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Effects of collaborative learning-based food literacy program on healthy eating behavior and hemoglobin A1c among older adults with uncontrolled type 2 diabetes: A randomized controlled trial study in Thailand

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Abstract

Background: Uncontrolled type 2 diabetes mellitus (T2DM) is a prevalent issue among older adults. Healthy eating behavior (HEB) is a significant factor contributing to blood sugar control. It is a complex behavior that requires knowledge, attitudes, and skills in food literacy, which can be achieved through collaborative learning by nurses. Although collaborative learning has successfully improved food literacy and HEB among adults and older adults in general, its effectiveness has not been investigated among older adults with uncontrolled T2DM.

Objective: This randomized controlled trial aimed to examine the effects of the Collaborative Learning-Based Food Literacy Enhancement Program (CLFLEP) on HEB and hemoglobin A1c (HbA1c) levels among older adults with uncontrolled T2DM.

Methods: Participants were 80 older adults with uncontrolled T2DM attending primary care units (PCUs) or sub-district health promotion hospitals in northern Thailand. They were randomly assigned to either the experimental group (n = 40) or the control group (n = 40). The experimental group received the CLFLEP to enhance four domains of food literacy through five major elements of collaborative learning, while the control group received standard care. Data were collected between January and June 2023 using the Demographic Data Form, the Eating Behavior Questionnaire, the HbA1c test, and the Short Food Literacy Questionnaire. Data analysis involved descriptive statistics for demographic characteristics and independent t-test and paired sample t-test for HEB and HbA1c based on intention-to-treat (ITT) and per-protocol (PP) analyses.

Results: The experimental group had a higher HEB score than the control group (p <0.001 for ITT and PP) and higher than their scores before program participation (p <0.001 for ITT and PP). The effect size (Cohen's d) was 1.46. The experimental group also had a lower HbA1c level than the control group (p = 0.002 for ITT and PP) and lower than their levels before program participation (p = 0.005 for ITT and 0.001 for PP). The effect size (Cohen's d) was 0.70.

Conclusion: The CLFLEP was effective in promoting food literacy, HEB, and blood sugar control. Nurses can be trained to use this program to provide collaborative health education for older adults with uncontrolled T2DM. Nursing administrators can use these findings to develop organizational policies that enhance nurses' competencies as educators skilled in collaborative learning.

Trial Registry Number: TCTR20221222005 [Thai Clinical Trials Registry]

Keywords

Thailand; collaborative learning; food literacy; uncontrolled type 2 diabetes; hemoglobin A1c; older adults; blood glucose; randomized controlled trial; health promotion

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Background

Diabetes mellitus is a serious and increasingly common health issue, with rising concerns worldwide (International Diabetes Federation, 2022). Of all diabetes cases, 90 to 95% are type 2 diabetes mellitus (T2DM) (Centers for Disease Control and Prevention (CDC), 2024). T2DM is characterized by pancreatic β-cell failure, insulin resistance, and hepatic gluconeogenesis (The Royal Australian College of General Practitioners, 2020). It is also a prevalent form of diabetes among older adults, accounting for approximately 25% of all cases (CDC, 2020). In Thailand, the prevalence of diabetes

among older adults is higher compared to other age groups (Aekplakorn, 2021), with more than 60% of these cases being uncontrolled T2DM (Bunnag et al., 2024). Uncontrolled T2DM in older adults is defined as diabetes that does not achieve the target glycemic goal, indicated by Hemoglobin A1c (HbA1c) levels higher than 7.5% (American Diabetes Association, 2020a). This condition leads to various complications, which exacerbate the aging process and drive dysregulated metabolism, decreased insulin production, impaired glucose tolerance, and hyperglycemia (Ismail et al., 2021). Chronic hyperglycemia from uncontrolled T2DM results in microvascular and macrovascular complications, as well as long-term organ dysfunction and failure (American Diabetes Association, 2020b).

Uncontrolled T2DM among older adults is often caused by unhealthy eating behaviors (Ong-Artborirak et al., 2023), which result in excessive carbohydrate intake (Kieudee & Saengrut, 2020). Healthy eating behavior (HEB), which involves balancing carbohydrates, lean protein, and healthy fats (American Diabetes Association, 2020a), is associated with better glycemic control (Salvia & Quatromoni, 2023). HEB includes planning and managing food, selecting, preparing, and eating (Chongmontri, 2019). Proper carbohydrate consumption reduces insulin secretion because carbohydrates are the first macronutrient to be broken down into glucose (Holesh et al., 2023). A high fiber intake also lowers blood glucose levels by inhibiting glucose absorption, which helps maintain normal blood glucose levels (Giuntini et al., 2022).

HEB requires complex skills that include knowledge of healthful eating, motivation to eat healthily, and the ability to prepare and consume healthy food (Truman & Elliott, 2019). Food literacy is a set of interconnected knowledge, attitudes, and capabilities needed for effectively organizing and managing food intake and meeting needs through food selection, preparation, and consumption (Vidgen & Gallegos, 2014). Food literacy is categorized into three levels: 1) functional literacy (recognizing nutritional information and creating a well-balanced meal), 2) interactive literacy (communicating about nutrition with others), and 3) critical literacy (examining the long-term effects of eating patterns on health and critically assessing nutrition information) (Krause et al., 2018). In particular, critical food literacy significantly contributes to one's level of food knowledge, which can influence shifts in attitudes toward food and, consequently, food behaviors (Truman & Elliott, 2019). Food literacy strongly predicts HEB among adults with T2DM (Bastami et al., 2023). Unfortunately, in Thailand, older adults with uncontrolled T2DM have only moderate levels of overall, functional, and interactive nutrition literacy, a subset of food literacy (Krause et al., 2018), while critical nutrition literacy is low (Julsukon et al., 2019). Therefore, promoting food literacy is essential for this population.

