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ORIGINAL RESEARCH

Association Between Dietary Habits and Type 2 Diabetes Mellitus in Thai Adults: A Case-Control Study

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Background: The prevalence of T2DM is escalating in Thailand affecting over 10% of adults aged 20–79 years old. It is imperative to identify modifiable risk factors that can potentially help mitigate the risk of developing diabetes.

Objective: This study aimed to investigate the relationship between dietary habits and type 2 diabetes in Chiang Mai, Thailand.

Methods: This case-control study involved 300 individuals aged 25–74 years residing in Chiang Mai, Thailand including 150 newly diagnosed T2DM patients (cases) and 150 community residents without diabetes (controls). Dietary habits were assessed based on Food Frequency Questionnaire (FFQ). Socio-demographic characteristics and anthropometric information of the participants were collected. Data analysis was performed using the STATA-17.

Results: The case group participants were older and had a higher proportion of males compared to the control group. The case group exhibited a significantly higher consumption of meat, beans, nuts, soft drinks, and topping seasonings ($p<0.001$), conversely, a lower intake of vegetables ($p<0.001$), fruits ($p=0.006$), fish, rice ($p<0.001$), eggs ($p=0.032$), milk products, coffee, and tea ($p<0.001$) compared to the control group. Furthermore, the case group demonstrated a higher level of certain dietary practices such as a greater frequency of having meals with family, not removing visible fat from food ($p<0.001$), and eating snacks between meals compared to controls. Multiple logistic regression analysis showed that after adjusting for potential confounding factors not removing visible fat from food (aOR 5.61, 95% CI: 2.29–13.7, $p<0.001$) and using topping seasonings (aOR 3.52 95% CI: 1.69–7.32 $p=0.001$) were significantly associated with the risk of T2DM, whereas daily vegetable intake (aOR 0.32 95% CI: 0.15–0.68 $p=0.003$) was inversely associated with T2DM.

Conclusion: The study findings caution against the consumption of food rich in fat and using salty seasonings, while advocating for an increased intake of vegetables to prevent the prevalence of T2DM.

Keywords: Thailand, T2DM, dietary habits, food frequency questionnaire, diabetes prevention, global health

Introduction

Type 2 Diabetes Mellitus (T2DM) is a common non-communicable disease and its upward trend is one of the major concerns in Global Health. Worldwide, the prevalence of diabetes was approximately 537 million (1 in 10 adults 20–79 years) in 2021 and is expected to increase to 643 million by 2030 and 783 million by 2045 (International Diabetes Federation; IDF).[1] The majority of diabetes patients are living in low- and middle-income countries; in 2030, 69% of the incidence of diabetes mellitus will occur in the developing world.[2,3] Thailand, an upper-middle-income country in Southeast Asia,[4] has an age-adjusted prevalence of diabetes of around 10% of the adult population aged 20–79 years (10.8% in women and 8.9% in men).[5] The number of Thai people with diabetes is estimated to reach 5.3 million in 2040 according to the IDF; which means one out of every five people aged over 60 years will be diabetic.[6] Despite

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improvement in the diabetes detection rate and treatment in Thailand, glycaemic control remains sub-optimal and complications due to diabetes are still prevalent.[7]

Diabetes refers to complex metabolic disorders characterized by hyperglycemia and develops with deficiencies in insulin secretion, and/or insulin action commonly known as insulin resistance.[8] The etiology of T2DM is linked to modifiable lifestyle habits such as an energy-dense diet and less physical activity.[9] A Cluster Randomized Controlled Trial shows that changes in dietary habits and physical activity can reduce the incidence of T2DM by 50% among people with impaired glucose tolerance.[10] Previous studies on the relationship between dietary patterns and T2DM have identified that diets rich in meat, high-fat foods, and refined carbohydrates such as sweets and desserts are linked to the elevated risk of metabolic syndrome and its components including T2DM.[11,12] Studies conducted in Korea and Japan have reported the association of carbohydrate-rich food with diabetes.[13,14] High intake of red meat has also been associated with an increased risk of diabetes.[15] Conversely, adopting certain diets such as the Mediterranean diet which is mainly composed of raw vegetables, fish, whole grains, nuts, and beans has been reported to be associated with a protective effect against diabetes and metabolic syndrome.[16,17] Based on the evidence, dietary behaviors such as skipping breakfast, speed eating, and eating alone are associated with obesity and T2DM.[18–20]

