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ORIGINAL RESEARCH

Health Literacy and Behaviors of Patients and Caregivers Related to Glycemic Control Among Individuals With Type 2 Diabetes in Chiang Mai Province, Thailand

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Background: The impact of caregivers' health literacy (HL) and patient care behaviors on glycemic control in type 2 diabetes mellitus (T2DM) is not well known.

Purpose: This study examined the HL and behaviors of both patients and caregivers in relation to glycemic control among T2DM patients.

Methods: A cross-sectional study in Fang district, Chiang Mai Province, involved 305 T2DM patients aged over 45 and their caregivers, selected through simple random sampling. Data were collected via questionnaires, and blood samples were analyzed for fasting blood sugar (FBS) and glycated hemoglobin (HbA1c).

Results: The findings revealed that most patients and caregivers had diabetes HL scores at the functional literacy level (53.77% and 37.05%, respectively). The majority of patients scored moderately in self-care behaviors (SCB) at 76.10%, while caregivers' patient care behaviors also scored moderately at 68.20%. Mean FBS and HbA1c levels were 129.81 mg/dl and 7.3%, respectively. Linear regression analysis showed that, after adjusting for sex, age, education level, financial status, duration of diabetes, smoking, and alcohol consumption, FBS was significantly associated with patients' HL (Beta = −0.161), SCB (Beta = −0.197), caregivers' HL (Beta = −0.217), and caregivers' patient care behaviors (Beta = −0.181). Similarly, HbA1c was significantly correlated with patients' HL (Beta = −0.265), SCB (Beta = −0.233), caregivers' HL (Beta = −0.255), and caregivers' patient care behaviors (Beta = −0.200).

Conclusion: These results highlight the importance of enhancing health literacy (HL) and behaviors in both patients and caregivers to achieve optimal glycemic control, underscoring the need for caregivers to develop strong HL skills and improve their competencies in effectively managing T2DM.

Keywords: health literacy, self-care behavior, diabetes mellitus, glycemic control, caregiver

Introduction

Type II diabetes mellitus (T2DM) is a chronic disease that requires significant behavioral changes within the family and is associated with psychosocial conflicts for both the patient and the family environment.[1] In 2019, the number of DM patients worldwide was 463 million, and it is expected to rise to 700 million by 2045.[2] In Thailand, the incidence of diabetes has been steadily increasing. In 2023, there were 300,000 new cases per year.[3] In 2022, the total number of diabetes patients reached 3.3 million, an increase of 150,000 from 2021.[3] In 2020, there were 16,388 deaths due to diabetes (a mortality rate of 25.1 per 100,000 people).[3] This has resulted in healthcare costs for diabetes treatment averaging as high as 47.596 billion baht per year.[3] Additionally, the incidence and mortality rates of diabetes have increased in northern Thailand, with the highest rates observed in Chiang Mai Province.[4] According to the Chiang Mai Health Data Repository for 2021–2023, the number of new diabetes cases

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increased by 88,319, 91,978, and 94,779 (5.48%, 5.67%, and 5.81%).[4] Furthermore, the blood sugar control of these patients remained below the recommended standard.[4] The alarming trend of DM in Thailand over the past three decades has placed a tremendous burden on the healthcare system.[3] Previous studies have found that chronic illness impacts both patients and caregivers due to the condition and severity of the disease.[5,6] Some studies suggest that DM patients may affect the personal and social lives of caregivers.[7] As a result, there is an increasing need for assistance or care from caregivers, particularly from family members, community members, or volunteers.[5]

DM is a chronic, degenerative, non-communicable disease caused by abnormal insulin secretion, with the key indicator for blood sugar control being Hemoglobin A1c (HbA1c).[8] Lower HbA1c levels are associated with reduced mortality rates and fewer complications in diabetes patients.[9,10] Seriou's illness, a reduced life expectancy, and impaired quality of life are related to type 2 diabetes.[11] As a chronic disease, diabetes requires long-term treatment, and those with the condition must make lifestyle changes.[11,12] DM patients experience dependency on others, which affects both their mental and physical functioning.[12] Therefore, they need support from family members to engage in beneficial activities that help control blood sugar levels.[7,13] In addition, the aid and social connections provided by non-medical people are key for those suffering from the disease.[14] This type of informal care may help alleviate the suffering associated with diabetes and improve blood sugar control.[15]

Informal caregivers, such as family members, friends, and neighbors, play a crucial role in supporting patients with type 2 diabetes.[16] They can assist with various aspects of self-care, including visits to healthcare facilities, medication administration, exercise, and emotional needs, which contribute to improved health outcomes over time.[16,17] Consistent with studies indicating that families play a vital role in managing diabetes, they support daily diabetes management practices.[18] Systematic research also suggests that families can act as informal caregivers to assist patients with T2DM in managing their condition.[19]

