%
	Divorced	5	8	13
		5.3%	4.5%	4.8%
	Wid-owed	0	3	3
		0.0%	1.7%	1.1%
Educational level	Less than high school	23	5	28
		24.5%	2.8%	10.3%
	High school	22	27	49
		23.4%	15.1%	17.9%
	Diploma	14	27	41
		14.9%	15.1%	15.0%
	Bachelor	31	104	135
		33.0%	58.1%	49.5%
	Master	2	14	16
		2.1%	7.8%	5.9%
	PHD	2	2	4
		2.1%	1.1%	1.5%

Factors associated with T2DM prevalence

The results in Tables 3A and B show the association between socio-demographic profile and medical history with the prevalence of T2DM. Individuals who had a higher prevalence of T2DM were males compared to females (54.7% vs 28.7%) ($p < 0.001$) and older age than younger ($p < 0.001$). Also, marital status was significantly associated with the prevalence of T2DM, where the highest prevalence of T2DM was present in widowed participants, and the lowest were single (53.3% vs 15.2%) ($p = 0.001$).

Table 1B: *Sociodemographic profile of the participants.*

Variable	Cases (n=94)	Controls (n=179)	Total (n=273)	Variable
Occupation	Government	19	26	45
		20.2%	14.5%	16.5%
	Health worker	2	24	26
		2.1%	13.4%	9.5%
	Private	6	28	34
		6.4%	15.6%	12.5%
	Military	5	2	7
		5.3%	1.1%	2.6%
	Businessman	2	5	7
		2.1%	2.8%	2.6%
	Housewife / retired	57	73	130
		60.6%	40.8%	47.6%
	Students	2	15	17
		2.1%	8.4%	6.2%
	Health sector	0	1	1
		0.0%	.6%	.4%
	Other	1	5	6
		1.1%	2.8%	2.2%
Monthly income (SAR)	Less than 5000	43	92	135
		45.7%	51.4%	49.5%
	5000-10000	19	33	52
		20.2%	18.4%	19.0%
	10001-15000	17	31	48
		18.1%	17.3%	17.6%
	15001-20000	13	16	29
		13.8%	8.9%	10.6%
	More than 20000	2	7	9
		2.1%	3.9%	3.3%
Smoking	Yes	12	19	31
		12.8%	10.6%	11.4%
	No	82	160	242
		87.2%	89.4%	88.6%
Years of smoking	Less than two years	0	3	3
		0.0%	1.7%	1.1%
	2-3 years	1	2	3
		1.1%	1.1%	1.1%
	4-5 years	0	1	1
		0.0%	.6%	.4%
	More than 5 years	12	13	25
		12.8%	7.3%	9.2%

Data are presented as percentage (%)

There was a significant association between TDM2 and educational level, where those who had higher education degrees had the lowest prevalence of TDM2 ($p < 0.001$) except those with a PhD. Regarding comorbidity, those who had hypercholesterolemia had a significantly higher prevalence compared to those who did not ($p < 0.001$) (70.3% vs 29.2%), and those who had cardiovascular disorders or hypertension had a significantly higher prevalen

Table 2: *Clinical parameters of the participants.*

Variable			Cases (n=94)	Controls (n=179)	Total (n=273)
What is your treatment plan?	Diet	n	8	0	8
		%	8.5%	0.0%	2.9%
	Pills	n	59	0	59
		%	61.7%	0.0%	21.6%
	Insulin	n	10	0	10
		%	10.6%	0.0%	3.7%
	Insulin and pills	n	18	0	18
		%	19.1%	0.0%	6.6%
BMI category	Underweight	n	1	9	10
		%	1.1%	5.1%	3.7%
	Normal	n	20	62	82
		%	21.5%	35.0%	30.4%
	Overweight	n	24	54	78
		%	25.8%	30.5%	28.9%
	Obese	n	48	52	100
		%	51.6%	29.4%	37.0%
Variable			Cases	Controls	Total
Random blood sugar#		Mean ± SD	205.74±76.9	123.52±17.58	153.21±62.34
			p<0.0001*		
Fasting blood sugar#		Mean ± SD	157.75±62.63	89.63±12.85	127.23±58.15
			p<0.0001*		
BMI		Mean ± SD	32.03±10.65	26.94±6.15	28.69±8.33

