Original Article/นิพนธ์ต้นฉบับ

The Association between Processed Meat Intake and the Prevalence of Type 2 Diabetes in Thais: a Cross-Sectional Study from the Electricity Generating Authority of Thailand

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Abstract

Background: Type 2 diabetes (T2D) is a major health problem worldwide of which the complications are crushing burden. Previous studies reveal that consumption of processed meat is associated with higher incidence of T2D. However, the data outcomes are varied and the pathogenesis is still inconclusive.

Objective: This study aims to assess the association between processed meat consumption and T2D, and to investigate the influence of health-related factors and processed meat consumption and T2D.

Methods: A cross-sectional study was conducted in 2,017 subjects from population-based cohort study: the Electricity Generating Authority of Thailand study (EGAT) in 2013. Univariate and multivariate analysis were performed by logistic regression to reveal the association between processed meat intake and T2D and to adjust the potential confounders. The interaction terms were tested among these factors and T2D.

Results: The amount of processed meat consumption had a negative trend on T2D (P for trend = 0.03). The associations with T2D were also found in male (OR = 2.07; 95% CI, 1.43 - 2.99), high waist circumference (WC) (OR = 2.58; 95% CI, 1.77 - 3.77), undergraduated level (OR = 1.40; 95% CI, 1.06 - 1.85) and low serum non-HDL cholesterol (OR = 2.99; 95% CI, 2.27 - 3.92).

Conclusions: The higher processed meat intake had trend to increase a prevalence of T2D in all groups of BMI, WC, education level, serum cholesterol levels, smoking status and alcohol intake. Further long-term cohort study is warranted to confirm this finding.

Keywords: Processed meat, Diabetes, Socioeconomic status, Metabolic profile

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Background

In 2015, the prevalence of type 2 diabetes (T2D) is estimated to be 8% and has exponentially increased[1]. A growing population makes up the largest population of this prevalence[2]. T2D is a major health problem worldwide of which the complications are crushing burden including quality of life, morbidity and mortality of patient and socioeconomic impact of the country.

Our daily diet has continuously shown its significance in health and wellness. High intake of processed meat has been suspected as a major factor in development of T2D. Detrimental effects of saturated fat and animal protein contents of processed meat might account for this association. Other preservatives used in processed meats, such as nitrates and their byproducts (e.g. peroxynitrite); experimentally promote endothelial dysfunction and insulin resistance. Thus, higher nitrates/nitrites in processed meats could further explain their stronger relationships with T2D. High temperature commercial cooking or frying, commonly used in preparing processed meats, can introduce heterocyclic amines and polycyclic aromatic hydrocarbons, which could also increase risk of T2D[3, 4].

In a 2011 meta-analysis of 442,101 participants, consumption of both unprocessed and processed red meat products was significantly associated with increased risk of T2D[5-7] and a recent study following more than 2,000 Native Americans living in the South western of United States for a five-year period, found that those who ate processed meat products were more likely to develop diabetes[8].

A 17-year follow-up study conducted with 8,401 Seventh-day Adventists, researchers found that those who ate meat products were more likely to develop diabetes, compared to those who reported eating no meat products. These findings supported the research of other studies[9].

Previous studies revealed that consumption of processed meat is associated with higher incidence of T2D[5-10]. However, the data outcomes are varied and the pathogenesis of T2D influenced by consumption of processed meat is still inconclusive. This is likely due to differences in genetic background, several environmental factors and socioeconomic status[7, 10].

The aims of this study were to assess the association between processed meat consumption and the prevalence of T2D, and to investigate the influence of health-related factors and processed meat consumption and T2D. Document and quantifying the effect of processed meat consumption on these outcomes may be important to strengthen dietary recommendations that promote health.

Materials and Methods

Study population

A cross-sectional study was conducted in 2,017 subjects from population-based cohort study: the Electricity Generating Authority of Thailand study (EGAT) collected in year 2013. All subjects were age > 40 years old. A self-administered questionnaire including age, sex, meat consumption, smoking status, alcohol drinking, education background, and income was accomplished by all participants. Physical examination and anthropometric measurement were performed by physician and blood samples were collected.

