Original article

Relationship Between Food Insecurity and Diabetes Among Patients in Saudi Arabia

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Abstract. *Background:* Food insecurity (FI) is a major determinant of nutritional status, which could influence the self-care practices of diabetic patients. *Objective:* To assess the prevalence of FI and examine the relationship between FI and self-management practices among patients with diabetes. Methods: A cross-sectional survey was conducted on 229 patients at the diabetes clinic in King Abdulaziz University Hospital, Jeddah, Saudi Arabia. *Results:* The prevalence of FI was 26.2%, and it was more prevalent among non-Saudis, unemployed participants, and those with low household incomes (<5,000 SAR), as compared to food secure group (p <0.0001 for all comparisons). FI significantly predicted higher odds of irregular self-monitoring of blood glucose (OR = 2.47, 95% CI, 1.14–5.37, p = 0.022). Additionally, FI significantly predicted cost-related non-adherence to medication use (β = 1.95, 95% CI, 1.60–2.29, p <0.0001), and hypoglycemia-related complications (β = 0.69, 95% CI, 0.50–0.88, p <0.0001). These indicators were significantly influenced by severe FI. The intake of unhealthy food moderated the relationship of FI with hypoglycemia and its related complications (β = 0.11, 95% CI, 0.03–0.18, p = 0.006). *Conclusions:* Food assistance coverage and health awareness programs are required to support food insecure diabetic patients, a step that could optimize their healthy food choices and self-management practices.

Key words: food security; food insecurity; self-management; diabetes; socioeconomic factors

Introduction

Food is one of the fundamental necessities of life, and food security is a key determinant of human security, as well as an essential element of human rights (1). Conversely, food insecurity (FI) involves the disruption of the four domains of food security: the availability, access, utilization, and stabilization of the food system, which ultimately impacts the active and healthy lives of individuals (2,3). Several factors might influence food security, such as age, economic level, ethnicity, employment status, and dietary habits (4). Food-insecure populations are more likely to consume low-quality, energy-dense grains, sugars, and fats and have a concomitant reduction of fruit and vegetable intake (5). As a result, FI can be associated with health consequences that include dyslipidemia, depression, cancer, and hypertension due to consuming lower-cost foods (2). This, in turn, increases the likelihood of experiencing chronic illnesses such as diabetes. In addition, among those with established diabetes, food-insecure individuals might experience difficulties with optimal food choices for effective self-management.

Therefore, FI may represent a modifiable variable of glucose control and diabetes self-management, a matter that should be stressed given the growing burden of diabetes. Estimates indicate that diabetes is prevalent among 9.3% of the global population, projected to increase to 10.2% by 2030 (6). In Saudi Arabia, the burden is more significant; the combined prevalence of type 1 diabetes mellitus (T1DM) and type 2 diabetes mellitus (T2DM) has been recently estimated at 12.6% (7). Furthermore, the incidence of T2DM continues to grow linearly in concordance with sedentary lifestyles and the rising trend of consuming unhealthy diets (8).

Importantly, based on data from the Saudi Arabia Health Interview Survey, Al-Hanawi et al. (9) recently reported significant socioeconomic inequalities in the incidence of diabetes, with individuals who have a low income and low educational level more likely to experience diabetes. Such findings reveal an urgent need to assess different aspects of diabetes among individuals with limited incomes who may be experiencing variable degrees of FI (10). Understanding the impact of FI on diabetes control and self-management practices and diabetes control would allow tailoring of targeted interventions toward the modifiable factors of disease management. However, to the best of our knowledge, no studies to date have assessed the current status of FI among the Saudi Arabian diabetic population or the effects of FI on diabetes management. This study aimed to examine the associations between FI and glycemic control and diabetes self-management among patients residing in Jeddah, Saudi Arabia. The prevalence and determinants of FI among patients with diabetes were also investigated.

2. Materials and Methods

2.1 Study design and eligibility criteria

A cross-sectional study was carried out among 229 patients at the diabetes clinic in King Abdulaziz University Hospital, Jeddah, Saudi Arabia. A survey was distributed during the study period of 2019 to 2020. Eligible participants were adult males and females (aged ≥20 years) who had been diagnosed with T1DM or T2DM. Pediatric patients and those with gestational diabetes were excluded. All patients responding to the electronic and interview-based surveys provided informed consent before participation. Ethical approval was obtained from the Unit of Biomedical Ethics Research Committee at King Abdulaziz University (Reference No 575-19).

