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Alanood Al-Marri, Yosaf AlRabeei & Mohammed Al-Hamdani

Nutrition Literacy for People with Type 2 Diabetes and Its Associations with Demographic, Behavioral and Clinical Characteristics

Alanood Al-Marri[1,2]

Yosaf Al Rabeei[2]

Mohammed Al-Hamdani,*[1]

Affiliation

[1]Department of Public Health, College of Health Sciences, QU Health, Qatar University, Doha 2713, Qatar

[2]Health Education Department, Primary Healthcare Corporation, Doha, P.O. Box 26555, Qatar

*Corresponding author: Mohammed Al-Hamdani, Qatar University, Doha, Qatar, email: malhamdani@qu.edu.qa

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Abstract

This study aimed to develop a preliminary diabetes-specific Nutritional Literacy (NL) scale and examine its associations with key variables, including HbA1c%. A cross-sectional survey was disseminated to adults with Type 2 Diabetes (T2D) attending primary care clinics in Qatar via SMS. An NL scale and administered after answering sociodemographic and health-related variables. Following content validity, reliability and principal component analysis, we developed a preliminary unidimensional NL scale. We then assessed the relationship between demographic, behavioral and clinical characteristics and the developed NL scale, in a multivariate logistic regression test, after assessing covariate in bivariate tests. The NL scale demonstrated internal consistency and a unidimensional structure. Compared to having HbA1c% levels of 5.7–6.4%, those with levels of 6.5–8% (OR=0.45) and >8% (OR=0.28) had significantly lower odds of high NL. Relative to exercising 0-1 days/week, exercising 6–7 days/week (OR=18.0) and 4–5 days/week (OR= 2.78) were associated with increased odds of high NL. Further, those who had not visited a clinic in over a year (OR=0.22) had lower odds of high NL compared to those that visited a clinic 1-6 months ago. Marginal associations were found for clinical referrals (OR=1.99), smokers (OR=0.48), and having other chronic diseases (OR=0.60), relative to no referrals, not smoking and not having other chronic diseases

respectively. Higher NL is associated with better glycemic control, healthier behaviors, and healthcare utilization, highlighting the importance of integrating tailored nutrition education into diabetes care.

Key Words: Nutrition literacy; Diabetes; Type 2 Diabetes; HbA1c%; Qatar; Patient-provider communication.
Words (including abstract, references, tables and declaration statements): 5268 words

Background

Type 2 diabetes (T2D) continues to rise globally [1]. In 2024, around 589 million people were diagnosed with Diabetes around the world, which amounts to an approximate 11.1% prevalence [2]. The numbers are projected to increase by 45% worldwide, 10% in Europe, 18% in Western Pacific, 21% in North America, 45% in South and Central America, 73% in South America, 92% in the Middle East, and 142% in Africa, by 2050 [2]. The estimated prevalence of Diabetes in Qatar is 26%, which is higher than the global average [3]. According to the International Diabetes Federation (IDF), 90% of all Diabetes cases are T2D [4]. Diabetes is driven in large part by modifiable lifestyle factors such as high sugar intake and low physical activity levels [5]. These behaviors are increasingly common across age groups—including children, adolescents, and adults—and contribute to a growing public health burden [6,7]. In Qatar, the situation is especially urgent as current prevalence rates of T2D are already high, and projections

suggest a steep increase by 2050 [8]. Without effective prevention and management, the risk of complications—ranging from microvascular health issues (example: retinopathy to more severe macrovascular outcomes (example: stroke)—will only intensify [9].

Among the many tools available to address this crisis, food labeling policies is paramount [10]. Clear and accessible nutritional labeling, particularly regarding sugar content, can help reduce the risk of T2D over time [11]. But this only works if individuals possess the knowledge and skills to interpret that information—this is where nutritional literacy (NL) becomes essential. NL, the capability to comprehend and use nutrition information to make an informed decision [12], is important for people living with T2D. NL can shape how they read food labels, interpret serving sizes, manage carbohydrate intake, and make everyday decisions about what to eat—or avoid [13,14]. Yet, NL cannot be assumed, and it is often overlooked or subsumed within the broader concept of health literacy (HL), despite its unique and critical importance in diabetes care.

