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The moderating role of e-health literacy and patient-physician communication in the relationship between online diabetes information-seeking behavior and self-care practices among individuals with type 2 diabetes

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Abstract

Background This study examined the moderating role of e-health literacy (eHL) and patient-physician communication in the relationship between online diabetes information-seeking behavior (online DISB) and self-care practices.

Methods A total of 1143 individuals with type 2 diabetes mellitus completed a cross-sectional survey assessing sociodemographic characteristics, data relating to diabetes clinical history, online DISB, eHL (eHealth Literacy Scale), aspects of patient-physician communication (IPC survey), patient self-care (Self-Care Inventory-Revised), and medication adherence (measure of adherence to prescribed diabetes medications). The data were analyzed using both bivariate (correlation) and multivariate (multiple linear regression) analyses using maximum likelihood estimation procedures in Mplus.

Results Our results showed online DISB significantly predicted diabetes self-care ($p < 0.001$) and medication adherence behaviors ($p = 0.005$). Lower Hurried Communication ($p < 0.001$, $p = 0.03$), higher Elicited Concerns ($p = 0.005$, $p = 0.03$), higher Explained Results ($p = 0.03$, $p = 0.008$), and higher eHL ($p = 0.02$, $p = 0.02$) were significantly associated with better self-care and medication adherence. Explained Results and eHL moderated the relationship between online DISB and both self-care and medication adherence.

Conclusions Findings support the role of patient eHL and patient-physician communication in amplifying the positive impact of online DISB on patients' behavioral outcomes in diabetes.

Keywords Online health information seeking behavior, Type 2 diabetes mellitus, e-Health literacy, Patient physician communication, Self-care

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Introduction

In today's digital era, the internet has revolutionized the way people retrieve health information, particularly for chronic conditions like diabetes. With a vast array of online resources at their fingertips, individuals are increasingly turning to the internet to seek information about their health and well-being. National surveys conducted in low- and middle-income countries indicated that a large proportion of internet users frequently searched for health information, ranging from 35 to 54% of the respondents in those countries [1, 2].

Type 2 diabetes mellitus (T2DM), a complex and prevalent chronic disease, requires individuals to actively engage in self-managing their condition. In this regard, an important aspect of T2DM self-management is patients' knowledge, including their ability to seek diabetes information [3]. In this quest for knowledge, the internet has emerged as an invaluable response. Online platforms offer a wealth of information related to diabetes symptoms, treatment options, lifestyle modifications, and self-care practices. People with T2DM, their family members, and caregivers are tapping into these digital resources to access the information they need to make informed decisions and take control of their health journey [4, 5]. Results from a recent survey in the United States reported the prevalence of internet diabetes information seeking among these patients to be 64.5% [6].

Evidence demonstrates online health information seeking has the potential to positively impact on patients' behavioral outcomes in different care settings [4]. A recent meta-analysis showed that online health information seeking was associated with better medication adherence in people living with HIV/AIDS [7]. Research in patients with cancer is also promising [8], showing that using online platforms offering information about cancer care was directly related to patients' participation behavior and indirectly related to patients' satisfaction with the consultation [9, 10]. A mixed-method study showed that over one-third of patients with endocrine disease reported that their behavior positively changed after seeking online health information (e.g., by taking better care of themselves) [11]. The impact of online health information seeking may vary depending on the disease-specific conditions and the sociocultural context of the population [7, 12]. However, there is limited evidence in diabetes that addresses the direct and indirect associations between online health information seeking and patients' outcomes [3]. In this regard, one of the few studies conducted in the United States showed that patients who visited diabetes-specific websites reported greater adherence to lifestyle modifications and better compliance with insulin [13].

The effectiveness of online health information seeking as a facilitator of diabetes self-management practices may vary among patients due to differences in electronic health literacy (e-health literacy), which refers to an individual's ability to locate, evaluate, understand, and apply electronic health information to address their healthcare needs [14]. Research showed that e-health literacy acts as a vital determinant in the utilization and comprehension of health-related information from online sources [15]. Evidence supports the direct effect of e-health literacy on self-care behaviors among patients with diabetes [5]. Moreover, a meta-analysis result indicated a direct correlation between e-health literacy and health-related behaviors among diverse populations [16]. However, there is also the possibility of an indirect effect. The moderating model of e-health literacy postulates that online health information seeking will have more positive effects on health-related behaviors for those with a high level of e-health literacy, while these effects will be lessened for those with low literacy [17].

Another influential factor on the association between online health information seeking and diabetes self-management practices is patient-physician communication. Effective communication between diabetes patients and their physician plays a vital role in diabetes management, as it facilitates shared decision-making, enhances patient understanding of their condition, and encourages adherence to self-care practices [18]. Moreover, the patient-physician relationship can provide a valuable context for patients seeking online health information by guiding them towards reputable sources [19]. In addition, patients' discussions of online information with their physicians during consultations were found to lead to greater clarity, orientation, and certainty about the information [20]. These suggest a potential for patient-physician communication to strengthen the relationship between online information seeking behavior and health behavior change.

