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Original Article
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Evaluation and Comparison of Daily Total Energy Intake and Macronutrient Proportion Consumption Between Poor vs Good Glycemic Control Type 2 Diabetes Mellitus Patients: A cross-sectional study at Family Medicine OPD, Maharaj Nakorn Chiang Mai Hospital, Thailand

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ABSTRACT

OBJECTIVE To evaluate and compare daily total energy intake and macronutrient proportion consumption between poor and good glycemic control type 2 diabetic patients.

METHODS A cross-sectional study was conducted from December 2021 to March 2022 at Maharaj Nakorn Chiang Mai Hospital. Patient data was collected using a questionnaire. Dietary intake data was collected using 24-hour dietary recall and was analyzed by a dietitian. Factors and their association with poor glycemic control were analyzed.

RESULTS Of the 127 participants, 40.16% had poor glycemic control. The mean HbA1c level in the poor and the good glycemic control group was 7.67±0.61% and 6.39±0.44% respectively ($p < 0.001$). Among all patients, the mean total energy intake was 1,640.21±495.92 kcal/day, with mean proportions of 51.25% for carbohydrate, 16.56% for protein, and 32.12% for fat. There were no significant differences between the poor and good glycemic control groups in total energy intake (1702.63 ±503.48 kcal/day vs. 1598.32±489.65 kcal/day, $p = 0.247$), carbohydrate intake (222.78±89.98 g/day vs. 203.72±79.36 g/day, $p = 0.211$), protein intake (70.12±21.50 g/day vs. 65.44±21.38 g/day, $p = 0.230$), or fat intake (58.94±19.26 g/day vs. 57.86±24.33 g/day, $p = 0.790$).

CONCLUSIONS The poor glycemic control group was more likely to consume more total energy and a higher proportion of carbohydrate and fat, which suggests that proper individualized dietary energy intake and diet proportions may enhance nutritional status and glycemic control.

KEYWORDS DM, nutrition, diet, calories, glycemic control, consumption

INTRODUCTION

Type 2 diabetes mellitus (DM) is one of the most common non-communicable diseases worldwide. It can lead to various health problems and can have negative consequences, including heart disease, kidney damage, nerve damage, an increased mortality rate, rising healthcare costs, and a diminished quality of life (1). The incidence of diabetes is a major public health concern worldwide, and is anticipated to increase to 700 million by 2045 (2). Thailand ranks fifth among Western Pacific nations in the number of DM cases (3), with approximately 64.4% of DM cases experiencing poor glycemic control (4).

Effective treatment of diabetes involves several key components, including healthy diet, regular physical activity, and often the use of pharmacotherapy. The American Diabetes Association (ADA) suggests that daily energy intake balance has an impact on glycemic control and recommends reducing energy intake while maintaining a healthy eating pattern (5). A previous study in Korea found that individuals with high total energy intake were more likely to have poor glycemic control (6). Moreover, dietary proportions can also affect the outcome of diabetes treatment (7).

The proportion of dietary consumption is an important aspect of a healthy diet, as it can affect overall nutrient intake, energy balance, and blood sugar control. Macronutrients are essential nutrients that provide energy required to maintain body functions and daily activities. Macronutrients consist of carbohydrate, fat, and protein, each of which contribute energy at different rates: 4 kcal/g for carbohydrate, 9 kcal/g for fat, and 4 kcal/g for protein (8). Macronutrients not only provide energy but also have an impact on blood sugar levels. Carbohydrate directly and quickly impacts blood sugar levels by breaking down into glucose, which raises blood sugar levels (8). Fat and protein have a lesser effect on blood sugar levels compared to carbohydrate, but they can still impact glucose metabolism (8, 9). They can also be converted into glucose through gluconeogenesis when carbohydrate sources are insufficient (9). For individuals with diabetes, monitoring food proportions can be particularly important in managing blood sugar levels and preventing diabetic complications. Many published papers have reported that meal planning strategies that emphasize portion control, such as using measuring cups and portion plates, can be effective in improving blood sugar control and weight management in individuals with type 2 diabetes (10, 11), with the carbohydrates playing a significant role. A study in Iran found an association between carbohydrate intake and hyperglycemia (12). To ensure proper carbohydrate consumption, the Food and Nutrition Board of the National Academy of Sciences recommends a daily carbohydrate intake of 45-65% of total daily energy intake and a minimum of 130 g/day as essential to providing adequate glucose to the brain (13). Additionally, a study in Japan showed that eating a low-carbohydrate diet of 130 g/day can help reduce HbA1c in diabetic patients with poor glycemic control (14). However, the optimal amount of fat and protein intake for diabetic patients is still uncertain due to the limited evidence available (5). In general, dietary reference intakes (DRIs) recommend a daily protein intake to fulfill the needs of most individuals of 1-1.5 g/kg/day or 15-20% of daily total energy intake (15). For fat consumption, the National Academy of Medicine recommends a daily fat intake in the range of 20-35% of daily total energy intake (16). Additionally, the United States National Cholesterol Education Program (NCEP) suggests that fat intake should not exceed 30% of total daily energy intake (15). Thus, a proper proportion of macronutrient consumption is important to the outcome of diabetic treatment. Healthcare providers should regularly work with patients to evaluate and provide information regarding management of dietary intake tailored to each patient.