Food literacy can be enhanced through literacy-based educational interventions designed to promote critical knowledge (Truman & Elliott, 2019), which can be achieved through collaborative learning. Collaborative learning is an educational method that improves the learning process by involving groups of learners and educators working together to achieve a goal or create a product (Smith & MacGregor, 1992). Its five essential components are 1) positive interdependence (each individual is linked with others and can succeed together); 2) face-to-face promotive interaction (individuals encourage and facilitate each other's efforts to complete tasks); 3) individual accountability (the perceived responsibility of individuals and groups); 4) interpersonal or social skills; and 5) processing through educational activities (Johnson & Johnson, 1994). Collaborative learning enhances critical health literacy in older adults (De Wit et al., 2018) and improves knowledge retention and diabetes self-care behaviors (Heng et al., 2020). Thus, collaborative learning is a promising approach for nurses in patient education.

Nurses play a pivotal role in educating patients, as they are the closest healthcare providers and make up the majority of the global healthcare workforce (Diabetes Australia, 2020). Nurse educators can effectively enhance knowledge of diabetes and its complications, which contributes to maintaining optimal blood glucose levels and overall diabetes control (Shi & Liang, 2024). For older adults with uncontrolled T2DM, nurses provide routine health education tailored to the patients' needs to increase their awareness of blood sugar control (Ma et al., 2021). However, despite its promising effects, collaborative learning has not yet been utilized in nursing health education for older adults with uncontrolled T2DM. Previous education programs have been effective in enhancing food literacy and HEB in community-dwelling older adults (Chongmontri, 2019; Wallace et al., 2016) and in mixed samples of adults and older adults (Begley et al., 2019), but none have applied collaborative learning or specifically focused on older adults with uncontrolled T2DM. Moreover, many of these studies used single-group designs, lacked rigorous methods, and did not measure final clinical outcomes, such as HbA1c, at the end of the programs.

Therefore, this study aimed to examine the effects of the Collaborative Learning-Based Food Literacy Enhancement Program (CLFLEP) on HEB and HbA1c levels among older adults with uncontrolled T2DM. It was hypothesized that older adults receiving the CLFLEP would show higher HEB and lower HbA1c levels compared to those who did not receive the CLFLEP and compared to their levels before receiving the program. As nurses play a crucial role in patient education, especially for older adults with uncontrolled T2DM, they can use these findings to significantly improve food literacy, HEB, and blood sugar control in this population.

Methods

Study Design

A randomized controlled trial (RCT) design with two groups was employed. The trial is registered under identification number TCTR20221222005 on the Thai Clinical Trials Registry (https://www.thaiclinicaltrials.org/). A single-blinded method was used to prevent research assistants (RAs) who collected data from knowing which group the participants were in. This study adhered to the guidelines outlined in the Consolidated Standards of Reporting Trials (CONSORT) (Schulz et al., 2010). The experimental group received the Collaborative Learning-Based Food Literacy Enhancement Program (CLFLEP) and standard care. In contrast, the control group received only standard care, which included diabetic assessments, treatments, and health education provided by a

multidisciplinary care team at an outpatient clinic consisting of physicians, pharmacists, dietitians, and nurses.

Samples/Participants

Power analysis was used to determine the sample size, aiming for a standard power of 80% and a significance level of 0.05 (Gray et al., 2017). The effect size for this study was based on a similar study focusing on changes in HbA1c levels, with an effect size of 0.71 (Hashim et al., 2021). The G*Power program, with a power of 0.80 and an effect size of 0.71, indicated a required sample size of 66. Considering a 20% dropout rate (Hashim et al., 2021), the total number of participants was set at 80, with 40 participants in each group.

Participants were randomly selected from Thai individuals aged 60 and above with uncontrolled T2DM attending primary care units (PCUs) or sub-district health promotion hospitals in a northern province of Thailand. These facilities provide various essential healthcare services at the community level, serving as the initial point of contact for individuals seeking medical care and playing a vital role in promoting health, preventing disease, and managing common health issues. They offer routine outpatient services for local older adults with uncontrolled T2DM.

The inclusion criteria were: 1) diagnosed with T2DM for more than six months before recruitment; 2) a history of HbA1c > 7.5% within the previous three months; 3) receiving only oral glucose-lowering medications; 4) inadequate food literacy, with a score below 31 on the Short Food Literacy Questionnaire (SFLQ) Thai version (Panuthai et al., 2023); 5) cognitively intact, with a score of at least 8 points on the Mental State Questionnaire (SPMSQ) Thai version (Pfeiffer, 1975); 6) independent, with a score of at least 12 points on the Barthel Activities of Daily Living (BADL) Thai version (Jitapunkul et al., 1994); 7) able to read and write in Thai; and 8) willing to participate in the study. Exclusion criteria included a diagnosis of a mental disorder as identified in the patients' medical records. Criteria for withdrawal included 1) non-completion of all CLFLEP sessions; 2) changes in medication regimens or the initiation of insulin injection therapy; 3) acute illness such as severe hypoglycemia or hospitalization during the program; and 4) requesting to terminate participation. Initially, 120 older adults with uncontrolled T2DM were approached, but 40 were excluded (30 did not meet the inclusion criteria, and 10 refused participation).