In diabetes patients, health literacy (HL) serves as a strategy for self-care management, relying on an understanding of the role of knowledge and access to health information as a guide to improve diabetes care.[20] Consequently, the ability to effectively utilize health information and healthcare services is critically important.[21,22] Effective self-management is closely associated with HL, which is defined as

> the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions.[22]

A systematic review found that HL plays a significant role in diabetes knowledge, self-care, medication adherence, and clinical outcomes,[23] such as blood sugar control.[24] Several studies indicate that HL is effective in improving health outcomes, such as self-care behaviors (SCB) in diabetes patients.[25–27] Recent research suggests that HL and SCB are significantly associated with blood sugar levels in elderly patients with type 2 diabetes.[28] However, some studies indicate that limitations in HL are common among diabetes patients[29] and are associated with poor diabetes knowledge, leading to decreased SCB and an increased risk of complications,[23,29] as well as poorer blood sugar control.[28,30]

SCB refers to the choices and actions an individual can undertake to address a health concern or improve their overall well-being.[31] Improving SCB is the first step in helping diabetes patients manage their condition more effectively. Caregiver assistance with everyday responsibilities, financial support, meal preparation, access to medical services, encouraging exercise, medication adherence, and blood sugar monitoring can significantly reduce the strain on patients.[17,18] Prior reviews have examined patient health literacy and caregiver patient-care practices, but they have not explored the relationship between patients and caregivers in the context of glycemic control.[13,28] Therefore, this study aimed to investigate HL and behaviors of patients and caregivers related to glycemic control among individuals with type 2 diabetes in Chiang Mai Province, Thailand. The goal is to utilize the findings to enhance the quality of life for individuals with this disease and reduce the economic burden of diabetes on families and society through strengthening this relationship, as well as designing activities and promoting health-related SCB that are suitable for the target group and their caregivers.

Materials and Methods

Study Design, Population, and Area

This cross-sectional study was conducted from January to April 2024 in a remote mountainous area of Chiang Mai Province. After receiving ethical approval from University of Phayao, simple random sampling was employed through a lottery method from the 25 districts in Chiang Mai. We selected one district, Fang, which comprises 8 sub-districts. Using simple random sampling, we chose 4 sub-districts (Mae Kha, Mae Sun, Mae Ka, and Mae Ngon) that had a similar population (homogeneous). Next, a random number method was used to select participants from the list of patients diagnosed with type 2 diabetes and registered in the Health Data Center (HDC) of Chiang Mai Province. The sample size was calculated using Daniel's formula,[32] with a confidence level of 95% and a margin of error of 5%, resulting in 290 samples for both the patient and caregiver groups. To prevent data loss, the sample size was increased by approximately 5%, leading to 305 individuals in each group, for a total of 610 participants in this study.

Procedure and Data Collection

The selection criteria for the sample of diabetes patients were as follows: (1) Males or females aged 45 years and older, diagnosed by a physician with type 2 diabetes and registered for at least 1 year; (2) Having a primary caregiver in the family; (3) Able to speak and communicate in the local language; (4) Willing to participate in the research project. The selection criteria for the caregiver sample included: (1) Individuals aged 18 years and older who have a relationship with the patient with type 2 diabetes, such as spouses, parents, children, relatives, friends, or voluntary caregivers who do not receive compensation; (2) Having cared for the patient for at least the past year; (3) Able to speak and communicate in the local language; (4) Voluntarily consenting and signing written consent to participate in the research. The exclusion criteria included individuals with cognitive or mental disorders, dementia diagnosed by a physician, and blindness. Before the research operations, announcements were made to recruit five research assistants from each sub-district.

This included 2 public health scholars and 3 community health volunteers, who could communicate in the local language and had access to the sample population. A 4-hour meeting was organized for the research assistants to clarify the objectives of the data collection, the techniques and procedures for administering the questionnaires, and to ensure a mutual understanding. The meeting also addressed scheduling interviews and protecting participants' rights. The researchers translated formal language into the local dialect to enhance the understanding of the research assistants. Data collection involved coordination with the district public health office and the sub-district health promotion hospital in Fang District, Chiang Mai Province, as well as in the research area. After receiving written consent, the research team performed face-to-face interviews with diabetic patients and their caregivers using a unified questionnaire and research assistants at the sub-district health promotion hospital and at the patients' homes during the hours of 1:00 PM to 5:00 PM or at a convenient time. The duration of each interview was approximately 20–30 minutes.

Measurements

All the tools used for the interviews were validated for content by three experts in public health, health behavior, and community medicine. The content validity of the questionnaire was assessed by specialists, which found that the Index of Item-Objective Congruence (IOC) was 0.95. The questionnaire, which had five sections of questions, had been modified for the research setting to a sample population of people with type 2 diabetes and their caregivers. Section 1 includes questions related to demographics and social factors, such as sex, age, marital status, education, employment, financial status, comorbidities, duration of DM, body mass index (BMI), smoking, and alcohol consumption.