Nutrition, both daily total energy intake and dietary proportions, plays an important role in maintaining glycemic control. However, there has been only limited research on the effects of dietary intake on glycemic control in Thailand (17), particularly regarding dietary proportions and including dietitian-conducted dietary assessments. Thus, the purpose of this study is to evaluate and compare daily total energy intake and the proportions of macronutrient consumption by type 2 diabetic patients with poor and good glycemic control.

METHODS

A cross-sectional descriptive study was conducted from December 2021 to March 2022 at the Outpatient Clinic of the Family Medicine Department, Maharaj Nakorn Chiang Mai Hospital, Chiang Mai, Thailand. The study was approved by the Research Ethics Committee of the Faculty of Medicine, Chiang Mai University, Thailand (FAM-2564-08500). The study included individuals who met the following criteria: 1) known cases of type 2 diabetes with scheduled appointments and HbA1c testing during the study period, 2) at least 18 years of age, 3) able to complete the questionnaire, and 4) voluntarily willing to participate. Written informed consent was obtained from all participants following an explanation of the study's purpose. Individuals who were not willing to participate were excluded from the study.

The study recruited a total of 127 patients who met the inclusion criteria using consecutive sampling. The sample size was calculated using the estimating an infinite population proportion formula (18), and was based on an estimated 50.2% of patients having poor glycemic control type 2 diabetes (19), error(d) = 0.10, alpha = 0.05, Z(0.975) = 1.96. The calculated sample size was 96 patients. An additional 20% was added to minimize potential data collection errors.

$$n = \frac{z^2_{1-\frac{\alpha}{2}} p(1-p)}{d^2}$$

Data collection was conducted using a questionnaire consisting of three parts including 1) the questionnaire regarding personal and behavioral characteristics obtained during interviews with one research data collection assistant. Information included age, sex, marital status, education level, occupation, income, health insurance, comorbidities, duration of type 2 diabetes, smoking, alcohol consumption, cognitive screening results, and physical activity. Cognitive screening was performed using the Thai version of the Mini-Cog©, a brief cognitive screening test (Cronbach's α = 0.80) (20), with a score ≤ 3 indicating cognitive impairment. Physical activity data were collected using the Thai version of the Global Physical Activity Questionnaires (GPAQ) (Cronbach's α = 0.82) (21) which collected physical activity data in three categories: work-related activities, leisure-time activities, and transportation. The data were then converted into metabolic equivalents (METs) (21, 22), and categorized into different levels of physical activity (PAL): sedentary, light active, moderately active, very active, and extra active (23, 24). The study also evaluated total daily energy expenditure (TDEE), which represents the calories an individual burns in a day as well as their resting metabolism and physical activity. Estimated TDEE can be calculated using the formula TDEE = REE x PAL (23, 24). Resting Energy Expenditure (REE) represents the energy the body needs at rest. This study used the Mifflin St-Jeor equation to calculate REE which is widely used and considered accurate for estimating REE (25). This equation calculates REE based on weight, height, and age (26). PAL refers to physical activity level (24). 2) Medical characteristics data were obtained from medical records, including weight, height, waist circumference, blood pressure, fasting blood sugar (FBS), glycated hemoglobin (HbA1c) and diabetes treatment modalities. Anthropometric data (weight, height, and waist circumference) and blood pressure were measured by a clinic nursing assistant using the hospital's regularly calibrated standard tools. Blood pressure was taken with standard digital sphygmomanometers, while standing height and body weight were measured using a portable stadiometer and an electronic scale. Waist circumference was measured in centimeters at the midpoint between the lowest rib and the iliac crest using a standard non-elastic measuring tape. Abdominal obesity was defined as a waist circumference exceeding 90 cm in men and 80 cm in women (27). Glycemic control was determined according to ADA Guideline 2023 with a target HbA1c < 7%, while HbA1c ≥ 7% was considered to indicate poor glycemic control (28). 3) Dietary assessment was collected using a 24-hour dietary recall. The research assistant instructed participants to provide details about the name, type, and quantity of foods and beverages consumed within the previous 24 hours. To aid in this process, standard food exchange models and sample household containers were utilized, e.g., a 9-inch diameter plate or bowl, a 240 mL glass, measuring cup, teaspoon, tablespoon, etc. (29).