Block randomization was used to assign the 80 participants to the experimental (E) or control group (C). With a fixed block size of four, there were six possible patterns: EECC, CCEE, ECEC, ECCE, CEEC, or CECE. Twenty blocks were used, with sequential numbers placed in sealed opaque envelopes. Central allocation concealment was performed by a nurse not involved in the study. As a result, each sub-district health promotion hospital and PCU had a control group and an experimental group (40 participants in each group). During the study, four participants in the experimental group withdrew: two discontinued the intervention due to personal reasons (one had to care for a husband's injury, and another did not complete three sessions and began insulin therapy), and two others began insulin therapy. In the control group, three participants withdrew due to starting insulin therapy. Consequently, the final number of participants was 40 in each group for the intention-to-treat (ITT) analysis, and 36 in the experimental group and 37 in the control group for the per-protocol (PP) analysis (**Figure 1**).

Intervention

The Collaborative Learning-Based Food Literacy Enhancement Program (CLFLEP) was developed using Truman and Elliott's (2019) food literacy model, which incorporates four domains of food literacy (Vidgen & Gallegos, 2014), the collaborative learning method (Smith & MacGregor, 1992), and the five major elements of collaborative learning (Johnson & Johnson, 1994). The program was validated for content and revised by six experts: one physician specializing in T2DM, two advanced practice nurses specializing in adult and elderly care, one faculty member specializing in gerontology, one faculty member specializing in nutrition, and one educator specializing in collaborative learning. It was then pilot-tested with three older adults with uncontrolled T2DM, and the results indicated that the program was suitable. The CLFLEP was implemented in small groups of 10 participants and was divided into four modules consisting of eight sessions (two sessions per week) over four weeks. Each session, guided by the researcher, lasted approximately two hours (see **Table 1**).

Instruments

Demographic data were collected using a Demographic Data Form created by the researchers. This form included information on gender, age, marital status, number of household members, education level, duration of residence in the study setting, monthly income, medical benefit scheme, duration of having T2DM, comorbid diseases, types of comorbid diseases, number of hospitalizations due to diabetes in the previous year, complications of T2DM, physical activity, and types of diabetic medication.

HEB was measured using the Eating Behavior Questionnaire (EBQ) developed by Chongmontri (2019) in Thai. Permission was obtained from the original developer for its use. The EBQ consists of 21 items divided into four components: (1) food selection (six items), (2) planning and management (five items), (3) food preparation (five items), and (4) food consumption (five items). Each item is rated on a Likert scale with four possible values: 1 (never) to 4 (every time). Scores are summed to produce a total ranging from 21 to 84, with a higher mean score indicating better HEB. The Cronbach's alpha was 0.90 in a pilot test with 20 older T2DM patients and 0.95 in the actual study.

HbA1c levels were measured using the ADAMS A1c HA-8180, a system for quantitatively determining the percentage of HbA1c and mmol/mol HbA1c in human capillary and venous whole blood through photometric transmission measurement (ARKRAY, 2023). Venous blood samples were obtained using blood draw equipment containing 2 mL of EDTA-anticoagulated blood. The HbA1c test was conducted by the Diagnostic Laboratory at a district hospital in northern Thailand using High-Performance Liquid Chromatography. The ADAMS A1c HA-8180 was certified for traceability by the Reference Material Institute for Clinical Chemistry Standards, and a calibration test was performed as part of the study.

Food literacy was assessed only in the experimental group (n = 40) after program completion using the Short Food Literacy Questionnaire (SFLQ), originally developed by

Krause et al. (2018) and translated into Thai by Panuthai et al. (2023). Permission was obtained from both the original developers and the authors of the translated version. This unidimensional, 12-item questionnaire requires respondents to answer using four- or five-point Likert scales, with various response ranges such as “very bad” to “very good,” “disagree strongly” to “agree strongly,” “very difficult” to “very easy,” and “never” to “always.” Total scores range from 7 to 52 and are categorized as adequate-excellent (score ≥31) and inadequate-limited food literacy (score <31) (Gökler et al., 2020). The Cronbach’s alpha was 0.85 in a pilot test with 20 older T2DM patients and 0.98 in the actual study.