Written informed consent was obtained from each participant and the protocol was approved by the Ethical Clearance Committee on Human Rights Related to Researches Involving Human Subjects, Faculty of Medicine, Ramathibodi Hospital, Mahidol University.

Assessment of processed meat consumption

The amount of processed meat consumption was categorized into 4 groups by portion: non-eater,

< 2 portions/week, 2 to 4 portions/week and > 4 portions/ week. One portion of processed meat was defined as 1 palm size portion or 3 ounces. Total processed meat was considered to be the sum of bacon, sausage, ham and minced pork or beef. T2D was defined as a fasting plasma glucose level at more than 126 mg/dl on a regular basis, self-reported history or taking glucose-lowering agents.

Measurement and laboratory determinations

Anthropometric parameters including weight, height and waist circumference were measured with standard techniques. Waist circumference was measured at the midpoint between the lower border of rib cage and the iliac crest during end expiratory phase.

Blood samples were obtained under aseptic conditions after 12-hour overnight fast and were stored at -80°C. Serum triglycerides, total cholesterol, LDL-c and HDL-c concentrations were measured using enzymatic assays method at baseline. Plasma glucose levels were measured using Hexokinase method.

Statistical analysis

Mean (± standard deviation, SD) for continuous variable and frequency (%) for binary or categorical variable were presented. Univariate and multivariate analysis were performed by logistic regression analysis to reveal the association between processed meat intake and T2D. Three adjusted models for potential confounders were constructed: adjusted model for sex and age (model 1), adjust model include age, sex and other potential confounders such as systolic blood pressure (SBP), WC, HDL cholesterol (HDL-c), triglyceride (TG) (model 2) and adjust model include age, sex, smoking, alcohol drinking, education level, income, SBP, BMI, WC, HDL-c and non-HDL-c (model 3). In all models, the first quartile of the processed

meat consumption was considered as the reference. The interaction terms were tested among these factors and T2D and present by forest plot in OR (95% CI) and P for interaction. P - value < 0.05 is considered statistical significant and all reported probability tests were 2-sided. All statistical analyses were conducted using SPSS for Windows, Version 16.0. Chicago, SPSS Inc; 2007.

Results

Two thousand and seventeen subjects from cohort EGAT study were enrolled in this study. The baseline demographic, clinical parameter and laboratory characteristics were shown in Table 1. The prevalence of T2D was 15.7% (n = 318). Their mean age at baseline was 57.48 ± 4.78 years old and 79.9% (n = 254) of them were male. The percentage of subjects with BMI ≥ 25 kg/m^2 and WC ≥ 90 cm in men and ≥ 80 cm in women in T2D group were significantly higher than in non-T2D: 64.5% and 73.3%, respectively. The mean SBP was 137.21 ± 17.86 mmHg; diastolic blood pressure (DBP) was 80.75 ± 9.17 mmHg in T2D group. The components of serum lipid profile were also inversely associated with the risk of insulin resistance: 61.6% had cholesterol level < 200 mg/dl and TG level < 150 mg/dl, 84.6% had HDL-c ≥ 40 mg/dl in men and ≥ 50 mg/dl in women. Nevertheless, this association became non-significant with additional adjustments.

Univariate analysis between diabetes and health-related variables was shown in Table 2. By multivariate logistic regression model after statistical controlling for known or possible potential confounders, the consumption of processed meat had a negative trend on T2D in all models. Nonetheless, no statistically significant reach was found in each level of process meat consumption. In the model 1, age and sex were adjusted for reason of commonly related factors.

Model 2 was designed as confounders concerning metabolic syndrome. Smoking, alcohol drinking, education level, income, SBP, BMI, WC, HDL-c level and non HDL-c level as potential confounders were adjusted in model 3 analysis. *P* for trend of each models were presented in Table 3. By model 3 analysis, the associations with T2D were found in male gender (OR = 2.07; 95% CI, 1.43 to 2.99; *P* < 0.001), waist circumference (WC) < 90 cm in male and < 80 cm in female (OR = 2.58; 95% CI, 1.77 to 3.77; *P* < 0.001), education level lower than bachelor degree (OR = 1.40; 95% CI, 1.06 to 1.85; *P* = 0.017) and serum non-HDL cholesterol level < 160 mg/dl (OR = 2.99; 95% CI, 2.27 to 3.92; *P* < 0.001).