Nevertheless, although few studies have focused on the complex relationship between online health information seeking and health-related behaviors, between online health information seeking and e-health literacy, and between online health information seeking and patient-physician communication among patients with T2DM, no studies have explored the moderating role of e-health literacy and patient-physician communication in these relationships in these patients.

The aim of this study was to test the following hypotheses:

1. Online diabetes information-seeking behavior is positively associated with self-care behaviors and medication adherence in patients with T2DM;

2. e-Health literacy moderates the relationship between online diabetes information-seeking behavior and self-care behaviors, such that the positive effects are stronger for individuals with higher levels of e-health literacy;
3. Patient-physician communication moderates the relationship between online diabetes information-seeking behavior and self-care behaviors, such that the positive effects are stronger for individuals with higher perceived quality of patient-physician communication.

Methods

Study design, setting and study population

This correlational study investigated the moderating role of e-health literacy and also the aspects of patient-physician communication in the relationship between online diabetes information seeking and self-care practices in patients with T2DM. The conceptual model tested builds on that investigated by Vâjâean and colleagues [17] and is shown in Fig. 1.

Participants were recruited from a diabetes specialty clinic at Tehran University of Medical Sciences (Tehran, Iran) between February and June 2023. To be eligible, patients needed to meet the following criteria: diagnosed T2DM, regular clinic visits for at least one year, internet access (computer or smartphone), current use of diabetes medication (oral or insulin), ability to provide informed consent. Patients who were illiterate were excluded from the study.

Sample size and data collection

The sample size was calculated based on the Kish formula using a prevalence of 45% of respondents who had experience of searching online health information in Tabriz, Iran [2]. Using a confidence interval of 95%, a sample size of 1143 diabetes patients was needed for this study.

Data collection occurred at a diabetes clinic with approximately 50–60 daily patients. A list of eligible patients was identified through the diabetes electronic medical records ($n=3000$). We recruited our sample via this list using computer-generated random numbers. We approached the randomly selected patients in the clinic waiting room, explained the study purpose, and asked for participation. We continued approaching patients in the waiting room until reaching the target sample size of 1143 at the 1550th contacted patient, resulting in a final response rate of 73.7%. Participants provided written informed consent, ensuring information privacy, confidentiality, and the right to withdraw. They then filled out anonymous paper surveys in private rooms. Afterward, a researcher performed data quality checks to ensure all questions were answered.

Main variables

Table 1 illustrates key aspects of the study variables, including their operational definitions and measurement tools. The survey questionnaire is provided in Appendix 1.

Online diabetes-related information-seeking behavior

Robinson et al. characterized interactive health communication as "the interaction of an individual with or through an electronic device or communication

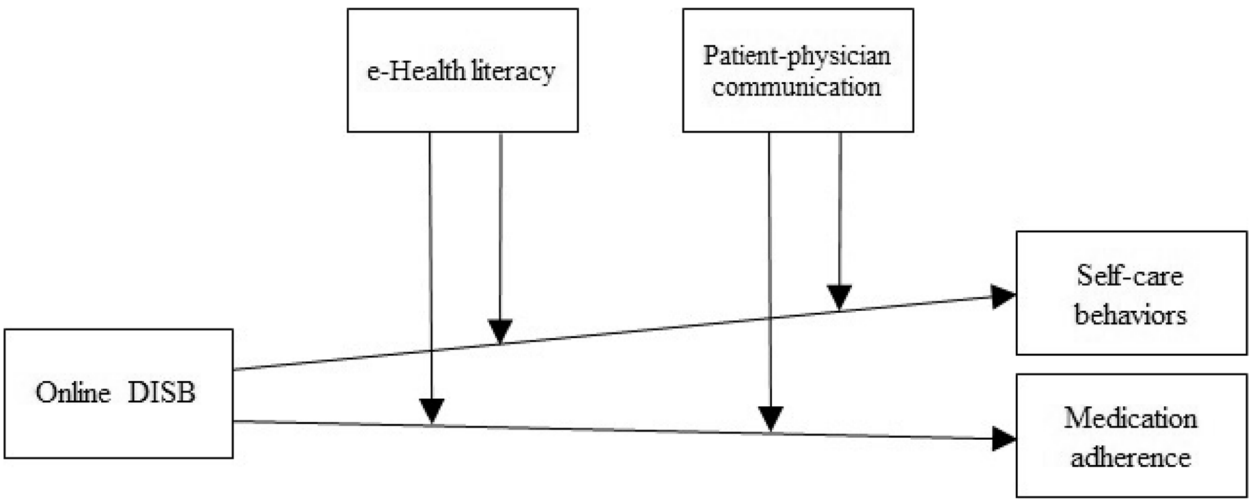

Fig. 1 Research model tested: hypothesis as to whether e-health literacy and aspects of patient-physician communication moderate the relationship between online diabetes information-seeking behavior (online DISB) and self-care practices