This part of the questionnaire inquired about the HL of both patients and their caregivers. Section 2 includes the HL interview based on a review of relevant literature and research.[21,28,33,34] It consists of six components, each containing six questions, for a total of 36 questions. These components include (1) access to information about diabetes, with sample questions focusing on searching for and accessing diabetes in-formation, such as accessibility to data, information retrieval, and reliable sources related to diabetes. (2) the component on knowledge about diabetes includes sample questions such as: the pathology, mechanisms of the disease, causes, symptoms, complications of diabetes, risk behaviors, and common abnormalities associated with diabetes. (3) the health communication component involves establishing interactions and exchanging

information among family members, friends, or fellow patients, village health volunteers, hospital staff, and community members regarding diabetes information. (4) the component on decision-making focuses on selecting appropriate actions for diabetes prevention. The questions are designed to emphasize the analysis of pros and cons, as well as the benefits of behaviors aimed at preventing diabetes. It also assesses individuals' competencies and skills in decision-making or choosing actions for diabetes prevention, along with seeking advice from village health volunteers for guidance regarding diabetes information. (5) the component on health self-management focuses on modifying personal health behaviors for diabetes prevention. Sample questions include topics such as food labeling, monitoring dietary intake, exercising, medication adherence, stress management, and setting daily self-reminders. Finally, (6) the component on media literacy and health information such as selecting information from reliable sources, choosing products or health-related items that have correct labeling for diabetes prevention. The questions are formatted as multiple-choice, with responses being "Yes" "Unsure" and "No." Scoring criteria assign 1 point for correct answers and 0 points for incorrect answers, with total scores ranging from 0 to 36. The scores are categorized into three levels: Critical Literacy Level (28–36 points), Interactive Literacy Level (21–27 points), and Functional Literacy Level (scores 0–20 points). The reliability coefficient was determined using the Kuder-Richardson Formula: KR20 = 0.80.

Section 3: A questionnaire focusing on patients' self-care behaviors (SCB) for diabetes prevention[5,12,28,34,] which includes (1) dietary consumption (20 items), (2) medication adherence (10 items), (3) exercise (10 items), and (4) stress management and rest (10 items), totaling 50 items. The measurement uses a rating scale with three levels: "Never" "Occasionally (1–3 times/week)" and "Regularly (4–7 times/week)." The scores are categorized into three levels: high (scores 120–150 points), moderate (scores between 90–119 points), and low (scores 0–89 points). The reliability of the questionnaire, analyzed using Cronbach's alpha coefficient, was found to be 0.86.

Section 4: For the caregiver's (CG) questionnaire, the questions related to the personal factors of the respondents included sex, age, marital status, education, employment, financial status, underlying disease, times spent caring, caring relationship to patient, smoking, and alcohol consumption. The last, Part 5: The caregiver behavior questionnaire for patient care is based on prior studies.[5,12,28,34] It includes 50 items across 4 dimensions, similar to the patient questionnaire. Sample questions are I ensure patients eat all 5 food groups daily, I motivate patients to exercise at home, and I accompany patients to their scheduled doctor visits. The reliability of the questionnaire, analyzed using Cronbach's alpha coefficient, was found to be 0.89.

For glycemic control, blood samples were collected from the patients to analyze fasting blood sugar (FBS) and HbA1c levels. Patients were instructed to fast for at least 12 hours before the blood draw, starting from 8:00 PM the previous day. They were then scheduled to have their blood drawn the following morning at 7:00 AM. A medical technologist or professional nurse performed the blood draw, collecting 5 cc of blood, which was then sent for analysis at the Fang Hospital laboratory. The results were reported through the Health Data Center (HDC) of Chiang Mai Province.

Data Analysis

A computer program, SPSS version 28 (IBM Corp., Armonk, NY, USA), was used to perform statistical analysis, with all variables presented descriptively. As assumptions such as normal distribution of data and the test for homogeneity of variance were checked, independent t-tests and one-way ANOVA were used to examine mean differences in continuous variables (patients' HL, SCB, FBS, HbA1c, caregivers' HL, and behaviors) between two groups (ie, male vs female, employed vs unemployed) and across various categories (eg, marital status, BMI, caregiver relationships). Pearson's correlation coefficient (r) assessed relationships among these continuous variables. Linear regression was used to investigate HL and behaviors of patients and caregivers related to glycemic control, adjusting for potential patient factors including sex, age, education level, duration of DM, smoking, alcohol consumption, and financial status.[13,28,35] No collinearity was observed using the Variance Inflation Factor (VIF). The level of statistical significance was set at 0.05.

