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Association between dietary patterns and depression symptoms among adults with or without diabetes in Qatar: a population-based study

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Abstract

Background Diabetes is a major public health problem in Qatar and is associated with an increased risk of depression. However, no study has been conducted in Qatar on the relationship between dietary patterns and depression symptoms in adults. The aim of this study was to assess the association between dietary patterns and depression symptoms among adults with or without diabetes in Qatar.

Methods A total of 1000 participants from the Qatar Biobank (QBB) were included in this cross-sectional study. Food intake was assessed using a computer-administered food frequency questionnaire (FFQ), and dietary patterns were identified using factor analysis. Depression symptoms were evaluated using the Patient Health Questionnaire-9 (PHQ-9).

Results Depression symptoms were present in 13.5% of the sample. Two dietary patterns were identified: "unhealthy" (high consumption of fast food, biryani, mixed dish (chicken/meat/fish), croissant) and "prudent" (high consumption of fresh fruit, salads/raw vegetables, canned/dried fruit, and dates). After adjusting for sociodemographic, lifestyle factors (smoking and physical activity), diabetes and medication use for diabetes and hypertension, a high intake of "unhealthy" pattern was associated with an increased prevalence of depressive symptoms in individuals with diabetes (prevalence ratio, PR = 1.41; 95% CI = 1.28, 1.56; p-value < 0.001), while there was no statistically significant association between depressive symptoms and the "prudent" dietary pattern. The "prudent" pattern was inversely and significantly associated with depressive symptoms in individuals with a normal body weight (PR = 0.21; 95% CI = 0.06, 0.76; p-value = 0.018).

Conclusion The "unhealthy" dietary pattern was positively associated with depression symptoms in those with diabetes, whereas the "prudent" dietary pattern was inversely associated with depression symptoms in those with a normal body weight. Promoting healthy eating habits should be considered in the prevention and management of depression.

Keywords Depression symptoms, Diabetes, Dietary pattern, Factor analysis

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Introduction

Diabetes is currently one of the biggest challenges for the healthcare system [1]. According to the 2021 International Diabetes Federation (IDF) report, 536.6 million adults between 20 and 79 years of age suffer from diabetes globally [2], representing 10.5% of adults in this age group. The highest age-adjusted prevalence of diabetes in adults aged > 20–79 years was in the Middle East and North Africa (MENA) region (18.1%). Within the MENA region, Qatar has an even greater age-adjusted prevalence of diabetes (19.5%) [2].

Depression, defined as a continuous loss of interest or pleasure in previously enjoyed activities, sadness, or hopelessness followed by a failure to carry out daily activities for at least two weeks [3], is the most common comorbidity among people with diabetes. The lifetime prevalence of major depression is estimated to range from 2 to 21% in the general population [4]. However, among people with diabetes, the lifetime risk of depression is approximately double [5, 6]. In Qatar, a recent study revealed that 15.4% of people with diabetes in Qatar reported depressive symptoms [7]. Moreover, the relationship between diabetes and depression is likely to be bidirectional [8]. Previous meta-analyses have shown that depression increases the risk of developing type 2 diabetes mellitus (T2DM) by 32–60% [9–13]. The coexistence of diabetes and depression is a major clinical challenge [14] and may lead to a deterioration in quality of life, poor self-management of diabetes, an increase in complications, and a shorter life expectancy [14].

Over the past decade, an increasing number of studies have assessed the association between different posteriori dietary patterns and the risk of depression [15, 16]. Although the results of these studies were inconclusive, there appears to be a link. A meta-analysis of studies associating dietary patterns with depression revealed that individuals who follow a healthy dietary pattern characterized by a high intake of fruits, vegetables, whole grains, olive oil, seafood, poultry, or low-fat dairy products tend to have a lower risk of depression. On the other hand, those who adhered to a dietary pattern characterized by high consumption of refined grains, red or processed meat, high-fat dairy items, or sweets and low intake of vegetables and fruits were associated with a greater risk of depression [15]. Among people with diabetes, dietary patterns also seem to be related to the incidence of depression. One multicenter randomized controlled trial in Europe showed that a "Mediterranean" diet with mixed nuts reduced the relative risk of depression in individuals with T2DM by 41% compared to that in the control group (those with a low-fat diet) [17]. Moreover, among type 1 diabetes patients, dietary patterns involving a high consumption of vegetables, fruits, legumes, fish, potatoes, meat dishes, cold cuts, and sausages were associated with lower depression scores, while a "sweet" dietary pattern characterized by high consumption of ice cream, sweets, chocolate, and sweet pastry was associated with increased levels of depressive symptoms [18].

In Qatar, a modern dietary pattern characterized by a high consumption of refined grains, sugar, and fast food was inversely associated with poor diabetes control among adults with diabetes [19]. However, it is unknown whether dietary patterns are associated with depression in Qatar. The aim of this study was to fill this research gap and examine the association between dietary patterns and depressive symptoms among adults with or without diabetes in Qatar.