*# Independent t-test used for comparison. *P value considered significant*

Table 3A: *The association of sociodemographic profile and medical history with the prevalence of T2DM.*

Factor	Type 2 Diabetes Mellitus: Cases n=94	Controls n=179	P-Value
Sex^^			**< 0.001***
Female	60 (28.7%)	149 (71.3%)	
Male	35 (54.7%)	29 (45.3%)	
Age^^			**< 0.001***
18 - 29 years	7 (11.1%)	56 (88.9%)	
30 - 39 years	12 (17.1%)	58 (82.9%)	
40 - 50 years	31 (43.1%)	41 (56.9%)	
51 - 64 years	40 (65.6%)	21 (34.4%)	
65 years and older	5 (71.4%)	2 (28.6%)	
Marital Status^^			**0.001***
Single	10 (15.2%)	56 (84.8%)	
Engaged	71 (40.3%)	105 (59.7%)	
Married	72 (40.9%)	104 (59.1%)	
Widowed	8 (53.3%)	7 (46.7%)	
Divorced	5 (38.5%)	8 (61.5%)	
Separated	0 (0.0%)	3 (100%)	

ce of T2DM compared to those who did not ($p < 0.001$) (74.3% vs 29%). Also, BMI was significantly associated with the prevalence of DM2 ($p < 0.001$), whereas the mean BMI for diabetic participants was 32.0 ± 10.59 compared to 26.92 ± 6.16 in non-diabetic. On the other hand, there was no significant association between smoking and T2DM prevalence.

Table 3B: *The association of sociodemographic profile and medical history with the prevalence of T2DM.*

Factor	Type 2 Diabetes Mellitus: Cases =94	Controls =179	P value
Educational Level^^			**≤ 0.001***
Less than high school	23 (82.1%)	5 (17.9%)	
High school	22 (44.9%)	27 (55.1%)	
Diploma	15 (36.6%)	26 (63.4%)	
Bachelor	31 (23%)	104 (77%)	
Master	2 (12.5%)	14 (87.5%)	
PhD	2 (50%)	2 (50%)	
Hypercholesterolemia^^			**≤ 0.001***
Yes	26 (70.3%)	11 (29.7%)	
No	69 (29.2%)	167 (70.8%)	
Hypertension^^			**≤ 0.001***
Yes	26 (74.3%)	9 (25.7%)	
No	69 (29%)	169 (71%)	
Smoking^^			0.365
Smoker	12 (12.8%)	19 (10.6%)	
Non- smoker	82 (87.2%)	160 (8/9.6%)	
BMI Association with Type 2 Diabetes Mellitus (mean, SD)			
BMI#	32.01 ± 10.59	26.92 ± 6.16	**≤ 0.001***

*Data are presented as numbers (%) or as mean± SD.^^ chi-square test used, # independent t-test used, *P value considered significant*

The frequency of consumption habits and physical activity level between cases and controls

Tables 4A, B, C, D, E, and F demonstrate the association between dietary consumption habits and physical activity with T2DM. The number of meals significantly differed between cases and controls (p=0.02), where T2DM cases consumed more meals than controls. The consumption of cooked rice (p = 0.011) was significantly higher among T2DM. In addition, the consumption of the following foods was lower among TDM2 patients as they are risk factors: consumption from restaurants (p = 0.01), potato chips consumption (p < 0.001), cake muffins or Arabic sweets consumption (p < 0.001), sweet biscuits consumption (p = 0.007), salty pies and pasties consumption (p = 0.012), frequency of consumption of pasta (p < 0.001), frequency of sausage, cold meats, and salami consumption (p = 0.016), and additive sugar consumption (p = 0.013).