2.2 Study procedure

Participants were recruited using a convenience sampling technique. To administer the questionnaire to participants in their native language, the questionnaire items were translated from English to Arabic by two consultants. The tool used has been validated for use in Sub-Saharan Africa, (11) but no validation studies have been carried out in the Middle East. A structured questionnaire was distributed to eligible patients, and it was completed during a face-to-face interview in the clinic waiting area. However, due to the COVID 19 pandemic and quarantine, we could not continue collecting the data from patients in the clinic. Therefore, the survey link was sent through WhatsApp to all diabetic patients receiving care at the diabetes clinic at King Abdulaziz University Hospital (n=248). In addition, the link was sent through WhatsApp to the supervisor of the Diabetes Friends Association, who sent it to members with diabetes. The minimum number of participants required for this study was 176, based on a power of 80%, alpha = 0.05 (two-sided), and estimated standardized effect size of 0.30 (12).

2.3 Survey instrument

The survey included 48 questions and five major domains.

Sociodemographic characteristics: The sociodemographic characteristics of participants were collected, including gender, age, occupation, income, and household size.

Clinical characteristics: Questions regarding the clinical characteristics of participants included self-reported body weight (kg), height (m), type of diabetes, and smoking status. Body mass index (BMI) was calculated based on the reported weight and height, and obese participants were defined as those with a BMI of ≥30 kg/m^2 (13).

Eating habits: Based on a six-item food frequency instrument (14), eating habits were examined by assessing how frequently participants consumed fruits, vegetables, and diabetes products (favorable eating habits), as well as fast foods, sugar, and soft drinks (unfavorable eating habits). The categorization of favorable and unfavorable eating habits was based on each food item's effects on HbA1c levels (15-17). The responses used a four-point Likert scale, with answers ranging from never (1), rarely (2), sometimes (3), and daily (4). Two dietary habit scores were computed by summing the responses related to the consumption of fruits, vegetables, and diabetes products (a favorable eating habits score ranging between 3 and 12) and the consumption of fast foods, sugar, and soft drinks (an unfavorable eating habits score ranging between 3 and 12). In addition, participants were asked to submit their answers regarding the number of daily meals they consumed and the typical time between meals.

Food insecurity: FI was assessed using the Arabic version of the eight-item Food Insecurity Experience Scale Survey Module (FIES-SM) (18). The scale assesses conditions that may have been experienced within the last 12 months due to a lack of money or other resources. These include the inability to eat healthy and nutritious food, skipping a meal, eating only a few kinds of food, and going without eating for a whole day. The responses were collected as no (0) or yes (1). One or more affirmative answers indicated FI. Based on the total number of affirmative responses, FI was categorized as mild (1–3 affirmative responses), moderate (4–6), or severe (7–8).

Diabetes self-management: Diabetes self-management was assessed using four indicators: (**1) HbA1c values**, categorized as poor, moderate, or good glycemic control (>8%, 7–7.9%, and <7%, respectively); (**2) non-adherence to blood glucose testing**, assessed by asking whether blood glucose levels were measured regularly (yes or no); (**3) cost-related non-adherence to medication regimens,** assessed by five items asking about the last 12 months, adopted from a study conducted by Ngo-Metzger et al. (2012) (19), which comprised (a) taking smaller doses of medication to make it last longer, (b) spending less on food to have enough money to buy medicine, (c) delaying buying medication to have enough money to buy food, (d) deciding not to refill a prescription because it is expensive, and (e) spending less on food, electricity, or other basic needs to have enough money to buy medicine; (**4) hypoglycemia or related health complications,** measured by asking three questions adopted from a study conducted by Kersey et al. (1999) and Seligman et al. (2010) (20, 21) which addressed (a) experiencing extreme anxiety when medicines or healthy foods were not regularly available, (b) blood sugar becoming too low because of inadequate food or medication, (c) emergency room visit due to low blood sugar. The responses about cost-related non-adherence to medications and hypoglycemia complications were collected as no (0) or yes (1). A composite score was computed for each variable, with a range of 0–5 for non-adherence and 0–3 for complications from hypoglycemia.

2.4 Statistical analyses

Statistical analysis was performed using the Statistical Package for Social Sciences version 26.0 (SPSS Inc., Chicago, IL, USA). Categorical data were presented as frequencies and percentages, and continuous variables were expressed as means ± standard deviations (SDs). The relationships between FI and the sociodemographic and clinical characteristics of participants were investigated using a Fisher's exact test. The associations of FI and poor HbA1c control and irregular glucose monitoring were evaluated using logistic regression analysis, whereas linear regression models were applied to assess the relationships between FI and the scores for eating habits, cost-related non-adherence to medication regimens, and hypoglycemia or related health complications. First, we carried out univariate regression models using the following dependent variables: status of HbA1c control (coded as 0 for good or moderate and 1 for poor control), irregular self-monitoring of blood glucose (0 = no and 1 = yes), cost-related medication non-adherence (continuous, 0–5), and complications due to hypoglycemia (continuous, 0–3). The status of FI was added as an independent variable (food-secure = 0 and food-insecure = 1). Second, multivariate models were additionally adjusted for sociodemographic and clinical characteristics. The results of the binary logistic regression models were expressed as odds ratios (ORs) and 95% confidence intervals (95% CIs), and the β coefficients and 95% CIs were used to express the outcomes of the linear regression models. Finally, the PROCESS macro in SPSS (model 1) was used to examine the potential moderating role of participants' dietary habits on the relationship between FI and diabetes management (22). Statistical significance was considered at $p < 0.05$, using two-tailed tests.

