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Research Paper

The association of meat intake and the risk of type 2 diabetes may be modified by body weight

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Aim: To investigate the association between meat intake and incidence of type 2 diabetes (type 2 DM) in a large cohort of middle-aged women.

Design, subjects and methods: Incident cases of type 2 DM were identified during an average of 4.6 years of follow-up in a prospective cohort study of 74,493 middle-aged, Chinese women (mean age ± SD =51.7± 8.97 years). Participants completed in-person interviews that collected information on type 2 DM risk factors such as dietary factors and physical activity in adulthood. Anthropometric indices were measured. Dietary intake was assessed using a validated food frequency questionnaire (FFQ). We included in the current analysis 70,609 women who had no prior history of type 2 DM at study recruitment and who had valid dietary data. The association of type 2 DM with unprocessed meat intake (g/day) and the frequency of consumption of processed meat was evaluated using the Cox model with adjustment for age, kcals/day, body mass index (BMI), waist to hip ratio (WHR), vegetable intake, smoking, alcohol consumption, physical activity, income level, education level, occupation status, and history of hypertension and chronic disease at baseline.

Principal results: We identified 1972 incident cases of type 2 DM during a total of 326,581 person-years of follow up. Intake of unprocessed meat, particularly poultry, was associated with a decrease in the risk of type 2 DM in this cohort. The fully adjusted relative risks (RRs) for quintiles of total unprocessed meat intake were 1.00, 0.78, 0.83, 0.74, and 0.83 (P for trend: <0.01). When the joint effect between meat intake and BMI categories was evaluated, high intake of total unprocessed meat appeared to be associated with an increased risk of type 2 DM among obese women but a reduced risk among lean women (P value for the interaction tests = 0.05). Processed meat consumption was positively associated with the risk of type 2 DM. The adjusted RR was 1.15 (95% 1.01-1.32) in women consuming processed meats compared to those who did not consume processed meats (P=0.04).

Conclusions: Processed meat intake was positively associated with the risk of type 2 DM. There was an indication that the effect of unprocessed meat intake on type 2 DM may be modified by BMI.

Key words: type 2 diabetes, meat intake, middle-aged women

1. INTRODUCTION

A diet high in red meat has been suspected as an independent contributor to the risk of type 2 diabetes mellitus (type 2 DM) in ecological and migrant studies [1;2]. However, data on associations between total meat and type of meat intake and the risk of type 2 DM are inconsistent and limited [3]. Total meat intake was associated with a higher risk of diabetes in one cross-sectional study, the Seventh Day Adventist Study, a population with a large proportion of vegetarians [4]. Red meat was associated with a higher diabetes risk in prospective studies of female health professionals, the Women's Health Study (WHS) [3] and in the Nurses' Health Study (NHS) I and II [5;6], but not in the Health Professionals Follow-up Study [7]. Poultry intake was related to a moderate decrease in risk in one study [6]. Processed meat was associated with a higher risk of type 2 DM in four prospective studies [3;5-7]. The available data on the association between meat intake and the risk of type 2 DM are limited to four health professionals cohorts and the Seventh Day Adventist cross-sectional study and thus, may not be directly generalizable to the general population.

To better understand the relationship between the intake of meat and the risk of type 2 DM we prospectively investigated the association between meat consumption and the incidence of type 2 DM in a population-based cohort of middle-aged women in urban Shanghai.

2. METHODS

Study population

The Shanghai Women's Health Study (SWHS) is a population-based prospective cohort study conducted

in seven urban communities in Shanghai, China. Details of the SWHS survey have been reported elsewhere [8]. Briefly, all eligible women (n=81,170) who were aged 40-70 years and resided in these communities were contacted. Participants were identified using a roster obtained from the resident registry offices in the study communities. A trained interviewer visited potential study participants' homes, explained the study, obtained written consent and administered an interview between March 1997 and May 2000. A total of 75,221 women were enrolled, yielding a participation rate of 92.7%. After exclusion of 278 women who were later found to be younger than 40 or older than 70 at the time of the interview, 74,942 women remained for the SWHS. The major reasons for non-participation were refusal (3.0%), absence during the enrolment period (2.6%), and other miscellaneous reasons (i.e., health, hearing, or speaking problems; 1.6%). All study participants completed a detailed survey including an in-person interview for assessment of dietary intake, physical activity, and measurement of anthropometrics and other lifestyle factors. Protocols for the SWHS were approved by the Institutional Review Boards of all institutes involved in the study.