Diabetes self-management goes far beyond medication. Patients are often tasked with monitoring their glucose levels, planning meals, balancing physical activity, and avoiding high-sugar foods—tasks that require practical knowledge and decision-making skills [15,16]. In clinical settings, dietitians and health educators provide guidance tailored to these needs [17], but outside these environments, individuals must rely on their own

understanding of nutrition to make healthy choices. NL is what helps bridge that gap.

Despite its relevance, research on NL in the context of T2D remains limited. Most existing studies examine NL in general populations or among individuals with chronic diseases broadly [18]. For example, one study examined NL in adolescents and found that nearly half had low NL and evident with a subset of the sample—those with inability to comprehend information, consuming unhealthy food products, and perceiving information as being difficult to understand [19]. Others have developed a generic NL scale for people with chronic disease and found it to be related to diet quality [20].

The literacy demands for people managing T2D may be quite specific—especially given the focus on carbohydrates and sugar both of which influence clinical improvements beyond medications [21]. NL levels are unlikely to be uniform across patients whose diabetes management is molded by a range of factors, including education, cultural norms, and economic factors [22]. In the Middle East, the need for culturally appropriate tools to assess NL is particularly pressing. Current measures may not reflect local dietary practices, food availability, or language use. The purpose of this study was to address gaps related to the lack for tools to assess NL specifically, and its associations with key demographic, behavioral and clinical measures. Specifically the aims were to:

1- To develop a preliminary NL scale for T2D that is sensitive to cultural and contextual factors in the region.
2- Assess the relationship between demographic variables, lifestyle behaviors, and diabetes-specific self-management practices.

Methods

Sample

This study employed a purposive sampling strategy targeting individuals diagnosed with T2D attending family medicine clinics operated by the Primary Health Care Corporation (PHCC) in Qatar. Eligible participants were adults aged between 18 and 65 years, had a confirmed T2D diagnosis, as recorded in PHCC's electronic health records. Individuals were excluded if they had Type 1 diabetes, gestational diabetes, or were pregnant. Ethical approval was granted by the institutional review board of Primary Health Care Corporation (IRB/PHCC) (approval no. BUHOOTH-D-24-00777) and Qatar University’s institutional review board (QU-IRB 108/2025-EM).

Recruitment and Procedure

Participants were recruited over a six-week period between March 13 and April 23, 2025. Recruitment involved disseminating a Google Forms survey link via SMS to a randomized list of patients with T2D registered at PHCC clinics. Upon clicking the link, potential participants were presented with a digital information sheet detailing the study’s aims, risks, benefits, and data

confidentiality. Informed consent was obtained electronically through an "I agree" option before proceeding to the questionnaire.

The survey followed a structured sequence: eligibility screening, demographic data collection, and administration of the NL scale. In total, 269 individuals responded to the survey invitation. Of these, seven declined to participate, 30 were excluded due to a diagnosis of Type 1 diabetes, four were excluded for having gestational diabetes, and one was excluded due to pregnancy, leaving a sample of 227 participants. Another two had more than 50% missing data for NL, leaving a final sample of 225 that is suitable for analysis. For the remaining 225 participants, missing data were minimal, with fewer than 5% of responses missing for some categorical demographic variables, for which mode imputation was applied. For missing responses within the NL scale (also <5%), mean imputation was used.

Sample Size

A sample of N = 100 was required to conduct principal component analysis (PCA), based on a 10:1 ratio of participants to items (10 items × 10). Additionally, to assess the correlates of NL using multiple linear regression, a minimum sample of N = 185 was calculated (for 12 predictors, effect size f^2 =.10 (small-to-medium effect size), power = 0.80, α = 0.05) using G*Power 3.1.1.9 [23].

Study Instrument

The survey was designed for individuals with T2D registered in PHCC databases and was structured to be completed in approximately 15 minutes. It comprised two main sections:

Demographic and health-related characteristics, including age, sex, education level, body weight, duration of diabetes, presence of other chronic conditions, dietary regimen, HbA1c%, frequency of diabetes clinic visits, referrals to specialists, smoking status, and physical activity habits.

Nutritional literacy scale, consisted of 10 items, rated on a 5-point Likert scale. The typical range from 1 (strongly disagree) to 5 (strongly agree) was used. The scale was developed to measure participants' self-reported confidence and capability to comprehend and use nutrition knowledge to informed decisions. An example item is: "I am confident about reading and comprehending food labels (e.g., when shopping for cereal, I read the sugar content and make my choice based on this reading)."