3. Results

3.1 Sociodemographic and clinical characteristics of participants

A total of 229 patients participated in this study (**Figure 1)**.

More than half of the respondents were female (51.5%), Saudi (67.7%), and married (68.6%). Approximately one-third were older adults (37.6%), had 5–6 family members (32.3%), had a low household income (<3,000 SAR, 29.7%), and had a primary level education (31.4%). The overall prevalence of FI was 26.2% (n = 60), of which 23 had mild FI (38.3%), 19 had moderate FI (31.7%), and 18 had severe FI (30.0%). A significantly higher proportion of FI participants were non-Saudis (48.6% versus 15.5%, p <0.001), had no current occupation (p <0.001), and had a monthly household income of <3,000 SAR or 3,000–<5,000 SAR (p <0.001, **Table 1**).

Regarding the clinical characteristics (**Table 2**), around half of the participants were obese (48.9%) and had been diagnosed with T2DM (65.9%). Notably, FI was significantly more prevalent among diabetic participants whose medical costs were partially or not at all covered by the hospital (p = 0.004) or medical insurance (p = 0.001, **Table 2**).

3.2 Dietary habits and food insecurity

The dietary habits patterns of participants are depicted in **Figure 2**. A significantly higher proportion of FI participants reported never consumed diabetes products (53.3% versus 37.3% for food-secure participants, p = 0. 034, **Figure 2C**). Daily sugar consumption was more frequent among food-secure participants compared to those with FI (34.3% versus 11.7%, respectively, p = 0.005, **Figure 2D**).

Based on the FI status, no significant differences existed in the number of meals consumed per day or the periods between meals (**Figure 3**).

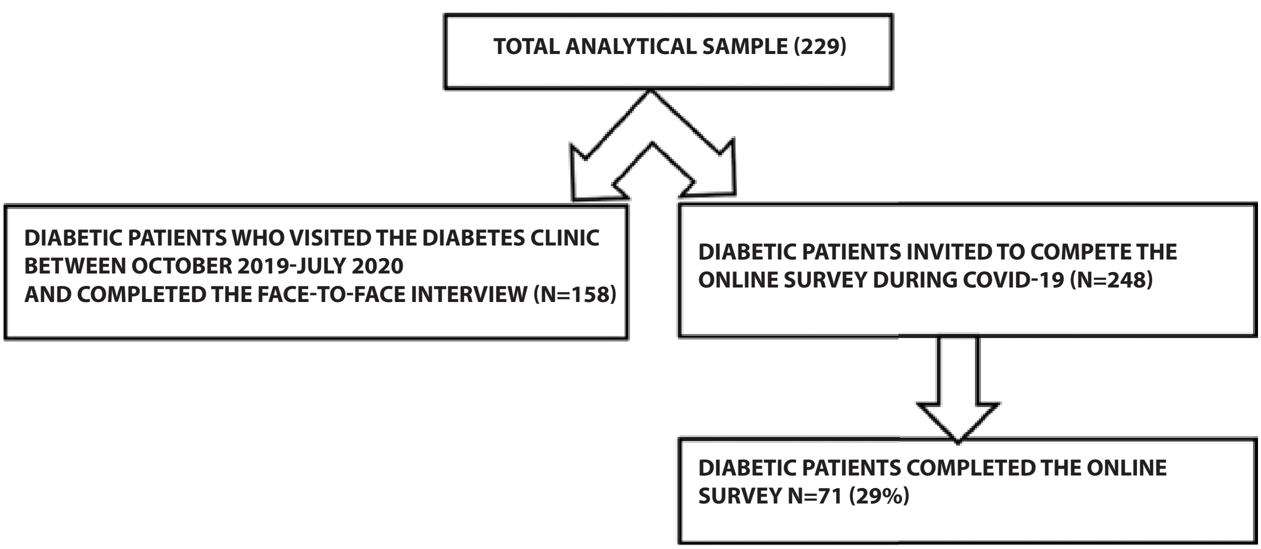

Figure 1. Flowchart of participants recruitment

Table 1. Sociodemographic characteristics and the levels of food security of diabetic patients (N = 229)