Methods

Study design and sample

In this cross-sectional study, data from 1000 adults were extracted from the Qatar Biobank (QBB) database. Established in 2012, the QBB began as a large population-based cohort study and recruits Qatari and non-Qatari adults aged ≥ 18 years who have been in Qatar for ≥ 15 years (long-term residents) [20]. The sample for the current study was randomly selected from the QBB database (~ 20,000 participants) by the QBB team and included information on sociodemographic and lifestyle factors, food intake, and chronic conditions, including diabetes and depression. The inclusion criterion was age 18 to 75 years and provided information on self-reported diabetes status. The exclusion criteria were pregnancy/lactation during the study period and suffering from other psychiatric comorbidity or cognitive impairment. The analytical sample was divided into two groups: the first group consisted of 500 participants with self-reported diabetes, and the second group included 500 participants without diabetes. Based on age in years and on sex, each participant with self-reported diabetes was matched with one without known diabetes. Furthermore, the comparison group had the same exclusion criteria as the group with diabetes. The use of the case–control approach was performed because only the data of 1000 participants were available for free. Selecting 500 participants would provide adequate sample power to examine the association between dietary patterns and depression among those with diabetes. According to the literature, the prevalence of depressive symptoms in Qatar is approximately 15% [7]. We estimated the prevalence of depression to be 10% and 20% among those with an unhealthy dietary pattern below and above the median, respectively. To detect this difference with 90% power, we needed a sample of 266 participants per group, totaling 532 participants. Sample size was calculated, using the following Stata syntax: power twoproportions 0.1 0.2, power (0.9). Second, persons with diabetes were older than were those without diabetes [7]. This study was planned, performed, and reported in accordance with the guidelines for strengthening the reporting of observational studies in Epidemiology–Nutritional Epidemiology (STROBE-nut) [21].

Outcome variable: depressive symptoms

The Patient Health Questionnaire (PHQ-9) was used in the QBB to assess depressive symptoms [22]. This self-reporting questionnaire is designed to screen for depressive symptoms [23]. The PHQ-9 has nine statements regarding symptoms in the two weeks preceding its administration, each with a four-choice response. A composite score was calculated based on the nine items. The score for depressive symptoms was classified as follows: no or minimum depression (0–4), mild depression (5–9), moderate depression (10–14), moderately severe depression (15–19), or severe (20–27) [23]. We defined participants as experiencing depression symptoms based on a widely used cutoff value of ≥10 [23]. This specific cutoff point has been previously validated for defining clinically relevant depressive symptoms [24–26].

Exposure variable: dietary patterns

A food frequency questionnaire was used to assess dietary intake in the previous year and was developed based on consultation with local nutrition researchers, focus groups, and field assessments of the food environment locally [22]. In total, 102 food and beverage items were assessed based on a computer-administered FFQ. Depending on the nature of the food item, there are five or six frequency options. This diet questionnaire included questions about the frequency of eating from a common dish, reasons for recent modifications in dietary habits (if applicable) and snacking between meals. Individual food intake data one year prior to the survey were recorded as the number of times per week [22]. The internal validity of the FFQ was evaluated before being used in the survey [22]. The validity of the FFQ was assessed using Spearman's rank correlation, which compares the frequency of consumption of broad food categories (fish, salads, snacks, chicken, fast/takeaway foods, and meat) to the total frequency of consumption of individual foods within the broad category. Correlations (rho) varied from 0.3 for snack consumption to 0.74 for fish consumption [22].

Covariates

Sociodemographic factors, lifestyle factors, and chronic conditions were treated as potential confounders. Education was categorized as low (<=secondary school), medium (professional or technical school), or high (university or above). Leisure-time physical activity was measured in metabolic equivalent (MET) hours per week to account for both the amount of time spent on activities and their intensity. It was calculated by multiplying the amount of time spent in each activity by particular MET values derived from the "Compendium of Physical Activities" [27]. Leisure-time physical activity was categorized as sedentary/light (<10 MET-hours/week) or moderate/vigorous (≥10 MET-hours/week) [28]. Participants were asked whether they were on a diet. The status of smoking was recorded as smoker, nonsmoker, or ex-smoker. The BMI data were grouped as underweight (<18.5 kg/m^2), normal (18.5 to 24.9 kg/m^2), overweight (25.0 to 29.9 kg/m^2), or obese (≥30 kg/m^2). Medication use for hypertension or diabetes, and vitamin D supplement use was categorized as yes or no. Diabetes status was defined on the basis of a fasting glucose ≥ 7 mmol/dL, a glycated hemoglobin (HbA1C) ≥ 6.5%, or self-reported doctor-diagnosed diabetes. Self-reported diabetes and medication use was assessed based on the following questions: "Has a doctor ever told you that you had or have diabetes? Are you being treated for your diabetes? (1) No; (2) Don't know; (3) Prefer not to respond; (4) Diet; (5) Increased physical activity; (6) Tablets; (7) Insulin".

Statistical analysis

Descriptive statistics were used to summarize the participants' demographic data and dietary patterns. The standard deviation (SD) and mean ± were used to report continuous variables. The percentage was used to present categorical variables. The chi-square test was used for categorical variables to compare differences between groups, while ANOVA was used for continuous variables.

Factor analysis was used to construct dietary patterns. Based on previous studies using QBB data, food intake was collapsed into 38 categories based on nutrient profile similarities or cooking techniques before conducting factor analysis [19]. Food groups and their constituents are provided in Supplementary Table 2. Sample adequacy was checked using the Kaiser–Meyer–Olkin (KMO) test. The results revealed a large KMO value of 0.88; therefore, factor analysis was considered appropriate. The number of dietary patterns was determined by (1) Eigenvalue > 1; (2) scree plot, and (3) interpretability based on food culture in Qatar. Varimax rotation was used to aid in interpretation by minimizing the correlation between factors. Each participant was assigned a dietary pattern score. The sum of the factor loading coefficients and standardized weekly frequency consumption of each food group linked to that pattern was used to determine the scores for each pattern. A higher factor score suggested high consumption of that dietary pattern. The factor scores were divided into tertiles, with tertile 1 (low intake) as the reference group in the analyses and tertile 3 representing a high intake of the food pattern.