Table 4A: *Frequency consumption in cases and controls (n = 273).*

Factors	Type 2 Diabetes Mellitus		P - Value
	Cases n= 94	Controls n=179	
How many main meals (i.e., breakfast, lunch, dinner) do you usually eat daily (not including snacks)?			
One meal	2 (2.1%)	15 (8.4%)	**<u>0.02*</u>**
Two meals	44 (46.3%)	97 (54.5%)	
Three meals	49 (51.6%)	66 (37.1%)	
How many snacks do you usually eat a day?			
None	16 (16.8%)	21 (11.8%)	0.695
One snack	41 (43.2%)	85 (47.8%)	
Two snacks	29 (30.5%)	49 (27.4%)	
Three snacks	8 (8.5%)	19 (10.8%)	
Four snacks	1 (1.0%)	2 (1.1%)	
Five snacks	0 (0.0%)	2 (1.1%)	
How many portions of meat, chicken and fish do you consume?			
I do not consume them	7 (7.4%)	5 (2.8%)	0.099
Moderate consumption (1 - 3 portions a week)	53 (55.8%)	90 (50.6%)	
High consumption (4 portions a week or more)	35 (36.8%)	83 (46.6%)	
How many portions of red meat do you consume?			
I do not consume them	13 (13.7%)	23 (12.9%)	0.327
Moderate consumption (1 - 3 portions a week)	68 (71.6%)	139 (78.1%)	
High consumption (4 portions a week or more)	14 (14.7%)	16 (9.0%)	

Table 4B: *Frequency consumption habits in cases and controls (n = 273).*

Factors	Type 2 Diabetes Mellitus		P value
	Cases n= 94	Controls=179	
How many times do you consume sausage, cold meats, and salami?			
I do not consume them	80 (84.2%)	126 (70.8%)	**<u>0.016*</u>**
Moderate consumption (1 - 3 portions a week)	12 (12.6%)	49 (27.5%)	
High consumption (4 portions a week or more)	3 (3.2%)	3 (1.7%)	
How many portions of vegetables (Fresh, Frozen, or canned, not including potatoes) do you eat?			
I do not consume them	10 (10.5%)	9 (5.1%)	0.177
Moderate consumption (1 - 3 portions a week)	49 (51.6%)	106 (59.6%)	
High consumption (4 portions a week or more)	36 (37.9%)	63 (35.3%)	
How many cups of milk do you consume, including milk in tea and coffee?			
I do not consume them	14 (14.7%)	22 (12.4%)	0.857
Moderate consumption (1 - 3 portions a week)	35 (36.8%)	68 (38.2%)	
High consumption (4 portions a week or more)	46 (48.5%)	88 (49.4%)	
How many portions of yogurt do you consume?			
I do not consume them	18 (18.9%)	24 (13.5%)	0.489
Moderate consumption (1 - 3 portions a week)	56 (58.9%)	111 (62.4%)	
High consumption (4 portions a week or more)	21 (22.2%)	43 (24.1%)	
How often do you eat at restaurants, take-away food, or delivered food?			
I do not eat from restaurants	19 (20.0%)	14 (7.8%)	**<u>0.010*</u>**
Moderate food consumption from restaurants (1 - 3 times a week)	63 (66.3%)	142 (79.8%)	
High food consumption from restaurants (4 times a week or more)	13 (13.7%)	22 (12.4%)	

In the current study, butter consumption was lower among the T2DM group (p = 0.019), and vegetable oil consumption (p = 0.044) was higher among non-diabetic individuals. Significant differences were found in the consumption of fresh fruits: higher consumption among TDM2 patients (p = 0.005) compared to controls, the consumption of whole wheat bread was higher among T2DM patients (p = 0.041), and the frequency of water glasses consumption was significantly higher among T2DM (p = 0.001). The level of physical activity was also significantly different between cases and controls (p = 0.008); T2DM patients performed more low-intensity physical activity than non-diabetic patients. In contrast, non-diabetic patients performed more moderate-intensity physical activity than the case group.