Parameter	Category	Total	Food-secure (N = 169)	Food-insecure (N = 60)	p*
Gender	Male	111 (48.5)	84 (75.7)	27 (24.3)	0.551
	Female	118 (51.5)	85 (72)	33 (28)	
Nationality	Saudi	155 (67.7)	131 (84.5)	24 (15.5)	**<0.0001**
	Non-Saudi	74 (32.3)	38 (51.4)	36 (48.6)	
Age category (years)	18–29	30 (13.1)	26 (86.7)	4 (13.3)	0.097
	30–39	21 (9.2)	17 (81)	4 (19)	
	40–49	26 (11.4)	19 (73.1)	7 (26.9)	
	50–59	66 (28.8)	41 (62.1)	25 (37.9)	
	60 and above	86 (37.6)	66 (76.7)	20 (23.3)	
Marital status	Single	27 (11.8)	22 (81.5)	5 (18.5)	0.077
	Married	157 (68.6)	117 (74.5)	40 (25.5)	
	Divorced	12 (5.2)	11 (91.7)	1 (8.3)	
	Widowed	33 (14.4)	19 (57.6)	14 (42.4)	
Educational attainment	Illiterate	39 (17)	26 (66.7)	13 (33.3)	0.108
	Primary	72 (31.4)	54 (75)	18 (25)	
	Intermediate	21 (9.2)	15 (71.4)	6 (28.6)	
	High School	50 (21.8)	33 (66)	17 (34)	
	University/College and above	47 (20.5)	41 (87.2)	6 (12.8)	
Occupation	Employee	50 (21.8)	42 (84)	8 (16)	**<0.0001**
	Unemployed	18 (7.9)	10 (55.6)	8 (44.4)	
	Student	12 (5.2)	12 (100)	0 (0)	
	Self-employed	16 (7)	10 (62.5)	6 (37.5)	
	Unable to work	8 (3.5)	4 (50)	4 (50)	
	Retired	55 (24)	49 (89.1)	6 (10.9)	
	Housewife	70 (30.6)	42 (60)	28 (40)	
Number of family members	1–2	20 (8.7)	13 (65)	7 (35)	0.315
	3–4	67 (29.3)	48 (71.6)	19 (28.4)	
	5–6	74 (32.3)	60 (81.1)	14 (18.9)	
	7 and above	68 (29.7)	48 (70.6)	20 (29.4)	
Household income (SAR)	<3,000	68 (29.7)	29 (42.6)	39 (57.4)	**<0.0001**
	3,000–<5,000	33 (14.4)	21 (63.6)	12 (36.4)	
	5,000–<10,000	51 (22.3)	46 (90.2)	5 (9.8)	
	10,000–<15,000	37 (16.2)	35 (94.6)	2 (5.4)	
	>15000	40 (17.5)	38 (95)	2 (5)	

Results are expressed as frequencies and percentages. SAR: Saudi riyal. *Statistical differences were assessed using a Fisher's exact test.

Table 2. Clinical characteristics and levels of food security among diabetic patients (*N* = 229)

Parameter	Category	Total	Food-secure (*N* = 169)	Food-insecure (*N* = 60)	*p**
Body mass index (kg/m^2)	<18.5 (Underweight)	4 (1.7)	2 (50)	2 (50)	0.728
	18.5–24.9 (Normal weight)	54 (23.6)	40 (74.1)	14 (25.9)	
	25–29.9 (Overweight)	59 (25.8)	44 (74.6)	15 (25.4)	
	30 and above (Obese)	112 (48.9)	83 (74.1)	29 (25.9)	
Type of diabetes	Type 1 diabetes	78 (34.1)	60 (76.9)	18 (23.1)	0.526
	Type 2 diabetes	151 (65.9)	109 (72.2)	42 (27.8)	
Smoking status	Smoker	38 (16.6)	30 (78.9)	8 (21.1)	0.586
	Former smoker	41 (17.9)	28 (68.3)	13 (31.7)	
	Non-smoker	150 (65.5)	111 (74)	39 (26)	
Physical activity for at least 30 minutes	Daily	43 (18.8)	32 (74.4)	11 (25.6)	0.855
	Sometimes	81 (35.4)	62 (76.5)	19 (23.5)	
	Rarely	55 (24)	40 (72.7)	15 (27.3)	
	Never	50 (21.8)	35 (70)	15 (30)	
Choosing the right food to achieve optimal blood sugar	Daily	60 (26.2)	44 (73.3)	16 (26.7)	0.513
	Sometimes	112 (48.9)	85 (75.9)	27 (24.1)	
	Rarely	24 (10.5)	15 (62.5)	9 (37.5)	
	Never	10 (4.4)	9 (90)	1 (10)	
	Don't know	23 (10)	16 (69.6)	7 (30.4)	
Costs of the medicine covered by the hospital	Comprehensive coverage	133 (58.1)	108 (81.2)	25 (18.8)	**0.004**
	Partial coverage	62 (27.1)	35 (56.5)	27 (43.5)	
	Rarely	9 (3.9)	7 (77.8)	2 (22.2)	
	The medicine is not dispensed	25 (10.9)	19 (76)	6 (24)	
Medical insurance	Comprehensive	38 (16.6)	36 (94.7)	2 (5.3)	**0.001**
	Partial	12 (5.2)	7 (58.3)	5 (41.7)	
	I don't have insurance	179 (78.2)	126 (70.4)	53 (29.6)	

Results are expressed as frequencies and percentages. *Statistical differences were assessed using a Fisher's exact test.