Results

Participant and Variables

The demographic characteristics of type 2 diabetes patients are shown in Table 1. Out of a sample of 305 patients, most were female (63.61%) and aged 60 or above (58.36%), with an average age of 62.24 years. Most individuals are married

Table 1 Personal Characteristics of Type 2 Diabetes Patients and Their Associations With Health Literacy, Self-Care Behaviors, and Glycemic Control (n = 305)

Patient Characteristics	n (%)	Patients' HL		Patients' SCB		FBS		HbA1c	
		Mean±SD	*p*	Mean±SD	*p*	Mean±SD	*p*	Mean±SD	*p*
Sex			0.127[b]		0.584[b]		0.766[b]		0.088[b]
Male	111(36.39%)	20.76±4.03		105.35±10.72		129.04±31.09		7.08±1.70	
Female	194(63.61%)	20.03±4.00		106.04±10.48		130.25±36.03		7.43±1.70	
Age			0.752[a]		0.471[a]		0.597[a]		0.321[a]
≤60 years	127(41.64%)	20.38±3.87		106.31±10.32		131.04±34.63		7.42±1.93	
≥61 years	178(58.36%)	20.23±4.14		105.42±10.74		128.93±34.08		7.21±1.52	
Marital status			0.870[b]		0.494[b]		0.248[b]		0.077[b]
Single	31(10.20%)	20.65±4.51		105.42±12.65		120.26±22.22		6.75±1.57	
Married	222(72.80%)	20.27±3.85		106.19±10.18		130.55±35.99		7.30±1.66	
Widowed/Divorced/Separated	52(17.00%)	20.19±4.48		104.29±10.85		132.33±32.16		7.62±1.88	
Education level			0.737[a]		0.669[a]		0.378[a]		0.223[a]
No/Primary school	239(78.36%)	20.25±4.03		105.67±10.89		130.72±35.44		7.37±1.75	
Secondary school or higher	66(21.64%)	20.44±4.00		106.24±9.31		126.52±29.65		7.08±1.50	
Employment			0.214[a]		0.072[a]		0.600[a]		0.392[a]
Unemployed	99(32.46%)	19.88±4.21		104.13±11.57		128.32±30.06		7.42±1.59	
Employed	206(67.54%)	20.49±3.92		106.59±9.96		130.52±36.17		7.25±1.75	
Financial status			0.122[a]		0.195[a]		0.652[a]		0.581[a]
Insufficient	253(82.95%)	20.13±3.96		105.43±10.75		129.41±33.56		7.33±1.74	
Sufficient	52(17.05%)	21.08±4.24		107.52±9.48		131.77±37.83		7.18±1.52	
Comorbidities			<0.001[*,a]		<0.001[*,a]		0.850[a]		0.001[*,a]
No	47(15.41%)	26.45±2.35		115.96±5.47		128.94±32.36		6.16±0.65	
Yes	258(84.59%)	19.17±3.15		103.94±10.20		129.97±34.66		7.51±1.75	
Duration of DM			0.001[*,a]		0.005[*,]		0.033[*,a]		0.001[*,a]
≤10 years	183(60.00%)	20.93±4.19		107.19±10.45		126.40±36.49		6.98±1.70	
≥11 years	122(40.00%)	19.33±3.55		103.70±10.41		134.92±30.08		7.79±1.60	
BMI			0.491[b]		0.478[b]		0.371[b]		0.136[b]
<18.50 kg/m^2	194(63.61%)	20.11±3.98		105.47±10.45		131.60±36.42		7.43±1.78	
18.51–22.99 kg/m	102(33.44%)	20.68±4.06		106.65±10.68		125.97±29.30		7.03±1.46	
^{2}≥23.00 kg/m^2	9(2.95%)	19.89±4.62		103.00±11.83		134.67±38.73		7.64±2.26	
Smoking			0.941[a]		0.793 [a]		0.105[a]		0.050[*,a]
No	272(89.18%)	20.30±4.01		105.85±10.63		128.70±33.09		7.20±1.53	
Yes	33(10.82%)	20.24±4.15		105.33±10.08		138.94±42.31		8.15±2.63	
Alcohol Consumption			0.732[a]		0.992[a]		0.699[a]		0.940[a]
No	220(72.13%)	20.34±4.11		105.79±10.61		129.34±34.51		7.31±1.68	
Yes	85(27.87%)	20.16±3.80		105.80±10.48		131.04±33.82		7.29±1.77	

Notes: *Independent Samples *T*-Test: The significance level is 0.50.a. Independent Samples *T*-Test b. Nonparametric Tests One-way ANOVA.

(72.80%), have completed primary education (78.36%), more than half employed (67.54%), and three-quarters face income insufficiency (82.95%). For health status, most of the sample group had comorbidities (84.59%) including hypertension (73.44%), over half had been living with diabetes for 1–10 years (60.00%), more than half had a BMI below the normal range (≤18.50 kg/m2) (63.61%, mean ± SD = 24.56±3.83, min – max= 15.58–39.38). Only 10.82% smoked and 27.87% consumed alcohol.