Table 1 Dependent and independent variables and definitions

Measure	Number of items	Definitions
Online diabetes information-seeking behavior: Endorsed statements about having online interactions to access, transmit, or receive diabetes information in the past 12 months		
Online diabetes-related information-seeking behavior (Online DISB)	3	Participants participated in an online support group for people with diabetes, used email or the Internet to communicate with the diabetes physician, and used the Internet to look up information regarding diabetes and its care
e-Health literacy: Extent of perceived self-confidence at finding, evaluating, and applying online health information		
eHEALS	8	Know how to find health resources on the Internet, how to use the Internet to answer questions, be familiar with available health resources on the Internet, where to find health resources on the Internet, how to use the health information found, have the skills to evaluate the resources found, can tell high-quality from low-quality resources, and feel confident in using information from the Internet for decisions
Patient-physician communication: Experiences with their physician in the diabetes clinic in the past 12 months		
Hurried communication	5	Physician spoke in hurried manner, used difficult-to-understand words, appeared distracted, ignored what patient said, irritated by patient's questions
Elicited concerns, responded	3	Physician asked about patient's concerns, let patient say what they thought was important, took worries about sickness seriously
Explained results, medications	4	Physician explained results of tests and physical exam, explained what would happen if patient does not take a prescribed medicine, and explained possible side effects from a medicine
Self-care behaviors: Extent of current practice in diabetes self-care over the previous 1–2 months		
Diet	4	Eat the correct portions, eat meals/snacks on time, keep food records, read food labels
Glucose self-monitoring	2	Check blood glucose with monitor, record blood glucose results
Medication administration	3	Take the correct dose, take pills or insulin at the right time, adjust insulin dosage
Exercise	1	Do physical activity and exercise
Low glucose levels	2	Treat low blood glucose, carry quick acting sugar
Preventative/ routine aspects of care	3	Come in for clinic appointments, carry a diabetes ID card, check ketones
Medication adherence: Endorsed statements about taking diabetes medications		
Adherence to diabetes medications (pills and insulin)	8	Forgot/did not take diabetes medications, cut down/stopped taking medications because felt worse, forgot to take diabetes medications along when traveling, stopped taking diabetes medications because blood sugar is under control, felt hassled about diabetes treatment plan

technology to access or transmit health information or to receive guidance and support on a health-related issue" [21]. Accordingly, we considered participation in an online support group, email communication with diabetes physicians, and using the Internet to look up information related to diabetes in the past 12 months as online diabetes-related information-seeking behaviors (Online DISB) in this study (Table 1). A positive response to at least 1 of 3 questions was coded as "yes" on online diabetes-related information-seeking behaviors (no = 0, yes = 1).

e-Health literacy

We used the eHealth Literacy Scale (eHEALS), developed by Norman and Skinner in 2006 [22], which measures perceived skills in finding, evaluating, and applying online health information to make health-related decisions. The eHEALS comprises 8 items rated on a 5-point Likert scale (1 as strongly disagree; 5 as strongly agree). Possible scores range from 8 to 40, with higher scores representing higher perceived levels of eHealth literacy. In this study, we utilized the Persian version of the eHEALS, which had its validity and reliability previously investigated in Iranian individuals with heart failure [23]. Cultural differences were carefully considered during the translation process in that study, and cognitive interviews were conducted to ensure comprehensibility and cultural appropriateness. For the current study, the estimate of internal consistency, as measured by Cronbach's Alpha, was 0.87.

Patient-physician communication

Patient-physician communication was measured using the Interpersonal Processes of Care (IPC) Survey. The IPC measures several aspects of patients' perceptions of their provider's communication, decision-making, and

interpersonal style [24]. We used the Persian version of the IPC (P-IPC), which has demonstrated reliability and construct validity in patients with T2DM in previous research by our team [25]. Confirmatory factor analysis provided strong evidence of construct validity and internal-consistency reliability and stability for all scales of the Persian IPC were satisfactory. In the present study, we focused on the communication domain of the IPC, which includes three scales: Hurried Communication (5 items); Elicited Concerns/Responded (3 items); and Explained Results/Medications (4 items) (see definitions in Table 1). As there is no validated composite score for the IPC, each scale is calculated as an independent outcome. Patients report the frequency with which various processes occurred in the past 12 months with their diabetes physician. All items are rated on a five-point Likert scale (1 = never to 5 = always), and scores are averaged for each scale. For the Hurried Communication, lower scores indicate better quality interactions, while for the Elicited Concerns/Responded and Explained Results/Medications, higher scores indicate better quality interactions.

Self-care behaviors

We used the Self Care Inventory-Revised (SCI-R) questionnaire, which assesses patients' perceptions of the degree to which they adhere to treatment recommendations for their diabetes self-care in the past 1–2 months [26]. The SCI-R is a 15-question measure that covers six areas of self-care behaviors: diet (4 items), glucose self-monitoring (2 items), medication administration (3 items), exercise (1 item), low glucose levels (2 items), and preventative/routine aspects of care (3 items) (see Table 1). All questions were graded on a Likert scale of 1 (never do it) to 5 (always do this as recommended). Item scores are averaged and converted to a 0- to 100-point scale, with higher scores indicating higher levels of self-care behaviors. A score of 70 and higher is considered adequate. In this study, we utilized the Persian version of the SCI-R, which had been investigated for validity and reliability in a study on patients with diabetes [27]. For the current study, the internal consistency of the SCI-R was $\alpha = 0.85$.