Data Analysis

IBM SPSS Statistics (Version 27) was used for analyses [24].

Content Validity and Pilot Testing of Preliminary Nutritional Literacy Scale

To establish content validity, the survey instrument underwent a two-phase pilot process. The first phase involved feedback from 14 clinical experts in diabetes care (2 from Hamad Medical Corporation, 10 from PHCC, and 2 from the Abbott diabetes education team), which led to language

refinements and improved item clarity. In the second phase, the revised survey was piloted with four patients living with T2D. Their responses indicated that the questions were comprehensible and relevant, and only minor modifications were required. Based on this iterative process, the instrument was deemed content-valid for the study population, and according to both clinical experts and patients, the scale reflected nutritional literacy components while being practical in length.

Reliability and Principal Component Analysis of the Nutritional Literacy Scale

We assessed internal consistency using Cronbach's alpha. The factor structure was assessed through principal components analysis. A threshold of .3 was considered to characterize cross loadings and an Eigenvalue of 1 was considered as the threshold for determining the number of factors.

Bivariate Tests and Regression Analysis

Although the initial intent was to conduct multiple linear regression, we used a logistic regression test because the assumptions of the former were not met. Next, we attempted ordinal regression, but the test of proportional odds was statistically significant, which violated this important assumption. Therefore, the next step was to turn the scale into a dichotomy based on a median split where 1 to 3.88 was low, the median is 3.9, and 3.9 to 5 was high NL in order to run logistic regression test. To determine the variables that enter the logistic regression analysis, we used bivariate tests for the

association between the sociodemographic variables and NL level. Specifically, we used Pearson's chi-square tests (if < 20% of the cells had an N < 5), fisher test (for 2 x 2 comparisons) or likelihood ratio tests (if ≥ 20% of the cells had an N < 5). Variables with associations of $p \leq .2$ with NL in the bivariate analyses were entered into the multivariate logistic regression tests. For the logistic regression test, adjusted odds ratios, Wald statistics, and confidence intervals (95%) were reported. Prior to the logistic regression test, we tested for multicollinearity by observing the correlations between independent variables, and none were above $r = .3$.

Results

Reliability and Principal Component Analysis

The NL scale had good reliability (Cronbach's alpha = 0.894). Only one factor with an Eigen value for 1 and above emerged yielding a unidimensional scale with all items loading above .30 and explained 52.1% variance (see Table 1 for all items loading). The Kaiser–Meyer–Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = .89. Bartlett's test of sphericity indicated that correlations between items were large enough for analysis, $\chi^2(45) = 1039.22$, $p < .001$.

Table 1. Principal Components Analysis of the nutritional literacy scale for Type 2 Diabetes.

Component 1: Nutritional literacy	Loading
1. I am confident about reading and comprehending food labels. (Example: When you shop for cereal, you read the sugar content and make your choice based on this reading)	0.508
2. I can identify food items with high added sugar content. (Example: When you plan your meals, you avoid items with high added sugar content)	0.687
3. I know that incorporating fiber in my diet several days per week is important. (Example: When you select your carbohydrates, you look for beans, whole grains and other food items that specifically have high fiber content)	0.616
4. I am aware that portion size has a direct impact on my blood sugar levels. (Example: Before eating, you roughly measure your food portions to avoid eating too much and spiking your blood sugar)	0.394
5. I am knowledgeable about balancing different food groups such as carbohydrate, protein and fat in my diet in a way that helps control my blood sugar. (Example: You know how to divide your meals to ensure that you have the right amount of each food group)	0.551
6. I choose low glycemic index foods rather than high glycemic index foods to control my blood sugar levels.(Example: You select a whole fresh fruit instead of sweetened cornflakes for breakfast)	0.587 0.551
7. I adjust my diet after receiving my blood sugar test results to help control my blood sugar level. (Example: You receive a blood sugar test with high blood sugar level and become stricter with choosing low glycemic index food in order to lower your blood sugar levels)	0.597
8. I understand dietary guidelines for managing my diabetes condition.(Example: You know how that it is important to eat Fibers regularly)	0.415
9. I select complex carbohydrates over simple carbohydrates.(Example: You know that a whole apple is a complex carbohydrate, and a sweetened juice is a simple carbohydrate and choose the whole apple because of this knowledge)	0.311
10. I select low fat products to better control my diabetes. (Example: You choose low fat yoghurt over full fat flavored yoghurt)	