A sedentary lifestyle, low consumption of fruits and vegetables, and high consumption of added sugar are common among Thai people.[21] Northern Thailand is known for its distinctive cultures and lifestyles, which encompass unique cooking practices. The staple food is sticky rice and oily noodles consumption is also widespread.[22] In recent years, the northern region has been labeled as having the highest percentage of citizens over 60 years and having one of the highest prevalence of diabetes mellitus in Thailand, while its economic status ranks lower compared to the central and southern regions.[23]

Since dietary behavior is based on individual lifestyle choices, such as food selection, frequency, and intake schedule, establishing further evidence and understanding the mechanism is crucial for designing interventions and programs aimed at improving dietary patterns. Despite the importance of nutritional behaviors and dietary patterns as modifiable risk factors in the prevention and control of diabetes, they have been only marginally evaluated in Thailand. In this study, we aimed to identify the prevailing dietary habits and their relationship with the prevalence of T2DM in adult residents in Chiang Mai, Northern Thailand. The present study will contribute to filling the knowledge gap in the existing literature and its findings can assist policy designs that aim at nutritional behavior change, thereby reducing the social and economic burden of this disease.

Materials and Methods

Study Design and Setting

This observational study applied a case-control design conducted in 2019–2020; recruiting 300 participants (150 cases and 150 controls) aged 25–74 years and residing in Sanpatong district, Chiang Mai province, Thailand.

Eligibility Criteria for Case and Control Groups

Case group definition: T2DM patients who were newly diagnosed within 6 months before data collection and attending the diabetes clinic of Sanpatong District Hospital. According to the Thailand National Guideline for Diabetes, diagnostic criteria for T2DM diagnosis are fasting plasma glucose level ≥126 mg/dL and/or 2 hours Oral Glucose Tolerance Test (OGTT) ≥200 mg/dL.

Control group definition: control group participants were recruited from one of the primary care settings under Sanpatong District Hospital and gave informed consent to become part of the study. Controls were confirmed as non-diabetes participants after obtaining negative results from a plasma glucose test, which is a common screening method for diabetes (Table 1).

Sample Size

In the current study, the sample size was calculated based on the findings of "Sociodemographic differences affecting insufficient fruit and vegetable intake: a population-based household survey of Thai people".[24] The survey reported that the overall prevalence of insufficient fruit and vegetable intake (FV) was 65.6% among respondents. Therefore, we assumed diabetes patients had fewer FV intake per day and the proportion of exposure to the risk factor was 75% in the case group. Assuming that people without diabetes had a higher rate of FV intake, we set the proportion of exposure for the control group as 55%. The formula for the unmatched case-control study was utilized with a power of 80% and a confidence interval (CI) of 95%.[25] The sample size was calculated using the following formula:

Table 1 Inclusion and Exclusion Criteria for Study Participants

	Case	Control
Inclusion	25–74 years old; either sex	25–74 years old; either sex
	Residents of Chiang Mai province	Residents of Chiang Mai province
	All races and religions	All races and religions
	Diagnosed as T2DM within 6 months before data collection	Residents who are not diabetes (excluded based on blood glucose screening test)
	Diagnosed according to fasting plasma glucose level ≥126 mg/dL (7.0mmol/L) or two hours OGTT level ≥200 mg/dL (11.1 mmol/L)	
Exclusion	Non-residents of Chiang Mai, neither foreigners nor tourists	Non-residents of Chiang Mai, neither foreigners nor tourists
	Who is not able to undertake an interview and measurements personally and/or not willing to participate	Who is not able to undertake an interview and measurements personally and/or not willing to participate
	In a long-term modification of diet	Those diagnosed with chronic diseases like kidney failure

Abbreviation: OGTT, Oral Glucose Tolerance Test.

$$\text{Sample size} = \frac{r+1}{r}\,\frac{(p*)(1-p*)(Z\beta + Z\alpha/2)2}{(p1-p2)2}$$

Data Collection

A face-to-face interview was conducted by primary health care nurses after obtaining written informed consent from all participants. The standardized questionnaire included demographic characteristics (age, sex, occupation, marital status), anthropometric measurements (height, weight, BMI), and behavioral factors (tobacco use, alcohol consumption, physical activity knowledge) (Tables 2 and 3). Participants were requested to recall their last week's eating habits to answer the dietary habits questions (Tables 4 and 5). The survey instrument and consent cover letter were translated into Thai according to the WHO guidelines on translation.[26] To confirm the accuracy, the translated questionnaire was revised by native experts.

