CARB COUNT APPLICATION AND FOOD CONSUMING BEHAVIOR MODIFICATION IN TYPE 2 DIABETES MELLITUS PATIENT

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Abstract. The purpose of the study was to determine the effect of a food consumption behavior modification program together with a carbohydrate count app on blood glucose level. Pre- and post-program assessments were employed in this quasi-experimental study on a group of individuals with type 2 diabetes mellitus who were free of comorbidities and aged 41-70, as well as a control group (n = 30 per group). The experimental group underwent the diet behavior modification program, using a "Carbs App", a mobile application for counting carbohydrate intake. In contrast, the control group members were not enrolled in the program. Every participant's blood HbA1c level was measured both before and after the 12-week program. Upon program completion, participants in the experimental group showed statistically significant improvement in self-efficacy awareness, carbohydrate consumption behavior and mean blood HbA1c level (decreasing from 8.5 to 6.9%) (p=0.001), while the mean blood HbA1c level in the control group did not alter. Hence, the food consumption behavior modification program aided with a carbohydrate counting app can effectively lower blood sugar levels in type 2 diabetes mellitus patients.

Keywords: behavior modification, blood glucose level, carb-counting, food consumption behavior, hemoglobin A1c, type 2 diabetes mellitus

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a noncommunicable chronic disease, which poses a major public health problem globally, including Thailand. In 2021, there were 537 million people worldwide with T2DM, which is continuously rising (International Diabetes Federation, 2021). The global prevalence of T2DM is already at 24.0% and additionally, approximately 541 million people (10.6% of the worldwide population) have impaired glucose tolerance, which can lead to T2DM. Annual deaths from T2DM reached 6.7 million people, with one patient dying every five seconds (International Diabetes Federation, 2021).

Statistics from Thailand's Ministry of Public Health indicate that T2DM is steadily rising in the country, with approximately 300,000 new patients diagnosed each year (Department of Disease Control, 2021). In 2020, about 3.3 million people were officially registered as T2DM patients. By 2021, the prevalence reached 6,067 patients per 100,000 population (9.70%). The morbidity rate was 25.1 per 100,000 people (International Diabetes Federation, 2021). Thailand's Ministry of Public Health spends an average of 47,596 million baht annually on T2DM treatment (Department of Disease Control, 2021). In addition, T2DM is a leading cause of many other serious non-communicable diseases (NCDs), such as cerebrovascular disease, chronic renal failure, heart disease, and hypertension (Department of Disease Control, 2021).

The conceptual framework of this research is based on Bandura's social learning theory (Bandura, 1977), which posits that human learning behavior arises from a multi-faceted process involving genetics, environment, social interaction, experience, and individual aptitude. Consequently, a program was developed aimed at raising people's awareness of their self-efficacy through Bandura's four methods: 1) performance accomplishments, 2) vicarious experiences from observing others, 3) verbal persuasion, and 4) emotional arousal.

The study focused on finding ways to reduce blood glucose levels in T2DM subjects as high blood glucose level leads to other serious co-morbidities as described above. One of the means to lower blood

glucose levels is through reducing carbohydrate (carb) consumption (Tuomilehto *et al*, 2001). T2DM patients often lack awareness of their self-efficacy and understanding of the disease and appropriate nutrition, particularly regarding carb consumption. Carb counting helps T2DM patients modify their eating behavior.

Thus, the study developed a food consumption behavior modification program based on carb counting to help reduce blood glucose levels among T2DM patients and prevent further disease complications.

MATERIALS AND METHODS

Study design and population

The research employed a quasi-experimental design using a two-group pre-test and post-test procedure carried out in Nong Boonmak District, Nakhon Ratchasima Province, Thailand from November 2023 to February 2024. The sample population size was determined using G*Power 3.1 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The parameters determined consist of statistical analysis by t-test, power of the test of 0.90, significance level α of 0.05, and effect size of 0.812 using the method of Wang *et al* (2018). The recommended sample population size is 54, or 2 groups of 27. The size was increased by 10% to 60, or 2 groups of 30.