Sample Characteristics

The sociodemographic characteristics by NL level of 225 participants are summarized in Table 2. Most participants in this study were male, with an average age of 50 years. The age distribution of the sample was as follows: 28% were between 18 and 44 years, 52% between 45 and 60 years, and

20% over 60 years old. Of all participants, 43.1% had HbA1c% levels of between 6.5% - 8%, followed by 29.8% with HbA1c% levels of 5.7% - 6.4%, 18.7% had HbA1c% above 8%, and 8.4% had HbA1c% less than 5.7%. A large proportion of the participants (42.7%) reported a decrease in weight compared to the last year, 35.1% mentioned no change in weight compared to last year and 19.1% had gained weight compared to last year. For educational level, 64.4% of participants completed university. The highest proportion of participants had been living with diabetes for over 10 years (36.9%), followed by those with 1 to 5 years (31.6%), 6 to 10 years (23.1%), and less than one year (8.4%). More than half of the participants (55.6%) reported reducing carbohydrates intake as their main dietary regimen, a smaller proportion reported avoided high carbohydrates (23.1%) or reducing fat consumption (21.3%). The majority of participants (72.4%) had not been referred to a specialist. Approximately half of the participants (51.6%) reported no chronic diseases. Most participants (62.2%) reported, visiting the diabetes clinic within 1-6 months. Most participants (64.9%) were non-smokers. Among all the participants, 50.6% were considered with high NL.

Bivariate Associations between Sociodemographic Variables and Nutritional Literacy

Bivariate analysis are displayed in Table 2. Bivariate analyses revealed significant association between some sociodemographic factors and NL levels (Low vs. High). HbA1c% levels were associated with NL (p=0.004).

Lower HbA1c% levels were related to high NL. Additionally, smoking status was statistically significant with NL (p= 0.003). There were higher proportions of non-smokers with high NL. Exercise frequency was associated with NL (p= <0.001). Higher proportions of higher NL levels were observed for those with higher exercise frequency per week (p < 0.001). One variable showed marginal significance of association with NL: visits to diabetes clinic (p= 0.053).

Table 2. Sociodemographic characteristics and bivariate associations with nutritional literacy level

Variables	**Nutritional literacy**		**Total sample (n=225)**	**P-value**
	Low (n=111)	**High (n=114)**		
Sex				
Male	64 (57.7%)	74 (64.9%)	138 (61.3%)	0.277[c]
Female	47 (42.3%)	40 (35.1%)	87 (38.7%)	
HbA1c%				
Less than 5.7%	7 (6.3%)	12 (10.5%)	19 (8.4%)	
5.7-6.4%	23 (20.7%)	44 (38.6%)	67 (29.8%)	**0.004[a]**
6.5-8%	53 (47.7%)	44 (38.6%)	97 (43.1%)	
Above 8%	28 (25.2%)	14 (12.3%)	42 (18.7%)	
Weight since past year				
Higher	20 (18%)	23(20.2%)	43 (19.1%)	
Lower	42 (37.8%)	54 (47.4%)	96 (42.7%)	0.258[b]
No difference	44 (39.6%)	35 (30.7%)	79 (35.1%)	
Not sure	5 (4.5%)	2 (1.8%)	7 (3.1%)	
Educational level				
University	68 (61.3%)	77 (67.5%)	145 (64.4%)	
High school	34 (30.6%)	25 (21.9%)	59 (26.2%)	0.503[b]
Not complete high school	7 (6.3%)	9 (7.9%)	16 (7.1%)	
No education	2 (1.8%)	3 (2.6%)	5 (2.2%)	
Duration of diagnosis				
Less than 1 year	8 (7.2%)	11 (9.6%)	19 (8.4%)	
1 – 5 years	36 (32.4%)	35 (30.7%)	71 (31.6%)	0.911[a]
6 – 10 years	25 (22.5%)	27 (23.7%)	52 (23.1%)	
More than 10 years	42 (37.8%)	41 (36%)	83 (36.9%)	