A certified dietitian analyzed the estimated daily total energy intake in kcal and interpreted the intake of macronutrients (carbohydrate, fat, and protein) in grams, converting them into calories and percentages using Microsoft Excel

(1 gram of carbohydrate and protein equals 4 kcal, and 1 gram of fat equals 9 kcal). The nutrition analysis was based on the Thai Food Composition Tables 2015 (30). There was only one dietitian in this study, so to prevent bias the dietitian was kept blinded to other data.

Statistical analysis was performed using Stata version 16.0 software (StataCorp, College Station, Texas, USA). For descriptive statistics, categorical data are presented as frequencies and percentages, while numerical data are presented as mean ± SD or median (IQR) depending on the underlying distribution. Factors and their association with poor glycemic control type 2 diabetes were analyzed using the independent t-test, Fisher's exact test, and the Mann-Whitney U test. A p-value of <0.05 was considered statistically significant.

RESULTS

In this study, 127 type 2 diabetic patients, with mean age of 66.23±7.34 years, were enrolled of whom 65.35% were aged 65 or older and 51.97% were female. Most were married (73.21%). The median personal monthly income was 18,000 Thai baht, and 44.88% had a bachelor's degree or higher. Furthermore, 87.40% of patients had more than one additional underlying disease, including hypertension (83.46%), dyslipidemia (96.85%), chronic kidney disease (14.17%), and osteoarthritis (7.87%). However, all patients had a good functional status, were not dependent, and did not have severe diseases or conditions limiting life expectancy. Among the patients, 94.49% showed no cognitive impairment on the Mini-Cog© test. The mean waist circumference was 87.68±9.79 cm and 61.42% had abdominal obesity. Few patients were currently alcohol drinkers (25.98%) or smokers (4.72%). The median duration of diabetes was 8 years, with a mean HbA1c level of 6.91±0.88%, and 40.16% of the patients had poor glycemic control. Most patients (88.19%) were currently taking medication for diabetes.

Table 1 presents a comparison of baseline characteristics between type 2 diabetic patients with poor and with good glycemic control. The mean HbA1c levels were 7.67 ± 0.61% and 6.39 ± 0.44% in the poor and good glycemic control groups, respectively (p < 0.001). Demographi-

Table 1. Comparison of general characteristics between poor and good glycemic control type 2 diabetic patients (n=127)

Factor	n (%)	DM treatment outcome: Poor glycemic control (n=51) n (%)	DM treatment outcome: Good glycemic control (n=76) n (%)	*p*-value
Personal characteristics				
Age (years) (mean±SD)	66.23±7.34	65.55±7.21	66.68±7.44	0.395[a]
Age < 65 years old	44 (34.65)	20 (39.22)	24 (31.58)	
Age ≥ 65 years old	83 (65.35)	31 (60.78)	52 (68.42)	0.448[c]
Sex				
Male	61 (48.03)	22 (43.14)	39 (51.32)	
Female	66 (51.97)	29 (56.86)	37 (48.68)	0.469[c]
Marital status				
Married	93 (73.21)	36 (70.59)	57 (75.00)	
Single, widow, divorce	34 (26.77)	15 (29.41)	19 (25.00)	0.683[c]
Education level				
Lower than bachelor's degree	70 (55.12)	31 (60.78)	39 (51.32)	
Bachelor's degree or higher	57 (44.88)	20 (39.22)	37 (48.68)	0.363[c]
Occupation				
Have a job	48 (37.80)	23 (45.10)	25 (32.89)	
No job/Pensioner	79 (62.20)	28 (54.90)	51 (67.11)	0.193[c]
Personal monthly income (Thai baht) (median (IQR))	18,000 (10000,32000)	20,000 (10000,30000)	17,883 (10,000,32,000)	0.819[b]
Health Insurance				
Government	121 (95.28)	50 (98.04)	71 (93.42)	
Non-government	6 (4.72)	1 (1.96)	5 (6.58)	0.400[c]