Inclusion criteria were individuals 41-70 years of age, diagnosed with T2DM and having blood glucose HbA1c levels ≥7%, without serious medical complications or co-morbidities, such as cardiovascular disease, cerebrovascular disease, hypertensive retinopathy, or renal complications, and have a rate of kidney blood flow per minute (eGFR) >59 ml/min/1.73 m^2. Additionally, participants needed to be proficient in the Thai language, possess adequate communication skills and own a smartphone or have access to one via a caregiver. Exclusion criteria included participation in <80% of the scheduled activities and incomplete data collection. Participants were randomly assigned to an experimental group or a control group, were evaluated for all participants before and after the behavior modification program. The experimental group participated in a 12-week diet behavior modification program using the "Carbs App"

a mobile application for counting carbohydrates. This application helps users calculate their daily carbohydrate intake, allowing them to plan their diet for each meal effectively. With its carbohydrate counting function, users can control their carbohydrate consumption accurately. The app shows users the equivalent amount of food for one carbohydrate serving (1 carb), such as one ladle of steamed rice or three pieces of jackfruit. One carb is approximately 15-18 grams, depending on the type of carbohydrate-containing food. Meanwhile, the control group did not receive the dietary behavior modification program, nor the "Carbs App".

Data collection

The researcher scheduled the experimental group to participate in the 12-week program over six sessions. These activities were organized at a health-promoting hospital. During the first meeting, the researchers assessed the participants' health status, measured their weight and height, performed fingertip blood sugar tests two hours after meals, and recorded health information in their individual notebooks. The activities aimed to build self-efficacy by enhancing knowledge about diabetes, including its signs and symptoms, pathology, complications, treatment, and carbohydrate consumption through carb counting. Participants learned how to count carbs and practiced using the carb-counting application. The researchers encouraged the experimental group to learn from both positive and negative experiences of others to increase awareness. Follow-up telephone notifications were provided during the 2nd and 4th weeks (Fig 1).

Research instrument

The research instrument consists of a food consumption behavior modification program integrated with a carb counting app specifically designed for the study. Based on Bandura's social learning theory (Bandura, 1977), the program consists of four recommended methods to enhance self-efficacy awareness: 1) performance accomplishments, 2) vicarious experiences, 3) verbal persuasion, and 4) emotional arousal. Success of the program activities was based on results from fasting and post-prandial blood sugar measurements. The "Carbs App",