Variables	Nutritional literacy		Total sample (n=225)	P-value
	Low (n=111)	High (n=114)		
Dietary regimen				
Avoid high carbohydrate	22 (19.8%)	30 (26.3%)	52 (23.1%)	
Reduce fat consumption	28 (25.2%)	20 (17.5%)	48 (21.3%)	0.273[a]
Reduce carbohydrate in diet	61 (55%)	64 (56.1%)	125 (55.6%)	
Referral for specialist				
No	36 (32.4%)	26(22.8%)	62 (27.6%)	0.135[c]
Yes	75 (67.6%)	88 (77.2%)	163 (72.4%)	
Chronic diseases				
No	51 (45.9%)	65 (57%)	116 (51.6%)	
Yes	60 (54.1%)	49 (43%)	109 (48.4%)	0.110[c]
Last visit to a diabetes clinic	63 (56.8%)	77 (67.5%)	140 (62.2%)	
1 – 6 months	20 (18%)	16 (14%)	36 (16%)	**0.053[a]***
7 – 12 months	11 (9.9%)	15 (13.2%)	26 (11.6%)	
Once a year	17 (15.3%)	6 (5.3%)	23 (10.2%)	
Before more than year				
Smoking status	64 (57.7%)	82 (71.9%)	146 (64.9%)	
No	37 (33.3%)	16 (14%)	53 (23.6%)	**0.003[a]**
Yes	10 (9%)	16 (14%)	26 (11.6%)	
Former smoker				
Exercise	74 (66.7%)	48 (42.1%)	122 (54.2%)	
0 -1 day per week	28 (25.2%)	32 (28.1%)	60 (26.7%)	**<**
2-3 days per week	8 (7.2%)	22 (19.3%)	30 (13.3%)	**0.001[a]**
4-5 days per week	1 (0.9%)	12 (10.5%)	13 (5.8%)	
6-7 per week				
Age	33 (29.7%)	30 (26.3%)	63 (28%)	
18-44 years	61 (55%)	56 (49.1%)	117 (52%)	
45-60 years	17 (15.3%)	28 (24.6%)	45 (20%)	0.222[a]
Over 60 years				
Employment status	26 (23.4%)	28 (24.6%)	54 (24%)	
Not employed	63 (56.8%)	71 (62.3%)	134 (59.6%)	
Employed	22 (19.8%)	15 (13.2%)	37 (16.4%)	0.399[a]
Retired				

Note. Values presented are frequencies (%); p-values were obtained using chi-square tests or Fisher's exact tests, as applicable; p-values in bold are statistically significant with (*) indicate marginal statistical significance*; a* = Chi-Square tests*; b* = Likelihood tests; *c* = Fisher's exact tests.

Multivariate Logistic Regression

The multivariate logistic regression results with adjusted odds ratios are displayed in table 3. The Hosmer and Lemeshow test of goodness of fit suggests that the model fits the data well, as p=0.302 (>.05). A significant association was observed between self-reported HbA1c% levels and NL. Participants with HbA1c% levels between 6.5–8% had lower odds of having high NL (OR=0.45, 95% CI: 0.22–0.93) while those who had HbA1c% levels above 8% had even lower odds (OR=0.28, 95%CI: 0.11-0.70) of having high NL in comparison to those who had HbA1c% between 5.7% - 6.4%. There was also a significant association between referrals and NL levels. Those who had referral to a specialist had approximately twice the odds for having high NL (OR=1.99, 95%CI=0.991-4.032). Additionally, those had chronic diseases had marginally lower odds (OR=0.6, 95%CI: 0.32-1.10) of having high NL in comparison to the those with no chronic diseases. Further, there was a marginally significant association between frequent visits to diabetes clinic and better NL levels. Those who visited a diabetes clinic more than a year ago had much lower odds (OR=0.266, 95%CI: 0.08-0.80) of having high NL compared to those who had recent visits (visit every 1-6 months). For smoking status, there was a marginally significant association between smoking status and NL level, those who reported currently smoking had lower odds (OR=0.483, 95%CI: 0.22-1.02) of having high NL, while those who were former smokers had higher odds of 1.26 of having high NL (OR=1.26, 95%CI: 0.480-3.346) as compared to the non-smokers. Lastly, there was a significant association between frequent exercise days

per week and NL levels. Relative to exercising 0-1 day per week, those who exercised 6-7 days per week (OR=18, 95%CI: 2.123-161.8), and 4-5 days per week (OR=2.78, 95%CI: 1.061-7.31) both had higher odds of higher NL. (see Table 3).