Table 1 Baseline data, clinical parameter and laboratory characteristics of the studied populations

Factor	Non-T2D (N = 1,699)	T2D (N = 318)	*P* - value
Processed meat (portion(s)/ week)			
None	957 (56.3%)	164 (51.6%)	0.21
< 2	627 (36.9%)	125 (39.3%)	
2 - 4	81 (4.8%)	18 (5.7%)	
> 4	34 (2.0%)	11 (3.5%)	
Age (years)	56.63 (± 4.53)	57.48 (± 4.78)	0.002
Sex			
Male	1164 (68.5%)	254 (79.9%)	< 0.001
Female	535 (31.5%)	64 (20.1%)	
Smoking			
Yes	1023 (60.7%)	162 (50.9%)	0.001
No	667 (39.3%)	156 (49.1%)	
Alcohol drinking			
Yes	568 (33.4%)	94 (29.6%)	0.17
No	1131 (66.6%)	224 (70.4%)	
Education			
Undergraduates	846 (49.8%)	195 (61.3%)	< 0.001
Bachelor degree or higher	853 (50.2%)	123 (38.7%)	
Income (baht/year)			
0 - 284,000	385 (22.7%)	96 (30.3%)	0.003
284,001 - 813,000	400 (23.6%)	86 (27.1%)	
813,001 - 1,138,000	428 (25.2%)	63 (19.9%)	
> 1,138,000	484 (28.5%)	72 (22.7%)	
Systolic blood pressure (mmHg)	133.92 (± 17.86)	137.21 (± 17.86)	0.001
Diastolic blood pressure (mmHg)	80.75 (± 10.77)	80.75 (± 9.17)	0.99
BMI (kg/m^2)			
< 25	981 (57.7%)	113 (35.5%)	< 0.001
≥ 25	718 (42.3%)	205 (64.5%)	

Table 1 Baseline data, clinical parameter and laboratory characteristics of the studied populations (continued)

Factor	Non-T2D (N = 1,699)	T2D (N = 318)	P - value
Waist circumference (cm)			
Male < 90, Female < 80	854 (50.5%)	85 (26.7%)	< 0.001
Male ≥ 90, Female ≥ 80	838 (49.5%)	233 (73.3%)	
Cholesterol (mg/dl)			
< 200	504 (29.7%)	196 (61.6%)	< 0.001
≥ 200	1194 (70.3%)	122 (38.4%)	
HDL-c (mg/dl)			
Male < 40, Female < 50	205 (12.1%)	49 (15.4%)	0.1
Male ≥ 40, Female ≥ 50	1493 (87.9%)	269 (84.6%)	
Triglyceride (mg/dl)			
< 150	1152 (67.8%)	195 (61.6%)	0.02
≥ 150	546 (32.2%)	123 (38.7%)	
Non-HDL-c (mg/dl)			
< 160	768 (45.2%)	226 (71.1%)	< 0.001
≥ 160	930 (54.8%)	92 (28.9%)	

BMI = body mass index

Table 2 Univariate analysis between T2D and health-related variables (n = 2,017)

Variable	OR	95% CI	P - value
Sex (female)	0.55	0.41 - 0.74	< 0.001
Age	1.04	1.01 - 1.07	< 0.001
Processed meat (portion(s)/week)			
P for trend			0.44
None	1		
< 2	1.16	0.90 - 1.50	
2 - 4	1.30	0.76 - 2.22	
> 4	1.89	0.94 - 3.80	
Smoker	1.49	1.17 - 1.90	< 0.001
Alcohol	1.20	0.92 - 1.55	0.18
Education			
Undergraduated	1		
Bachelor degree or higher	0.77	0.67 - 0.87	< 0.01
Income (baht/year)			
0 - 284,000	1		
284,001 - 813,000	0.86	0.62 - 1.20	0.37
813,001 - 1,138,000	0.59	0.42 - 0.84	< 0.001
> 1,138,000	0.60	0.43 - 0.83	< 0.001
Systolic blood pressure (mmHg)	1.01	1.00 - 1.02	< 0.001
Diastolic blood pressure (mmHg)	1.00	0.99 - 1.01	1.00