Given that the prevalence of depression was above 10%, to investigate the link between dietary patterns and depression, Poisson regression with robust variance was used to evaluate the association between dietary patterns and depression as prevalence ratios (PRs) [29]. Five models were used: the first model was adjusted for sex and age; the second model was further adjusted for physical activity, smoking status, education, and on diet (those who mentioned that they were following a specific type of diet). The third model was further adjusted for diabetes, while the fourth model was additionally adjusted for BMI (continuous), diabetes medication other than insulin, insulin usage, and hypertension medication.

Table 1 Factor loadings of dietary patterns

Variable	Unhealthy pattern	Prudent pattern
Fast food	0.70	
Biryani	0.66	
Chicken/meat fish mixed dish	0.61	
Croissant	0.58	
Soft drink	0.56	
Lasagna	0.56	
Zaatar fatayer	0.55	
Arabic/Iranian bread	0.54	
White bread	0.52	
Ice-cream	0.49	
Red meat	0.48	
Desserts	0.48	
Asian noodle	0.47	
Potato	0.43	
Chicken	0.39	
Chocolate	0.38	
Butter	0.35	
White rice	0.34	
Cheese	0.33	
Other bread	0.33	
Eggs	0.32	
Tea	-	
Milk shakes	-	
Coffee	-	
Milk	-	
Salad and raw vegetables		0.71
Fresh fruit		0.70
Canned/dried fruit and dates		0.63
Fresh fruit juice		0.54
Salad and cooked vegetables		0.54
Brown bread		0.52
Soups/starters	0.44	0.51
Grilled/fried/baked Fish		0.49
Fish		0.47
Nuts		0.44
Yogurt		0.37
Breakfast Cereal		0.33
Milk added to cereal	-	-
Variance explained (%)	15.3%	10.9%

The fifth model was further adjusted to account for the use of vitamin D supplements. The fully adjusted model included 999 participants. This means that 99.9% of the participants had complete data. Thus, we did not impute missing values.

We tested the multiplicative interactions between dietary patterns and age group, sex, diabetes, education, leisure-time physical activity, BMI, and smoking status by including a product term of the two variables in the Poisson regression model. For the interaction analysis of BMI categories, we did not consider the underweight category because there were only 4 participants in that category. A p value < 0.05 was considered to indicate statistical significance. Stata 17.0 software was used to conduct all the statistical analyses.

Results

Dietary patterns

Two dietary patterns were identified and explained 26.2% of the variance in overall food consumption (15.3% in the first and 10.9% in the second patterns). The factor loadings of each pattern are shown in Table 1. Pattern 1 (the 'Unhealthy' pattern) was distinguished by a high intake of fast food, Biryani (rice-based dish), chicken/meat fish mixed dish, croissant, soft drink, Lasagna, Zaatar fatayer, Arabic/Iranian bread, and white bread. Pattern 2 ('prudent' pattern) had a high consumption of raw vegetables and salad, fresh fruit, canned/dried fruit and dates, fresh fruit juice, cooked vegetables, brown bread, and soups/starters.

Sample characteristics

The mean age of the 1000 QBB participants was 48.6 years (SD 10.5). The overall smoking prevalence was 15.2%. The sample population was highly educated, with approximately 75.7% holding postsecondary diplomas or university degrees. The majority of participants (48.6%) reported earning more than 20,000 QAR per month. Furthermore, 45.1% of individuals reported being on a diet, with no variation according to diabetes status (Table 2).

There were no differences in these sociodemographic and lifestyle variables between individuals with and without diabetes, in terms of age, sex, nationality, smoking status, physical activity level, dietary supplement use, or diet (see Supplementary Table 1). Individuals without diabetes had higher levels of education and income than did those with diabetes. The prevalence of obesity was 56.1% and 48.4% among those with and without diabetes, respectively. Compared to those with diabetes, those without diabetes used significantly fewer vitamin D and hypertension medications.

There were significant differences in age, education, depression status, and vitamin D supplement use across

Table 2 Characteristics of participants according to the tertiles of dietary patterns ($n = 1000$)[a]