Measurements

Dietary Habits Assessment

The Food Frequency Questionnaire (FFQ) was used to gather information on the dietary habits of research subjects.[27] This questionnaire has been used widely to estimate the daily food intake frequency over a certain period of time. The food items: rice,

Table 2 Socio-Demographic Characteristics of the Participants

	Control (n= 150) n (%)	Case (n= 150) n (%)	Value χ^2	*p*-value
Sex			7.1	0.008**
Male	41 (27.3)	63 (42.0)		
Female	109 (72.7)	87 (58.0)		
Age			1.9	0.165
Under 60 years	85 (56.7)	73 (48.7)		
60 years and older	65 (43.3)	77 (51.3)		

(*Continued*)

Table 2 (Continued).

	Control (n= 150) n (%)	Case (n= 150) n (%)	Value χ^2	*p*-value
Level of education			1.3	0.262
No formal schooling	19 (12.7)	13 (8.7)		
Primary, Secondary, or High school completed	131 (87.3)	137 (91.3)		
Marriage status			0.8	0.676
Single	13 (8.7)	16 (10.6)		
Divorce	30 (20.0)	25 (16.7)		
Currently married	107 (71.3)	109 (72.7)		
Work status over the past 12 months			2.6	0.109
Employed	95 (63.3)	108 (72.0)		
Unemployed	55 (36.7)	42 (28.0)		
Average household monthly income (Baht/monthly)[a]			12.7	<0.001***
<12,842	108 (72.0)	78 (52.0)		
≥12,842	42 (28.0)	71 (48.0)		
BMI			0.6	0.751
<22	39 (26.0)	42 (28.0)		
22–25	49 (32.7)	43 (28.7)		
>25	62 (41.3)	65 (43.3)		
High Waist Circumference			1.2	0.282
No	60 (40.3)	51 (34.0)		
Yes	89 (59.7)	99 (66.0)		

Notes: Chi-square test was used to compare categorical variables; %: ratio of valid responses; *p*-value for the comparison between two groups: ***$p<0.001$, **$p<0.01$. All *p*-values are two-sided. [a]The mean of valid responses was used as a cut-off point for average monthly household income. There is 1 missing value for the average household monthly income. High Waist Circumference is defined as a waist ≥ 90 cm for males and a waist ≥ 80 cm for females. 1 missing data in the control group for high waist circumference.

Table 3 Lifestyle-Related Behaviors of the Participants

	Control (n=150) n (%)	Case (n=150) n (%)	Value χ^2	*p*-value
Family history of diabetes			19.0	<0.001***
No	128 (85.3)	95 (63.3)		
Yes	22 (14.7)	55 (36.7)		
Medication for T2DM			292.1	<0.001***
No	150 (100)	2 (1.3)		
Yes	0	148 (98.7)		

(Continued)

Table 3 (Continued).

	Control (n=150) n (%)	Case (n=150) n (%)	Value χ^2	*p*-value
Hypertension			103.4	<0.001***
No	122 (81.3)	34 (22.7)		
Yes	28 (18.6)	116 (77.3)		
Physical activity knowledge			26.0	0.001**
No	31 (20.7)	3 (2.0)		
Yes	119 (79.3)	147 (98.0)		
Alcohol consumption			32.3	0.001**
Never	58 (38.7)	105 (70.0)		
Quit	34 (22.7)	10 (6.7)		
Regularly drinking	58 (38.7)	35 (23.3)		
Smoking			0.5	0.775
Never	110 (73.3)	112 (74.7)		
Ex-smoker	23 (15.3)	19 (12.7)		
Current smoker	17 (11.3)	19 (12.7)		

Notes: Chi-square test was used to compare categorical variables; %: ratio of valid responses; *p*-value for the comparison between two groups: ***$p<0.001$, **$p<0.01$. All *p*-values are two-sided. Those who had taken medicine to treat raised blood pressure during the past two weeks were categorized as hypertensive.

Table 4 Comparison of Food Intake by High-Frequency Analysis Between Diabetes and Non-Diabetes Participants

	Control (n=150) n (%)	Case (n=150) n (%)	Value χ^2	p-value
Rice	149 (99.3)	100 (66.7)	56.7	<0.001***
Bread	7 (4.7)	6 (4.0)	0.1	0.777
Noodles	2 (1.3)	0	2.0	0.156
Meat	39 (26.0)	46 (30.7)	0.8	0.370
Fish	9 (6.0)	6 (4.0)	0.6	0.427
Egg	28 (18.7)	15 (10.0)	4.6	0.032*
Beans	0	2 (1.3)	2.0	0.157
Nuts	0	1 (0.7)	1.0	0.317
Diary milk product	15 (10.0)	9 (6.0)	0.2	0.202
Non-dairy milk product	8 (5.3)	6 (4.0)	0.3	0.593
Deep fried food	48 (32.0)	1 (0.7)	54.3	<0.001***
Stir-fried food	55 (36.7)	4 (2.7)	54.9	<0.001***
Vegetables (every day)	104 (69.3)	71 (47.3)	14.9	<0.001***

(*Continued*)

Table 4 (Continued).