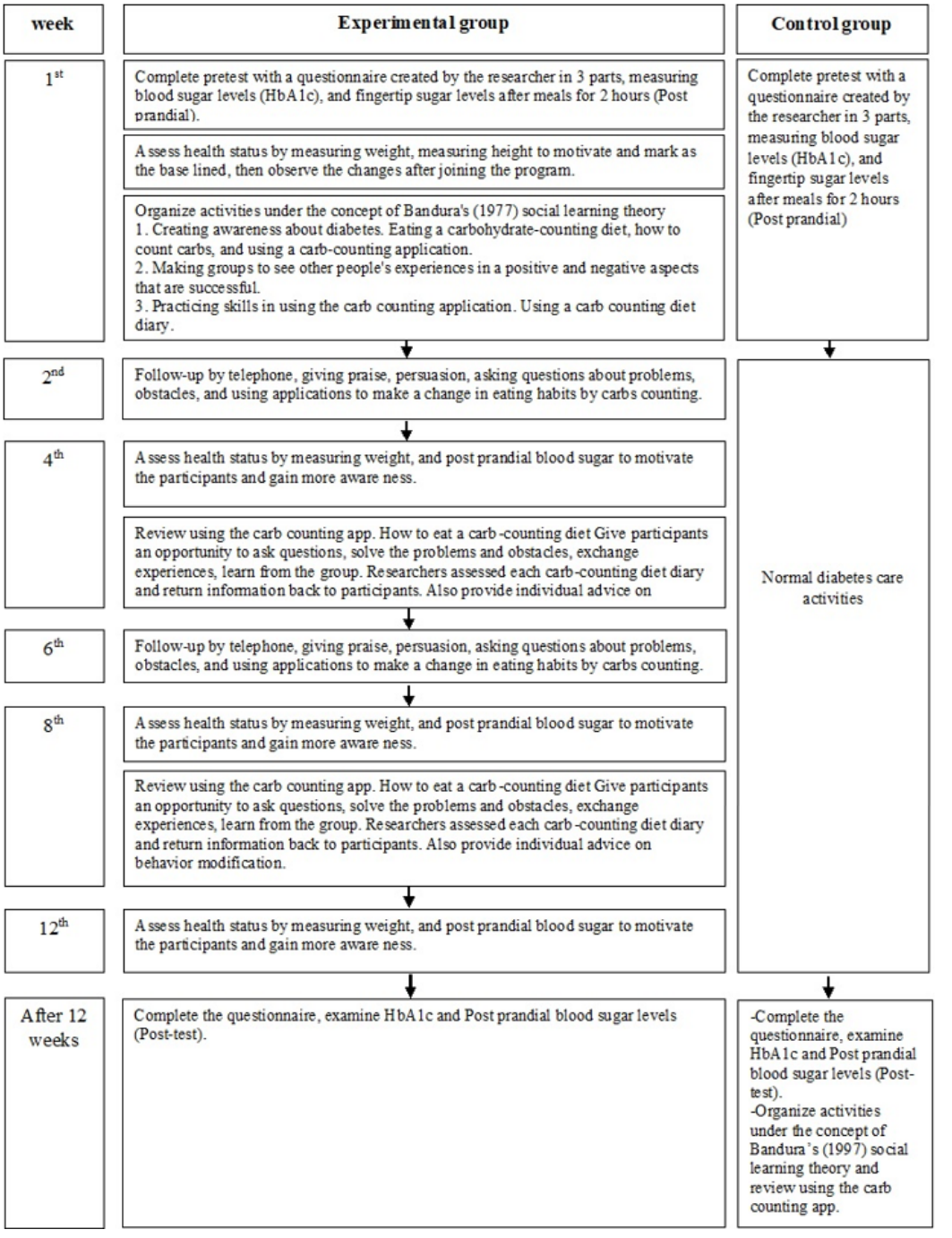

Fig 1 - A food consuming behavior modification program using carb-count to control bloodglucose level in type 2 diabetes mellitus subjects

Fig 1 - (cont)

The diagram outlines a 12-week intervention for the experimental and control groups. Both groups started with a pretest, measuring blood sugar levels (HbA1c) and fingertip sugar levels after meals (postprandial). The experimental group also had their weight and height assessed and participated in activities based on Bandura's (1977) social learning theory, focusing on diabetes awareness, carb-counting diets, and using a carb-counting app.

Throughout the program, the experimental group received follow-up phone calls in the 2nd and 6th weeks for encouragement and problem-solving. In the 4th and 8th weeks, they had reassessments, and app reviews, and received individual advice. The control group continued with normal diabetes care activities.

By the 12th week, the experimental group had another health assessment. After 12 weeks, both groups completed a post-test, reexamined HbA1c and postprandial blood sugar levels, and the control group reviewed the intervention activities.

FPG: fasting plasma glucose; HbA1c: hemoglobin A1c

developed specifically for the current research, was employed following an assessment by a panel of 5 experts, consisting of doctors, nurses and academics, which resulted in a content validity index (CVI) (Polit and Beck, 2006) of 1.00.

The data collection instrument comprises a questionnaire divided into three parts. Part 1 contains 13 questions concerning general personal and health data, featuring both multiple-choice and fill-in-the-blank formats. Part 2 evaluates awareness of self-efficacy in carb-counting food consumption, consisting of 12 affirmative statements for respondents to rank on a scale of 1 to 5, where 1 was the lowest score and 5 was the highest score. Part 3 contains 14 questions addressing carb consumption behavior, comprising 8 positive and 6 negative behavior attributes. Respondents rate the frequency of each behavior on a scale of 1 to 5, with 1 being the lowest score and 5 being the highest score for positive behaviors while 1 being the highest score and 5 being the lowest score for negative behaviors. In addition, data were collected through a form for recording carb-counting food

consumption behavior. The CVI for Parts 2 and 3 was 0.92 and 0.96, respectively, and Cronbach's α coefficient (Polit and Beck, 2006) was 0.86 and 0.66, respectively.