3.3 Relationship between food insecurity (FI) and diabetes management

As demonstrated in **Table 3**, FI diabetic participants were more likely to experience poor diabetic control than food-secure participants (OR = 2.05, 95% CI, 1.07–3.92). However, the relationship between FI and diabetes control was attenuated when the regression model was adjusted for sociodemographic and clinical characteristics of the participants. Furthermore, fully adjusted regression models revealed that FI was independently associated with higher odds of irregular self-monitoring of blood glucose (OR = 2.47, 95% CI, 1.14–5.37, p = 0.022), as well as higher scores on non-adherence to medication regimens (β = 1.95, 95% CI, 1.60–2.29, p <0.0001) and hypoglycemia-related complications (β = 0.69, 95% CI, 0.50–0.88, p <0.0001).

Moderation analysis with bootstrapping showed that increased consumption of unhealthy food was a significant moderator of the effect of FI on experiencing hypoglycemia-related complications (β = 0.11, 95% CI, 0.03–0.18, p = 0.006, **Table 4**). The model explained 30.7% of the variance in experiencing

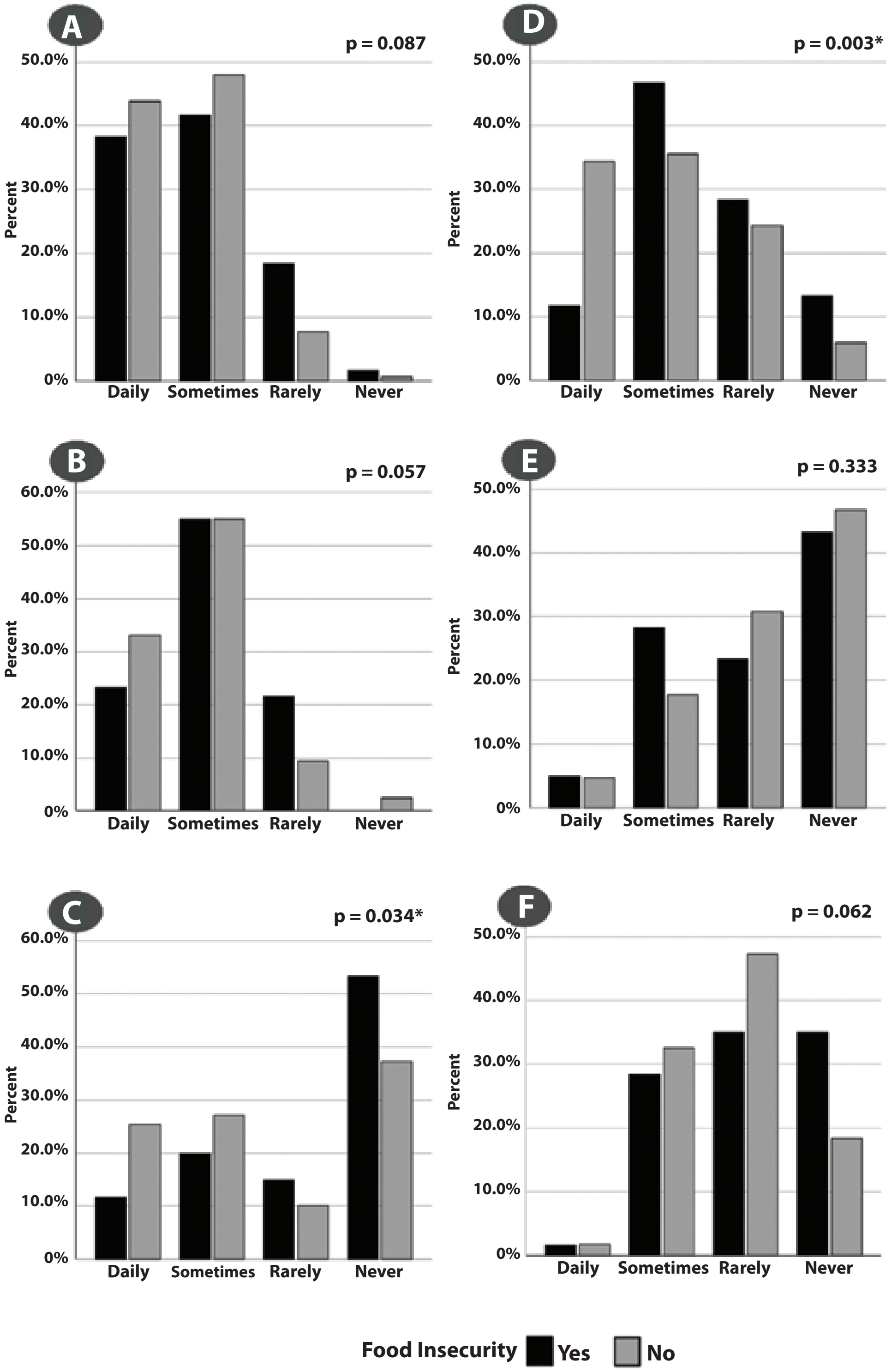

Figure 2. Participants' responses regarding their dietary habits for the consumption of vegetables (A), fruits (B), diabetes products (C), sugar (D), soft drinks (E), and fast food (F). The reported p-value indicates the differences between food-secure and food-insecure patients as revealed by a Fisher's exact test. * Indicates a statistically significant difference between groups.