The personal traits of the caregivers are presented in Table 2. Among the 305 participants, most caregivers were female (52.79%) and married (64.92%). The average age was 46.74 years. More than half had completed secondary

Table 2 Caregiver Characteristics of Type 2 Diabetes Patients and Their Associations With Caregivers' Health Literacy and Behaviors for Patient Care (n = 305)

Caregiver Characteristics	n (%)	Caregivers' HL		Caregivers' Behavior	
		Mean±SD	*p*	Mean±SD	*p*
Sex			< 0.001*,a		0.056a
Male	144(47.21%)	21.82±4.88		103.16±11.96	
Female	161(52.79%)	24.16±5.18		105.76±11.72	
Age			< 0.001*,a		< 0.001*,a
≤60 years	173(56.72%)	25.87±4.16		108.29±9.07	
≥61 years	132(43.28%)	19.36±3.87		99.61±13.29	
Marital status			< 0.001*,a		0.004**,b
Single	84(27.54%)	25.85±4.04		107.76±8.71	
Married	198(64.92%)	22.04±5.28		103.22±12.54	
Widowed/Divorced/Separated	23(7.54%)	23.05±5.17		104.04±14.17	
Education level			< 0.001*,a		< 0.001*,a
None/Primary school	149(48.85%)	19.50±3.84		99.76±12.76	
Secondary school or higher	156(51.15%)	26.45±3.52		109.10±8.87	
Employment			< 0.001*,a		0.031*,a
Unemployed	37(12.13%)	17.97±4.49		99.81±14.07	
Employed	268(87.87%)	23.75±4.86		105.19±11.43	
Financial status			< 0.001*,a		< 0.001*,a
Insufficient	140(45.90%)	21.50±5.15		101.39±13.10	
Sufficient	165(54.10%)	24.374.82		107.20±10.04	
Underlying disease			< 0.001*,a		< 0.001*,a
No	253(77.05%)	24.59±4.65		109.11±8.84	
Yes	70(22.95%)	17.89±3.01		89.19±6.86	
Time spent caring			0.007*,a		0.018*,a
≤**3** hours	124(40.66%)	24.02±4.75		106.48±11.11	
≥**4** hours	181(59.34%)	22.39±5.35		103.20±12.24	
Caregiver relationship to patient			< 0.001**,b		< 0.001**,b
Parents	92(30.16%)	23.68±4.92		106.12±11.78	
Spouse	96(31.46%)	19.40±4.14		98.92±12.51	
Son/daughter/relatives	117(38.38%)	25.56±4.39		107.90±9.67	
Smoking			< 0.001*,a		< 0.001*,a
No	251(82.30%)	23.87±4.97		106.49±11.05	
Yes	54(17.70%)	19.26±4.35		95.43±11.48	
Alcohol consumption			0.373a		0.738a
No	187(61.31%)	23.26±5.14		104.35±12.22	
Yes	118(38.69%)	22.72±5.22		104.82±11.37	

Notes: *Independent Samples *T*-Test: The significance level is 0.50. **Nonparametric Tests One-way. The significance level is 0.50. [a]Independent Samples *T*-Test [b]Nonparametric Tests One-way ANOVA.
Abbreviation: ANOVA, Asymptotic significances are displayed.

education (51.15%), were employed (87.87%), and had sufficient income (54.10%). Moreover, fewer than half had underlying diseases (22.95%), only 17.70% smoked, and 38.69% consumed alcohol. Regarding patient care, more than half of the caregivers dedicated over 4 hours to patient care (59.34%). The relationships between caregivers and patients were son/daughter (38.38%), spouse (31.46%), and parents (30.16%).

Table 3 presents the HL and behavior scores for both groups, including the patients' biological markers. The HL scores of type 2 diabetic patients were at the functional literacy level, with 53.77% (mean = 20.29, SD = 4.02). Most of these patients had moderate SCB scores, at 76.10% (mean = 105.79, SD = 10.55). Regarding FBS, nearly half had abnormal levels ≥126 mg/dl (49.20%, mean ± SD = 129.81 ± 34.27), while more than half had high HbA1c levels >6.5% (60.70%, mean ± SD = 7.30 ± 1.70). Caregivers' HL scores were 37.05% at the functional literacy level and 35.41% at the interactive literacy level, with an average score of 28.19 (SD = 8.85). For caregivers' behaviors related to patient care, over half scored moderately at 68.20%, with an average score of 104.53 (SD = 11.88).