Statistical analysis

Descriptive statistics, including frequency distribution, percentage, mean, and standard deviation, were calculated. Chi-square and independent t-test analyses were employed with a significance level of 0.05. Data distribution was assessed using a One-Sample Kolmogorov-Smirnov Test (Clinch and Keselman, 1982; Cochran and Cox, 1992). Data with normal distribution underwent analysis via paired and independent t-tests, while non-normal distributed data were subjected to the Wilcoxon Signed-Rank Test, with significance set at 0.05. Statistical analyses were carried out using the IBM Statistical Package for the Social Sciences (SPSS) Version 27 (IBM Corporation, Armonk, NY).

Research ethical conduct

The research protocol received approval from the Human Research Ethics Committee of the School of Nursing, Sukhothai Thammathirat Open University, under Human Research Ethics Certification No. 21/2566, valid from 11 August 2023 to 11 August 2024. Prior written consent was obtained from each participant.

RESULTS

Demographic characteristics

Nakhon Ratchasima, a major province in northeastern Thailand located approximately 260 kilometers from Bangkok, has a rising prevalence of T2DM, *ie* increasing from 7.31 per 100,000 population from 2020 to 7.77 and 8.16 per 100,000 population in 2021 and 2022, respectively (Department of Disease Control, 2023). During the same period, the T2DM mortality rate in Nakhon Ratchasima fluctuated slightly between 2.40 and 2.60 per 100,000 population, while the percentage of patients with well-controlled T2DM was 32.8, 35.73, and 37.4 in 2020, 2021 and 2022, respectively (Nakhon Ratchasima Provincial Public Health Office, 2022). It is consistently lower than the Ministry of Public Health's target of 40% (Ministry of Public Health, 2021).

A comparison of personal data was conducted for the parameters (Table 1) on a nominal

Table 1

Comparison of differences in personal characteristics between experimental and control groups

Personal data	Experimental group (N = 30)	Control group (N = 30)	*p*-value*
Gender, *n* (%)			1.000[a]
Male	1 (3)	1 (3)	
Female	29 (97)	29 (97)	
Age in years, mean ± SD	60.1 ± 7.2	60.0 ± 6.6	0.876[b]
Age group, *n* (%)			
41-50 years	3 (10)	3 (10)	
51-60 years	12 (40)	12 (40)	
61-70 years	15 (50)	15 (50)	
Marital status, *n* (%)			0.347[a]
Married	25 (83)	22 (73)	
Widowed/divorced/separated	5 (17)	8 (27)	
Education, *n* (%)			0.173[a]
Primary school	24 (80)	28 (93)	
Middle school	3 (10)	0 (0)	
Secondary school/vocational school	3 (10)	2 (7)	
Occupation, *n* (%)			0.025[a]
Agriculture	16 (54)	25 (83)	
Trade	1 (3)	2 (7)	
Homemaker	9 (30)	1 (3)	
Laborer	4 (13)	2 (7)	
Family income per month, mean ± SD	4,380 ± 2,990	4,033 ± 2,984	0.355[b]
THB ≤5,000	21 (70)	25 (83)	
THB 5,001-10,000	8 (27)	5 (17)	
THB >10,000	1 (3)	0 (0)	

Table 1 (cont)