	Control (n=150) n (%)	Case (n=150) n (%)	Value χ^2	p-value
Vegetables ≥ 3 servings/a day	27 (20.5)	105 (79.5)	82.3	<0.001***
Fruits (every day)	57 (38.0)	35 (23.3)	7.6	0.006**
Fruits ≥ 3 servings/a day	24 (16.0)	58 (38.7)	19.4	<0.001***
Seasonings	54 (36.0)	85 (56.7)	12.9	<0.001***
Fermented food and pickles	15 (10.0)	11 (7.3)	0.7	0.412
Dessert	4 (2.7)	3 (2.0)	0.1	0.702
Soft drinks	16 (10.7)	21 (14.0)	0.8	0.380
Coffee and/or tea	69 (46.0)	32 (21.3)	20.4	<0.001***
Fresh fruit juice everyday	2 (1.3)	0	2.0	0.156
Taking Supplements	4 (2.7)	8 (5.3)	1.4	0.239

Notes: Chi-square test was utilized to compare categorical variables; High frequency: eating every day, %: ratio of valid responses; *p*-value for the comparison between two groups: ****p*<0.001, ***p*<0.01, **p*<0.05. All *p*-values are two-sided. Beans 1 missing data, Deep fried food 1 missing data.

Table 5 Comparison of Dietary Behaviours by High Frequency Between Diabetes and Non-Diabetes Participants

	Control (n=150) n (%)	Case (n=150) n (%)	Value χ^2	p-value
Three meals a day	136 (90.7)	128 (85.3)	2.0	0.155
Breakfast skipping	62 (41.3)	32 (21.3)	13.9	<0.001***
Having meals with family	99 (66.0)	106 (70.7)	0.5	0.482
Cooking by yourself	109 (72.7)	108 (72.0)	0.0	0.897
Not removing visible fat	93 (62.0)	134 (89.3)	30.4	<0.001***
Eating out	12 (8.0)	12 (8.0)	0.0	0.986
Snacking between meals	4 (2.7)	8 (5.3)	1.4	0.239

Notes: Chi-square test was utilized to compare categorical variables; High frequency: eating every day, %: ratio of valid responses; *p*-value for the comparison between two groups: ****p*<0.001. All *p*-values are two-sided. Eating out 3 missing data (2 control 1 case), Having meals with family 2 missing data (control group).

noodles, meat, dairy products, beans, eggs, fish, seasonings, dessert, soft drinks, coffee or tea, fruit, and vegetables were selected based on the Association of Southeast Asian Nations (ASEAN) food composition table[28] and local common foods (Table 4). Questions asked also included portion sizes for different foods and eating behaviors: having three meals in a day, skipping breakfast, consuming a snack between meals, having meals with family, and eating out (Table 5). To estimate the frequency of dietary habits all respondents were asked to classify their daily food item intake by choosing the different time patterns from "never or rarely" to "every day".

Sociodemographic and Health Data

Data included sociodemographic characteristics, lifestyle-related questions, and medical test results. Anthropometric measurements were taken by trained investigators using the WHO STEPS protocol.[29] Blood samples were obtained from participants after fasting for at least 8 hours. Persons with fasting plasma glucose levels <110 mg/dL were selected as the control group. The surveys were comprised of information about age, gender, education level, employment rate, residing area, marital status, received knowledge related to nutrition, behavioral choices on food consumption, family history of diabetes, hypertension, and current medication use.

Statistical Analysis

Data in categorical variables were assessed by applying the chi-square test. Study participants were classified into two categories by age (<60 and ≥60 years old) and three categories by BMI (<22, 22–25, >25). The monthly household income level was classified into two groups based on the mean of valid responses (<12,842 and ≥12,842 Thailand Baht). The statistical significance level was considered at $P<0.05$ and a confidence interval (CI) of 95% with 80% power. Food intake frequency and dietary behavior were categorized as dichotomous categorical variables based on high frequency and low frequency. High frequency was defined as daily intake, while low frequency encompassed categories such as completely avoiding or very rarely consuming (1–2 times/week, 3–4 times/week, 5–6 times/week). We used univariate logistic regression analysis to identify factors associated with T2DM. Multivariable logistic regression models were constructed to adjust for potential confounders in the association between dietary habits and T2DM. The dependent variable was diabetes status as binary data and the independent variables were age, sex, BMI, employment status, household monthly income levels, hypertension, family history of diabetes, alcohol consumption, and dietary habits including food intake and eating behavior. All analyses were performed using the STATA version 17.0 (Stata Corp, College Station, TX, USA).