Factor	Total	Unhealthy				Prudent			
		T1	T2	T3	*P* value [b]	T1	T2	T3	*P* value [b]
N	1,000	334	333	333		334	333	333	
Age (years), mean (SD)	48.6 (10.5)	52.6 (8.4)	48.9 (10.3)	44.1 (11.0)	< 0.001	45.2 (10.6)	49.5 (10.3)	51.0 (9.8)	< 0.001
Age group, n (%)					< 0.001				< 0.001
< 50 years	501 (50.1)	101 (30.2)	168 (50.5)	232 (69.7)		219 (65.6)	146 (43.8)	136 (40.8)	
≥50 years	499 (49.9)	233 (69.8)	165 (49.5)	101 (30.3)		115 (34.4)	187 (56.2)	197 (59.2)	
Sex, n (%)					0.072				< 0.001
Female	500 (50.0)	181 (54.2)	168 (50.5)	151 (45.3)		138 (41.3)	182 (54.7)	180 (54.1)	
Male	500 (50.0)	153 (45.8)	165 (49.5)	182 (54.7)		196 (58.7)	151 (45.3)	153 (45.9)	
Nationality, n (%)					0.008				< 0.001
Non-Qatari	129 (12.9)	56 (16.8)	44 (13.2)	29 (8.7)		67 (20.1)	37 (11.1)	25 (7.5)	
Qatari	871 (87.1)	278 (83.2)	289 (86.8)	304 (91.3)		267 (79.9)	296 (88.9)	308 (92.5)	
Smoking, n (%)					< 0.001				0.050
Non	754 (75.4)	270 (80.8)	245 (73.6)	239 (71.8)		235 (70.4)	257 (77.2)	262 (78.7)	
Smoker	152 (15.2)	28 (8.4)	55 (16.5)	69 (20.7)		66 (19.8)	47 (14.1)	39 (11.7)	
Ex-smoker	94 (9.4)	36 (10.8)	33 (9.9)	25 (7.5)		33 (9.9)	29 (8.7)	32 (9.6)	
Education, n (%)					< 0.001				0.011
Low (< = secondary school)	242 (24.2)	98 (29.3)	83 (24.9)	61 (18.3)		70 (21.0)	90 (27.0)	82 (24.6)	
Medium (professional or technical school)	288 (28.8)	78 (23.4)	90 (27.0)	120 (36.0)		115 (34.4)	96 (28.8)	77 (23.1)	
High (university or above)	469 (46.9)	157 (47.0)	160 (48.0)	152 (45.6)		149 (44.6)	146 (43.8)	174 (52.3)	
Missing	1 (0.1)	1 (0.3)	0 (0.0)	0 (0.0)		0 (0.0)	1 (0.3)	0 (0.0)	
Total monthly income (QR), n (%)					0.67				0.79
Less than 10,000	172 (17.2)	56 (16.8)	64 (19.2)	52 (15.6)		63 (18.9)	57 (17.1)	52 (15.6)	
Between 10,000 and 20,000	207 (20.7)	70 (21.0)	65 (19.5)	72 (21.6)		66 (19.8)	68 (20.4)	73 (21.9)	
More than 20,000	486 (48.6)	155 (46.4)	158 (47.4)	173 (52.0)		164 (49.1)	153 (45.9)	169 (50.8)	
Missing	135 (13.5)	53 (15.9)	46 (13.8)	36 (10.8)		41 (12.3)	55 (16.5)	39 (11.7)	
BMI (kg/m2), mean (SD)	31.0 (6.1)	30.7 (5.7)	31.5 (6.0)	30.9 (6.6)	0.23	30.9 (6.2)	31.7 (6.6)	30.5 (5.5)	0.024
BMI categories, n (%)					0.18				0.17
Underweight (< 18.5 kg/m^2)	4 (0.4)	0 (0.0)	2 (0.6)	2 (0.6)		2 (0.6)	2 (0.6)	0 (0.0)	
Normal (18.5 to 24.9 kg/m^2)	136 (13.6)	45 (13.5)	37 (11.1)	54 (16.2)		52 (15.6)	36 (10.8)	48 (14.4)	
Overweight (25.0 to 29.9 kg/m^2)	337 (33.7)	125 (37.4)	111 (33.3)	101 (30.3)		115 (34.4)	103 (30.9)	119 (35.7)	
Obese (≥ 30 kg/m^2)	523 (52.3)	164 (49.1)	183 (55.0)	176 (52.9)		165 (49.4)	192 (57.7)	166 (49.8)	
PA (MET hours/week), mean (SD)	11.1 (30.6)	10.0 (26.4)	10.6 (31.2)	12.6 (33.7)	0.53	10.1 (31.5)	12.8 (35.2)	10.3 (24.0)	0.46
PA (MET hours/week), n (%)					0.43				0.64
Sedentary/light (< 10 MET-hours/week)	768 (76.8)	258 (77.2)	262 (78.7)	248 (74.5)		262 (78.4)	251 (75.4)	255 (76.6)	
Moderate/vigorous (≥ 10 MET hours/week)	232 (23.2)	76 (22.8)	71 (21.3)	85 (25.5)		72 (21.6)	82 (24.6)	78 (23.4)	
Fasting Glucose, mean (SD)	7.6 (3.9)	7.4 (3.5)	7.6 (3.8)	7.8 (4.2)	0.56	7.5 (3.8)	7.7 (4.1)	7.6 (3.6)	0.77
HbA1C%, mean (SD)	7.0 (1.9)	6.9 (1.8)	7.0 (1.9)	7.0 (2.0)	0.48	6.9 (2.0)	7.0 (1.9)	7.0 (1.8)	0.85
Depression score, mean (SD)	4.6 (4.5)	3.7 (3.9)	4.5 (3.9)	5.7 (5.3)	< 0.001	5.4 (5.2)	4.0 (3.7)	4.4 (4.4)	< 0.001
Depression symptoms severity, n (%)					< 0.001				0.005
None (0–4 points)	582 (58.2)	224 (67.1)	189 (56.8)	169 (50.8)		178 (53.3)	203 (61.0)	201 (60.4)	
Mild (5–9 points)	283 (28.3)	84 (25.1)	103 (30.9)	96 (28.8)		92 (27.5)	101 (30.3)	90 (27.0)	
Moderate (10–14 points)	100 (10.0)	20 (6.0)	34 (10.2)	46 (13.8)		44 (13.2)	23 (6.9)	33 (9.9)	
Moderately severe to severe (15–27 points)	35 (3.5)	6 (1.8)	7 (2.1)	22 (6.6)		20 (6.0)	6 (1.8)	9 (2.7)	
Depression symptoms (PHQ-9 ≥ 10), n (%)	135 (13.5)	26 (7.8)	41 (12.3)	68 (20.4)	< 0.001	64 (19.2)	29 (8.7)	42 (12.6)	< 0.001
Diabetes, n (%)	512 (51.2)	169 (50.6)	176 (52.9)	167 (50.2)	0.76	163 (48.8)	178 (53.5)	171 (51.4)	0.48