Medication adherence

We administered a Persian measure of adherence to prescribed diabetes medications (oral antidiabetic medications and insulin if prescribed) in patients with T2DM [18]. This tool has demonstrated evidence of reliability and validity in diabetes patients in our population [18]. Participants are asked to endorse statements about taking antidiabetic medications (pills and insulin if prescribed). This tool contains 8 yes/no questions. The total score is a summation of all 8 items and ranges between 0 and 8. The higher the total score of eight items, the greater the degree of adherence to antidiabetic medications. However, a score of 6 and higher is considered effective adherence. In this study, the internal-consistency reliability was $\alpha = 0.80$.

Demographic and clinical characteristics

Respondents also provided information on age, gender, education level, occupation, length of relationship with their physician, and health status. Data relating to T2DM clinical history, including diagnosis, diabetes duration, treatment regimen type, presence of diabetes complications, and HbA1c levels were obtained from electronic medical records.

Analyses

Participant characteristics were summarized using mean ± SD for continuous, and frequencies and percentages for categorical variables. Prior to statistical analysis, we assessed data normality using the skewness and kurtosis.

Our model tested whether e-health literacy level (eHL), and also aspects of patient-physician communication moderated the relationship between online diabetes-related information-seeking behavior (online DISB) and self-care practices. First, bivariate relationships among eHL, Hurried Communication, Elicited Concerns, Explained Results, online DISB, self-care behaviors and medication adherence were examined. Then, to assess the moderating effects of eHL, Hurried Communication, Elicited Concerns, and Explained Results in the relations between online DISB and self-care practices, we performed analyses using Mplus version 6.11 (Muthén and Muthén). Models in Mplus can include continuous variables, categorical variables, or a combination of continuous and categorical variables. For ability estimation, maximum-likelihood estimation procedures were used. Our study included age, gender, education level, communication duration, presence of diabetes complications, self-reported health status, and HbA1C level in the research model as control variables. We chose our control variables based on prior research that has demonstrated theoretically meaningful relationships between each control variable and our dependent variables [5, 16, 28].

After controlling for the aforementioned variables, we first entered online DISB, eHL level, Hurried Communication, Elicited Concerns, and Explained Results as independent variables, and self-care behaviors and medication adherence as dependent variables. Second, we entered the products of online DISB and each of moderator variables (eHL level, Hurried Communication, Elicited Concerns, and Explained Results) as interaction

terms. Because the independent variables in this model were either categorical or continuous, we did not center them. Adjusted R-squared values were reported to show the proportion of variance explained by the models, both before and after entering the interaction terms.

To aid in visualization of the moderation effects, we plotted significant interactions based on simple slope analyses for 1 standard deviation (SD) above the mean and 1 SD below the mean.

Results

Sample characteristics

The mean age was 58.84 years. Of the 1143 participants, 597 (52.2%) were women, and 50.9% (582/1143) had an education level of diploma and higher. The mean duration of diabetes was 10.17 years, and the mean HbA1C was 7.68%. Of the 1143 subjects, 42.3% (484/1143) reported their health status was good. The average length of patient-physician communication was 50 months (over 4 years). Online diabetes-related information-seeking behavior was reported by 59/9% (685/1143) of the respondents. Online seekers were more female, educated, and e-health literate ($P<0.05$) (Table 2).

The mean e-health literacy score was 24.10. Higher e-health literacy was associated with being female, younger than 65 years, having a diploma or higher education, and reporting better health status (Appendix 2). The mean self-care behaviors were 71.16, indicating adequate self-care. The medication adherence mean score was 6.46, indicating effective medication-taking behavior. The average scores of the communication scales were 1.74 for Hurried Communication, 2.98 for Explained Results, and 3.61 for Elicited Concerns.

Bivariate relationships among e-health literacy, aspects of patient-physician communication, online DISB, self-care and medication adherence

Correlations showed that patients who had sought diabetes information through the Internet were significantly more likely to report higher levels of self-care and medication adherence behaviors than patients who had not. There were significant positive correlations between self-care and e-health literacy, Elicited Concerns, and Explained Results. Moreover, significant positive correlations were seen between medication adherence and e-health literacy, Elicited Concerns, and Explained Results. Hurried Communication had negative correlations with self-care and medication adherence as well. A weak positive correlation was seen between online DISB and e-health literacy. No other significant relationships between online DISB and Hurried Communication, Elicited Concerns, and Explained Results were found. See Table 3.