Table 2. Multivariate logistic regression test for the relation between sociodemographic variables and nutritional literacy.

Variables	Wald	df	Odds	95% CI
HbA1c%				
5.7 – 6.4%			Reference	
6.5 – 8%	4.54	1	**0.459**	(0.224-
Above 8%	0.939)			
Less than 5.7%	7.42	1	**0.288**	(0.117-
	0.705)			
	0.909	1	0.554	(0.165-
	1.865)			
Referral to specialist				
No	Reference			
Yes	3.74	1	**1.999***	(0.991-4.032)
Having chronic disease				
No	Reference			
Yes	2.66	1	**0.602***	(0.327-1.107)
Visit for diabetes clinic				
1 – 6 months	Reference			
7-12 months	1.094	1	0.645	(0.283 –
Once every year	1.467)			
More than year	0.233	1	1.270	(0.481 –
	3.351)			
	5.56	1	**0.226**	(0.089-
	0.800)			
Smoking status				
No	Reference			
Former smoker	0.229	1	1.286	(0.480-3.346)
Yes	3.57	1	**0.483***	(0.227-
	1.027)			
Exercise				
0 – 1 day per week	Reference			
2 – 3 days per week	1.645	1	1.579	(0.786 –
4 – 5 days per week	3.172)			
6 – 7 days per week	4.331	1	**2.78**	(1.061-
	7.315)			
	6.977	1	**18.49**	(2.123-
	161.084)			

Note. Bolded Odds ratios are statistically significant at $p < 0.05$**;** Bolded odds ratios are statistically significantly, and if accompanied with "*" are marginal. Values for OR above 1 indicate higher likelihood for high nutritional literacy for the compared variable level relative to its reference and values for OR under 1 indicate lower higher likelihood for high nutritional literacy for the compared variable level relative to its reference.

Discussion

In this study, we developed a culturally relevant, preliminary scale to assess NL and explored its associations with clinical, demographic, and lifestyle factors among individuals living with T2D who access care in primary healthcare settings. Through the content validity involving patients with lived experience and health practitioners with expertise in nutrition and diabetes, we introduce a preliminary NL scale that captures key aspects of NL in relation in T2D. The scale captures literacy and perhaps elements of self-efficacy and adherence, which may in part explain its meaningful relationships between several key variables, including HbA1c% and exercising thereby demonstrating the potential value of this scale as a check of NL level in people with T2D. Conceptually, this extends prior work on generic NL by providing, T2D-specific , culturally grounded preliminary scale, where relevant competencies are emphasized such as choosing low-glycemic index foods, food label interpretation for sugar content, adjusting diet in response to blood work results, balancing macronutrients and the selection of complex over simple carbohydrates). Past scales assessed general understanding of nutrition but did not delve into diabetes-specific self-management behaviours such as portion-blood sugar links or post-test

dietary adjustments which are key behaviours relevant for T2D [25]. Our preliminary scale therefore presents a step towards extending prior measurement work by embedding glycemia-relevant behaviours in a specific NL scale for T2D.

One of the most notable findings was the inverse relationship between NL and HbA1c% levels. Participants with lower NL tended to have higher HbA1c% values, suggesting that limited understanding of nutrition may be linked to poorer glycemic control. This pattern is consistent with past evidence, such as studies showing that higher health literacy is related to lower HbA1c% [26]. However, past health literacy studies captured broad health system navigation and general information comprehension [26], and our NL scale presents a preliminary measure that captures, actionable, meal-level competencies such as low glycemic index food selection, portion size monitoring and adjusting diets based on blood tests. These glycemia-specific skills are more closely related to HbA1c% in comparison to general health literacy suggesting that nutrition-specific knowledge and behavior capabilities may themselves function as determinants of glycemic control but future studies are needed to confirm this hypothesis by testing NL its relation to HbA1c% readings over time.