Personal data	Experimental group (N = 30)	Control group (N = 30)	*p*-value*
Opinion concerning income, *n* (%)			1.000[a]
Adequate	15 (50)	15 (50)	
Not adequate	15 (50)	15 (50)	
Number of meals per day, *n* (%)			0.020[a]
2	0 (0.0)	5 (17)	
3	30 (100.0)	25 (83)	
Snacks per day, *n* (%)			0.328[a]
1 time	18 (60)	23 (77)	
2 times	7 (23)	5 (17)	
3 times	5 (17)	2 (6)	
Amount of rice consumed			
Breakfast (serving spoons per meal), mean ± SD	2.3 ± 0.6	2.0 ± 0.7	0.570[a]
Rice consumed for breakfast, *n* (%)			
None	0 (0)	1 (3.3)	
1 spoonful	2 (7)	3 (10.0)	
1.5 spoonful	1 (3)	1 (3.3)	
2 spoonsful	16 (53)	19 (63.3)	
3 spoonsful	11 (37)	6 (20.0)	
Lunch (serving spoons per meal), mean ± SD	1.8 ± 0.3	1.4 ± 0.8	0.026[a]
Rice consumed for lunch, *n* (%)			
None	0 (0)	4 (13)	
1 spoonful	4 (13)	10 (33)	
1.5 spoonful	1 (4)	0 (0)	
2 spoonsful	25 (83)	15 (50)	
3 spoonsful	0 (0)	1 (4)	

Table 1 (cont)

Personal data	Experimental group (N = 30)	Control group (N = 30)	*p*-value*
Dinner (serving spoonful per meal), mean ± SD	2.3 ± 0.5	2.1 ± 0.6	0.257[a]
Rice consumed for dinner, *n* (%)			
1 spoonful	1 (3)	4 (13)	
2 spoonsful	18 (60)	19 (63)	
3 spoonsful	11 (37)	7 (24)	
Type of rice normally consumed, *n* (%)			0.117[a]
White/polished	26 (87)	30 (100)	
Unpolished	1 (3)	0 (0)	
Brown	3 (10)	0 (0)	
Duration of T2DM (years), mean ± SD	12.0 ± 7.4	11.1 ± 6.9	0.732[b]
Duration of T2DM, *n* (%)			
1-5 years	6 (20)	6 (20)	
6-10 years	10 (33)	11 (37)	
11-15 years	5 (17)	6 (20)	
≥16 years	9 (30)	7 (23)	
Other condition (co-morbidity), *n* (%)			0.010[a]
Hypertension	26 (87)	26 (87)	
High blood TG	26 (87)	17 (57)	
T2DM medication, *n* (%)			
Metformin	29 (97)	28 (93)	0.554[a]
Glipizide	21 (70)	19 (63)	0.584[a]

*Statistically significant when *p*-value <0.05

[a]Chi-square test; [b]independent *t*-test

SD: standard deviation; TG: triglyceride; THB: Thai baht (THB 35.31 = USD 1.00); T2DM: type 2 diabetes mellitus

Table 2

Comparison of differences in clinical data between experimental and control groups

Clinical data	Experimental group (N = 30)	Control group (N = 30)	*p*-value*
Bodyweight (kg), mean ± SD	62.4 ±12.2	63.5 ± 12.3	0.668
Bodyweight, *n* (%)			
40-50 kg	4 (13)	3 (10)	
51-60 kg	12 (40)	12 (40)	
61-70 kg	8 (27)	7 (23)	
≥71 kg	6 (20)	8 (27)	
BMI (kg/m^2), mean ± SD	26.3 ± 5.1	26.0 ± 5.2	0.953
BMI, *n* (%)			
≤18.5 kg/m^2	0 (0.0)	1 (3)	
18.6-23.0 kg/m^2	7 (23)	7 (23)	
23.1-25.0 kg/m^2	9 (30)	6 (20)	
25.1-35.0 kg/m^2	11 (37)	14 (47)	
≥35.1 kg/m^2	3 (10)	2 (7)	
Blood glucose status			
HbA1c (%), mean ± SD	8.5 ± 2.0	8.4 ± 1.8	0.733
HbA1c, *n* (%)			
<6.5%	0 (0)	0 (0)	
6.6-7.0%	9 (30)	3 (10)	
>7.0%	21 (70)	27 (90)	
FPG (mg/dl), mean ± SD	149.1 ± 44.8	138.6 ± 51.7	0.243
FPG, *n* (%)			
≤125 mg/dl	10 (33)	13 (43)	
126-154 mg/dl	13 (43)	12 (40)	
155-182 mg/dl	2 (7)	4 (13)	
≥183 mg/dl	5 (17)	1 (4)	