Moderation analyses

To test whether e-health literacy and also aspects of patient-physician communication affect the relation between online DISB and self-care practices (self-care and medication adherence), we ran the model depicted in Fig. 1. We tested our model after controlling for age, gender, education level, communication duration, presence of complications, health status, and HbA1C level. As shown in Table 4, online DISB significantly predicted diabetes self-care behaviors ($\beta=0.49$, $p<0.001$). Hurried Communication decreased the likelihood of self-care behaviors ($\beta=-0.28$, $p<0.001$). Elicited Concerns ($\beta=0.27$, $p=0.005$), Explained Results ($\beta=0.25$, $p=0.04$), and e-health literacy ($\beta=0.26$, $p=0.02$) were significantly associated with increasing self-care behaviors.

In addition, e-health literacy moderated the relation between online DISB and diabetes self-care behaviors ($\beta=0.41$, $p=0.009$). The plot shown in Fig. 2A reveals that the patients who reported that they had sought diabetes information through the Internet were more likely to obtain higher scores in self-care behaviors when they had a high level of e-health literacy than when they did not. Explained Results moderated the relation between online DISB and diabetes self-care as well ($\beta=0.43$, $p<0.001$). The plot shown in Fig. 2B reveals that the patients who reported that they had sought diabetes information through the Internet were more likely to get higher scores in self-care behaviors when they received more explanations from their physician than when they did not. However, Hurried Communication and Elicited Concerns did not moderate the relation between online DISB and diabetes self-care behaviors. Hence, our results show that although lower Hurried Communication and higher Elicited Concerns, higher Explained Results, and higher e-health literacy increase the likelihood of self-care behaviors, only e-health literacy and Explained Results seem to have synergistic effects for patients who seek online diabetes information, thereby increasing diabetes self-care behaviors.

As shown in Table 5, online DISB significantly predicted medication adherence ($\beta=0.29$, $p=0.005$). Elicited Concerns ($\beta=0.09$, $p=0.03$), Explained Results ($\beta=0.11$, $p=0.008$), and e-health literacy ($\beta=0.11$, $p=0.02$) were associated with better medication adherence. Hurried Communication reduced the likelihood of adherence behavior ($\beta=-0.05$, $p=0.03$). Moreover, e-health literacy moderated the relation between online DISB and medication adherence ($\beta=0.23$, $p=0.001$). The plot shown in Fig. 2C reveals that the patients who reported that they had sought online diabetes information were more likely to have medication adherence when they had a high level of e-health literacy than when they did not. Also, Explained Results moderated the relation between online

Table 2 Participant characteristics and factors associated with online diabetes information-seeking behavior

Variable	Online diabetes information-seeking behavior			
	All participants *n* = 1143	**Yes *n* = 685**	**No *n* = 458**	***P*-value**
	n (%)	**n (%)**	**n (%)**	
Gender				
Male	546 (47.8)	259 (39.4)	287 (62.7)	0.006†
Female	597 (52.2)	399 (60.6)	198 (43.2)	
Educational level				
Primary school	153 (13.4)	43 (9.2)	110 (24)	0.02†
High school	408 (35.7)	224 (32.7)	184 (40.2)	
Diploma	353 (30.9)	223 (32.6)	130 (28.4)	
College	229 (20.0)	195 (28.5)	34 (7.4)	
Occupation				
Homemaker	402 (35.2)	265 (38.7)	137 (30)	0.85†
Self-employed	279 (24.4)	175 (25.5)	104 (22.7)	
Unemployed	30 (2.6)	13 (1.9)	17 (3.7)	
Worker	108 (9.5)	50 (7.3)	58 (12.6)	
Retired	324 (28.3)	182 (26.6)	142 (31)	
Self-rated health status				
Poor	209 (18.3)	109 (15.9)	100 (21.8)	0.67†
Fair	228 (20)	128 (18.7)	100 (21.8)	
Good	484 (42.3)	262 (38.2)	178 (38.9)	
Very good, excellent	222 (19.4)	186 (27.2)	80 (17.5)	
Treatment regimen				
Oral anti-DM drugs	621(54.3)	338 (49.3)	290 (61.3)	0.05†
Oral drugs + Insulin	476 (41.7)	319 (46.6)	150 (32.8)	
Insulin	46 (4)	28 (4.1)	18 (3.9)	
Diabetes complications				
No complications	457 (40)	287 (41.8)	170 (37.1)	0.52†
One to two complications	417 (36.5)	237 (34.6)	180 (39.3)	
Three or more complications	269 (23.5)	161(23.5)	108 (23.6)	
	mean[SD]	mean[SD]	mean[SD]	
Age, years	58.84 (10)	56.48 (10)	60.24 (10)	0.11§
Diabetes duration, years	10.17 (7.19)	8.12 (6.06)	11.98 (8.32)	0.41§
HbA1C, %	7.68 (1.33)	7.64 (1.13)	7.71 (1.23)	0.23§
Communication duration, months	49.98 (32.1)	43.78 (32.5)	54.88 (33.03)	0.99§
Patients' perceptions of their physician communication				
Hurried Communication	1.74 (0.54)	1.79 (0.52)	1.76 (0.54)	0.84§
Elicited Concerns	3.61(0.80)	3.55 (0.78)	3.64 (0.81)	0.82§
Explained Results	2.98 (0.67)	3.02 (0.65)	2.92 (0.70)	0.80§
e-Health literacy	24.10 (7.71)	25.11 (7.70)	23.21 (7.73)	0.038§
Medication adherence	6.46 (1.47)	6.90 (1.27)	5.48 (1.12)	0.007§
Self-care behaviors	71.16 (10.66)	78.10 (10.46)	63.16 (10.64)	0.003§