Table 2   Univariate analysis between T2D and health-related variables (n = 2,017) (continued)

Variable	OR	95% CI	P - value
BMI (kg/m^2)			
< 25	1		
≥ 25	2.48	1.93 - 3.18	< 0.001
Waist circumference (cm)			
Male < 90, Female < 80	1		
Male ≥ 90, Female ≥ 80	2.79	2.14 - 3.65	< 0.001
Cholesterol (mg/dl)			
< 200	1		
≥ 200	0.26	0.21 - 0.34	< 0.001
HDL-c (mg/dl)			
Male < 40, Female < 50	1		
Male ≥ 40, Female ≥ 50	0.75	0.54 - 1.06	0.10
Triglyceride (mg/dl)			
< 200	1		
≥ 200	1.33	1.04 - 1.08	0.02
Non HDL-c (mg/dl)			
< 160	1		
≥ 160	0.34	0.26 - 0.44	< 0.001

CI = confidence interval; OR = odd ratio

Table 3   Multivariate and logistic regression model in different model analysis between diabetes and adjusted health-related variables (n = 2,017)

	Multivariate logistic regression model 1*		Multivariate logistic regression model 2**		Multivariate logistic regression model 3***	
	95% CI	P for trend	95% CI	P for trend	95% CI	P for trend
Process meat (portion(s)/week)		0.02		0.04		0.03
0	1		1		1	
< 2	1.24 (0.96 - 1.60)		1.26 (0.97 - 1.64)		1.28 (0.98 - 1.69)	
2 - 4	1.41 (0.82 - 2.43)		1.28 (0.74 - 2.23)		1.22 (0.69 - 2.16)	
> 4	1.85 (0.89 - 3.86)		1.80 (0.85 - 3.81)		2.09 (0.92 - 4.76)	

CI = confidence interval

* adjusted by age, sex

** adjusted by age, sex, systolic blood pressure, waist circumference, HDL-c, triglyceride

*** adjusted by age, sex, smoking, alcohol drinking, education, income, systolic blood pressure, BMI, waist circumference, HDL-c, non-HDL-c

Additionally, the effect of processed meat and T2D was consistent between each group of BMI, WC, education level, smoking, alcohol drinking and serum cholesterol levels *(P for interaction = 0.22, 0.86, 0.55,* 0.6, 0.51 and 0.23, respectively). The OR (95% CI) of health-related variables and T2D risk were shown by Forest plot in Figure 1.
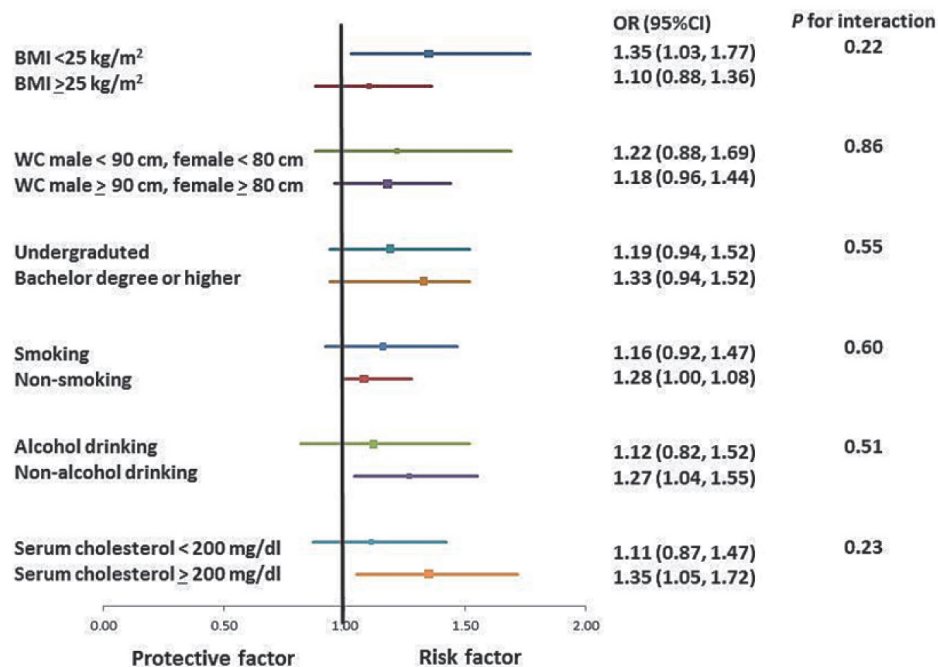