Our study also aligns with existing evidence emphasizing the role of tailored nutrition education in improving diabetes outcomes. For example, a study in Lebanon demonstrated that a culturally adapted diabetes self-management program led to significant reductions in HbA1c% among patients with

poorly controlled diabetes [27]. While the aforementioned study focused on a diabetes education program in Lebanon, many of its components including reading food labels, awareness about carbohydrate quality, and culturally-specific diet planning [27], mirror the items in our scale. This overlap in content provides a potential explanation for the convergence in findings—the skills promoted in diabetes education programs [27], correspond to the competencies assessed in our preliminary scale. Our study was a cross sectional study presenting correlates of a preliminary NL scale, showing that higher NL is associated with lower HbA1c% across broad glycemic range. Some past studies were interventions [27]. The consistency of the findings between our study and past findings, despite differing designs, strengthens the assertion that nutrition-specific knowledge and behaviours are related to glycemic outcomes.

In our study, participants who had been referred to specialists—such as dietitians or diabetes educators—were nearly twice as likely to demonstrate high NL. This highlights the important role of multidisciplinary care in supporting patients' understanding of food labels, dietary planning, and carbohydrate management—skills that are foundational to diabetes self-management. The association between specialist referral and NL further demonstrates the relevance of the NL scale in reflecting nutrition-focused patient education access. This aligns with past evidence from systematic reviews which pointed out that dietitian-delivered medical nutritional therapy (MNT) is associated with improved BMI and waist circumference

[28]. Although abovementioned review did not measure NL directly [28], many of the components of the review on MNT studies such as low fat food selection and carbohydrate distribution map closely onto our scale. Taken together, increased NL maybe the reason that nutritional therapy is associated with positive metabolic outcomes. However, future mediation studies that test whether NL is a mediator for the effect of MNT on BMI and waist circumferences are needed to confirm this hypothesis.

Lifestyle behaviors were also meaningfully associated with NL. Current smokers had lower odds of high NL, whereas individuals who reported exercising regularly were more likely to demonstrate higher NL. These associations point to the multifaceted nature of NL, shaped not only by clinical indicators like HbA1c%, but also by broader health behaviors and access to healthcare resources. This parallels past studies that highlighted physical activity as a central component of diabetes management [29], our results show that individuals with higher NL may engage in physical activity more consistently by virtue of their understanding of the role of lifestyle behaviours in glycemic control. Similarly, past studies demonstrated that smoking is related to negative metabolic outcomes [30], and our study suggests that smokers may have lower NL. Together, these findings suggest that incorporating structured nutrition education—whether through diabetes clinics or specialist referrals—can be instrumental for improving NL and empowering patients to make informed dietary choices. Physical activity and smoking have long been emphasized as factors contributing to

diabetes [29,30]. Our study 's contribution is to show that NL— in terms of the ability to interpret food labels, select low-glycemic food, and balance macronutrients—may be associated with positive lifestyle behaviors.

Strengths

Our study has a number of strengths. First, it extends existing knowledge on the relationship between health literacy and improved self-care, glucose level control and knowledge [31], by offering a preliminary NL scale that is associated with better health and life style outcomes. Secondly, it studied, patients from different primary clinics in Qatar, offering a sample that represents primary care diabetes patients to a reasonable extent. Third, it demonstrates the importance of NL as a specific measure for people with T2D and sets the ground for further work on scale improvements in order to capture more domains to refine such scales.

Limitations

Several limitations should be noted. First, the sample was drawn only from primary care clinics, which limits the generalizability of the findings to patients receiving care in secondary, tertiary, or private settings, where clinical characteristics and resources may differ. Second, recruitment via SMS may have excluded patients with limited digital literacy or access, potentially biasing the sample. Third, the sample size did not seem sufficient to capture small effects for some variables. This was evident in the many marginal effects that were observed, suggesting that a larger