Table 4C: *Frequency consumption habits in cases and controls (n = 273).*

Factors	Type 2 Diabetes Mellitus		P value
	Cases= 94	Controls=179	
How many portions of whole wheat bread (brown bread) or bran bread do you consume?			
I do not consume them	13 (13.7%)	25 (14.1%)	**0.041***
Moderate consumption (1 - 3 portions a week)	33 (34.7%)	88 (49.4%)	
High consumption (4 portions a week or more)	49 (51.6%)	65 (36.5%)	
How many portions of bran flakes do you consume?			
I do not consume them	70 (73.7%)	122 (68.5%)	0.46
Moderate consumption (1 - 3 portions a week)	25 (26.3%)	55 (30.9%)	
High consumption (4 portions a week or more)	0 (0.0%)	1 (0.6%)	
How many portions of fresh fruit do you consume on a regular day?			
I do not consume them	14 (14.7%)	24 (13.5%)	**0.005***
Moderate consumption (1 - 3 portions a week)	43 (45.3%)	114 (64.0%)	
High consumption (4 portions a week or more)	38 (40.0%)	40 (22.5%)	
How many portions of jam or honey do you consume?			
I do not consume them	36 (37.9%)	56 (32.5%)	0.5
Moderate consumption (1 - 3 portions a week)	45 (47.4%)	97 (54.5%)	
High consumption (4 portions a week or more)	14 (14.7%)	25 (14.0%)	
How many times do you consume cooked rice?			
I do not consume them	4 (4.2%)	1 (0.6%)	**0.011***
Moderate consumption (1 - 3 portions a week)	37 (38.9%)	96 (53.9%)	
High consumption (4 portions a week or more)	54 (56.9%)	81 (45.5%)	
How many times do you consume pasta?			
I do not consume them	21 (22.1%)	9 (5.1%)	**≤ 0.001***
Moderate consumption (1 - 3 portions a week)	68 (71.6%)	157 (88.2%)	
High consumption (4 portions a week or more)	6 (6.3%)	12 (6.7%)	

Table 4D: *Frequency consumption habits in cases and controls (n = 273).*

Factors	Type 2 Diabetes Mellitus		P value
	Cases =94	Controls=179	
How many portions of white bread do you consume?			
I do not consume them	29 (30.5%)	36 (20.2%)	0.144
Moderate consumption (1 - 3 portions a week)	36 (37.9%)	72 (40.4%)	
High consumption (4 portions a week or more)	30 (31.6%)	70 (39.6%)	
How many portions of potato chips do you consume?			
I do not consume them	37 (39.0%)	32 (18.0%)	**≤ 0.001***
Moderate consumption (1 - 3 portions a week)	50 (52.6%)	111 (62.4%)	
High consumption (4 portions a week or more)	8 (8.4%)	35 (19.6%)	
How many portions of cake muffins or Arabic sweets do you consume?			
I do not consume them	16 (16.8%)	12 (6.7%)	**0.013***
Moderate consumption (1 - 3 portions a week)	63 (66.2%)	119 (66.9%)	
High consumption (4 portions a week or more)	16 (16.8%)	47 (26.4%)	
How often do you consume sweetened drinks (including soft drinks, energy drinks, and sweetened hot beverages like tea and coffee)?			
I do not consume them	33 (34.7%)	42 (.236%)	0.145
Moderate consumption (1 - 3 portions a week)	36 (37.9%)	79 (44.4%)	
High consumption (4 portions a week or more)	26 (27.4%)	57 (32.0%)	
How many portions of sweet biscuits like chocolate digestive biscuits or cookies do you consume?			
I do not consume them	39 (41.1%)	41 (23.0%)	**0.007***
Moderate consumption (1 - 3 portions a week)	47 (49.5%)	112 (62.9%)	
High consumption (4 portions a week or more)	9 (9.4%)	25 (14.1%)	

DISCUSSION

To our knowledge, this is the first case-control study conducted in Makkah to report associations between dietary intake and physical activity habits with T2DM prevalence. Our results showed that the frequency consumption significantly differed between case and control groups for the following food items: pasta, rice, sausage, fruit, vegetable oil, whole wheat bread, potato chips, cakes and sweets, butter, and water. In addition, the