Table 2 (continued)

Factor	Total	Unhealthy				Prudent			
		T1	T2	T3	*P* value [b]	T1	T2	T3	*P* value [b]
Using Supplements, n (%)	290 (29.0)	86 (25.7)	101 (30.3)	103 (30.9)	0.27	88 (26.3)	101 (30.3)	101 (30.3)	0.42
Using Vitamin D, n (%)	398 (39.8)	156 (46.7)	126 (37.8)	116 (34.8)	0.005	107 (32.0)	135 (40.5)	156 (46.8)	< 0.001
On Diet, n (%)	451 (45.2)	174 (52.4)	142 (42.6)	135 (40.5)	0.006	125 (37.7)	152 (45.6)	174 (52.3)	< 0.001
Using diabetes medication other than insulin, n (%)	359 (35.9)	128 (38.3)	128 (38.4)	103 (30.9)	0.069	102 (30.5)	127 (38.1)	130 (39.0)	0.042
Using Insulin, n (%)	160 (16.0)	41 (12.3)	54 (16.2)	65 (19.5)	0.038	55 (16.5)	53 (15.9)	52 (15.6)	0.95
Using Hypertension medication, n (%)	216 (21.6)	97 (29.0)	72 (21.6)	47 (14.1)	< 0.001	63 (18.9)	76 (22.8)	77 (23.1)	0.33

Note PA = Physical activity, MET = metabolic equivalent, QR = Qatari Riyal

[a] Data from the Qatar Biobank. Continuous data are presented as the mean ± standard deviation, and categorical data are presented as n (%)

[b] Significance difference between individuals with and without diabetes. The chi-square test was used for categorical variables, and ANOVA was used for continuous variables

the tertiles of the "prudent" and "unhealthy" patterns. Age and education were inversely associated with the "unhealthy" pattern, whereas they were positively associated with the "prudent" pattern. Women were more likely to have a healthy pattern than men were. The corresponding percentages were 19.8% and 11.7% for those with low and high intakes, respectively, of the "prudent" dietary pattern. The prevalence of "on diet" increased with increasing consumption of the "prudent" dietary pattern. The prevalence of using diabetes medication other than insulin increased across the tertiles of the "prudent" dietary pattern. However, the use of insulin increased across the "unhealthy" dietary pattern tertiles.

Prevalence of depression symptoms

In this study, 13.5% of participants had depressive symptoms (16.2% and 10.7% of those with and without diabetes, respectively). Additionally, 12.1% of individuals with diabetes reported experiencing moderate depression symptoms, while 4.1% reported experiencing moderately severe to severe depression symptoms. In comparison, 7.8% of individuals without diabetes reported having moderate symptoms of depression, while 2.9% reported having moderately severe to severe depression symptoms (**see Supplementary Table 1**).

Dietary patterns and depression

The pattern labeled "unhealthy" was positively associated with the score for depression symptoms. However, the "prudent" pattern exhibited an inverse association with the depression score. Across the tertiles of the "unhealthy" dietary pattern, the prevalence of depression was 7.8%, 12.3%, and 20.4%, respectively. The corresponding percentages were 19.2%, 8.8%, and 12.6%, respectively, across the tertiles of the "prudent" pattern (Table 2). According to the unadjusted model, participants in the highest tertile (T3) of the "unhealthy" pattern had a greater prevalence of depression symptoms (PR = 2.62; 95% CI = 1.71, 4.02) than participants in the lowest tertile (T1). However, the crude model revealed no significant association between the "prudent" pattern and depression symptoms. (Table 3). In multivariable Poisson regression models, a significant positive association between the "unhealthy" pattern and symptoms of depression was identified. After we adjusted for sociodemographic, lifestyle, chronic condition variables, and use of vitamin D supplements individuals in T3 with the "unhealthy" pattern had a substantially greater prevalence of depressive symptoms (PR = 2.00; 95% CI = 1.28, 3.17) than individuals in T1. On the other hand, no significant association between the "prudent" pattern and depression symptoms was observed in the full model (Model 5) (Table 3). There was a joint effect of unhealthy dietary pattern and diabetes on depression (Fig. 1A). Compared with those with a low intake of "unhealthy" dietary pattern and without diabetes, those with diabetes and had a high consumption of "unhealthy" pattern had the highest prevalence of depression (PR = 2.93; 95% CI = 1.49, 5.72). However, we did not find a joint effect of the "prudent" pattern and diabetes on depression (Fig. 1B).

According to subgroup analyses, among those with diabetes, there was a significant positive association between the "unhealthy" pattern and symptoms of depression (PR = 1.41; 95% CI = 1.28, 1.56; p- value < 0.001), but not between the pattern and symptoms of depression in individuals without diabetes (PR = 1.13; 95% CI = 0.92, 1.39; p-value = 0.233) (Table 4**).** However, the interaction between the "unhealthy" pattern and diabetes was not statistically significant (p for interaction = 0.101). The association between the "unhealthy" pattern and depression seems to be stronger among those with a normal BMI. There was no interaction between "unhealthy" dietary pattern and vitamin D. Similarly, there was no interaction between "unhealthy" dietary pattern and age, sex, education, physical activity, or smoking (**data not shown**). When we limited our analysis to individuals with diabetes, the positive association between the "unhealthy" pattern and depression was significant only among those with poor glycemic control (HbA1c>7) (data not shown).

For the "prudent" dietary pattern, there was no significant interaction between the pattern and any of the other variables. However, a marginally significant interaction between the "prudent" pattern and BMI was found (p for interaction 0.098). Among those with a normal body weight, a "prudent" pattern was inversely and significantly associated with depression symptoms (PR=0.21; 95% CI=0.06, 0.76; p-value=0.018). No such associations were observed among those who were overweight or obese (Table 4).