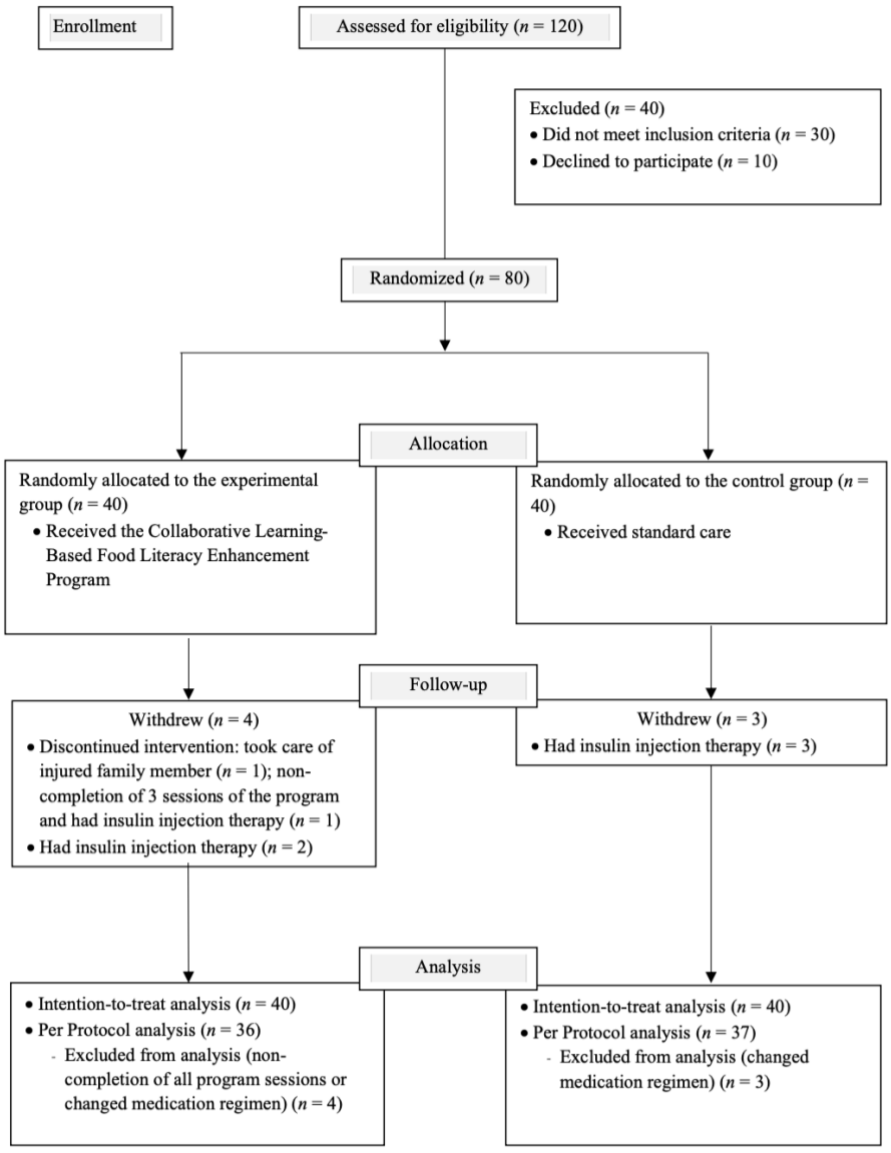

Figure 1 Study CONSORT flow chart

Data Collection

Data were collected between January and June 2023. Two RAs, registered nurses in the selected sub-district health promotion hospitals, were trained to recruit participants and collect data using questionnaires and blood samples. The effects of the program on HEB were assessed at baseline and four weeks after the completion of the program. HbA1c levels were measured at baseline and 12 weeks after the completion of the program.

Data Analysis

Demographic data were analyzed using descriptive statistics, including frequency, mean, percentage, and standard deviation. Comparisons of demographic data were made using Chi-square test, Fisher’s exact test, and independent sample *t*-test. To assess the normal distribution of mean scores for HEB and HbA1c levels in both the experimental and control groups, skewness and kurtosis were evaluated using a *z*-test. The *z*-values were -0.95 for HEB and 1.35 for HbA1c, indicating normal data distribution for medium-sized samples ($50 < n < 300$) (Kim, 2013). There were no missing data, as withdrawn participants were followed up for their posttest. Data were analyzed using intention-to-treat (ITT) and per-protocol (PP) methods. Independent *t*-test was used to compare mean scores for HEB and mean HbA1c levels between the experimental and control groups at baseline and after program completion. Paired sample *t*-test was employed to compare mean scores for HEB and HbA1c levels at baseline and at program completion within each group.