Table 2 (cont)

Clinical data	Experimental group (N = 30)	Control group (N = 30)	*p*-value*
Post prandial FPG (mg/dl), mean ± SD	175.7 ± 57.9	205.6 ± 81.9	0.109
Post prandial FPG, *n* (%)			
<140 mg/dl	11 (37)	5 (17)	
140-160 mg/dl	2 (6)	3 (10)	
>160 mg/dl	17 (57)	22 (73)	

*Statistically significant when *p*-value <0.05

BMI: body mass index; FPG: fasting plasma glucose; HbA1c: hemoglobin A1c; kg: kilogram; kg/m^2: kilogram per square meter; mg/dl: milligram per deciliter; SD: standard deviation

scale before and after the implementation of the program for both the experimental and control groups. Most parameters, including gender, marital status, education, occupation, adequacy of income, snacking behavior, the average number of spoonsful of rice consumed at breakfast and dinner, co-morbidities, and diabetes medication, were not significantly different between the two groups (all with *p*-values of >0.05). Additionally, there were no differences between the experimental and the control group on age (p=0.876), monthly family income (p=0.355), and duration of illness of diabetes (p=0.732).

However, there were significant differences between the experimental and the control group on occupation (p=0.025), number of meals consumed per day (p=0.020), number of spoons of rice consumed at lunch (p=0.026), and comorbidity (p=0.010), respectively.

Before the implementation of the food consumption behavior modification program, there are no statistically significant differences (p=0.001) in the means of clinical data between the experimental group and control groups (Table 2). However, there is a significant increase in the average awareness of self-efficacy in carb counting for the experimental group at

Table 3

Comparison of self-efficacy awareness in using carb-counting and carb consumption behavior, and blood glucose level of type 2 diabetes mellitus subjects before and after modification program between experimental and control groups

Parameter	Food consumption behavior before implementation of the modification program		Food consumption behavior after implementation of the modification program		*p*-value*
	Mean ± SD	Mean rank	Mean ± SD	Mean rank	
Awareness of self-efficacy in using carb-counting, (points)					
Experimental group (n = 30)	30.2 ± 2.3	**	45.1 ± 4.8	**	0.001
Control group (n =30)	29.5 ± 2.3	**	29.3 ± 2.3	**	0.682
Carbohydrate consumption behavior, (points)					
Experimental group (n = 30)	33.9 ± 3.1	15.5	53.3 ± 2.9	0	0.001
Control group (n =30)	33.9 ± 3.8	12.2	32.8 ± 3.7	14.9	0.056
Blood glucose (HbA1c), (%)					
Experimental group (n = 30)	8.5 ± 2.0	29.7	6.9 ± 1.4	21.2	0.001
Control group (n =30)	8.5 ± 1.8	31.3	8.5 ± 1.8	39.8	0.425

*Statistically significant when p-value <0.05; **paired t-test (without mean rank)

HbA1c: hemoglobin A1c; SD: standard deviation

the completion of the program, increasing from 30.2±2.3 points before the program to 45.1±4.8 points at week 12 (p=0.001) (Table 3). The average score for actual carbohydrate consumption behavior in the experimental group also significantly increased post-program from 33.9±3.1 points before the program to 53.3±2.9 points at week 12, surpassing that of the control group (p=0.001). This awareness was reflected in the decrease in blood glucose (HbA1c), from 8.5±2.0% before the program to 6.9±1.4% after the program (p-value = 0.001), whereas in the control group, HbA1c level remained unchanged (8.5±1.8% at first measurement vs 8.5±1.8% at week 12 (Table 3).