Table 4E: *Frequency consumption habits in cases and controls (n = 273).*

Factors	Type 2 Diabetes Mellitus		P value
	Cases=94	**Controls=179**	
How many times do you consume salty pies and pasties?			
I do not consume them	23 (24.2%)	19 (10.7%)	**<u>0.012*</u>**
Moderate consumption (1 - 3 portions a week)	66 (69.5%)	144 (80.9%)	
High consumption (4 portions a week or more)	6 (6.3%)	15 (8.4%)	
How many times do you consume butter?			
I do not consume them	43 (45.3%)	51 (28.7%)	**<u>0.019*</u>**
Moderate consumption (1 - 3 portions a week)	32 (33.9%)	84 (47.2%)	
High consumption (4 portions a week or more)	20 (21.1%)	43 (24.2%)	
How many times do you consume olive oil?			
I do not consume them	11 (11.6%)	23 (12.9%)	0.508
Moderate consumption (1 - 3 portions a week)	37 (38.9%)	80 (44.9%)	
High consumption (4 portions a week or more)	47 (49.5%)	75 (42.1%)	
How many times do you consume Vegetable oil (Sunflower)?			
I do not consume them	36 (37.9%)	42 (23.6%)	**<u>0.044*</u>**
Moderate consumption (1 - 3 portions a week)	28 (29.5%)	67 (37.6%)	
High consumption (4 portions a week or more)	31 (32.6%)	69 (38.8%)	
How many times do you consume trans-fatty acid?			
I do not consume them	65 (68.4%)	110 (61.8%)	0.554
Moderate consumption (1 - 3 portions a week)	22 (23.2%)	50 (28.1%)	
High consumption (4 portions a week or more)	8 (8.4%)	18 (10.1%)	
How many times do you consume ghee?			
I do not consume them	47 (49.5%)	93 (52.2%)	0.784
Moderate consumption (1 - 3 portions a week)	44 (46.3%)	80 (44.9%)	
High consumption (4 portions a week or more)	4 (4.2%)	5 (2.9%)	

frequency of food consumption from restaurants was associated with higher T2DM prevalence. Most T2DM patients were obese and showed low-intensity physical activity compared to the control group. The highest prevalence of T2DM was present in widowed participants (maybe due to age or stress). Female and male numbers were not the same in this study; this may be due to the different behaviors of women and men, exposition to specific impacts of the environment, different types of nutrition, lifestyles or stress, or attitudes towards treatments and prevention.

Our results showed that cooked rice consumption was higher among the T2DM group (p = 0.011). In contrast, sausage, cold meats, and salami consumption (p = 0.016), vegetable oil consumption (p = 0.044), and additive sugar consumption (p = 0.013) were higher among non-diabetic individuals. An American cohort study showed that participants in the highest quintiles of Glycemic Index (GI) or Glycemic Load (LD) (adjusted for total energy) had a significantly higher risk of T2DM than those in the lowest quintile (Ardisson Korat et al., 2014). This conclusion was supported by a meta-analysis that included cohorts from the US, Australia, and Europe (Bhupathiraju et al., 2014). In a study conducted among Asian populations who consumed white rice, with little fiber content as a primary food source of calories, the authors reported an increasing risk of developing diabetes (Hu et al., 2012).

Additionally, the Prospective Urban Rural Epidemiology (PURE) cohort study representing twenty-one countries in Asia, North and South America, Europe, and Africa evaluated the connection between white rice intake and diabetes risk. When compared to low rice consumption, high white rice consumption was linked to a 20% increased risk of diabetes. However, risk estimates varied by country, with a 65 percent higher risk in South Asia for high rice consumption versus low rice consumption and no significant association in China (Bhavadharini et al., 2020). Higher refined grain intake was strongly related to higher diabetes risk in the South Indian cohort sample, in line with the PURE study findings for South Asia (Anjana et al., 2015). The absence of a correlation in China between rice consumption and diabetes risk agrees with previous findings for Singapore Chinese and Japanese men but not for women in Shanghai and Japan (Nanri et al., 2010). There was also a mix of results from populations with lower rice consumption levels (Golozar et al., 2017). The rice intake variations for the different regions were so high that there was little overlap. As a result, the risk of the participants' risk factor profiles in the low and high rice consumption groups differed widely because they were mostly from different regions of the world. Thus, it is essential to determine whether white rice consumption contributes to the development of T2DM, particularly in populations with high levels of intake.