Ethical Approval

The present study was approved by the Ethical Review Committee for Research on Human Participants, Chiang Mai Provincial Health Office, and the Ethical Review Board of the Juntendo University, Tokyo (authorization number 2017141). The present study was conducted according to the guidelines in the Declaration of Helsinki.

Results

In this study, we analyzed the data collected from a sample of 300 participants consisting of 150 T2DM patients and 150 non-diabetes participants in Chiang Mai, Thailand. Table 2 shows the demographic and social characteristics of the participants. From examining the proportion of the age, it was found that the case group has a higher percentage (51.3%) compared to the control group (43.3%) of individuals 60 years old and above. The number of males was greater in cases (n=63, 42.0%) compared to controls (n=41, 27.3%) ($P=0.008$). In the case group, a larger proportion of participants were employed (72.0%) and had higher monthly income levels (48.0%) ($P<0.001$). Marital status, level of education, BMI, and HWC did not make a significant difference between the two groups.

The case group included a larger percentage of participants with a family history of diabetes ($P<0.001$), hypertension ($P<0.001$), and a lower percentage of participants with alcohol consumption ($P=0.001$, chi-square test) than the control group. Almost all participants in the case group (98.7%) were taking medicine for T2DM treatment during the data collection period, whereas, no one in the control group was on medication (Table 3).

Table 6 and Figure 1 show the knowledge related to nutrition among participants. Table 6 shows that in the case group, significantly more participants (95.3%) had received nutrition knowledge compared to controls (73.3%) (p<0.001, chi-square test). Figure 1 shows the sources of nutrition knowledge received by all participants in both case and control

Table 6 Knowledge Related to Nutrition

Have You Received Knowledge Related to Nutrition?	Control (n=150) n (%)	Case (n=150) n (%)	Value χ^2	P-value
Yes	110 (73.3)	143 (95.3)	27.5	<0.001***
No	40 (26.7)	7 (4.7)		

Notes: Chi-square test was used to compare categorical variables; %: ratio of valid responses; *p*-value for the comparison between two groups: ****p*<0.001.

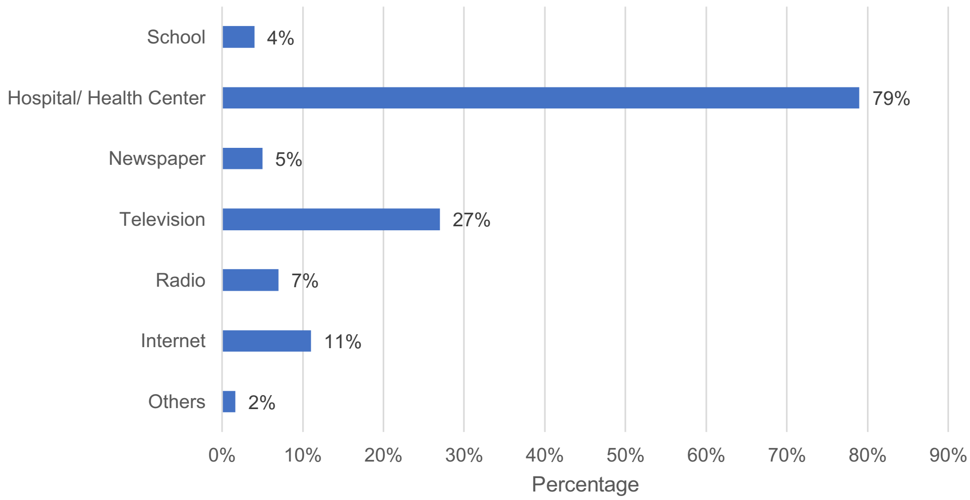

Figure 1 The sources of nutrition knowledge received by participants.
Note: Sources are not mutually exclusive.

groups. The majority of the individuals had received knowledge at a hospital and health centers. Some participants had obtained knowledge related to nutrition from the television, internet, radio, school, and newspapers.

Table 4 shows the comparison of food intake frequency analysis, the intake frequency of meat, beans, topping seasonings (such as salt, and soy sauce), and soft drinks was higher in the case group than in the control group. Conversely, the intake frequency of rice, fish, eggs, vegetables, and fruits daily was lower in the case group than in the control group.