† Chi-square test

§ Independent t-test

DISB and medication adherence ($\beta = 0.22$, $p < 0.001$). The plot shown in Fig. 2D reveals that the patients who reported that they had sought online diabetes information were more likely to have medication adherence when they received more explanations from their physician than when they did not. However, Hurried

Table 3 Correlation matrix

	Self-care	Medication adherence	Online DISB
Online DISB (yes/no)	0.72**	0.68**	–
e-Health literacy	0.50**	0.39**	0.10*
Hurried Communication	−0.31**	−0.29**	0.04
Elicited Concerns	0.31**	0.30**	0.05
Explained Results	0.41**	0.38**	0.03

Pearson correlation coefficients were used except for the dichotomous variable (i.e., online DISB), in which the eta coefficient was used

* $P<0.05$

** $P<0.01$

Communication and Elicited Concerns did not moderate the relation between online DISB and medication adherence.

Discussion and conclusion

Discussion

Our results showed that online DISB was linked to better self-care practices, aligning with limited previous studies in diabetes suggesting better glycemic control in patients who utilized online resources [13, 28]. Accessing online diabetes information seems to equip individuals with self-care knowledge, empowering them to actively manage their condition. Additionally, online communities provide a platform for diabetes patients to connect, share experiences, and support each other, potentially boosting self-care motivation [3].

In addition, our results support the hypotheses that e-health literacy and aspects of patient-physician communication would be positively associated with diabetes self-care practices. Greater e-health literacy, Elicited Concerns, and Explained Results were associated with increased self-care and medication adherence. Greater Hurried Communication was associated with reduced self-care and medication adherence. These relationships were independent of the online DISB. These findings are in line with previous studies, which found that mobile e-health literacy was related to self-care behaviors and skills using mobile technology [5] and that a higher perceived quality of provider-patient communication in patients with T2DM was associated with improved adherence to diabetes care [29]. Moreover, another study reported that e-health literacy affected chronic disease self-management, both directly and indirectly [30]. However, these studies did not examine the role of online DISB.

Table 4 Effects of e-health literacy and aspects of patient-physician communication on the relation between online DISB and diabetes self-care

	Diabetes self-care							
	Step 1				Step 2			
	β	s.e	*p*-value	Adjusted R^2	β	s.e	*p*-value	Adjusted R^2
Age	−0.01	0.02	0.67	0.60	−0.01	0.02	0.77	0.63
Gender	0.15	0.02	0.03		0.15	0.02	0.04	
Education level	0.18	0.04	0.019		0.20	0.04	0.017	
Communication duration	0.17	0.03	0.02		0.20	0.03	0.02	
Presence of complications	0.03	0.02	0.51		0.03	0.02	0.47	
Health status	0.20	0.05	0.001		0.19	0.05	0.004	
HbA1C	−0.25	0.07	0.001		−0.28	0.07	0.001	
Online DISB (1 = yes)	0.49	0.02	< 0.001		0.58	0.11	< 0.001	
e-Health literacy (eHL)	0.26	0.03	0.02		0.36	0.02	< 0.001	
Hurried Communication	−0.28	0.02	< 0.001		−0.29	0.03	< 0.001	
Elicited Concerns	0.27	0.03	0.005		0.31	0.04	0.005	
Explained Results	0.25	0.02	0.03		0.15	0.04	0.12	
Online DISB × eHL					0.41	0.04	0.009	
Online DISB × Hurried					−0.26	0.21	0.40	
Online DISB × Elicited					0.19	0.11	0.13	
Online DISB × Explained					0.43	0.04	< 0.001	

β indicates Beta (i.e., standardized regression coefficient); s.e. indicates standard error. The model controlled for age, gender, education level, communication duration, presence of complications, health status, and HbA1C. Online DISB along with the moderator variables were entered in Step 1. The interaction effects between online DISB and each of the moderator variables were entered in Step 2