In the current study, butter consumption was lower among the T2DM group (p = 0.019), while vegetable oil

Table 4F: *Frequency consumption habits and physical activity level in cases and controls (n = 273).*

Factor	Type 2 Diabetes Mellitus		P value
	Cases =94	Controls =179	
How many times do you consume Coconut oil?			
I do not consume them	89 (93.7%)	163 (91.6%)	0.658
Moderate consumption (1 - 3 portions a week)	5 (5.3%)	14 (7.8%)	
High consumption (4 portions a week or more)	1 (1.0%)	1 (0.6%)	
How many teaspoons of sugar do you add to tea, coffee, or breakfast cereal on a regular day?			
Low intake (0 - 1 teaspoons)	66 (69.5%)	100 (56.2%)	**0.013***
Moderate intake (2 - 3 teaspoons)	23 (24.2%)	73 (41.0%)	
High intake (4 teaspoons and more)	6 (6.3%)	5 (2.8%)	
How many glasses of water do you consume on a regular day?			
Low consumption (1 - 6 cups)	55 (57.9%)	137 (77.0%)	**0.001***
Appropriate consumption (7 cups or more)	40 (42.1%)	41 (23.0%)	
Level of Physical Activity			
Low-intensity physical activity	77 (81.1%)	122 (68.5%)	**0.008***
Moderate-intensity physical activity	15 (15.8%)	55 (30.9%)	
High-intensity physical activity	3 (3.1%)	1 (0.6%)	

*Data are presented as numbers (%) or as mean± SD. A comparison was done using the Chi-square test. *P value considered significant*

consumption (p = 0.044), was higher among non-diabetic individuals. These consumption differences between cases and controls could be due to the higher prevalence of obesity in the case group compared to the control. Although not measured, cases may try to control their weight by reducing fat intake. The consumption of fats is a matter of debate in studies, and a study reported that higher fat intake induced insulin resistance and weight gain, contributing to the overall burden of diabetes (Fareed et al., 2017). However, several studies reported no significant association between fat consumption and the risk of diabetes. Other studies reported that the intake of polyunsaturated fatty acids (PUFA), such as omega-3 and omega-6, contributes to lowering diabetes risk (Ardisson Korat et al., 2014; Fareed et al., 2017).

In the current study, the consumption of vegetables was higher among T2DM patients without a significant difference, while the consumption of fresh fruits was significantly higher among TDM2 patients (p = 0.005). T2DM patients had a low intake of sweets, cakes, and muffins, and the high consumption of fruits could be due to T2DM patients trying to substitute sweet foods with fruit. Several observational studies reported that fiber-rich diets were associated with a reduced risk of obesity and diabetes (Ardisson Korat et al., 2014; Fareed et al., 2017). A higher intake of green leafy vegetables was associated with a lower risk of T2DM in a meta-analysis of cohorts in the US, Finland, and China (Carter et al., 2010). Additionally, three prospective cohort studies reported that consumption of specific whole fruits, such as blueberries, bananas, apples, and pears, was significantly associated with a lower risk of diabetes (Ardisson Korat et al., 2014). At the same time, another study reported a significant increase in the risk of TDM2 and fruit juice consumption (Muraki et al., 2013).

In the current study, the consumption of whole wheat bread was higher among TDM2 patients (p = 0.041); this consumption of whole wheat bread could be explained by the fact that whole grain intake has been steadily associated with a lower risk of diabetes even after adjustment for BMI (Ardisson Korat et al., 2014; Fareed et al., 2017). In an American cohort study, whole grain consumption has been documented to have a strong converse association with the risk of T2DM; it was estimated that "every two-serving per-day increment in wholegrain consumption, the risk of T2DM decreased by 21%"(Ardisson Korat et al., 2014). Another reason could be that T2DM patients are more exposed to registered dietitians to assist them in controlling their blood glucose levels and, therefore, have more knowledge of healthy dietary patterns than controls. However, this study did not measure the frequency of visits to the clinical nutrition clinic due to COVID-19 restrictions.