	OR (95%CI)	P for interaction
BMI <25 kg/m²	1.35 (1.03, 1.77)	0.22
BMI ≥25 kg/m²	1.10 (0.88, 1.36)	
WC male < 90 cm, female < 80 cm	1.22 (0.88, 1.69)	0.86
WC male ≥ 90 cm, female ≥ 80 cm	1.18 (0.96, 1.44)	
Undergraduted	1.19 (0.94, 1.52)	0.55
Bachelor degree or higher	1.33 (0.94, 1.52)	
Smoking	1.16 (0.92, 1.47)	0.60
Non-smoking	1.28 (1.00, 1.08)	
Alcohol drinking	1.12 (0.82, 1.52)	0.51
Non-alcohol drinking	1.27 (1.04, 1.55)	
Serum cholesterol < 200 mg/dl	1.11 (0.87, 1.47)	0.23
Serum cholesterol ≥ 200 mg/dl	1.35 (1.05, 1.72)	

Figure 1   *Forest plot conventional risk factors and T2D*

Discussion

In this cross-sectional study, 15.7% of 2,017 EGAT subjects had T2D. Greater intake of processed meat was positively tends with the prevalence of T2D even after adjustment for confounding factors for T2D (P for trend = 0.03). This result was consistent with a previous study[8], in which a higher processed meat intake was associated with a higher risk of incident diabetes (OR = 1.63; 95% CI, 1.21 to 2.63; P = 0.03). The biological pathogenesis that might explain this finding was a dietary pattern high in processed meat decreased insulin sensitivity[11] by higher in sodium[7], nitrosamines[12] and glycation end products from the heating and processing of meats[13].

The current study had important strengths, including a large number of cases. For the consumption of process meat, we categorized to frequency portion(s)/week because we want to explore the dose-response relationship between process meat and T2D. Our finding suggests process meat intake had trend to increase risk of T2D (P for trend = 0.03), in spite of no statistically significant reach in the level of process meat consumption. Nevertheless, limitation of this study was small number of sample size in some categories that could be reduced the power of statistics, but our study showed the direction of dose-response relationship between process meat increase risk of T2D. Similar to previous study in Japan showed the trend of

association between process meat consumption and T2D[14]. Owing to the study design, this study was difficult to determine causal relationships. So the prospective association remains to be identified. Confounding by unmeasured factors such as dietary factors before baseline, genetic susceptibility, concentration of preservatives in processed meat and other foods or determinants of behavior, which might influence the T2D risk can never be ruled out. Nonetheless, the adjusted statistical models were tailored to control for known confounders. Relying on self-reported diabetes and history of glucose lowering agent use may cause bias in determination of diabetes prevalence.

In conclusion, the higher processed meat intake had trend to increase a prevalence of T2D in all groups of BMI, WC, education level, serum cholesterol levels, smoking status and alcohol intake. Further long-term cohort study is warranted to confirm this finding. The biological mechanisms for this possible interaction should be investigated. From a view of public health point, reducing processed meat consumption may reduce T2D.