Table 5 shows the comparison of the dietary behaviors by high frequency between diabetes and non-diabetes participants. The frequency of having meals with family, not removing visible fat from food (pork, chicken), and eating snacks between meals was higher in the case group than in the control group.

Table 7 shows the relationship between a high food intake frequency and T2DM by univariate and multivariable logistic regression analysis. Statistically significant association of variables such as skipping breakfast, eggs, deep-fried food, and stir-fried food to the outcome remain significant after adjusting with age, sex, and BMI.

Table 8 shows results from multiple logistic regression models. Not removing visible fat from food (aOR 5.61, 95% CI 2.29–13.70), and topping seasonings (aOR 3.52, 95% CI 1.69–7.32) were associated with a higher risk of T2DM, whereas daily vegetables (aOR 0.32, 95% CI 0.15–0.68) and fruits (aOR 0.95, 95% CI 0.43–2.11) intake were associated with lower risk of T2DM.

Table 7 Factors Associated with Diabetes Through Logistic Regression Analysis

Variable	Total n=300	Control n=150	Case n=150	Univariate Analysis		Multivariable Analysis	
		n (%)	n (%)	OR (95% CI)	p-value	OR (95% CI)	p-value
Breakfast skipping	94	62 (41.3)	32 (21.3)	0.40 (0.22–0.66)	<0.001	0.41 (0.24–0.69)	0.001
Not removing visible fat	227	93 (62.0)	134 (89.3)	5.13 (2.78–9.49)	<0.001	5.17 (2.76–9.70)	<0.001
Rice every day	249	149 (99.3)	100 (66.7)	0.01 (0.00–0.08)	<0.001	0.01 (0.00–0.09)	<0.001
Egg every day	43	28 (18.7)	15 (10.0)	0.48 (0.23–0.99)	0.032	0.50 (0.25–0.99)	0.048
Deep fried food	49	48 (32.0)	1 (0.7)	0.01 (0.00–0.08)	<0.001	0.01 (0.00–0.09)	<0.001
Stir-fried food	59	55 (36.7)	4 (2.7)	0.05 (0.01–0.13)	<0.001	0.05 (0.02–0.13)	<0.001
Vegetable every day	175	104 (69.3)	71 (47.3)	0.40 (0.24–0.65)	<0.001	0.42 (0.26–0.67)	<0.001

(*Continued*)

Table 7 (Continued).

Variable	Total n=300	Control n=150	Case n=150	Univariate Analysis		Multivariable Analysis	
		n (%)	n (%)	OR (95% CI)	p-value	OR (95% CI)	p-value
Vegetables ≥ 3 servings/a day	132	27 (18.0)	105 (70.0)	10.60 (6.17–18.3)	<0.001	10.53 (6.06–18.3)	<0.001
Fruit every day	92	57 (38.0)	35 (23.3)	0.50 (0.29–0.84)	0.006	0.56 (0.33–0.95)	0.031
Fruits ≥ 3 servings/a day	82	24 (16.0)	58 (38.7)	3.31 (1.86–5.98)	<0.001	3.29 (1.88–5.72)	<0.001
Seasonings	139	54 (36.0)	85 (56.7)	2.32 (1.46–3.70)	<0.001	2.25 (1.40–3.61)	0.001
Coffee and/or tea	101	69 (46.0)	32 (21.3)	0.32 (0.18–0.54)	<0.001	0.33 (0.19–0.56)	<0.001

Notes: Controlled by adjusting for Age, Sex, and BMI.

Table 8 Dietary Habits Associated with T2DM Among the Adult Residents of Chiang Mai, Thailand

Association of Dietary Habits to T2DM				
Dietary Behaviour/ Food Type	**OR**	**aOR**	**95% CI**	**p-value**
Not Removing visible fat				
Crude	5.13		2.69–10.10	<0.001***
Model 1		5.18	2.76–9.70	<0.001***
Model 2		5.35	2.36–12.10	<0.001***
Model 3		5.61	2.29–13.70	<0.001***
Vegetables every day				
Crude	0.40		0.24–0.65	<0.001***
Model 1		0.42	0.26–0.67	<0.001***
Model 2		0.31	0.16–0.62	0.001**
Model 3		0.32	0.15–0.68	0.003**
Fruits every day				
Crude	0.50		0.29–0.84	0.006**
Model 1		0.56	0.33–0.95	0.030*
Model 2		0.70	0.35–1.41	0.320
Model 3		0.95	0.43–2.11	0.910
Seasonings				
Crude	2.32		1.42–3.79	<0.001***
Model 1		2.25	1.40–3.61	0.001**
Model 2		2.19	1.15–4.16	0.017*
Model 3		3.52	1.69–7.32	0.001**