Table 1 Components of the CLFLEP

Component	Session	Content	Strategy	Material
Module 1: FL: Planning and managing CL: Positive interdependence, Face-to-face promotive interaction	1: 1st week (2 hours)	• Build trust through ice-breaking activity • Provide information about the program • Briefly introduce the principles of healthy eating for older adults with uncontrolled T2DM • Lead the group in providing knowledge on the principles of healthy food consumption using the Jigsaw processing technique. • Have a group chat to share experiences with healthy food consumption and introduce reliable sources of health information using Round Robin Presentation techniques. • Summarize the session.	• The Jigsaw procedure • Round Robin Presentation	• Name card • Powerpoint presentation • Video presentation • Thai nutrition flag • Handbook • Activity sheets
FL: Planning and managing CL: Face-to-face promotive interaction, Individual accountability	2: 1st week (2 hours)	• Review information from the previous session. • Brief overview of meal planning, nutritious meals and snacks, and an individual nutrition card with the appropriate portion sizes and proportions for meals and snacks. • Lead a group activity to plan the menu to determine the appropriate amount and proportion of food for T2DM control and evaluate participation in group activities using a four-point rubric. • Discuss problems, appropriate meal planning, and snacks for controlling T2DM and have participants share meal plans for the day. • Summarize the session.	• Four-point rubric • Round Robin Presentation	• Video presentation • Handbook • Nutrition card • Activity Sheets
Module 2: FL: Selecting CL: Positive interdependence, Face-to-face promotive interaction	3: 2nd week (2 hours)	• Review information from the previous session. • Brief overview of carbohydrate counting. • Group workshops on carbohydrate counting and portion size using the Jigsaw processing technique. • Share and exchange plans for implementing the best alternative for healthy eating in carbohydrate counting and portion size using Round Robin Presentation techniques. • Summarize the session.	• The Jigsaw procedure • Round Robin Presentation	• Video presentation • Handbook • Activity sheets • Food model • Food weighing scale • Calculator • Food containers, a ladle, teaspoon, tablespoon, plate, cup • Real foods: sticky rice, white rice, corn, pumpkin • Notebook
FL: Selecting CL: Face-to-face promotive interaction, Individual accountability	4: 2nd week (2 hours)	• Review information from the previous session. • A brief overview of food exchange. • Group workshops on food exchange and evaluate participation in group activities using a four-point rubric. • Discuss and share the plan for the best alternative for healthy eating on the topic of food exchange using Round Robin Presentation techniques. • Summarize the session.	• Four-point rubric • Round Robin Presentation	• Video presentation • Handbook • Activity sheets
Module 3: FL: Preparing CL: Face-to-face promotive interaction, Interpersonal and small-group skill	5: 3rd week (2 hours)	• Review information from the previous session. • A brief overview of food label reading. • Group workshops on food label reading using a think-pair-share model. • Share problems and successful experiences of food label reading for controlling T2DM using Round Robin Presentation techniques. • Summarize the session.	• Think pair-share model • Round Robin Presentation	• Video presentation • Food label poster • Food packaging with nutrition label • Handbook
FL: Preparing CL: Face-to-face promotive interaction, Interpersonal and small-group skill	6: 3rd week (2 hours)	• Review information from the previous session. • A brief overview of how to shop for food for older adults with T2DM. • Group workshops on how to shop for food using a think-pair-share model. • Discuss and share appropriate shopping techniques to resolve healthy eating problems to control T2DM using Round Robin Presentation techniques. • Summarize the session.	• Think pair-share model • Round Robin Presentation	• Video presentation • Handbook • Activity sheets

Table 1 *(Cont.)*

Module 4: FL: Eating CL: Face-to-face promotive interaction, Processing out	7: 4th week (2 hours)	• Review information discussed from the previous session. • Brief information about healthy eating out in special situations (travel, buffet, parties). • Discuss using the individual nutrition card with how to eat out in particular situations to control appropriate carbohydrate portions. Have participants share past experiences and solutions to these situations with each other using Round Robin Presentation techniques. • Summarize the session using slip reflections.	• Round Robin Presentation • Out slip reflections	• Video presentation • Handbook • Activity sheets
FL: Eating CL: Face-to-face promotive interaction, Processing out	8: 4th week (2 hours)	• Review information discussed from the previous session. • A brief overview of eating in normal life and at Northern Thai local party events. • Discuss and share the appropriate plan for eating, selecting an appropriate eating pattern in general and at local events to control diabetes. • Summarize the session using out slip reflections. • Conclude the program.	• Round Robin Presentation • Out slip reflections	• Video presentation • Handbook • Activity sheets

Note. FL: food literacy, CL: collaborative learning

Ethical Considerations

Study approval was obtained from the Research Ethics Committee of the Faculty of Nursing, Chiang Mai University (Approval number: 104/2022). Participation in the study was voluntary, and participants were informed about the study's objectives, methods, confidentiality, and potential risks and benefits. They were given ample time to consider their participation and had the opportunity to ask questions. The informed consent process ensured that participants fully understood their rights, including the right to withdraw from the study at any time after data collection. Written consent was obtained from each participant, confirming their understanding of the study and their voluntary agreement to take part. Additionally, participants were informed that their data would be handled with strict confidentiality and used solely for research purposes. They were also assured that their decision to participate or withdraw would not influence their current or future healthcare.

Results

Seven out of 80 participants withdrew, resulting in a dropout rate of 8.75%. This left 36 participants in the experimental group and 37 in the control group. The ITT analysis included all 80 participants. Most participants in both groups were female, with a mean age of approximately 66 years. Both groups were predominantly married, lived with two or more family members, and had completed primary education. A larger proportion of the experimental group had a personal monthly income of ≤2,500 Thai baht (68.25 USD), whereas the control group's income ranged from 2,501 to 5,000 Thai baht (68.28-136.50 USD). Nearly all participants in both groups were covered by the Universal Coverage scheme.

The mean duration of having T2DM was 10.45 years for the experimental group and 9.28 years for the control group. Most participants in both groups had comorbid conditions, such as hypertension and dyslipidemia, and none had been hospitalized due to diabetes. Diabetes-related complications included diabetic retinopathy and diabetic nephropathy. Over half of the participants in both groups engaged in physical activity, and most were prescribed Sulfonylureas and Biguanides for diabetes management. No statistically significant differences were observed between the experimental and control groups regarding demographics or health data, as shown in **Table 2**.

As shown in **Table 3**, the between-group comparison revealed no statistically significant differences in baseline HEB or HbA1c levels between the experimental and control groups (t = -0.601, p = 0.549; t = -0.671, p = 0.505, respectively, for ITT; t = -0.685, p = 0.495; t = 0.027, p = 0.979, respectively, for PP). However, there was a statistically significant difference in HEB between the groups four weeks after program completion (t = -6.537, p <0.001 for ITT; t = -6.353, p <0.001 for PP) and in HbA1c levels 12 weeks after program completion (t = 3.169, p = 0.002 for ITT; t = 3.278, p = 0.002 for PP).