Discussion

Using factor analysis, we identified two major dietary patterns in this cross-sectional study of 1,000 adults with and without diabetes in Qatar: "unhealthy" and "prudent" dietary patterns. The "unhealthy" pattern was characterized by a high intake of fast food, Biryani, mixed dish (meat/chicken/fish), croissant, soft drinks, lasagna, and white bread. The "prudent" pattern was characterized by a high intake of fresh fruits, salads and raw vegetables, canned/dried fruits, dates, fresh fruit juice, salads and cooked vegetables, brown bread, and soups/starters. The prevalence of depressive symptoms was high in the sample, especially among those with diabetes. A high consumption of the "unhealthy" pattern among individuals with diabetes was associated with an increased prevalence of depressive symptoms. The "prudent" pattern was inversely associated with symptoms of depression among individuals with a normal body weight but not among those with overweight/obesity.

Prevalence of depression symptoms

The high burden and associated factors of diabetes observed in the current study were supported by the findings of other studies. Depression symptoms were observed in 13.5% of participants overall (16.2% of participants with diabetes and 10.7% of participants without diabetes). Moreover, in the univariate analysis, we found that having diabetes was significantly associated with depression symptoms, as individuals with diabetes had a 52% increased prevalence of experiencing symptoms of depression than individuals without diabetes. This finding is consistent with the literature, which shows that depression is associated with a number of chronic illnesses, including diabetes [30]. Indeed, previous studies have revealed that people with diabetes have a 2–4 times greater risk of depression than people without diabetes [31]. These findings are also consistent with the literature showing that individuals with diabetes, who were taking insulin, and who had a higher BMI had a higher prevalence of depression-related symptoms [32, 33].

Table 3 Associations between dietary patterns and depression symptoms among adults in Qatar ($n=1000$) [a]

Depression symptoms	Unhealthy pattern						Prudent pattern					
	T1	T2		T3		*P* trend [b]	T1	T2		T3		*P* trend [b]
Crude	1.00	1.58	(0.99, 2.52)	2.62	(1.71, 4.02)	< 0.001	1.00	0.45	(0.30, 0.69)	0.66	(0.46,0.94)	0.348
Model1‡	1.00	1.44	(0.90, 2.31)	2.10	(1.33, 3.31)	< 0.001	1.00	0.49	(0.32, 0.74)	0.76	(0.52, 1.09)	0.779
Model2§	1.00	1.40	(0.87, 2.25)	2.06	(1.31, 3.26)	< 0.001	1.00	0.49	(0.32, 0.74)	0.75	(0.52, 1.09)	0.793
Model3‖	1.00	1.38	(0.86, 2.21)	2.04	(1.29, 3.24)	< 0.001	1.00	0.48	(0.32, 0.73)	0.74	(0.52, 1.07)	0.717
Model4¶	1.00	1.35	(0.84, 2.15)	1.99	(1.26, 3.14)	< 0.001	1.00	0.48	(0.32, 0.73)	0.81	(0.57, 1.15)	0.838
Model 5#	1.00	1.35	(0.84, 2.15)	2.00	(1.28, 3.17)	< 0.001	1.00	0.48	(0.32, 0.72)	0.80	(0.56, 1.13)	0.853

Note[a] Data from the Qatar Biobank. The values are prevalence ratios and 95% confidence intervals. Two dietary patterns were derived from factor analysis based on an eigenvalue > 1 and items with factor loading |≥ 0.30|; a scree plot was generated, and interpretability was based on Qatar food culture

[b] Significance in Poisson regression

‡ Model 1: adjusted for sex and age (continuous)

§ Model 2: additionally adjusted for smoking status, education, physical activity, and on diet

‖ Model 3: additionally adjusted for diabetes

¶ Model 4: additionally adjusted for BMI (continuous), diabetes medication other than insulin, insulin use, and hypertension medication

Model 5: additionally adjusted for vitamin D supplement use

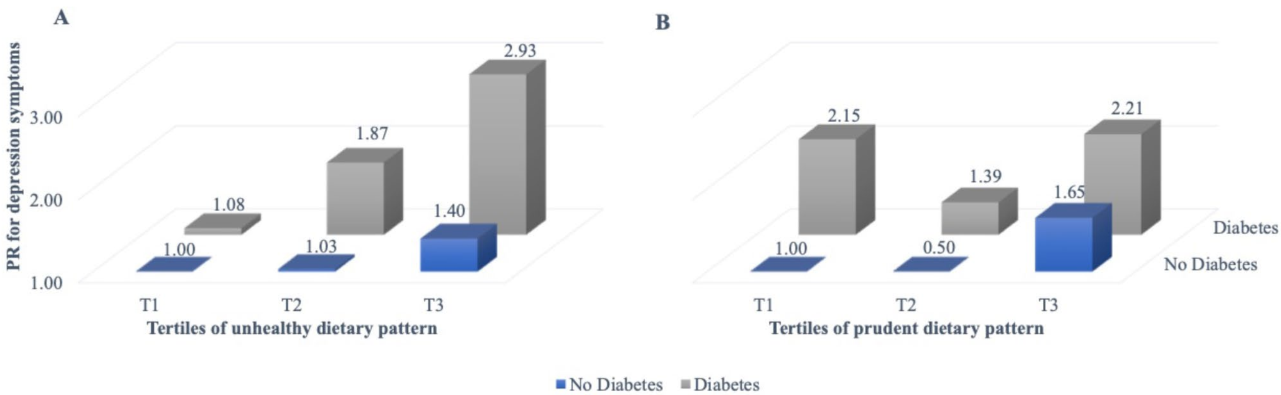

Fig. 1 Joint effect of depression symptoms and (**A**) unhealthy and (**B**) prudent dietary patterns on diabetes. Values were prevalence ratio adjusted for sex, age (continuous), smoking status, education, physical activity, on diet, diabetes status, BMI (continuous), diabetes medication other than insulin, insulin use, and hypertension medication