Table 1. Comparison of general characteristics between poor and good glycemic control type 2 diabetic patients (n=127) (continued)

Factor	n (%)	DM treatment outcome		*p*-value
		Poor glycemic control (n=51) n (%)	Good glycemic control (n=76) n (%)	
Medical characteristics				
Comorbidities				
Hypertension	106 (83.46)	39 (76.47)	67 (88.18)	0.093[c]
Dyslipidemia	123 (96.85)	49 (96.08)	74 (97.37)	1.000[c]
Chronic kidney disease	18 (14.17)	8 (15.69)	10 (13.16)	0.797[c]
Myocardial infarction	2 (1.57)	2 (3.92)	0 (0.00)	0.159[c]
Osteoarthritis	10 (7.87)	6 (11.76)	4 (5.26)	0.199[c]
Other (e.g., allergic rhinitis, dyspepsia, gout, benign prostate hyperplasia, etc.)	46 (36.22)	19 (37.25)	27 (35.53)	0.853[c]
> 1 other underlying disease	111 (87.40)	42 (82.35)	69 (90.79)	0.181[c]
Body weight (kg) (mean±SD)	64.14±11.89	64.76±11.01	63.72±12.49	0.628[a]
Height (cm) (mean±SD)	158.91±8.47	157.14±8.22	160.09±8.48	0.053[a]
Waist circumference (cm) (mean±SD)	87.68±9.79	87.41±10.91	87.03±10.25	0.840[a]
Abdominal obesity (Waist circumference ≥ 90 cm in male, ≥ 80 cm in female)	78 (61.42)	31 (60.78)	47 (61.84)	1.000[c]
Blood pressure (BP)				
BP < 140/90 mmHg	64 (50.39)	22 (43.14)	42 (55.26)	
BP ≥ 140/90 mmHg	63 (49.61)	29 (56.86)	34 (44.74)	0.208[c]
Cognitive screening by mini-Cog				
No cognitive impairment (mini-Cog > 3)	120 (94.49)	48 (94.12)	72 (94.74)	
Cognitive impairment (mini-Cog ≤ 3)	7 (5.51)	3 (5.88)	4 (5.26)	1.000[c]
Behavioral characteristics				
Current smoking	6 (4.72)	4 (7.84)	2 (2.63)	0.218[c]
Current alcohol drinking	33 (25.98)	15 (29.41)	18 (23.68)	0.538[c]
Physical activity (MET score) (median (IQR))	1120 (600,2520)	1120 (600,2880)	1120 (660,2060)	0.779[b]
Diabetes characteristics				
FBS (mg/dL)(mean±SD)	132.49±27.58	149.39±31.99	121.14±16.47	<0.001[a]
HbA1c (%)(mean±SD)	6.91±0.88	7.67±0.61	6.39±0.44	<0.001[a]
Duration of DM (years) (median (IQR))	8 (3,11)	9 (2,10)	8 (3,11)	0.816[b]
Diabetes treatment				
Lifestyle modification without any medication	15 (11.81)	6 (11.76)	9 (11.84)	
Medical treatment with lifestyle modification	112 (88.19)	45 (88.24)	67 (88.16)	1.000[c]
Type of medication treatment (single or combination regimen)				
Biguanide	108 (85.04)	44 (86.27)	64 (84.21)	0.805[c]
Sulfonylureas	34 (26.77)	17 (33.33)	17 (22.37)	0.220[c]
Thiazolidinedione	5 (3.94)	3 (5.88)	2 (2.63)	0.390[c]
DPP-4 inhibitor	48 (37.80)	20 (39.22)	28 (36.84)	0.853[c]
SGLT-2 inhibitor	4 (3.15)	2 (3.92)	2 (2.63)	1.000[c]
Insulin	1 (0.79)	0 (0.0)	1 (1.32)	1.000[c]

[a]Independent t-test, b Mann-Whitney U test, c Fisher's exact test

cally, there were no significant differences in age, sex, marital status, education level, occupation, personal monthly income, or health insurance between the two groups. Behaviorally, there were no significant differences in smoking, alcohol consumption, or physical activity. Additionally, no significant differences were found between the two groups in comorbidities, body weight, height, waist circumference, blood pressure, cognitive screening test results, duration of diabetes or type of diabetes treatment.