Dietary intake and other exposure information

Dietary intake was assessed through an in-person interview using a validated food frequency questionnaire (FFQ) [9] at the baseline survey and at the first follow-up survey, which took place approximately two years after study recruitment. A total of 77 items and food groups were included on the questionnaire, which covered about 90% of the commonly consumed foods in Shanghai in 1996. For each food item or food group, subjects were asked how frequently (daily, weekly, monthly, yearly or never) they consumed the food or food groups, followed by a question on the amount consumed in lians (50g/lian) per unit of time. A lian is the unit of weight in China equivalent to 50 g.

The reproducibility and validity of the FFQ was assessed in a random sample of 200 participants who completed 24-hour dietary recalls twice a month during a 12-month period and 2 FFQs that were administered two years apart. Correlation coefficients between the 24-hour dietary recall and the second FFQ ranged from 0.59 to 0.66 for macronutrients, 0.41 to 0.59 for micronutrients, and 0.41 to 0.66 for food groups. The correlation coefficient for red meat was 0.52 and for poultry 0.48. The correlations between the 2 FFQs were 0.48 to 0.51 for macronutrients and 0.47 for red meat and 0.49 for poultry [9].

For women who developed type 2 DM, cancer, or cardiovascular disease between the baseline and follow-up FFQs, only dietary data from the baseline FFQ were included in this analysis. For other participants the average of the baseline and follow-up FFQ data were used in the analyses. The average daily intake of individual food items (g/day) was combined to compute intake of red meat (pork, beef, lamb, organ meat), poultry (chicken, duck, goose), and total unprocessed meat (red meat and poultry combined). We also obtained information on the frequency of consumption of processed meat. Processed meats included smoked meat/bacon, salted meat/preserved meat and Chinese sausage.

A structured questionnaire was used to collect information on participant characteristics such as age, level of education, family income, occupation, smoking, alcohol consumption and history of hypertension, coronary heart disease (CHD), stroke, and cancer. Anthropometric measurements, including weight, height, and circumferences of the waist and hips, were taken at baseline recruitment according to a standard protocol by trained interviewers who were retired medical professionals [10]. From these measurements, the following variables were created: BMI: weight in kg divided by the square of height in meters, WHR: waist circumference divided by hip circumference.

A detailed assessment of physical activity was obtained using a validated questionnaire [11]. The questionnaire evaluated regular exercise and sports participation during the previous 5 years and provided information on daily activity such as walking, stair climbing, cycling, household activities and daily commuting to and from work (walking and cycling). We calculated the metabolic equivalents for each activity, using a compendium of physical activity values [12]. One MET-h/d is roughly equivalent to 1kcal/kg/d or about 15 minutes of participation in moderate intensity (4 METS) activity for an average adult [12]. We combined each of the exercise and lifestyle activity indices to derive a quantitative estimate of overall non-occupational activity (MET-hr/day).

Cohort follow-up and endpoint ascertainment

In-person follow-up for all living cohort members was first conducted from 2000 to 2002 by an in-home visit. Follow-up of disease outcomes was completed for 74,755 of cohort members, a response rate of 99.8%. A second in-home follow-up survey was launched in May 2002 and completed in December 2004 with a response rate of 98.7%; only 934 participants were lost to follow-up.

Incident type 2 DM was identified through the follow-up surveys. A total of 1972 new cases of type 2 DM were reported. For the current study we considered a case of type 2 DM to be confirmed if the participants reported having been diagnosed with type 2 DM and met at least one of the following criteria: fasting glucose level of at least 7 mmol/L on at least two occasions or an oral glucose tolerance test (OGTT) with a value of at least 11.1 mmol/L and/or use of hypoglycaemic medication (i.e., insulin or oral hypoglycaemic drugs). The study outcome criteria were met by 1094 participants, which are referred to herein as confirmed cases of type 2 DM. We performed analyses with both confirmed and all type 2 DM cases and found similar trends. Thus, in this paper we present results that include all self-reported cases of type 2 DM. We excluded women from the current

analysis who had diabetes or had a positive urinary glucose test at the baseline survey. The total follow-up was 4.6 years.