List of abbreviations

BMI: Body mass index, **CI:** Confidence interval, **DBP:** Diastolic blood pressure, HDL-c: HDL cholesterol, OR: Odd ratio, **SBP:** Systolic blood pressure, **T2D:** Type 2 diabetes, **TG:** Triglyceride, **WC:** Waist circumference

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การศึกษาความสัมพันธ์ระหว่างการบริโภคเนื้อสัตว์แปรรูป และความชุกของโรคเบาหวานชนิดที่ 2 ในการศึกษาของ การไฟฟ้าฝ่ายผลิตแห่งประเทศไทย

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บทคัดย่อ

บทนำ: โรคเบาหวานชนิดที่สองเป็นปัญหาสำคัญของระบบสุขภาพทั่วโลก โดยที่ภาวะแทรกซ้อนของโรคดังกล่าว ก่อให้เกิดผลกระทบที่รุนแรง จากการศึกษาที่ผ่านมาแสดงให้เห็นถึงความสัมพันธ์ของการบริโภคเนื้อสัตว์แปรรูป มีผลต่อการเกิดโรคเบาหวานชนิดที่สอง อย่างไรก็ตาม ผลของการศึกษาและกลไกของการเกิดโรคยังไม่มีข้อสรุปที่แน่ชัด

วัตถุประสงค์: เพื่อหาความสัมพันธ์ระหว่างการบริโภคเนื้อสัตว์แปรรูปกับการเกิดโรคเบาหวานชนิดที่สองและ หาปัจจัยทางสุขภาพอื่นๆ ที่มีส่งผลต่อการบริโภคเนื้อสัตว์แปรรูปกับการเกิดโรคเบาหวานชนิดที่สอง

วิธีการศึกษา: รูปแบบการศึกษาเป็นการศึกษาแบบตัดขวาง โดยนำกลุ่มตัวอย่างมาจากการศึกษาติดตามของ การไฟฟ้าฝ่ายผลิตแห่งประเทศไทยทั้งหมด 2,017 รายในปี พ.ศ. 2556 การวิเคราะห์ข้อมูลใช้เป็นการวิเคราะห์การถดถอย โลจิสติกทั้งแบบตัวแปรเดี่ยวและรวมหลายตัวแปร โดยมีการควบคุมตัวแปรกวนเพื่อหาความสัมพันธ์ระหว่าง การบริโภคเนื้อสัตว์แปรรูปกับการเกิดโรคเบาหวานชนิดที่สอง และปฏิสัมพันธ์ของปัจจัยอื่นๆ ที่เกี่ยวข้อง

ผลการศึกษา: การบริโภคเนื้อสัตว์แปรรูปมีแนวโน้มที่สัมพันธ์กับโรคเบาหวานชนิดที่สองอย่างมีนัยสำคัญทางสถิติ (P for trend = 0.03) และพบตัวแปรที่มีความสัมพันธ์กับการเกิดโรคเบาหวานคือ เพศชาย (Odd ratio [OR] = 2.07; 95% CI, 1.43 - 2.99) ขนาดเส้นรอบเอวที่สูง (OR = 2.58; 95% CI, 1.77 - 3.77) ระดับการศึกษาต่ำกว่าระดับปริญญาตรี (OR = 1.40; 95% CI, 1.06 - 1.85) และระดับไขมันชนิดไม่ดีต่ำ (OR = 2.99; 95% CI, 2.27 - 3.92)

สรุป: การบริโภคเนื้อสัตว์แปรรูปมีแนวโน้มที่สัมพันธ์กับโรคเบาหวานชนิดที่สองในทุกกลุ่มดัชนีมวลกาย ขนาดเส้นรอบเอว ระดับการศึกษา ระดับคอเลสเตอรอลในซีรั่ม การสูบบุหรี่ และการดื่มสุรา อย่างไรก็ตาม เพื่อยืนยันความสัมพันธ์นี้จะต้องทำการศึกษาเพิ่มเติมในรูปแบบ cohort ระยะยาวต่อไป

คำสำคัญ: เนื้อสัตว์แปรรูป โรคเบาหวานชนิดที่สอง เศรษฐานะ ระดับไขมัน

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