Table 2 presents a comparison of total energy intake and dietary composition. The mean daily energy intake was 1,640.21±495.92 kcal, with macronutrient intakes of 211.38±83.96 g/day of carbohydrate, 67.32±21.47 g/day of protein, and 58.29±22.36 g/day of fat, accounting for 51.25%, 16.56%, and 32.12%, respectively, of total consumption. More than half (51.97%) of the patients exceeded the recommended carbohydrate intake (carbohydrate intake > 50% total energy intake), 42.52% exceeded the recommended fat intake (fat intake > 30% total energy intake), and 47.27% had inadequate protein intake (protein intake < 1 g/kg/day). Regarding the association between dietary intake and glycemic control, the poor glycemic control group had a higher daily total energy intake and consumed a greater amount of carbohydrate and fat than the good glycemic control group. However, there were no significant differences in total energy intake (1702.63±503.48 kcal/day vs. 1598.32±489.65 kcal/day, ***p*** = 0.247), carbohydrate intake (222.78±89.98 g/day vs. 203.72±79.36 g/day, *p* = 0.211), protein intake (70.12±21.50 g/day vs. 65.44±21.38 g/day, *p* = 0.230), or fat intake (58.94±19.26 g/day vs. 57.86±24.33 g/day, *p* = 0.639) between the two groups.

DISCUSSION

This study aimed to evaluate and compare the daily total energy intake and macronutrient proportion consumption between type 2 diabetic patients with poor and good glycemic control in the OPD of Family Medicine at Maharaj Nakorn Chiang Mai Hospital, Thailand. The mean daily energy intake was 1,640.21±495.92 kcal, with 35.43% consuming above their TDEE. The mean proportion of consumption of each macronutrient that provides energy to the body included carbohydrate 51.25%, protein 16.56%, and fat 32.12%. Among the patients, 51.97%

Table 2. Comparison of daily total energy intake and macronutrient composition between poor and good glycemic control type 2 diabetic patients (n=127)

	n (%)	DM treatment outcome		*p*-value
		Poor glycemic control (n=51) n (%)	Good glycemic control (n=76) n (%)	
Total daily energy intake (TDEE) (kcal) (mean±SD)	1640.21±495.92	1702.63±503.48	1598.32±489.65	0.247[a]
Total energy intake ≤ TDEE	82 (64.57)	31 (60.78)	51 (67.11)	
Total energy intake > TDEE	45 (35.43)	20 (39.22)	25 (32.89)	0.571[c]
Carbohydrate (kcal) (mean±SD)	845.51± 335.85	891.14±359.93	814.89±317.44	0.211[a]
Carbohydrate (gm/day) (mean±SD)	211.38±83.96	222.78±89.98	203.72±79.36	0.211[a]
Carbohydrate intake < 130 g/day	15 (11.81)	3 (5.88)	12 (15.79)	
Carbohydrate intake ≥ 130 g/day	112 (88.19)	48 (94.12)	64 (84.21)	0.102[c]
Protein (kcal) (mean±SD)	269.26±85.87	280.47±85.99	261.74±85.54	0.230[a]
Protein (gm/day) (mean±SD)	67.32±21.47	70.12±21.50	65.44±21.38	0.230[a]
Protein intake ≥ 1 g/kg/day	67 (52.76)	30 (58.82)	37 (46.68)	
Protein intake < 1 g/kg/day	60 (47.27)	21 (41.18)	39 (51.32)	0.288[c]
Fat (kcal) (mean±SD)	524.63±201.24	530.47±173.33	520.71±219.01	0.790[a]
Fat (gm/day) (mean±SD)	58.29±22.36	58.94±19.26	57.86±24.33	0.790[a]
% Carbohydrate (mean±SD)	51.25±10.39	51.67±10.76	50.97±10.20	0.711[a]
≤ 50% total energy intake	61 (48.03)	22 (43.14)	39 (51.32)	
> 50% total energy intake	66 (51.97)	29 (56.86)	37 (48.68)	0.469[c]
% Protein (mean±SD)	16.56±2.91	16.65±2.97	16.50±2.88	0.774[a]
≥ 20% total energy intake	15 (11.81)	9 (17.65)	6 (7.89)	
< 20% total energy intake	112 (88.19)	42 (82.35)	70 (92.11)	0.159[c]
%Fat (mean±SD)	32.12±9.13	31.65±9.22	32.43±9.13	0.639[a]
≤ 30% total energy intake	73 (57.48)	26 (50.98)	47 (61.84)	
> 30% total energy intake	54 (42.52)	25 (49.02)	29 (38.16)	0.273[c]

[a]Independent t-test, [b]Mann-Whitney U test, [c]Fisher's exact test

consumed excess carbohydrates (> 50% total energy intake), 42.45% consumed excess fat (> 30% total energy intake), and 47.27% had inadequate protein intake (protein intake < 1 g/kg/day).