The independent *t*-test showed a mean difference in HL, SCB, and HbA1c between patients with and without comorbidities (all p-values < 0.001). Duration of DM was associated with HL, SCB, FBS, and HbA1c (all p-values < 0.05), and HbA1c levels differed significantly between smokers and non-smokers (p-value = 0.05) (Table 1). In terms of caregiver characteristics, the mean difference analysis revealed that caregivers' HL varied by sex (p-value < 0.05). Nearly all factors age, marital status, education level, employment, financial status, underlying disease, time spent caring, caregiver patient relationship, and smoking showed statistically significant differences in caregivers' HL and behaviors related to patient care (all p-values < 0.05) (Table 2).

Correlation Between Research Variables

Table 4 shows the Pearson correlation coefficients among patients' and caregivers' HL, behaviors, and patients' glycemic controls. Significant positive correlations were found between patients' HL and SCB (r = 0.755), between patients' and

Table 3 Characteristics of Key Variables: Patient and Caregiver Health Literacy, Behaviors, and Glycemic Control (n = 305)

Variable		n (%)
Patients' health literacy	Functional Literacy level (scores 0–21) Interactive Literacy level (scores 22–27) Critical Literacy level (scores 28–36) Mean±SD Min. – Max.	164(53.77%) 113(37.05%) 28(9.18%) 20.29±4.02 9–30
Patients' self-care behaviors	Low level (scores 0–89) Moderate level (scores 90–119) High level (scores 120–150) Mean±SD Min. – Max.	40(13.10%) 232(76.10%) 33(10.80%) 105.79±10.55 82–124
Fasting blood sugar (FBS)	Normal (< 125 mg/dl) Abnormal (≥ 126 mg/dl) Mean±SD Min. – Max.	155(50.80%) 150(49.20%) 129.81±34.27 81–377
Hemoglobin A1c (HbA1c)	Normal (< 6.5%) Abnormal (≥ 6.5%) MeanSD Min. – Max	120(39.30%) 185(60.70%) 7.30±1.70 4.7–15.2
Caregivers' health literacy	Functional Literacy level (scores 0–21) Interactive Literacy level (scores 22–27) Critical Literacy level (scores 28–36) Mean±SD Min. – Max	113(37.05%) 108(35.41%) 84(27.54) 28.19±8.85 10–33
Caregivers' behaviors for patient care	Low level (scores 0–89) Moderate level (scores 90–119) High level (scores 120–150) Mean±SD Min. – Max.	63(20.66%) 208(68.20%) 34(11.15%) 104.53±11.88 81–137

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Table 4 Pearson's Correlation Coefficient (r) Between Patient and Caregiver Health Literacy, Behaviors, and Glycemic Control

Variable	1	2	3	4	5	6
1. Patients' health literacy	1					
2. Patients' self-care behaviors	0.755*	1				
3. Caregivers' health literacy	0.556*	0.561*	1			
4. Caregivers' behaviors for patient care	0.723*	0.968*	0.541*	1		
5. Patients' fasting blood sugar	−0.178*	−0.207*	−0.220*	−0.189*	1	
6. Patients' hemoglobin A1c	−0.316*	−0.261*	−0.272*	−0.223*	0.437*	1

Note: *Correlation is significant at the 0.01 level (2-tailed).

caregivers' HL (r = 0.556), between SCB and patient-care behaviors (r = 0.968), and between caregivers' HL and patient-care behaviors (r = 0.541). The highest negative correlation for FBS was with caregivers' HL (r = −0.220, p-value < 0.01), while HbA1c had the highest negative correlation with patients' HL (r = −0.316, p-value < 0.01).

Factors Associated With Clinical Indicators

Table 5 shows the association of HL and behaviors of patients and caregivers with glycemic control among individuals with type 2 diabetes, as determined by linear regression. The analysis, adjusted for patient sex, age, education level, financial status, duration of DM, smoking, and alcohol consumption, revealed that FBS was significantly associated with

Table 5 Health Literacy and Behaviors of Patients and Caregivers Associated With Glycemic Control in Type 2 Diabetes, as Determined by Linear Regression

Outcome	Factor	Model	B	S.E.	Beta	*p*	95% CI
FBS	Patients' health literacy	Unadjusted	−1.518	0.482	−0.178	0.002	−2.467, −0.570
		Adjusted*	−1.375	0.498	−0.161	0.006	−2.355, −0.396
	Patients' self-care behaviors	Unadjusted	−0.673	0.182	−0.207	< 0.001	−1.032, −0.314
		Adjusted*	−0.639	0.185	−0.197	0.001	−1.004, −0.274
	Caregivers' health literacy	Unadjusted	−1.456	0.372	−0.220	< 0.001	−2.187, −0.724
		Adjusted*	−1.438	0.375	−0.217	< 0.001	−2.177, −0.700
	Caregivers' behaviors	Unadjusted	−0.544	0.163	−0.189	0.001	−0.864, −0.224
		Adjusted*	−0.523	0.167	−0.181	0.002	−0.851, −0.195
HbA1c	Patients' health literacy	Unadjusted	−0.134	0.023	−0.316	< 0.001	−0.179, −0.088
		Adjusted*	−0.112	0.023	−0.265	< 0.001	−0.157, −0.067
	Patients' self-care behaviors	Unadjusted	−0.042	0.009	−0.261	< 0.001	−0.060, −0.024
		Adjusted*	−0.038	0.009	−0.233	< 0.001	−0.055, −0.020
	Caregivers' health literacy	Unadjusted	−0.090	0.018	−0.272	< 0.001	−0.125, −0.054
		Adjusted*	−0.084	0.018	−0.255	< 0.001	−0.118, −0.049
	Caregivers' behaviors	Unadjusted	−0.032	0.008	−0.223	< 0.001	−0.048, −0.016
		Adjusted*	−0.029	0.008	−0.200	< 0.001	−0.044, −0.013