DISCUSSION

The results revealed that after completion of the food consumption behavior modification program, the experimental group achieved heightened awareness of self-efficacy in carb counting, an increase in knowledge of T2DM, enhanced awareness of carbohydrate consumption, and improved familiarity with the "Carbs App" smartphone application for carb counting. As expected, at week 12 (duration of the program) the scores assessed for these parameters are significantly higher than those of the control group (p=0.001). These enhancements stemmed from a learning process incorporating Bandura's four methods: performance of accomplishments, observation of positive and negative behaviors in others, verbal persuasion, and emotional arousal (Bandura, 1977).

The mastery of experiences method comprised activities that promoted skill training using a carb counting food report and a carb counting app developed for the current study that participants could install and use at home. After the demonstration on the use of the "Carbs App", participants were encouraged in a group setting to share opinions and assist one another in mastering the "Carbs App", thereby gaining experience to allow its use on their own.

The model method is to learn from the experience of others. A good role model is a person who can control a blood sugar (HbA1c) level of <7%. This allows another participant with an HbA1c level >7% to share their lifestyles, particularly food consuming behavior. Rice constitutes a large

portion of every meal in this region. The role model can relate ways to reduce the portion of carbohydrate consumed, describing the menus that allow cutting down the portion of rice and the importance of measuring daily carbohydrate intake. Problems are identified and solutions are discussed to tailor to each participant's way of life. The role of the group moderators is to stimulate and encourage the participants so that they are empowered to change their habits geared towards lowering their blood sugar levels.

The verbal persuasion method provides knowledge on T2DM, modification of eating habits and carb counting. The program builds awareness and self-efficacy of the participants with T2DM by sharing knowledge about the disease, such as signs and symptoms of diabetes, causes and pathologies, and severity complications and treatments, and sharing information on carb counting diet and carb calculation using the "Carbs App" at every meal and for the whole day. The participants consulted among themselves to devise a feasible, personal plan for the management of blood sugar levels. During the program duration, one of the researchers made a phone call in the second and sixth week to check on the progress and motivate continued adherence to the agreed upon plan.

The tool for emotional arousal was the phone call, which the researcher used to provide positive and encouraging statements, such as asking about problems resolved, symptoms (if any), changes in eating habits through carb counting, and feelings on the progress made, thereby reinforcing the participant's commitment to behavioral changes for a healthier life.

The experimental group's success in modifying their carbohydrate consumption behavior aligns with the earlier studies of Siriburanont (2012) in Nakhon Pathom Province on promoting self-efficacy among T2DM individuals and of Yoschamras and Nippanon (2013) in Khon Kaen Province on the impacts of self-efficacy development and goal-setting on behavior change and blood glucose level control in T2DM patients. Both studies revealed that intervention programs significantly increase awareness of self-efficacy in food consumption compared to the non-intervention group (p-values <0.05 in both studies). Phrompahakul *et*

al (2020) reported positive results of a self-regulation program on eating behavior in elderly T2DM subjects who previously were unable to control their blood sugar levels.

These findings are consistent with those of several studies on T2DM subjects conducted in other countries. These included a randomized control trial in the USA by Gannon and Nuttall (2004) of the effect of a high protein, low carbohydrate diet on blood glucose control, in China by Wang *et al* (2018) of a low carbohydrate diet on post-prandial blood sugar level, and in Japan by Ebe *et al* (2017) of a low carbohydrate diet on HbA1c level. In addition, a meta-analysis of the literature from 2010 to 2015 by Dyson (2015) suggested that low carbohydrate diets appear to be safe and effective over the short term for T2DM patients.

In conclusion, a food consumption behavior modification program was effective in enhancing awareness of self-efficacy in carb counting, improving carbohydrate consumption behavior, and contributing to better glycemic control among participants with type 2 diabetes mellitus. These findings highlight this type of program's potential efficacy in managing this syndrome and emphasize the importance of implementing similar interventions in public health programs to improve health outcomes of diabetic patients in the country.

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CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflict of interest.

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