Statistical analysis

The Chinese Food Composition Tables [13] were used to estimate intake of nutrients and energy (kcals/day). We excluded participants who had extreme values for total energy intake (<500 or > 3500 kcals/day) [14], (n=37), leaving 70,609 participants for the analysis, of whom 1969 developed type 2 diabetes.

Person-years for each participant were calculated as the interval between baseline recruitment to diagnosis of type 2 DM, censored at death or last date of contact. Total unprocessed meat intake, red meat and poultry (g/day) were categorized by quintile distribution with the lowest quintile serving as the reference. Consumption of processed meats was low in this population, thus we compared women who consumed processed meat less than once per month or at least once per month with women who did not consume processed meats.

The Cox proportional hazards model was used to assess the effect of meat intake on the incidence of type 2 DM. Socio-demographic factors and other risk factors for diabetes such as age, kcal/day, BMI, WHR, vegetable intake (all entered as continuous variables), level of education (none, elementary school, middle/high school, college), family income in yuan/year (<10000, 10000-19999, 20000-29999, >30000), occupation (professional, clerical, farmer/others, housewife/retired), smoking (smoked at least one cigarette per day for more than 6 months continuously), and alcohol consumption (ever drank beer, wine, or spirits at least 3 times per week), physical activity (quintiles of METs), and hypertension were adjusted for in the analyses as potential confounders. We also adjusted for the presence of the following chronic diseases at baseline: coronary heart disease (CHD), stroke, and cancer and repeated the analyses after exclusion of subjects with these chronic diseases. Tests for trend were performed by entering the categorical variables as continuous parameters in the models.

Finally, we investigated the joint effect of meat intake categories and BMI categories on the risk of type 2 DM. Total unprocessed meat, red meat and poultry were categorized into 3 groups (lower quartile, second and third quartiles combined, and upper quartile) and frequency of processed meat consumption was categorised (never, less than once per month, and at least once per month). BMI was categorised according to WHO obesity categories [15]. The likelihood ratio test was used to assess the significance of the interaction terms.

All analyses were performed using SAS (version 9.1) and all tests of statistical significance were based on two-side probability.

3. RESULTS

In this study population we found that higher intake levels of total unprocessed meat, red meat, poultry, and consumption of processed meat (yes/no) were associated with higher energy intake, alcohol consumption, higher education and income level, and being employed and were inversely associated with leisure-time physical activity (Table 1). Participants with higher intake of meat were more likely to be younger and less likely to have ever smoked, have a history of CHD, stroke, hypertension, or cancer. Overall 12.35% of study participants did not consume any processed meat. Smoked meat was consumed by 37.51% of study participants, while 81.31% of cohort members had consumed salted/preserved meat and 46.24% consumed Chinese sausage (data not shown in Table).

During the 4.6 years of follow up (326,625 person-years) we documented 1972 new cases of type 2 DM. We found that consumption of total unprocessed meat and poultry was, in general, inversely related to the risk of type 2 DM (Table 2). As compared with the lowest quintile of intake, the multivariate adjusted RRs of type 2 DM across quintiles were 1.00, 0.78, 0.83, 0.74 and 0.83 (p for trend <0.01) for total unprocessed meat intake and 1.00, 0.74, 0.80, 0.69, and 0.78 for poultry (p for trend <0.001). No clear linear dose-response was evident for red meat intake. We repeated the analysis after exclusion of participants already diagnosed with chronic diseases (CHD, stroke, and cancer) and found similar results (Table 2).