The frequency of water consumption was significantly higher among T2DM (p = 0.001) in our study. Drinking recommendations are less common and detailed than food recommendations, where the evidence for the positive effects of water in improving glycemic parameters in diabetic persons is inconsistent (Naumann et al., 2017). In a meta-analysis, a higher intake of sugar-sweetened beverages was found to be associated with a greater risk of T2DM, while the substitution of one serving of sugar-sweetened beverages with water was significantly associated with a lower risk of T2DM (Ardisson Korat et al., 2014; Fareed et al., 2017). Our study did find a significant difference between cases and controls regarding sugar-sweetened beverage intake. However, the high frequency of water consumption in T2DM patients could be due to substituting sugar-sweetened beverages with water.

In the current study, the consumption of the following foods was lower among T2DM patients as they are risk factors: potato chips consumption (p < 0.001), cake muffins or Arabic sweets consumption (p < 0.001), sweet biscuits consumption (p = 0.007), salty pies and pasties consumption (p = 0.012). The reason for the lower frequency of consumption of these foods could be that the participants with T2DM may have received some nutrition education when they were diagnosed and are aware that they should avoid these risky foods. Several studies reported that these foods are risk factors for T2DM as they are rich in saturated fats and processed carbohydrates (Ardisson Korat et al., 2014). A study conducted in the USA reported that replacing 1 serving a day of whole grains with 1 serving a day of potatoes reduced the risk of T2DM to 30% (Ardisson Korat et al., 2014).

Regarding physical activity in the current study, the level of physical activity was significantly different between cases and controls (p = 0.008), where T2DM patients performed more low-intensity physical activity than non-diabetic patients. Several studies confirmed that physical activity is associated with advantageous physiological changes (Ardisson Korat et al., 2014; Fareed et al., 2017). In addition, a greater risk for T2DM and metabolic syndrome was observed in sedentary individuals. Consistently, another study reported that every 2 hours/day increase in TV watching and sitting at work were associated with a 14% and a 7% increase in the risk of T2DM, respectively (Hu et al., 2012). The results of the current study could be due to several reasons; COVID-19 lockdown restrictions may have impacted participants' ability to participate in the gym or perform intense and moderate physical activity (Balducci & Coccia, 2021). Another reason could be that most T2DM participants had comorbidities, which may affect their ability to perform moderate and intense physical activity (Pati et al., 2020).The variation between the results of the current study and those of other studies could be due to the differences in the geographic area that may influence their dietary intake and physical activity performance. Other possible reasons for the variation in results include socioeconomic factors, sample size, and different dietary intake and physical activity assessment methods.

This study has several strengths; to our knowledge, this is the first retrospective case-control study conducted in Makkah, Saudi Arabia, to study the dietary and physical activity factors associated with T2DM. Another strength is using the validated questionnaires: the short form IPAQ and the FFQ. The study has some limitations: the shortage of data collection time, the data was collected online during the COVID-19 lockdown, the subjective nature of the questionnaire and the study, the small sample size, and not conducting sample size calculations considering the prevalence of diabetes in the community, the data collected from one city (Makkah) which limited the chance to generalize the findings to the Saudi population. Prospective studies with larger sample sizes are required in future studies.

CONCLUSION

T2DM Saudi participants were obese, consumed more cooked rice, had more meals, and performed low-intensity physical activity compared to controls. These results may be used in prevention and treatment programs to control T2DM in Saudi Arabia. Further extensive prospective and intervention studies are needed to identify T2DM risk factors in Saudis and highlight the importance of lifestyle behavior in the prevalence of T2DM.

AUTHOR CONTRIBUTION

Conception and design, E.N. and K.G.; Methodology, E.N., and K.G.; Data collection, L.A. and B.N. Statistical analysis, E.N, L.A., and B.N.; Data interpretation, E.N, L.A., and B.N.; Writing-original draft: L.A. and B.N. Writing- review and editing: E.N, L.A., B.N. and K.G. All authors approved the final version for submission.

DECLARATIONS

Ethical Approval

The study was approved by The Biomedical Research Ethics Committee, Umm Al-Qura University (Approval No. HAPO-02-K-012-2022-11-1262).

Participants Consent

Oral consent was obtained from the participants.

Source of Funding

This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

All authors have declared that no financial support was received from any organization for the submitted work. All authors have declared that no other relationships or activities could appear to have influenced the submitted work.

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