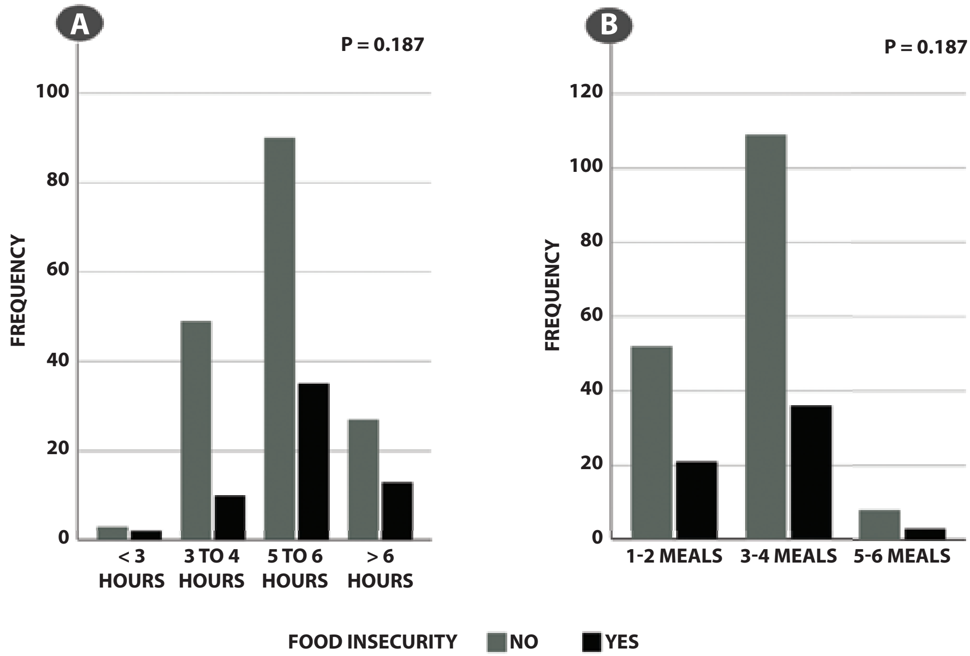

Figure 3. The association between food insecurity status and the time periods between meals (A) the number of meals (B). The reported p-value indicates the between-group differences based on a Fisher's exact test.

Table 3. The impact of food insecurity (FI) on diabetes management and eating habits of patients with diabetes (N = 229)

Parameter	Simple regression		Multivariate*	
Categorical variables (logistic regression)	**OR (95% CI)**	***p*-value**	**OR (95% CI)**	***p*-value**
Poor HbA1c control	2.05 (1.07 to 3.92)	**0.029**	1.07 (0.47 to 2.46)	0.869
Irregular self-monitoring of blood glucose	2.54 (1.39 to 4.65)	**0.002**	2.47 (1.14 to 5.37)	**0.022**
Continuous variables (linear regression)	**β (95% CI)**	***p*-value**	**β (95%CI)**	***p*-value**
Cost-related medication non-adherence (0–5)	2.22 (1.91 to 2.54)	**<0.0001**	1.95 (1.60 to 2.29)	**<0.0001**
Complications due to hypoglycemia (0–3)	0.77 (0.61 to 0.93)	**<0.0001**	0.69 (0.50 to 0.88)	**<0.0001**

*Multivariate regression analyses were adjusted for sociodemographic and clinical characteristics of patients. CI: confidence interval; OR: odds ratio; SD standard deviation.