The risk of type 2 DM for participants who consumed processed meat compared to those who did not consume processed meat was 1.15 (95%CI 1.01-1.32 (Table 3). The fully adjusted RRs associated with frequency of consumption were 1.00 for never, 1.20 for <1/month, and 1.10 for ≥1/month (p for trend=0.67). We repeated the analysis stratified by categories of BMI. The adjusted relative risks for never, <1/month, ≥1/month were 1.00, 1.08 and 0.97 (p=0.56) in participants with a BMI<25 kg/m^2, 1.00, 1.22 and 1. 09 (p=0.99), in participants with a BMI between 25 and 30 kg/m^2 and 1.00, 1.44 and 1.51 (P=0.06) in participants with a BMI≥30 kg/m^2 (data not shown in Table 3). When types of processed meat were considered, we found that salted/preserved meat consumption (yes/no) was associated with a higher risk of type 2 DM (RR 1.16; 95%CI: 1.04-1.31, P<0.01), while consumption of bacon/smoked meat or Chinese sausage was unrelated to the risk of type 2 DM (data not shown in Table 3). Analyses excluding participants with chronic diseases at baseline showed similar results. We investigated the association between salted/preserved meat and the risk of type 2 DM stratified by BMI categories (data not shown in Table 3). Salted/preserved meat intake (yes/no) was associated with a higher risk of type 2 DM in participants with a BMI ≥30 kg/m^2 (RR 1.50; 95%CI: 1.11-2.03, P<0.01) but was not associated with the risk of diabetes in participants with BMI<25 kg/m^2 or BMI between 25 and 30 kg/m^2.

We conducted further analysis to evaluate joint associations between meat intake and obesity categories and the incidence of type 2 DM (Table 4).

We found that total unprocessed meat consumption was associated with a modest reduction in risk of type 2 DM for normal weight participants, but related to a modest increase in risk of type 2 DM for obese participants (P for interaction: 0.05). A similar trend was observed for red meat but the factor for interaction failed to reach significance (P=0.16). Poultry was modestly related to a reduction in the risk of type 2 DM for normal weight and overweight participants, but was unrelated to the risk of type 2 DM in obese participants and the interaction factor was of marginal significance (P=0.07). Processed meats were associated with a higher risk of type 2 DM in overweight and obese participants (interaction factor P value =0.08). Participants who were obese (BMI$\geq$30 kg/m^2) and in the highest intake category of processed meat had a higher risk of type 2 DM (RR= 3.46; 95% CI 2.67-4.48) compared to participants with normal weight (BMI<25 kg/m^2) who did not consume processed meat. Analyses excluding subjects with chronic diseases at baseline showed the same pattern, although the RRs associated with processed meat intake among overweight and obese women were more pronounced (data not shown in tables). We repeated all the analyses after exclusion of participants whose type 2 DM diagnosis could not be confirmed and found similar trends (data not shown in tables).

4. DISCUSSION

In this large prospective study of middle-aged Chinese women living in Shanghai, we found differences in the association of unprocessed total meat intake and type 2 DM risk depending on the BMI of the women. A higher consumption of total unprocessed meat was related to a modest reduction in the risk of type 2 DM among normal weight women, but was associated with a modest increase in risk of type 2 DM among obese women. However, poultry consumption was not associated with a higher risk of type 2 DM among obese participants. Processed meat consumption was associated with an increased risk of developing type 2 DM, particularly for obese participants.

Some studies have examined the association between meat consumption and the risk of type 2 DM. Total meat was associated with a higher prevalence of diabetes in the Seventh Day Adventist Study conducted in California [4]. In that study there was no information on associations of different types of meat and the risk of diabetes. Poultry consumption was associated with a moderate decrease in risk of type 2 DM in the NHS II [6]. No association between poultry consumption and risk of type 2 DM was found in the Health Professionals Follow-Up Study [7], the WHS [3], or the NHS I [5]. Poultry consumption has been indirectly linked to lower risk of type 2 DM as high consumption of poultry was found to be part of a 'prudent dietary pattern' that has been associated with a lower risk of type 2 DM [5;16]. However, in a recent report from the German arm of the European Prospective Investigation into Cancer (EPIC) Study, poultry consumption was part of a dietary pattern associated with a higher risk of type 2 DM [17]. To our knowledge there are no other reports of a direct link between poultry consumption and risk of diabetes or of interactions between poultry consumption and BMI and the risk of type 2 DM.