Note: *Adjusted for sex, age, education level, financial status, duration of DM, smoking, alcohol consumption.

patients' HL (Beta = −0.161), SCB (Beta = −0.197), caregivers' HL (Beta = −0.217), and caregivers' behaviors for patient care (Beta = −0.181). For HbA1c, patients' HL had the highest standardized regression coefficient (Beta = −0.265), followed by caregivers' HL (Beta = −0.255), SCB (Beta = −0.233), and caregivers' behaviors for patient care (Beta = −0.200).

Discussion

The results of this study emphasize that the HL of both patients and caregivers is associated with their behaviors and has a significant impact on controlling blood sugar levels in patients with type 2 diabetes. When examining the biological markers of these patients, it was found that more than half (60.70%) had abnormal HbA1c levels, with an average HbA1c of 7.30%. Additionally, nearly half (49.20%) had abnormal FBS levels, with an average FBS of 129 mg/dL, indicating an increase. Our univariate analysis revealed that sex, marital status, comorbidity, duration of DM, and smoking were significantly associated with changes in FBS or HbA1c levels. The findings from this study of diabetic patients are consistent with several case studies from other countries, including Saudi Arabia [36] and Iran. [37] However, FBS and HbA1c are interconnected and influenced by general personal factors, which may vary based on social, cultural, and geographical contexts. [35,38] Previous studies have shown that demographic characteristics, such as comorbidity, duration of DM, and smoking, are associated with bio-logical markers such as HbA1c and FBS. [34–36,38,39] A systematic review indicates that poor HbA1c control has significant physical consequences, and the functional literacy level plays a critical role in poor blood sugar control.[24,39] Therefore, controlling HbA1c and FBS in diabetic patients is crucial to reduce complications and bodily abnormalities. The involvement of caregivers is particularly beneficial in helping to lower blood sugar levels in diabetic patients. [35,39,40] These findings indicate that individuals manage their abnormal blood biochemical markers through self-care techniques. Consequently, adherence to dietary plans among diabetes patients is an issue that needs both empowerment and education.

The overall HL of both caregivers and patients was found to be at the functional literacy level. Additionally, it was observed that fundamental factors such as comorbidities and duration of DM were associated with patient HL. For caregivers, key factors including sex, age, marital status, education level, employment, financial status, underlying disease, time spent caring, caregiver's relationship to the patient, and smoking were significantly associated with caregiver HL. When examining the components of HL that are still insufficient among patients and caregivers, aspects such as cognitive skills related to disease knowledge, causes and risk factors, prevention methods, and correct behavior for disease management were identified. This also includes understanding medication (types, indications, timing, and side effects). Furthermore, self-management skills, particularly regarding dietary behavior, scored low. This aligns with the concept that social skills and an individual's ability significantly influence their understanding and ability to seek methods for self-care.[21] Systematic studies indicate that caregivers may play a crucial role in improving clinical outcomes for patients with type 2 diabetes by supporting self-management and monitoring long-term patient outcomes. To do so, caregivers need in-depth knowledge and skills in patient care.[40] Similarly, studies in Southeast Ethiopia, China, and Korea found that diabetes patients had low HL scores.[38,41,42] Some studies have revealed that knowledge about diabetes significantly moderates the relationship between HL and self-regulation of glucose levels.[43] This finding is consistent with several studies indicating that comorbidities, and disease duration are associated with health literacy scores and influence self-management in diabetic patients.[28,38,44] This suggests that promoting health literacy and awareness of risk factors among diabetic patients is crucial. Access to accurate information for monitoring complications and related comorbidities requires ongoing support and management.[7] Several studies have found that caregiver demographic variables such as age, being female, married, low income, and lower education positively influence the caregiving burden within families.[5,7,13,45] Similarly, a study in Iran found that if patients have low income, caregivers are required to spend more on patient care, thereby increasing the caregiving burden.[45] Therefore, enhancing the capacity of CG for patients with diabetes requires improving knowledge, increasing health awareness regarding the burden of disease, and providing social, economic, and psychological support to alleviate the burden on family caregivers, ultimately leading to better caregiving behaviors for patients with diabetes.[45]