Notes: Multiple Logistic Regression Analysis; Crude: unadjusted; *p*-value: ***$p<0.001$, **$p<0.01$, *$p<0.05$. Model 1: adjusted for age, sex. Model 2: Model 1 + BMI, Occupation status, Household monthly income level, Hypertension, Family history of diabetes, Alcohol consumption. Model 3: Model 1 + Model 2+ not removing visible fat/ vegetables/ fruits/ seasonings.
Abbreviations: OR, odds ratio; aOR, adjusted odds ratio; CI, confidence interval.

Discussion

This study identified dietary habits and assessed the association between T2DM in Northern Thailand. Our results revealed that an increased prevalence of T2DM was linked to dietary practices such as not removing visible fat from food or only partially removing it before eating (Table 8). Moreover, using seasonings on a daily basis was significantly associated with T2DM risk, and daily vegetable and fruit intake was found to have a protective effect against T2DM (Table 8). The northern region of Thailand has been reported to have one of the highest prevalence of diabetes mellitus among other regions where the culinary practice is popular with the consumption of sticky rice and oily foods.[23]

A descriptive analysis of socio-demographic characteristics and lifestyle behaviors showed the case group consisted of more male participants and had higher household income compared to controls (Table 2). These findings are consistent with previous studies reported that T2DM is more frequently diagnosed in men.[30] Regarding the risk factors of diabetes, the case group had a higher proportion of family history of diabetes (36.7%) and elevated blood pressure (77%) (Table 3). A family history of diabetes and hypertension has long been recognized as a potent risk factor for the development of T2DM.[31,32] In terms of alcohol consumption, the case group participants reported a lower percentage of alcohol drinking which might be the result of the active promotion of education related to health risk factors among diabetes patients (Table 3). Both case and control groups received physical activity and nutrition knowledge with the dominance of “cases” (Tables 3 and 6). The dietary habits of the participants revealed the statistically significant difference between diabetes and non-diabetes groups by intake frequency of rice, eggs, deep-fried food, stir-fried food, vegetables, fruits, seasonings, and coffee/tea (Table 4) as well as dietary practice eg skipping breakfast and not removing visible fat from food (Table 5).

Our findings indicate a significant association between the habit of not removing visible fat from food and an increased risk of T2DM (Tables 7 and 8 Crude: 5.13 CI 2.69–10.1; Model 1: aOR 5.18 CI 2.76–9.70, Model 2: aOR 5.35 CI 2.36–12.1, Model 3: aOR 5.61 CI 2.29–13.7). These results are consistent with previous research demonstrating that excessive fat intake, particularly when combined with other lifestyle factors, can contribute to the development of T2DM.[33] The association between visible fat intake and T2DM risk can be understood through several mechanisms. Firstly, high-fat diets, including those containing visible fat, have been linked to weight gain and obesity, which are well-established risk factors for T2DM.[33] Excess body weight, especially visceral adiposity, contributes to insulin resistance, a key pathophysiological feature of T2DM.[34]

The role of dietary fat in T2DM is still being studied, and the evidence is not entirely conclusive. Some studies have suggested a positive association between a higher intake of saturated fats, typically found in animal products and certain tropical oils, and an increased risk of T2DM.[35] However, other studies found no significant association between them.[36] It is worth noting that the impact of visible fat intake on T2DM risk should be considered within the context of overall diet quality. The consumption of visible fat alone may not fully explain the association with T2DM. Diets high in processed foods, sugary beverages, and unhealthy fats are consistently associated with an increased risk of T2DM, while diets rich in whole foods, fruits, vegetables, lean proteins, and healthy fats have been shown to lower the risk.[37] Therefore, the overall dietary pattern should be taken into account when assessing the relationship between visible fat intake and diabetes risk. Individual variations also play a role in the association between visible fat intake and T2DM. Genetic, environmental, and lifestyle factors influence an individual`s response to dietary fat intake.[38] Moreover, the impact of visible fat consumption on T2DM risk may vary depending on an individual`s metabolic health, physical activity levels, and other contextual factors.[35] Regular physical activity plays a crucial role in the prevention of T2DM by enhancing metabolic health and reducing the overall risk associated with dietary habits.[39]