Table 4 Subgroup analysis of the Association of "Unhealthy" and "Prudent" dietary patterns scores with depression symptoms

Subgroup	Unhealthy pattern				Prudent pattern			
	N	PR	95% CI	*P* interaction [a]	*N*	PR	95% CI	*P* interaction [a]
Diabetes				0.101				0.094
No	488	1.13	0.92, 1.39		488	0.80	0.57, 1.11	
Yes	511	**1.41**	**1.28**, **1.56**		511	1.10	0.92, 1.32	
BMI categories				0.071				0.098
Normal (<25 kg/m^2)	135	**5.84**	**1.63**, **21.00**		135	**0.21**	**0.06**, **0.76**	
Overweight (25.0 to 29.9 kg/m^2)	337	**1.29**	**1.09**, **1.54**		337	1.04	0.70, 1.54	
Obese (≥ 30 kg/m^2)	523	**1.26**	**1.11**, **1.42**		523	1.08	0.91, 1.29	
Vitamin D supplement use				0.928				0.134
No	602	**1.32**	**1.16**,**1.50**		602	0.83	0.63, 1.09	
Yes	397	**1.32**	**1.15**,**1.52**		397	1.09	0.90, 1.33	

Note PA = Physical activity, MET = metabolic equivalent, QR = Qatari Riyal

The values are prevalence ratios (PRs) and 95% confidence intervals (95% CIs) based on Poisson regression. The models were adjusted for sex, age (continuous), smoking status, education, physical activity, diet, diabetes status, BMI (continuous), diabetes medication other than insulin, insulin use, and hypertension medication. Stratification variables were not adjusted in the corresponding models

[a] Significance in Poisson regression

Bold = P-value significant

Dietary patterns and depressive symptoms

In this study, the two identified dietary patterns were comparable to previously identified patterns in Qatar and the Middle East region [19, 34–36]. The findings of the current study are consistent with earlier studies, which have shown a positive association between a Western/unhealthy diet and the risk of developing depression [15, 37–39].

We did not find an overall association between the "prudent" pattern and depression symptoms, which is not consistent with most of what was found in the literature. According to a meta-analysis, individuals with a high intake of a healthy dietary pattern had a lower incidence of depression than did those with a low intake (OR = 0.64; 95% CI = 0.57, 0.72; p-value < 0.00001) [15]. However, in the present study, among participants with a normal body weight, the "prudent" pattern was inversely and significantly associated with symptoms of depression. This finding is consistent with earlier research indicating that a diet high in vegetables, fruits, legumes, whole grains, and seafood contributes to a decrease in obesity, inflammation, and mental health problems in adolescents [40].

The association between dietary patterns and depression could be partly due to vitamin D status. In the study, "prudent" dietary pattern was positively but "unhealthy" dietary pattern was inversely associated with the use of vitamin D supplement. Existing research reveals a link between vitamin D levels, depression, and BMI. For example, a meta-analysis found that vitamin D supplementation may lower depression incidence, particularly in people with normal body weight, but its effects in overweight people tend to be less consistent [41]. Furthermore, there was a significant interaction between vitamin D levels, obesity, and depression [42]. Genetic influences on depression and BMI should also be taken into account. Depression has been linked to specific polymorphisms in the vitamin D receptor gene [43].

Depressive symptoms and diabetes

Existing evidence indicates that diabetes and depression have a bidirectional link. Indeed, a diabetes diagnosis raises the likelihood of developing depression. In comparison, depression is a well-known risk factor for diabetes in people without diabetes, and it leads to poor glycemic control and hastens the onset of complications in people with diabetes [44, 45]. According to the findings, among individuals with diabetes, the prevalence of depression symptoms was 5.5% higher than that among individuals without diabetes. Bawadi et al. reported that the prevalence of depression-related symptoms among T2DM participants in Qatar was 15.4% [7], which is roughly similar to what we observed. Additionally, a meta-analysis of 24 studies revealed that diabetes was associated with a 28% increased risk of depression [45]. However, in this study, we found a much higher prevalence of having depression symptoms among individuals with diabetes, who had a 52% increased prevalence of suffering from depression symptoms than did those without diabetes. The well-established association between dietary patterns and diabetes and depression may suggest the role of diet on the bidirectional association between diabetes and depression [46].

The role of diabetes in the association between dietary patterns and depressive symptoms

In this study, we hypothesized that there is a positive association between "unhealthy" pattern and depression, which is stronger among individuals with diabetes than among those without diabetes. The results from the data analysis support our hypothesis. Furthermore, we found a joint effect of diabetes and "unhealthy" dietary pattern. Individuals with diabetes who had the highest intake of the "unhealthy" dietary pattern had the highest prevalence ratio of depression symptoms than people without diabetes who consumed the lowest intake of the "unhealthy" dietary pattern (PR=2.93; 95% CI=1.49–5.72). However, there was no significant interaction between the "prudent" pattern and depression symptoms stratified by diabetes status. Our findings are consistent with those of other studies. For example, Akbaraly et al. [38] showed that a high intake of fried food, processed meat, sweetened desserts, high-fat dairy products, and refined grains is associated with depressive symptoms. In that study, the prevalence of diabetes was significantly higher among participants who experienced depressive symptoms than among those without [38]. T2DM is commonly associated with an unhealthy lifestyle that includes inactivity, an unhealthy diet, and poor sleep [47]. These lifestyle factors can be considered unspecific sources of stress that disrupt the body's homeostasis and thus increase the risk of depression.