The behavior of elderly diabetes patients and their caregivers was generally at a moderate level. Furthermore, fundamental factors related to the patients, such as comorbidities and the duration of diabetes mellitus, were found to

be associated with patients' SCB. When examining the self-care practices of patients, it was found that the scores for dietary behaviors were low, such as consuming local foods that are sweet (eg, khao soi, hung lay curry, and green curry), eating sweet fruits like mangoes, regularly snacking between meals, and forgetting to take medication. This is similar to reviews that state individual characteristics and experiences are factors influencing health behavior practices through emotional and cognitive aspects specific to those behaviors, such as biological factors, which include comorbid conditions.[46] Furthermore, sociocultural factors such as education, status, occupation, and physical environment can vary among individuals and significantly influence subsequent health-promoting behaviors.[46] Similar to many previous studies, it has been reported that the level of self-care among patients is low and undesirable.[13,37,47]

Additionally, the fundamental factors of caregivers, including age, marital status, education level, employment, financial status, underlying diseases, time spent caring, caregiver relationship to the patient, and smoking, were significantly associated with caregivers' behaviors for patient care. When examining the caregivers' disease prevention behaviors in managing patients, it was found that there were low scores in areas such as providing high-fat foods (eg, fatty pork leg, fried chicken skin, and grilled pork neck), allowing patients to consume soft drinks and sweet snacks, and regularly cooking with lard and adding sugar. This reflects a misunderstanding that self-management of diabetes by patients is not an urgent issue that caregivers need to address and monitor. Similar to previous studies, it was noted that the activities care-givers engaged in the least with patients were related to daily routines, such as eating.[5] This is especially true for children and spouses, which may be due to their familiarity with traditional practices and the lifestyle inherent in Thai culture[5] Additionally, some caregivers have not received formal education, and the family's income is insufficient. The relationships of most elderly caregivers are primarily with grandchildren and others, such as daughters-in-law and sons-in-law. This lack of adequate information may lead to increased stress for the caregivers.[48] Several previous studies have found that caregivers exhibit low to moderate scores in patient care behaviors.[13,28,37,47] It appears that the differences in self-care status among patients in each study result from variations in factors such as knowledge level.[47] This indicates that training and capacity building for family caregivers of patients is crucial and should be strongly supported to promote appropriate food choices, enhance nutritional status, and improve blood glucose control in diabetic patients.

Limitation

This research is a cross-sectional study, so it cannot determine causality. It only identifies associations between health literacy and caregiver health behaviors with type 2 diabetes, as well as biochemical markers like FBS and HbA1C. Our study was conducted in a single district, and the results may not be generalizable to all patients with diabetes and their caregivers. Therefore, further studies are necessary in multiple locations to improve understanding. Although the study instruments, adapted to suit the sample area, were evaluated for validity by experts and tested for reliability before use with participants, they still require further validation. In future studies, additional standardized instruments should be incorporated to ensure accuracy. Additionally, it may be beneficial to consider studying other factors related to diabetic patients and caregivers, such as blood pressure levels, complications, family history, history of NSAID or steroid use, access to information, and the use of herbal medicines and dietary supplements by patients. The findings of this study should inform the development of health education programs tailored to the HL needs of each caregiver component, ensuring they acquire the necessary skills to effectively care for patients with type 2 diabetes.

Conclusion

HL and behaviors of patients and caregivers are associated with glycemic control, including FBS and HbA1C, among individuals with type 2 diabetes in Chiang Mai Province. This indicates that caregivers need to possess comprehensive HL skills and enhance their competencies regarding the proper care of patients with type 2 diabetes. Specifically, the limited aspects of HL seem to influence cognitive skills related to diabetes complications and self-management skills for diabetes prevention or adherence to medication guidelines. Moreover, access to accurate and reliable information about diabetes and its complications, effective communication, and informed decision-making regarding health care are essential for diabetes prevention and the sharing of self-care experiences. Additionally, organizing self-management skills activities can help patients read and understand food labels, particularly regarding the limits on sugar, sodium, and

fat or alternative foods. Skills in physical activity and exercise in rural areas, reinforcing and encouraging timely medication adherence, and fostering participation in community activities are also important. Furthermore, addressing various factors related to both caregivers and patients comprehensively is vital to achieving better health outcomes.

Data Sharing Statement

The datasets generated during and/or analyzed during the current study will be available upon reasonable request from the corresponding author. Katekaew Seangpraw.

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Ethical Approval and Information Consent

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the University of Phayao Human Ethics Committee, Thailand (HREC-UP-HSST 1.2/159/66, approved 20 November 2023). The trial was registered participants gave a written informed consent prior to data collection.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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