As illustrated in **Table 4**, the within-group comparison revealed significant differences in the mean scores for HEB between baseline and four weeks after program completion in the experimental group (t = -9.082, p <0.001 for ITT; t = -8.670, p <0.001 for PP). In contrast, no significant difference was observed in the control group (t = -1.944, p = 0.059 for ITT; t = -1.925, p = 0.062 for PP).

For HbA1c, significant differences were found between baseline and 12 weeks after program completion in both the experimental group (t = 2.999, p = 0.005 for ITT; t = 2.508, p = 0.001 for PP) and the control group (t = -4.205, p <0.001 for ITT; t = -3.612, p = 0.001 for PP). For ITT, the experimental group's mean HbA1c decreased from 8.56 (SD = 1.39) at baseline to 8.13 (SD = 1.16) at 12 weeks. In contrast, the control group's mean HbA1c increased from 8.37 (SD = 1.09) at baseline to 9.04 (SD = 1.41) at 12 weeks. The effect size (Cohen's d) for HEB was 1.46 in the ITT analysis and 1.49 in the PP analysis. Conversely, for HbA1c, the effect size was 0.70 in the ITT analysis and 0.77 in the PP analysis.

Table 2 Demographic characteristics and health data of the participants (*N* = 80)

Characteristics	Experimental group (*n* = 40)		Control group (*n* = 40)		*p*-value
	n	%	*n*	%	
Gender					0.091[a]
Male	9	22.50	16	40.00	
Female	31	77.50	24	60.00	
Age (years)					0.969[t]
Range	60-84		60-79		
Mean (SD)	66.55 (5.91)		66.60 (5.37)		
60-69 (Young-old)	27	67.50	33	82.50	
70-79 (Old-old)	12	30.00	7	17.50	
≥ 80 (Oldest-old)	1	2.50	0	0	
Marital status					0.469[a]
Single/widowed/divorced	14	35.00	11	27.50	
Married	26	65.00	29	72.50	
Number of household members					0.816[b]
1	4	10.00	2	5.00	
2	9	22.50	9	22.50	
3	9	22.50	13	32.50	
4	5	12.50	5	12.50	
≥ 5	13	32.50	11	27.50	
Education level					0.354[b]
Primary school	31	77.50	30	75.00	
Secondary school/college	9	22.50	8	20.00	
Bachelor	0	0	2	5.00	
Personal monthly income in baht (USD)					0.0546[b]
≤2,500 (68.25 USD)	18	45.00	12	30.00	
2,501-5,000 (68.28-136.50 USD)	13	32.50	15	37.50	
5,001-7,500 (136.53-204.75 USD)	6	15.00	8	20.00	
≥7,501 (204.78 USD)	3	7.50	5	12.50	
Medical benefit scheme					0.365[b]
Universal Coverage	38	95.00	37	92.50	
Civil Servant Medical Benefit Scheme	1	2.50	3	7.50	
Social Security Scheme	1	2.50	0	0	
Duration of having T2DM (years)					0.489[t]
Range	1-30		1-30		
Mean (SD)	10.45 (7.55)		9.28 (7.55)		
1-10	24	60.00	25	62.50	
11-20	13	32.50	13	32.50	
21-30	3	7.50	2	5.00	
Comorbid diseases					0.481[b]
No	6	15.00	3	7.50	
Yes	34	85.00	37	92.50	
Type of comorbid diseases					0.174[b]
Hypertension	8	20.00	16	40.00	
Dyslipidemia	1	2.50	1	2.50	
Hypertension, dyslipidemia	20	50.00	12	30.00	
Hypertension, dyslipidemia with others	5	12.50	8	20.00	
Hospitalization due to diabetes in a year					-
No	40	100.00	40	100.00	
Complications of T2DM					0.359[b]
No	39	97.50	36	90.00	
Yes	1	2.50	4	10.00	
Type of Complications					
Diabetic retinopathy	1	2.50	3	7.50	0.615[b]
Diabetic nephropathy	0	0	1	2.50	1.000[b]
Physical activity (≥ 30 minutes/time, 3-5 times/week)					0.366[a]
No	15	37.50	19	47.50	
Yes	25	62.50	21	52.50	
Types of diabetic medication					0.207[b]
Sulfonylureas	8	20.00	4	10.00	
Biguanides	1	2.50	4	10.00	
Sulfonylureas, Biguanides	31	77.50	32	80.00	

Note. [a] = Chi-square test, [b] = Fisher exact test, [t] = Independent sample *t*-test
p <0.05

Table 3 Differences in HEB scores and HbA1c levels between the control and the experimental groups by ITT and PP analysis

Variables	Experimental group	Control group	*t*	*p*-value
	Mean (SD)	Mean (SD)		
HEB				
ITT analysis	(*n* = 40)	(*n* = 40)		
- Baseline	59.45 (12.06)	57.80 (12.48)	-0.601	0.549
- 4 weeks after the end of the program	74.85 (6.84)	59.93 (12.72)	-6.537	<0.001
PP analysis	(*n* = 36)	(*n* = 37)		
- Baseline	59.19 (12.67)	57.16 (12.67)	-0.685	0.495
- 4 weeks after the end of the program	75.00 (6.93)	59.43 (13.02)	-6.353	<0.001
HbA1c				
ITT analysis	(*n* = 40)	(*n* = 40)		
- Baseline	8.56 (1.39)	8.37 (1.09)	-0.671	0.505
- 12 weeks after the end of the program	8.13 (1.16)	9.04 (1.41)	3.169	0.002
PP analysis	(*n* = 36)	(*n* = 37)		
- Baseline	8.33 (1.22)	8.34 (1.12)	0.027	0.979
- 12 weeks after the end of the program	7.97 (1.05)	8.92 (1.39)	3.278	0.002