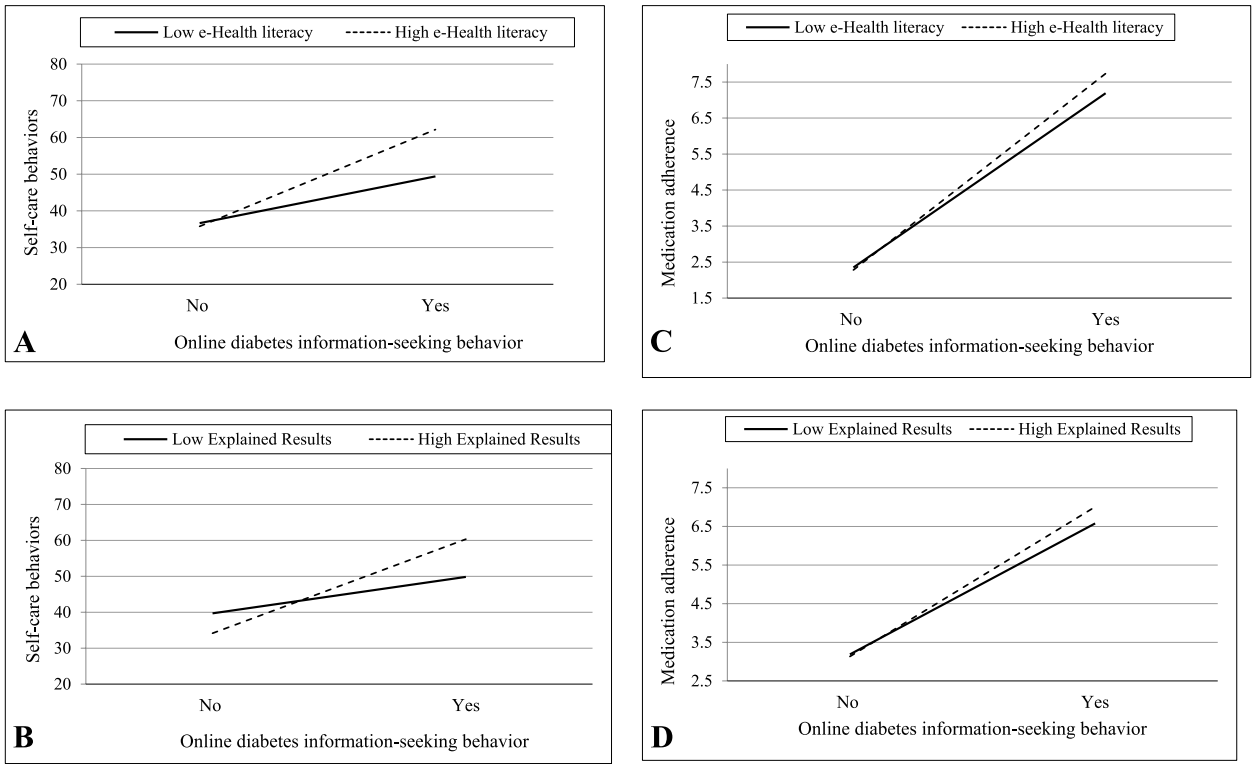

Fig. 2 **A** Estimated association between Online diabetes information-seeking behavior and self-care behaviors at the two levels of e-Health literacy (low versus high) ($n=1143$). **B** Estimated association between Online diabetes information-seeking behavior and self-care behaviors at the two levels of Explained Results (low versus high) ($n=1143$). **C** Estimated association between Online diabetes information-seeking behavior and medication adherence at the two levels of e-Health literacy (low versus high) ($n=1143$). **D** Estimated association between Online diabetes information-seeking behavior and medication adherence at the two levels of Explained Results (low versus high) ($n=1143$)

Our findings also provide evidence that Explained Results/Medications and e-health literacy moderate the relationship between online DISB and self-care practices in patients with T2DM. Patients who had sought diabetes information through the Internet were more likely to adhere to self-care behaviors and medications when they received more information and explanations from their physician and when they had high e-health literacy. These findings address a gap in previous knowledge by revealing specific moderators that enhance the positive impact of online DISB on diabetes self-care. A study in the general population found that seeking health information online and from physicians was associated with perceived care quality, with patient-centered communication moderating this relationship [31]. Another study in a general population sample found that patient-physician communication directly influenced the frequency of online information seeking, the perceived quality of online health information, and indirectly influenced patient compliance [32]. It seems that while vast and potentially unreliable online health information can hinder self-care efforts, especially for individuals with lower health literacy, engaging with online sources can still be beneficial when paired with clear communication from physicians. Our study found that when physicians explained test and physical exam results, the potential consequences of skipped medications, and possible side effects, it strengthened the positive influence of online information seeking on diabetes self-care. Regarding e-health literacy, a study by Vajaean and Baban showed that e-health literacy moderated the relationship between online health information seeking and both emotional distress and engaging in health-promoting activities among university students [17]. Previous studies have shown that e-health literacy positively affects online health information seeking, self-care behaviors, and patient empowerment in diabetes care [5, 33, 34]. However, these studies investigated e-health literacy as an independent variable rather than a moderating variable that changes the nature of the relationship between online DISB and self-care practices. Future research should focus on empowering patients through innovative e-health literacy initiatives (e.g., integrating ChatGPT into e-health literacy programs, establishing online peer support networks). This would enable patients to critically evaluate technology-based resources for improved self-care. Healthcare providers

Table 5 Effects of e-health literacy and aspects of patient-physician communication on the relation between online DISB and medication adherence