Energy intake is crucial for glycemic control. Reducing energy intake has been linked to improved glycemic control, either through direct restriction or by balancing energy (31). A high energy intake is related to poor glycemic control (6). This study found a mean energy intake of 1,640.21±495.92 kcal/day, similar to an Italian study (1,725±497 kcal/day) (7). Notably, 35.43% of patients in this study consumed more energy than they expended daily, which can lead to weight gain and increased blood glucose (6, 32). Even though it was not statistically significant, those with poor glycemic control had a tendency to consume more energy than those with good glycemic control, a finding which is consistent with a previous study (33). The lack of statistical significance in this study might be due to the small sample size. A larger sample size might enhance the ability to detect significant differences. Counseling and strategies for caloric restriction should be promoted for better glycemic management.

High carbohydrate intake substantially affects post-meal glucose levels which is correlated with hyperglycemia due to its conversion into glucose which elevates blood glucose levels, especially in diabetics (34). Although fat does not directly affect glucose levels, excessive fat intake can lead to weight gain and insulin resistance and can result in higher blood sugar levels (35). Although there is evidence suggesting that macronutrient intake (carbohydrate, fat, and protein) can affect glycemic control, studies in this area are still inconclusive (6, 36). A systematic review of previous studies found that carbohydrate-restricted diets result in short-term reductions in HbA1c levels (3-6 months), but that their effectiveness tends to decline over the longer term (12-24 months) (37). One study reported an association between high carbohydrate intake and poor glycemic control (17). However, the present study did not find a significant association: it only found that the group with poor glycemic control was more likely to consume higher amounts of carbohydrates and fats. This may be due to the small sample size. A larger sample size might enhance the ability to detect significant differences. This discrepancy with previous studies may be attributed to differences in sociodemographic factors and healthcare settings. In this study, the patients had higher levels of education and personal monthly income compared to those in previous studies. Regarding the healthcare setting, our Family Medicine OPD is located in a university hospital with comprehensive facilities and a multidisciplinary team. These factors may contribute to a more comprehensive and holistic approach to care and may more effectively encourage healthy dietary choices than in other primary care settings. Although protein intake has a minimal effect on blood glucose levels in healthy individuals, excessive protein consumption can lead to hyperglycemia in diabetic patients (9). One study reported that adequate protein and reduced carbohydrate intake are associated with weight loss and improved glycemic out come (38). Conversely, insufficient protein intake in diabetic patients, particularly in elderly individuals, can affect kidney function (GFR) (39) and can lead to sarcopenia (4). Sarcopenia, a gradual loss of muscle mass and strength which can increase the risk of fractures, is associated with frailty, disability, and death (40). However, similar to a previous study (6), this study did not find a significant association between protein intake and glycemic control. For that reason, it is necessary to evaluate and plan personalized dietary interventions for each diabetic patient, especially total energy intake and appropriate food proportions.

A strength of this study is that it included detailed information about dietary intake, including total caloric intake, carbohydrates, proteins, and fats, data which has been lacking in previous studies in Thailand. Another strength is that having only a single assistant to collect data helped to reduce inconsistencies in data collection and potential bias. Additionally, the expertise of a certified dietitian helped ensure the quality of dietary assessment results. However, there are also some limitations to this study. First, due to the cross-sectional design, the study was not able to confirm a causal relationship between dietary intake and glycemic control. Future research should use a cohort-based design to confirm causality. Second, there may have been some recall bias due to the high proportion of elderly patients, although that bias is likely to have been minimal as most of the patients had no cognitive impairment. The lack of statistical significance in some areas of this study may be due to the small sample size and the fact that the study population was restricted to patients at the OPD of Family Medicine, Maharaj Nakorn Chiang Mai Hospital, so the findings of the study may have limited generalizability. Future studies should include a larger and more diverse population to improve the generalizability.