We found a significant positive association between salt intake, particularly in the form of salty seasonings like salt and different types of sauces, and the risk of T2DM (Tables 7 and 8 Crude: 2.32 CI 1.42–3.79; Model 1: aOR 2.25 CI 1.40–3.61, Model 2: aOR 2.19 CI 1.15–4.16, Model 3: aOR 3.52 CI 1.69–7.32). Our findings align with previous research conducted in different countries, advocating the notion that excessive sodium consumption may contribute to an increased risk of T2DM.[40,41] Several mechanisms may explain the association between excessive salt intake on the development of T2DM, including the effects of high salt consumption on blood pressure, insulin resistance, and pancreatic function.[42,43] High dietary salt intake has long been recognized as a significant contributor to hypertension.[43] Hypertension is a known risk factor for T2DM; evidence suggests that salt intake may play a role in the development of insulin resistance is a key underlying factor in the pathogenesis of T2DM.[42]

Furthermore, a recent meta-analysis showed that patients with T2DM had higher levels of sodium intake when compared to non-diabetic controls.[44] This suggests that excessive sodium consumption may play a role in the development risk of T2DM. According to a study result examining the association between dietary habits and T2DM conducted by our research team in Myanmar, it was observed that the consumption of salty seasonings with daily meals is significantly linked to a higher prevalence of T2DM.[45] Rasouli et al confirmed the notable association between high sodium intake and the elevated risk of T2DM through the findings of their population-based study conducted in Sweden.[46]

The intake of vegetables (Tables 7 and 8 Crude: 0.40 CI 0.24–0.65; Model 1: aOR 0.42 CI 0.26–0.67, Model 2: aOR 0.31 CI 0.16–0.62, Model 3: aOR 0.32 CI 0.15–0.68) and fruits (Tables 7 and 8 Crude: 0.50 CI 0.29–0.84; Model 1: aOR 0.56 CI 0.33–0.95, Model 2: aOR 0.70 CI 0.35–1.41, Model 3: aOR 0.95 CI 0.43–2.11) has a significant inverse association with the prevalence of T2DM in our study. Daily consumption of vegetables has a consistently significant inverse association with diabetes prevalence in multivariate analysis, while daily intake of fruits has a significant inverse association in the first two models of multivariate analysis (Table 8). Similar results have been observed in studies exploring associations of incidence of T2DM with a higher intake of fruits and vegetables.[47,48] High fruit and vegetable consumption was found to be linked to a lower risk of T2DM, hypertension, and dyslipidemia in Korean adults regardless of their gender.[49] The risk of T2DM decreased by 9–10% with increasing intake of vegetables and fruits up to 200–300 gr/day according to the meta-analysis comparing high versus low intake.[15] The observed protective effect of fruits and vegetables on the reduction of type 2 diabetes risk can potentially be attributed to their rich composition of dietary fibers, antioxidants, vitamins, and various phytochemicals. Additionally, the intake of fruits and vegetables might contribute to reducing adiposity and controlling weight gain, eventually decreasing the risk of T2DM over the long term.[50]

T2DM not only leads to increased morbidity and mortality rates but also affects both society and the national economy.[51] Therefore, prioritizing preventive measures is paramount to mitigate the far-reaching consequences of T2DM.

Strengths and Limitations of This Study

The notable strength is we used a case-control design with well-defined eligibility criteria for the selection of both groups, cases were selected from a hospital setting, while controls were chosen from the community site to maintain the distribution of parameters within the target population. Furthermore, the use of multiple logistic analysis enhanced the precision of the association between dietary habits and T2DM, providing a more comprehensive assessment of the research findings by adjusting potential confounding factors, including age, gender, BMI, employment status, household monthly income level, and health conditions: hypertension, family history of diabetes, also lifestyle behaviors such as alcohol consumption.

Despite the robustness of our findings, there are some limitations to be considered. The use of self-reported data may be subject to recall bias as participants responded to the questions based on their dietary habits in the previous seven days. Secondly, during the six-month period following the initial consultation, it is possible that certain participants in the case group may have made lifestyle behavior changes, including adjustments to their dietary habits. This could be attributed to the information they received during the consultation regarding lifestyle modifications.

Conclusion

The study indicates that the traditional dietary practice in Thailand, which involves consuming food rich in fat and adding salty seasonings to meals is associated with an increased risk of T2DM. The study findings highlight the adverse effects of these seasonings and "unhealthy" fats on T2DM and promote the consumption of vegetables to prevent the accelerating prevalence of diabetes. Study findings contribute recommendations and opportunities for the primary prevention of T2DM in Thailand.

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Disclosure

The authors report no conflicts of interest in this work.

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