	Medication adherence							
	Step 1				Step 2			
	β	s.e	*p*-value	Adjusted R^2	β	s.e	*p*-value	Adjusted R^2
Age	−0.04	0.02	0.18	0.57	−0.04	0.04	0.21	0.62
Gender	0.19	0.03	0.028		0.17	0.02	0.039	
Education level	0.15	0.04	0.025		0.21	0.02	0.007	
Communication duration	0.21	0.02	0.01		0.24	0.01	0.004	
Presence of complications	0.008	0.01	0.67		0.02	0.02	0.47	
Health status	0.19	0.01	0.001		0.20	0.02	0.001	
HbA1C	−0.29	0.03	0.005		−0.33	0.03	0.001	
Online DISB (1 = yes)	0.29	0.01	0.005		0.35	0.05	0.001	
e-Health literacy (eHL)	0.11	0.03	0.02		0.13	0.02	0.01	
Hurried Communication	−0.05	0.02	0.03		−0.08	0.05	0.02	
Elicited Concerns	0.09	0.03	0.03		0.11	0.03	0.002	
Explained Results	0.11	0.02	0.008		0.06	0.09	0.15	
Online DISB × eHL					0.23	0.04	0.001	
Online DISB × Hurried					−0.04	0.11	0.58	
Online DISB × Elicited					0.04	0.12	0.65	
Online DISB × Explained					0.22	0.03	< 0.001	

β indicates Beta (i.e., standardized regression coefficient); s.e. indicates standard error. The model controlled for age, gender, education level, communication duration, presence of complications, health status, and HbA1C. Online DISB along with the moderator variables were entered in Step 1. The interaction effects between online DISB and each of the moderator variables were entered in Step 2

should develop targeted educational programs that specifically address how to find, evaluate, and use online diabetes-related information. This can also be achieved by integrating e-health literacy training into telehealth consultations. Moreover, parallel efforts should focus on targeted training for diabetes physicians to hone communication skills for the digital age, emphasizing interactive and informative discussions and explanations.

Our study did not support the hypotheses that Hurried Communication and Elicited Concerns moderate the relationship between online DISB and self-management practices. In fact, Hurried Communication and Elicited Concerns exerted their influence on self-care and medication adherence individually, without any interaction or combined effect. These results could be because health information-seeking behavior per se helps to develop coping capacity, decrease unnecessary health concerns, and induce preventive behaviors through various emotional supports [35]. Another explanation could be due to the participants' characteristics. In our study, most participants (61.7%) reported their self-rated health status as good or very good. It has been shown that a higher perception of health status and well-being is positively associated with fewer concerns about the disease [36]. So, maybe because of these, Elicited Concerns could not strengthen the relationship between online DISB and self-management practices. Additionally, the quality of the patient-physician relationship might play a role. Patients with strong, trusting relationships with their physicians might be less affected by Hurried Communication [37]. In our study, the average length of time patients had been in contact with their physicians was more than 5 years, which can lead to greater trust in their physicians. Cultural factors could also influence these findings. In some cultures, patients might be less likely to express concerns or might view hurried communication as a norm, which could affect the perceived impact of these factors [38].

This study has several limitations. Given the cross-sectional design, we are unable to infer causal relationships between online DISB and self-care and medication adherence behaviors. Future research directions could include longitudinal studies or intervention studies to further explore the dynamics of the relationships identified. Another limitation is that our study focuses on patient self-report of patient-physician communication and e-health literacy level that may be subject to social desirability biases. We tried to minimize this bias as much as possible by guaranteeing confidentiality and anonymity. However, we cannot determine the effects

of an unknown degree of measurement error on our findings. The other limitation relates to recruiting from a single specialty and university clinic, which may not be representative of the general diabetic population, and the cultural and geographical context of our study may limit the generalizability of the results to other populations. Moreover, we did not take into account the intensity of online diabetes information-seeking behavior. Some patients might have done this behavior multiple times a year, and others may have done it less frequently. We were probably able to take the variability within this scale into account as our sample size was rather large. However, future research should consider the variability of this online information-seeking behavior.

Conclusion

Our study highlights the significant role of patient e-health literacy and patient-physician communication in amplifying the positive impact of online DISB on self-care and medication adherence among individuals with T2DM. By recognizing and fostering e-health literacy skills, healthcare providers can empower patients to effectively navigate online resources, leading to improved self-care practices and adherence to medication regimens. Additionally, enhancing patient-physician communication ensures comprehensive understanding, tailored guidance, and mutual decision-making regarding diabetes management. These findings underscore the importance of integrating digital health literacy and strengthening the patient-physician relationship to optimize diabetes care outcomes in the digital age.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions
M.P., E.N., and R.G. have made significant contributions to the concept and design, the acquisition of data, and the analysis and interpretation of the data; A.S. and M.P. were involved in drafting and making significant changes to the manuscript; M.P. and A.O. ensured that issues relating to the accuracy or completeness of any part of the work were properly investigated; M.P. and E.N. provided final approval of the version to be published. All authors reviewed the manuscript.

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Data availability
The datasets analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was performed in accordance with the ethical standards in the 1964 Declaration of Helsinki and its amendments. The study protocol was reviewed and approved by the medical research ethics committee of the Tehran University of Medical Sciences (IR.TUMS.EMRI.REC.1401.093). All participants have completed an informed consent form to conduct the study and all scales have been completed anonymously.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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