Note. t = Independent sample *t*-test
p <0.05

Table 4 Differences in HEB scores and HbA1c levels pre-post the program of the control and the experimental groups

Variables	Baseline	After the end of the program	*t*	*p*-value
	Mean (SD)	Mean (SD)		
HEB		(4 weeks)		
ITT analysis				
- Experimental group (*n* = 40)	59.45 (12.06)	74.85 (6.84)	-9.082	<0.001
- Control group (*n* = 40)	57.80 (12.48)	59.93 (12.72)	-1.944	0.059
Effect size (Cohen's d)		1.46		
PP analysis				
- Experimental group (*n* = 36)	59.19 (12.67)	75.00 (6.93)	-8.670	<0.001
- Control group (*n* = 37)	57.16 (12.67)	59.43 (13.02)	-1.925	0.062
Effect size (Cohen's *d*)	-	1.49		
HbA1c		(12 weeks)		
ITT analysis				
- Experimental group (*n* = 40)	8.56 (1.39)	8.13 (1.16)	2.999	0.005
- Control group (*n* = 40)	8.37 (1.09)	9.04 (1.41)	-4.205	<0.001
Effect size (Cohen's *d*)	-	0.70		
PP analysis				
- Experimental group (*n* = 36)	8.33 (1.22)	7.97 (1.05)	2.508	0.001
- Control group (*n* = 37)	8.34 (1.12)	8.92 (1.39)	-3.612	0.001
Effect size (Cohen's *d*)	-	0.77		

Note. t = paired sample *t*-test
p <0.05

Discussion

The findings indicated that the CLFLEP increased HEB and decreased HbA1c among older individuals with uncontrolled T2DM, supporting the research hypotheses. HEB is achieved when individuals possess food literacy proficiency, which consists of competence in food-related knowledge, attitudes, and behaviors. This proficiency can be developed through food literacy educational interventions, which promote knowledge acquisition, including functional knowledge and critical understanding (Truman & Elliott, 2019).

The CLFLEP incorporated five essential components of collaborative learning (Johnson & Johnson, 1994). For positive interdependence, a jigsaw procedure was used to emphasize that the success of each individual in the group was interconnected and dependent on the success of others. This created a cooperative and supportive learning environment that fostered collaboration and mutual assistance among participants (Jones & Jones, 2008). As participants learned from each other, they developed a sense of shared responsibility.

Face-to-face promotive interaction involved utilizing jigsaw and round-robin techniques in group discussions and reflections, allowing participants to share their knowledge, support each other by sharing successful experiences, and provide assistance to enhance comprehension. Regarding individual accountability, a four-point rubric technique was used to evaluate each participant's involvement in group activities. Participants who received a low score in participation were encouraged to increase their engagement. This approach highlighted individual accountability and collective responsibility to achieve the group's objectives (Jones & Jones, 2008).

For interpersonal skills, the program incorporated the think-pair-share model, enabling participants to treat each other respectfully, contribute equally, value others' opinions, disagree agreeably, listen attentively, stay focused, and encourage others to speak (Jones & Jones, 2008). Lastly, processing out involved participants reflecting on the benefits

of food literacy, their confidence in analyzing nutritional labels and selecting appropriate foods, and their ability to share food knowledge with others. This reflection enhanced intrapersonal and interpersonal competencies, allowing participants to provide constructive feedback to their peers and fostering an awareness that strengthened group synergy for continuous improvement (Johnson & Johnson, 1994).

The collaborative learning procedures helped participants enhance their knowledge, cultivate positive attitudes, and develop essential skills. Knowledge enhancement was achieved through active participation in various self-learning activities. These activities included answering questions, engaging in discussions, collaborating with peers, solving problems, and stimulating creative thinking. The interdependence among participants in these activities, including knowledge sharing and communication, facilitated experience-based insights (Johnson & Johnson, 1994). This process facilitated a deep understanding and the conversion of information into practical knowledge about diabetes-related dietary practices. As a result, participants gained functional knowledge, including fundamental competencies (Truman & Elliott, 2019), such as recognizing foods high in carbohydrates that should be consumed in moderation. They also developed critical knowledge through analytical processes, such as understanding how carbohydrate-rich foods can raise blood sugar levels (Truman & Elliott, 2019). This understanding enabled them to make informed decisions regarding appropriate food substitutions and avoidance strategies.

Attitude change was achieved as participants assumed leadership roles and collaborated in a group setting. This environment fostered the growth of decision-making skills, trust, effective communication, and collaborative problem-solving. Participants were accountable for the group's outcomes, learned from successes and failures, gained insights into their peers' perspectives, and articulated their views (Jones & Jones, 2008). These shared experiences contributed to the development of more positive attitudes toward food and nutrition for diabetes.