Potential Biological mechanisms

The association between diet, depression, and diabetes may be explained by a variety of biological mechanisms. According to the literature, food components are involved in inflammatory processes, neurogenesis, and hypothalamic-pituitary-adrenal axis (HPA) regulation [48]. Increased consumption of processed and refined foods, as well as dishes with a high sugar and fat content, has been associated with higher levels of inflammation and an increased risk of depression [49, 50]. Neurotransmitters require a certain amount of amino acids, vitamins, and minerals to function properly; this could explain why some deficits in nutrition have been related to a higher risk of depression [51]. This type of diet has been linked to chronic diseases such as diabetes, cardiovascular disease, and neurocognitive disorders [52]. Inflammation could be one of the factors causing microvascular dysfunction, which could explain changes in regional brain blood flow linked to depression [53]. The microbiota–gut–brain axis has been implicated in the regulation of physiological processes such as cognitive function, neuropsychiatric diseases, and behavior according to a rapidly developing body of literature [54]. Numerous mechanisms involved in depression pathophysiology (for example, inflammation [55], tryptophan metabolism [56], and neurogenesis [57]) may be influenced by the gut microbiome, given that it is one of the first body systems to interact with ingested food. Short-term food intake and long-term dietary habits are known to be significant variables that affect the gut microbiota composition and diversity [58, 59].

Microvascular dysfunction is linked to hyperglycemia [60], glycation [61], and changes in circulating lipids [62]. All of these metabolic abnormalities, which lead to depression via microvascular dysfunction, can be triggered by dietary changes, among other lifestyle factors [63]. However, other factors, such as obesity, smoking, mental stress, and hypertension, can also cause microvascular dysfunction [64, 65].

Strengths and limitations

The cross-sectional study design is the main limitation. Although we cannot claim causation, the findings are in line with existing knowledge and point to the importance of diet in the prevention/management of both diabetes and depression. This provides direction for future research. The second limitation is that we could not adjust for energy intake in the analyses due to the use of the FFQ without portion size. Nevertheless, the FFQ can be utilized to classify people in large-scale epidemiological studies to reflect their typical long-term intake. The relative validity of the FFQ employed in the EPIC study has been demonstrated [66]. The third limitation is that the two patterns explained only 26.2% of the variance.

However, in population-based studies, dietary patterns identified via factor analysis commonly explain only a small proportion of the variation in the entire diet. The percentage of variance in food intake explained by dietary patterns varied with the number of food categories used in the factor analysis. The variance explained by dietary patterns reduces as the number of food groups increases. In our study, we used 38 food groups, which is similar to the findings of previous studies in Qatar [19]. The fourth limitation is that depressive symptoms were self-reported using the PHQ-9, which is a screening tool, not a diagnostic tool for depression. Furthermore, the dose of vitamin D supplement use was not available.

On the other hand, this study's main strength is that we used a comprehensive food consumption list of 102 food items, which captures a wide range of food consumption. Furthermore, we were able to adjust for sociodemographic factors, lifestyle factors, and medications.

Future directions

This study suggests the need for further research and the expansion of methodology. Replicating the factor analysis with a larger national sample is recommended, allowing for subgroup analyses on how individual food intake relates to depression. A national sample could reveal differences based on diabetes control and duration and include individuals under 18 years of age. Longitudinal studies using larger samples are essential for understanding the bidirectional links between depression symptoms and diet. Qualitative research is proposed to provide detailed insights complementing quantitative results. Additionally, investigating the mechanisms by which dietary patterns affect depressive symptoms and diabetes risk requires longitudinal studies with adequate sample sizes. Future studies could explore data linkage through the primary health care system, examining associations between dietary patterns and depression medication use and building on the insights gained from the Qatar Biobank study.

Conclusion

In conclusion, this study demonstrated a significant and complex relationship between dietary patterns, health conditions, and depression among adults in Qatar. Our findings revealed that adherence to an "unhealthy" dietary pattern is associated with increased depression symptoms, particularly among individuals with diabetes. Conversely, a "prudent" dietary pattern appears to be inversely associated with depression symptoms among individuals with a normal body weight. These findings highlight the potential of dietary interventions to serve as complementary strategies for both the prevention and management of depression, particularly in high-risk populations such as individuals with diabetes. Further research is warranted to explore the underlying mechanisms of these associations and develop culturally tailored dietary interventions for depression prevention and management in Qatar.

Supplementary Information

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Supplementary Material 1

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Author contributions

N.H contributed to the conception, analysis, and interpretation of the data; drafting of the report; and approval of the final version for publication. H.F.A and Z.S contributed to the analysis and interpretation of the data and commented on the report. Z.S contributed to revising the manuscript. All authors approved the final version for publication.

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Data availability

A data request can be made by contacting the Qatar Biobank team.

Declarations

Ethics approval and consent to participate

This study acquired deidentified data from adults visiting the Qatar Biobank, which were collected with informed consent in compliance with the Helsinki Declaration. The study was reviewed by the Qatar Biobank Institutional Review Board in Qatar, and the ethical approval number QF-QBB-RES-ACC-00005-0149 was obtained.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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