CONCLUSION

A large proportion of the patients in this study consumed an excessive amount of food. Additionally, the group with poor glycemic control was more likely to consume a higher total energy intake as well as a greater proportion of carbohydrates and fat. Appropriate dietary control and management tailored to each patient's needs may be able to play an important role in improving nutritional status and glycemic control in diabetic patients.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Banday MZ, Sameer AS, Nissar S. Pathophysiology of diabetes: An overview. Avicenna J Med. 2020;10:174-88.
2. Saeedi P, Petersohn I, Salpea P, Malanda B, Karuranga S, Unwin N, et al. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. Diabetes Res Clin Pract. 2019;157:107843. PubMed PMID: 31518657
3. International Diabetes Federation. IDF Diabetes Atlas. 10th ed. Brussels, Belgium: International Diabetes Federation; 2021. p. 5-6.
4. Sakboonyarat B, Pima W, Chokbumrungsuk C, Pimpak T, Khunsri S, Ukritchon S, et al. National trends in the prevalence of glycemic control among patients with type 2 diabetes receiving continuous care in Thailand from 2011 to 2018. Sci Rep. 2021;11:14260. PubMed PMID: 34253809
5. Evert AB, Boucher JL, Cypress M, Dunbar SA, Franz MJ, Mayer-Davis EJ, et al. Nutrition Therapy Recommendations for the management of adults with diabetes. Diabetes Care. 2013;37(Supplement_1): S120-S43.
6. Kang HM, Kim DJ. Total energy intake may be more associated with glycemic control compared to each proportion of macronutrients in the korean diabetic population. Diabetes Metab J. 2012;36:300-6.
7. Rivellese AA, Boemi M, Cavalot F, Costagliola L, De Feo P, Miccoli R, et al. Dietary habits in type II diabetes mellitus: how is adherence to dietary recommendations? Euro J Clin Nutr. 2008;62:660-4.
8. Singh P, Kesharwani RK, Keservani RK. 6 - protein, carbohydrates, and fats: energy metabolism. In: Bagchi D, editor. Sustained energy for enhanced human functions and activity. Massachusett: Academic Press; 2017. p. 103-15.
9. Franz MJ. Protein: metabolism and effect on blood glucose levels. Diabetes Educ. 1997;23:643-51.
10. Ahn HJ, Han KA, Kwon HR, Min KW. The small rice bowl-based meal plan was effective at reducing dietary energy intake, body weight, and blood glucose levels in Korean women with type 2 diabetes mellitus. Korean Diabetes J. 2010;34:340-9.
11. Jia SS, Liu Q, Allman-Farinelli M, Partridge SR, Pratten A, Yates L, et al. The use of portion control plates to promote healthy eating and diet-related outcomes: a scoping review. Nutrients. 2022;14: 892. PubMed PMID: 35215542
12. Farvid MS, Homayouni F, Shokoohi M, Fallah A, Farvid MS. Glycemic index, glycemic load and their association with glycemic control among patients with type 2 diabetes. Eur J Clin Nutr. 2014;68:459-63.
13. Sheard NF, Clark NG, Brand-Miller JC, Franz MJ, Pi-Sunyer FX, Mayer-Davis E, et al. Dietary carbohydrate (amount and type) in the prevention

and management of diabetes: a statement by the American Diabetes Association. Diabetes Care. 2004;27:2266-71.