Skill development was attained by providing opportunities for participants to actively practice and improve skills such as meal planning, making informed dietary choices, meal preparation, and decision-making. These skills were refined through collaborative learning processes, where participants interacted and cooperated with peers, offered assistance, and supported one another in completing tasks. As a result, they achieved a higher level of food-related competencies.

Moreover, the researchers played a pivotal role in shaping the learning environment for seeking dietary knowledge by designing and recommending specific learning activities, as well as facilitating interactions among participants. These efforts were instrumental in helping participants clarify their objectives and understand the learning processes, thereby fostering an engaged learning atmosphere. The researchers also increased participants' motivation and enthusiasm for learning through inquiries and suggestions, diligent observation of participant behaviors, opportunities for discussion and idea exchange, and creating an environment conducive to stimulating discourse. Additionally, the researchers guided specialized skills in diabetic food and nutrition, which promoted active participation, facilitated the integration of real-world experiences, and deepened participants' understanding and problem-solving abilities (Johnson & Johnson, 1994). This approach motivated participants to become proactive learners and fostered the development of critical thinking, as demonstrated by Rutherford (2014). This progression ultimately contributed to the attainment of critical literacy. After the program, all participants in the experimental group had food literacy scores above the cutoff score of 31 (mean = 48.53, SD = 1.85), indicating critical food literacy (Gökler et al., 2020). Collaborative learning consistently contributes to the critical health literacy of older adults (De Wit et al., 2018).

With higher food literacy, participants were more likely to adopt HEB in their daily lives. These behaviors included effective food planning and management, informed food selection, appropriate food preparation, and mindful carbohydrate consumption, particularly sticky rice, while maintaining regular eating patterns and incorporating a variety of vegetables, appropriate portions of fruits, and minimizing added sweets and desserts. They were able to adapt these behaviors in both daily life and special events. The effect of the CLFLEP on HEB was consistent with findings from other studies (Begley et al., 2019; Chongmontri, 2019; Wallace et al., 2016). Regular HEB involving appropriate carbohydrate intake reduces insulin secretion since carbohydrates are the first macronutrient to be broken into glucose (Holesh et al., 2023). High fiber consumption also lowers blood glucose levels because fiber inhibits glucose absorption (Giuntini et al., 2022). This results in normal blood glucose levels by reducing the amount of glucose that binds to red blood cells. Consequently, the HbA1c levels of participants in the experimental group decreased after the program's completion, aligning with findings from another study in older adults (Thanh & Tien, 2021).

ITT analysis was employed as the primary method in this study to include all randomized participants, regardless of protocol violations or non-adherence. This approach allowed the analysis of participants based on their assigned treatment group, even if they deviated from the protocol or discontinued treatment (Gray et al., 2017). ITT analysis retains randomization, reduces selection bias, provides an estimate of the treatment effect in a real-world context, and reflects the intervention's practical effectiveness. However, ITT analysis might lead to potential dilution of the treatment effect, limited assessment of treatment efficacy, and lack of detailed information on treatment compliance (McCoy, 2017; Tripepi et al., 2020). As a complementary analysis, PP analysis was conducted to assess treatment efficacy under ideal conditions. This involved defining a per-protocol population consisting of participants who strictly adhered to the treatment protocol and excluding those with major protocol violations or substantial non-adherence. The advantages of PP analysis include providing insights into the potential benefits of treatment when administered as intended. However, PP analysis also has disadvantages, including potential selection bias, loss of the randomization principle, and lack of reflection of real-world conditions (McCoy, 2017; Tripepi et al., 2020). Therefore, our findings should be interpreted with caution.

Limitations

This study focused on older adults with uncontrolled type 2 diabetes who were still independent in their daily activities and

classified as “young-old.” As a result, the findings may not be applicable to other groups of older adults with uncontrolled type 2 diabetes, particularly those who are less independent or older.

Implications for Nursing Practice

The findings highlight the effectiveness of the CLFLEP in improving HEB and HbA1c levels among older adults with uncontrolled type 2 diabetes. These insights will enhance patient care and nursing practice by guiding the education of older adults with uncontrolled T2DM in clinical settings. Nurses can be trained to implement this program as part of their health education strategies, utilizing peer support within groups. These interactions will enhance knowledge and understanding of diabetic nutrition, foster critical food literacy, and ultimately contribute to better HEB and blood sugar control.

Conclusion

This study examines the impact of the CLFLEP on HEB and HbA1c levels in older adults with uncontrolled type 2 diabetes. It advances nursing science by validating Truman and Elliott’s food literacy proficiency model, which enhances critical thinking and promotes behavioral changes that can improve clinical outcomes over time. Nursing administrators should actively shape organizational policies to develop nurses’ competencies as educators skilled in collaborative learning. Policy-makers need to focus on evaluating and refining organizational policies, especially to support comprehensive educational services through collaborative learning methods. Future research should explore the program’s effectiveness across other groups of older adults with uncontrolled T2DM, including those who are middle-aged and dependent, to increase the generalizability of the findings.

Declaration of Conflicting Interest

All authors declared no potential conflict of interest.

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Authors’ Contributions

Each of the authors made a significant contribution to the conceptualization and design, as well as data collection and analysis. All authors contributed to the writing of the manuscript and approved the final draft.

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Data Availability

The data in this study are available from the corresponding author upon a reasonable request.

Declaration of Use of AI in Scientific Writing

None to declare.

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