Table 4. The interaction between food insecurity (FI) and dietary habits on the risk of poor diabetes management among participants in the current study (N = 229)

Parameter		**R^2 change**	**β (95% CI)**	***p*-value**
Poor HbA1c control	FI × favorable habits	0.162	-0.07 (-0.44–0.29)	0.687
	FI × unfavorable habits	3.965	0.34 (-0.01–0.69)	0.056
Non-adherence to blood glucose testing	FI × favorable habits	0.778	0.16 (-0.19–0.51)	0.378
	FI × unfavorable habits	0.051	-0.03 (-0.34–0.27)	0.822
Cost-related non-adherence to medication regimens	FI × favorable habits	0.006	-0.14 (-0.32–0.03)	0.104
	FI × unfavorable habits	0.003	0.09 (-0.06–0.24)	0.255
Hypoglycemia or related health complications	FI × favorable habits	0.001	-0.03 (-0.12–0.06)	0.530
	FI × unfavorable habits	0.024	0.11 (0.03–0.18)	**0.006**

FI: food insecurity.

complications (F (3,225) = 33.21, p <0.0001). No other moderating effects were apparent for the interaction between dietary habits and FI on other diabetes management domains.

3.4 Levels of food insecurity and diabetes management

To further investigate the association between FI severity and diabetes management, adjusted logistic regression models were developed using FI severity as a multi-categorical independent variable. The results revealed that participants with severe FI were more likely to be non-adherent to regular blood glucose self-monitoring on a regular basis than food-secure participants (OR = 3.88, 95% CI, 1.06–14.23, p = 0.041). Furthermore, adjusted multivariate linear regression models in UNIANOVA showed consistently higher scores for cost-related non-adherence to medication regimens and hypoglycemia-related complications among participants with mild, moderate, and severe FI, compared to those with food security **(Table 5)**.

Discussion

In this study, we assessed the prevalence of FI and examined the associations between FI and diabetes self-management practices among patients residing in Jeddah, Saudi Arabia. The results in this study showed that FI was an independent risk factor for irregular self-monitoring of blood glucose, cost-related non-adherence to diabetes medication regimens, and hypoglycemia-related complications. These indicators for poor self-management practices were more prominent with increased FI severity. Several barriers to successful diabetes self-management have been cited in the literature, such as frustration with the chronic nature of the disease, work- and environment-related factors, and self-efficacy in implementing coping strategies. The latter includes effective handling of medication adjustments and food intake to reach optimal blood glucose levels (23). Nevertheless, financial constraints due to poverty and unemployment might confer FI, as could limited access to fresh healthy food.

In our analysis, the prevalence of FI was 26.2%, which was relatively in agreement with other studies in developed countries. The prevalence of FI among the diabetic population has been reported at 9.3%–13.0% in Canada and the United States (24, 25) and 26% in a Puerto Rican community in the United States (26). However, FI prevalence in developing regions has been higher, ranging from 32% to 66.7% (27, 28). In the present study, household income played a significant role, with FI being more prevalent among participants with an income of <5,000 SAR (51, 50.5%) compared to those in the higher income

Table 5. The impact of different severity levels of food insecurity (FI) on various domains of diabetes management among patients in the current study (*N* **= 229)**

Parameter	**Food-secure (*N* = 169)**	**Mild FI (*N* = 23)**		**Moderate FI (*N* = 19)**		**Severe FI (*N* = 18)**	
Categorical variables (logistic regression)		**OR (95% CI)**	***p*-value**	**OR (95% CI)**	***p*-value**	**OR (95% CI)**	***p*-value**
HbA1c	Ref	0.84 (0.26–2.74)	0.767	2.52 (0.63–10.05)	0.190	0.95 (0.28–3.25)	0.938
Irregular self-monitoring of blood glucose	Ref	1.28 (0.39–4.19)	0.683	3.34 (0.79–14.08)	0.100	3.88 (1.06–14.23)	**0.041**
Continuous variables (linear regression)		**β (95% CI)**	***p*-value**	**β (95% CI)**	***p*-value**	**β (95% CI)**	***p*-value**
Cost-related medication non-adherence	Ref	1.85 (1.39–2.31)	**<0.0001**	1.52 (1.00–2.04)	**<0.0001**	2.48 (1.96–3.00)	**<0.0001**
Complications due to hypoglycemia	Ref	0.57 (0.31–0.82)	**<0.0001**	0.53 (0.24–0.81)	**<0.0001**	1.02 (0.73–1.30)	**<0.0001**

CI: confidence interval; FI: food insecurity; OR: odds ratio group (9, 7.0%). This might also explain the significantly higher prevalence of FI among unemployed participants than their employed counterparts. Furthermore, non-Saudi participants representing expatriate labor from foreign countries with low socioeconomic levels, also experienced higher FI levels. Other research has similarly emphasized the high prevalence of FI among low-income patients, which was >40% in several studies conducted in the United States (21, 29, 30). Therefore, plausible that food assistance coverage among FI-vulnerable populations should be augmented, particularly among diabetic patients with competing demands in Saudi Arabia.