14. Sato J, Kanazawa A, Makita S, Hatae C, Komiya K, Shimizu T, et al. A randomized controlled trial of 130 g/day low-carbohydrate diet in type 2 diabetes with poor glycemic control. Clin Nutr. 2017;36: 992-1000.
15. Sievenpiper JL, Chan CB, Dworatzek PD, Freeze C, Williams SL. Nutrition therapy. Can J Diabetes. 2018;42(Supplement_1):S64-S79.
16. Institute of Medicine. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. Washington, DC: The National Academies Press; 2005. p. 1358.
17. Duangsanjun W, Panuthai S, Suwankruhasn N, Kosachunhanun N. Carbohydrate intake and hemoglobin A1C in older adults with type 2 diabetes mellitus. Nursing Journal CMU. 2022;49:122-33.
18. Daniel WW. Biostatistics: a foundation of analysis in the health sciences. New York: John Wiley&Sons. 1995. p. 180.
19. Gouda M, Matsukawa M, Iijima H. Associations between eating habits and glycemic control and obesity in Japanese workers with type 2 diabetes mellitus. Diabetes Metab Syndr Obes. 2018;11:647-58.
20. Trongsakul S, Lambert R, Clark A, Wongpakaran N, Cross J. Development of the Thai version of Mini-Cog, a brief cognitive screening test. Geriatr Gerontol Int. 2015;15:594-600.
21. Jaturapatporn D, Hathirat S, Manataweewat B, Dellow AC, Leelaharattanarak S, Sirimothya S, et al. Reliability and validity of a Thai version of the General Practice Assessment Questionnaire (GPAQ). J Med Assoc Thai. 2006;89:1491-6.
22. World Health Organization. Global Physical Activity Questionnaire (GPAQ) Analysis Guide Switzerland: World Health Organization [Internet]. 2019 [cited 2022 Apirl 8]. Available from: https://www.who.int/docs/default-source/ncds/ncd-surveillance/gpaq-analysis-guide.pdf?sfvrsn=1e83d571_2
23. Ravussin E, Bogardus C. Relationship of genetics, age, and physical fitness to daily energy expenditure and fuel utilization. Am J Clin Nutr. 1989; 49(Supplement_5):968-75.
24. United Nations University, World Health Organization. Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation: Rome, 17-24 October 2001. Rome, IT: FAO; 2004. p. 35-50.
25. Frankenfield DC. Bias and accuracy of resting metabolic rate equations in non-obese and obese adults. Clin Nutr. 2013;32:976-82.
26. Mifflin MD, St Jeor ST, Hill LA, Scott BJ, Daugherty SA, Koh YO. A new predictive equation for resting energy expenditure in healthy individuals. Am J Clin Nutr. 1990;51:241-7.
27. Tham KW, Abdul Ghani R, Cua SC, Deerochanawong C, Fojas M, Hocking S, et al. Obesity in South and Southeast Asia-A new consensus on care and management. Obes Rev. 2023;24:e13520. PubMed PMID: 36453081
28. ElSayed NA, Aleppo G, Aroda VR, Bannuru RR, Brown FM, Bruemmer D, et al. 13. older adults: standards of care in diabetes—2023. Diabetes Care. 2022;46(Supplement_1):S216-S29.
29. Diabetes Association of Thailand. Carbohydrate counting for health and diabetes control. 3rd ed. Bangkok: Diabetes Association of Thailand under The Patronage of Her Royal Highness Princess Maha Chakri Sirindhorn; 2019.
30. Puwastien P, Judprasong K, Sridonpai P, Saiwan T. Thai food composition tables 2015. 2nd ed. Nakhon Pathom: Institute of Nutrition, Mahidol University (INMU); 2015. p. 312.
31. Heilbronn LK, Noakes M, Clifton PM. Effect of energy restriction, weight loss, and diet composition on plasma lipids and glucose in patients with type 2 diabetes. Diabetes Care. 1999;22:889-95.
32. Romieu I, Dossus L, Barquera S, Blottière HM, Franks PW, Gunter M, et al. Energy balance and obesity: what are the main drivers? Cancer Causes Control. 2017;28:247-58.
33. Thewjitcharoen Y, Chotwanvirat P, Jantawan A, Siwasaranond N, Saetung S, Nimitphong H, et al. Evaluation of dietary intakes and nutritional knowledge in Thai patients with type 2 diabetes mellitus. J Diabetes Res. 2018;2018:9152910. PubMed PMID: 30671482
34. Westman EC. Type 2 diabetes mellitus: a pathophysiologic perspective. Front Nutr. 2021;8:707371. PubMed PMID: 34447776
35. Riccardi G, Giacco R, Rivellese AA. Dietary fat, insulin sensitivity and the metabolic syndrome. Clin Nutr. 2004;23:447-56.
36. Sami W, Ansari T, Butt NS, Hamid MRA. Effect of diet on type 2 diabetes mellitus: A review. Int J Health Sci (Qassim). 2017;11:65-71.
37. Sainsbury E, Kizirian NV, Partridge SR, Gill T, Colagiuri S, Gibson AA. Effect of dietary carbohydrate restriction on glycemic control in adults with diabetes: A systematic review and meta-analysis. Diabetes Res Clin Pract. 2018;139:239-52.
38. Layman DK, Baum JI. Dietary protein impact on glycemic control during weight loss. J Nutr. 2004; 134:968S-73S.
39. Yamaoka T, Araki A, Tamura Y, Tanaka S, Fujihara K, Horikawa C, et al. Association between low protein intake and mortality in patients with type 2 diabetes. Nutrients. 2020;12:1629. PubMed PMID: 32492838
40. Huh Y, Son KY. Association between total protein intake and low muscle mass in Korean adults. BMC Geriatr. 2022;22:319. PubMed PMID: 35410179