Red meat consumption was associated with a modest increase in the risk of type 2 DM in the WHS (RR =1.28; 95%CI: 1.07-1.53), P<0.001 for the upper vs lower quintile) [3] and in the NHS I (RR=1.22; 95% CI: 1.05-1.41 , P=0.03 for the upper vs lower quintile) [5]. Frequency of total red meat consumption was also associated with a higher risk of type 2 DM in the NHS II [6]. In the NHS II, beef and hamburgers, but not pork, as a main dish were associated with a higher risk of diabetes. However, no association between red meat intake and the risk of type 2 DM was observed in the Health Professionals Follow-Up Study [7], in which consumption of red meat was 1.05, 95%CI 0.85-1.30 for highest vs lowest quintile. Data from studies of Japanese subjects living in Hawaii, indigenous subjects living in Quebec, Canada, and a population in the UK [1;18;19] all showed a positive association of red meat with type 2 DM risk either directly or as part of an unfavourable dietary pattern. High levels of saturated fat, cholesterol, animal protein, and heme-iron in red meat have all been suggested as reasons behind the higher risk for diabetes associated with high red meat intake [7].

In our population there was an indication that red meat consumption was associated with a modest decrease in risk of type 2 DM among normal weight women and a modest increase in risk among obese women, although the coefficient of interaction was not significant. None of the previous studies evaluated the interaction between BMI and meat consumption. Our findings of inverse associations between red meat and type 2 DM in participants with normal weight will have to be confirmed in other study populations.

An important point to be considered when interpreting these results is that the absolute amount of red meat intake in this population was 42.6 g/day (median). The cut off points for quintiles of red meat intake in this population are 24.5, 36.5, 49.2 and 67.6 g/day. Several European countries participating in the EPIC study have reported a much higher median intake of red meat: 70.1 g/day [20] which is 1.4-fold greater than the red meat intake in our study population. Thus, it is possible that what is considered a high level of intake in our population may not be high enough to put participants at risk for type 2 DM. In addition, in our population pork was the major component of red meat intake (90%). Only beef and hamburgers but not pork was associated with the risk of type 2 DM in the NHS II [6]. In our population the cut off points of red meat (other than pork) were 0.52, 1.63, 3.48 and 6.99 g/day.

Our results suggest that processed meat consumption may be associated with a higher risk of type 2 DM. This is broadly in agreement with other studies that have found processed meat consumption to be associated with a higher risk of type 2 DM. In the Health Professionals Follow-Up Study the RR for

diabetes was 1.46 (95% CI 1.14-1.86) for consumption of processed meat ≥5times/week vs <1/month [7]. In the WHS [3] total processed meat consumption ≥5/week vs <1/month had a RR of 1.43 (95%CI 1.17-1.75). Processed meat consumption has also been associated with higher type 2 DM risk in the NHS I and II [5;6]. In the NHS I the RR of type 2 DM for intake of total processed meat was 1.38 (95%CI 1.23-1.56), for hot dog intake was 1.49 (95% CI 1.04-2.11), and for bacon intake was 1.73 (95% CI 1.39-2.16) [5].

The joint effects between processed meat intake and obesity on the risk of type 2 DM was investigated in the NHS II and frequent intake of processed meat appeared to be associated with a higher risk of type 2 DM in women with a BMI ≥30 compared to women with BMI <30, although the test for interaction was not significant (p=0.34) [6]. In our study, we found similar results and the test for interaction between processed meat intake and BMI categories was of marginal significance (P=0.08).

Processed meats contain preservatives and additives that may put participants at a higher risk of type 2 DM. These may include nitrites, nitrates, and heterocyclic amines formed during cooking. Nitrosamines formed during cooking may be toxic to pancreatic cells [21]. Consumption of foods with a high content of nitrites and nitrosamines has been associated with type 1 diabetes [22;23]. In addition, advanced glycation and lipo-oxidation end products formed in meat and high fat products through heating and processing have been associated with insulin resistance in mice [24] and with diabetes complications in humans [25]. However, observed associations between processed meat consumption and type 2 DM may also reflect other unidentified factors.

It may be possible that consumption of red meat and processed meat may not increase the risk of type 2 DM, per se, but be part of a dietary pattern that has been associated with a higher risk of type 2 DM. Red and processed meats are two of the main components of the 'Western diet', while poultry has been reported as part of the 'prudent diet' in most studies [5;16;26], but not all [17]. It remains unclear whether the possible adverse effects that red and processed meat consumption have on type 2 DM risk are mediated through fat content or protein or if consumption of these foods is associated with food groups in the 'Western diet' which have been associated with a higher risk of type 2 DM and hyperglycaemia [5;16]. To date only two studies have reported an increase in the risk of type 2 DM associated with processed meat consumption independent of this Western dietary pattern [5;6]. Our study offers a unique opportunity to investigate associations between meat intake and the risk of type 2 DM with little confounding from a Western dietary pattern.