Notably, the co-existence of FI and diabetes has been associated with poor indicators of diabetes self-management, such as failure to regularly self-monitor glucose. Similarly, Seligman et al. (21, 31) showed that the presence of FI was associated with poor adherence to self-care practices, including adherence to regular blood glucose monitoring. FI has also been a significant predictor of hypoglycemia and its related complications (fatigue and/or hypoglycemia-related emergency department admission) (32, 33). Inadequate food supply may lead to skipping meals or reduced caloric intake, which can account for hypoglycemia. Furthermore, the risk of hypoglycemia may be related to the monthly availability of food; the rate of hypoglycemia increases toward the end of the month (34). Notably, FI patients might also make trade-offs between food and medications or supplies, which could influence their adherence to effective management plans. Ultimately, patients might experience hypoglycemia (if they put off buying food to buy medicines) or hyperglycemia (if they put off buying medications to buy food) (35, 36). Therefore, the clinical impact of budget-related decisions for FI patients should be considered in future interventions, and the importance of adherence to medications and regular glucose monitoring should be stressed.

Interestingly, the increased consumption of unhealthy food has positively influenced the unfavorable effects of FI on complications from hypoglycemia due to poor diabetes self-management. The fact that maintaining a healthy diet is deemed a real challenge among FI populations may partly underscore the importance of health-focused campaigns to increase patients' awareness about healthy food choices. Furthermore, financial aid and supplementary food programs may be warranted. In the United States, the US Supplemental Nutrition Assistance Program, which includes incentives for improving the consumption of fruits and vegetables as well as restriction of sugar-sweetened beverages for low-income households, has been a cost-effective and cost-saving approach to reducing the prevalence of diabetes and nutrition-related cardiovascular disorders and their related complications (37). Similar financial incentives and education programs for healthy food choices are needed in Saudi Arabia, particularly through technology-based and online platforms.

A higher proportion of diabetic participants with FI was found to have poor HbA1c control than food-secure participants (66.7% FI vs. 49.4% food-secure). However, relatively surprisingly that the relationship was nonsignificant when the analysis was adjusted for sociodemographic and clinical characteristics. A possible explanation is that HbA1c in our study was self-reported, and the last results of glucose control may be subject to recall bias; hence, it may be under- or over-reported. There were also several answers with "I don't know" responses, which might have affected HbA1c results as an important indicator of glycemic control. In contrast, FI was an independent risk factor for poor glycemic control according to an early cross-sectional investigation of a large cohort from the 1999–2008 National Health and Nutrition Examination Survey (poor glycemic control at HbA1c >9.0%) (38) and the Veterans Aging Cohort Study in the United States (poor glycemic control at HbA1c >7.0%) (39).

This study is the first in Saudi Arabia to assess the prevalence of FI and examine the relationship between FI and self-management practices among patients with diabetes. To the best of our knowledge, the moderating role of unhealthy food consumption on the association between FI and hypoglycemia has not been assessed before. We believe that the findings of this study can offer invaluable recommendations for diabetes management among food-insecure individuals. However, some limitations were encountered in our analysis. The significance of causal relationships may be limited by the cross-sectional design and the inherent limitations of participants' responses. In addition, other unreported factors, such as the history of co-morbidities, diabetes duration, access to care, and health literacy, were not included in the regression models; therefore, their effects have not been included as confounders of the relationship between FI and diabetes control and management. Although the results of our study can be generalized to other regions in Saudi Arabia, they are not generalizable to other parts of the world given the unique cultural environment and high number of expatriates in our study. We believe that the obtained outcomes contribute to information about how diabetes self-management programs could be structured and how supportive models of financial aid and incentives could be effectively delivered to target populations.

Conclusions

FI was prevalent among approximately one quarter of diabetic patients in Jeddah, Saudi Arabia. FI was a significant risk factor for three indicators of inadequate diabetes self-management: irregular glucose monitoring, non-adherence to diabetes medication regimens or supplies due to budgetary trade-offs, and hypoglycemia and its related complications. These indicators were strongly influenced by the severity of FI. Accordingly, targeted interventions should be tailored to increase food assistance coverage and reduce the clinical effects of FI among diabetic patients with competing demands in Saudi Arabia, such as those in low-income households, expatriates, and unemployed patients. Such programs must focus on promoting healthy food choices while reducing the consumption of inadequate food items. Additionally, efforts should aim to improve patients' adherence to medication regimens and regular glucose monitoring. Studying the impact of FI on glycemic control is warranted in prospective, controlled investigations, considering accurate clinical indicators of glycemic control.

Conflict of Interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

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