sample size would have likely captured significance rather than marginal significance. This happened due to an overestimation of the expected effect sizes when making the sample size calculation. Fourth, relying on self-reported data such as exercise and clinic attendance introduces the risk of recall and social desirability bias. Fifth, although the study introduced a preliminary NL scale, it serves a first step towards more validation including construct or criterion validity and confirmatory factor analysis. Sixth, given that HbA1c% was self-reported there is potential for misclassification bias which may impact the interpretation of the regression outcome. The use of medical records in future research is thus recommended to overcome these issues. In the same vein, the question used to ask participants about HbA1c% had fixed categorical responses: “less than 5.7%”, “5.7-6.4%”, and “6.5%+” which align with diagnostic thresholds rather than treatment targets. This is a limitation because an HbA1c% reading below 5.7%, is likely to reflect a reporting error or the low likelihood of remission. It is also a limitation because readings for treatment targets should be classified as controlled (<7.0%) or uncontrolled (>7.0%). Because we used predetermined categories that do not allow for post-hoc reclassification into controlled versus uncontrolled categories, we were unable to apply clinically recommended cut offs for T2D. Future studies should therefore use HbA1c% as a dichotomous variable with controlled (<7.0%) or uncontrolled (>7.0%) options or measured as a continuous variable to allow for more appropriate classification of treatment targets.

Seventh, large odd ratios and wide confident interval should be interpreted cautiously as they may indicate model instability and associations that involve the lifestyle factors such as exercise and smoking are susceptible to reverse causality given the cross sectional design of the study. Eighth, because the assumptions required for treating NL scale as a continuous predictor in linear regression were not met, we dichotomized NL scale at the median for logistic regression analysis. While it made the analysis feasible and intuitive to interpret, we recognize that dichotomization reduces power [32]. Therefore, the findings should be viewed as exploratory rather than definitive, and future studies should focus on preserving the continuous nature of the NL scale. Ninth, the age variable was collected using broad categories, and the “18–44 years” group may be problematic because its 18–29 subset could include individuals with type 1 diabetes (T1D). We expect this risk to be minor, as PHCC sent SMS invitations exclusively to adults with confirmed T2D and our survey included a screening question on diabetes type that excluded those reporting T1D. Even so, future studies would benefit from collecting age using more granular categories (such as 18–29 and 30–44 years old) to allow clearer differentiation among younger adults. Finally, while the preliminary NL scale performed well, it was relatively brief and may not capture the full complexity of nutritional literacy in T2D, indicating that future work should expand and refine its dimensions.

Conclusion

NL plays a vital role in how individuals with T2D understand and manage their condition, particularly through everyday food choices. This study suggests that lower NL may be related to poorer glycemic control, as reflected in higher HbA1c% levels, while higher NL may be associated with healthier lifestyle behaviors such as regular physical activity and non-smoking. Referrals to dietitians or diabetes educators were also associated with improved NL, underscoring the value of patient access to nutrition-specific support. These findings potentially highlight the importance of integrating structured, culturally relevant nutrition education into primary care pathways. While the preliminary NL scale developed in this study is a first step towards measuring NL for T2D, further research is needed to validate it across diverse populations and to explore how NL changes over time. Strengthening NL through tailored interventions may help patients make more informed dietary decisions and to increase their likelihood of achieving better diabetes outcomes. However, continued work to refine the preliminary scale in this study in future studies is needed.

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Ethical approval

This study received ethical clearance from the Institutional Review Board (IRB) of the Primary Health Care Corporation (PHCC) under approval number BUHOOTH-D-24-00777, as well as from the Qatar University IRB (approval number QU-IRB 108/2025-EM). All procedures conducted as part of this research adhered to applicable national regulations and guidelines, which are aligned with internationally recognized ethical standards, including the Declaration of Helsinki (1964), with amendments made in 2000.

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Generative AI, ChatGPT (version GPT-5, OpenAI, 2025), was used for the sole purpose of language improvement of some paragraphs.

Author contributions

Alanood Al-marri: Writing- original, Investigation, Formal analysis, and Conceptualization. Yosaf Al-rabeei: Writing – review & editing, Mohammed Al-Hamdani: Writing-original, Writing – review& editing, Supervision, Formal analysis, Methodology, and Conceptualization.

Data availability

Due to the highly sensitive nature of the patient data, it is confidential, and we are required to delete the data within three years of its collection as per PHCC regulations. Further queries can be directed to corresponding author.

Competing interests

The first and second authors are PHCC staff. However, the consent form stated that participation has no impact on patient care and the participants were recruited through the operations office.

Consent to participate

All participants completed an online consent form after reading a detailed information sheet. Only those that agreed to participating via clicking on “I agree to participate” that was preceded with statements that indicate that they agree to participate and fully understand the premise, risks and benefits associated with the study.

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