It is possible that participants who have been diagnosed with a chronic disease may have changed their diet. To address this concern we adjusted for the presence of chronic disease (CHD, cancer, and stroke) and hypertension throughout the analyses. We also repeated the analyses excluding participants with chronic diseases and found similar results.

The prospective design and high follow-up rates in our study minimized the possibility of selection or recall bias. In addition, the extensive information on potential confounders and the large study size allowed us to examine the effect of BMI and meat intake in detail. Misclassification of dietary assessment would most likely be non-differential and would have attenuated the true associations. The repeated dietary measurements are advantageous in helping to dampen measurement errors and take into account changes in eating behaviour over time.

In conclusion, we found that processed meat consumption was associated with a higher risk of type 2 DM, independent of other type 2 DM risk factors. Higher consumption of total unprocessed meat was associated with a higher risk of type 2 DM among obese women, although this was not the case for poultry. There was an indication that total unprocessed meat intake may be inversely associated with type 2 DM among normal weight women. The biological mechanisms for this possible interaction should be investigated.

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Conflicts of interest

The authors have declared that no conflict of interest exists.

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Tables

Table 1: Total meat*, red meat, poultry and processed meat intake by socio-demographic factors and other participant characteristics

	Total Meat		Red Meat		Poultry		Processed Meat	
	Q1[a]	Q5	Q1	Q5	Q1	Q5	No	Yes
Age	54.3	49.3	54.7	49.4	54.5	49.7	54.7	51.3
BMI	24.2	23.8	24.1	23.9	24.2	23.7	23.9	23.9
WHR	0.81	0.80	0.81	0.80	0.81	0.80	0.81	0.81
Kcals/day	1424.3	1948.1	1438.6	1939.7	1515.3	1833.8	1617.2	1659.4
Ever smoker (%)	3.4	2.1	3.1	2.3	3.7	1.8	2.8	2.2
Alcohol consumption (%)	2.1	2.9	2.2	2.7	2.0	2.9	2.2	2.68
Exercise (%)	38.7	31.6	38.6	30.9	36.0	33.8	38.8	34.3
Education (%)								
None	36.9	10.3	33.1	11.53	36.1	9.9	32.7	18.4
Elementary	31.9	41.6	32.3	42.3	34.3	38.9	31.8	38.3
Up to High School	21.9	31.9	23.7	30.6	21.1	33.8	22.8	29.3
College	9.2	16.1	10.8	15.5	8.5	17.3	12.6	14.1
Income Level (%)								
<10000	21.5	13.7	20.2	14.4	22.1	12.3	23.8	14.7
10000-19999	39.5	37.1	38.8	37.8	41.4	35.9	39.4	37.9
20000-29999	24.5	29.9	24.7	29.7	23.7	30.7	24.1	28.9
>30000	14.5	19.2	16.3	17.9	12.8	21.0	12.7	18.4
Occupation (%)								
Professional	12.8	22.1	14.6	20.9	11.7	23.6	14.5	19.8
Clerical	9.2	14.7	9.6	14.7	9.8	14.0	9.7	12.6
Farmers/others	14.8	26.1	15.3	26.3	17.5	24.4	15.6	22.3
Housewife/Retired	63.2	37.1	60.5	38.0	61.0	38.0	60.2	45.3
CHD (%)	9.9	4.7	9.7	4.4	8.3	5.6	9.1	6.4
Stroke (%)	0.4	0.1	0.4	0.1	0.3	0.1	0.2	0.7
Cancer (%)	2.5	1.4	2.3	1.4	2.7	1.4	3.6	1.6
Hypertension (%)	29.1	17.0	28.6	16.8	26.2	18.9	26.1	21.6

* Total meat: unprocessed meat (red meat and poultry combined)

[a] Q1: Quintile 1; Q5: Quintile 5

Table 2: Unprocessed meat intake and risk of type 2 diabetes

	All Participants N=70609				Chronic disease at baseline excluded N=64191		
	Cases	**RR1**	**95% CI**	**P trend**	**RR2**	**95% CI**	**P trend**
Total Meat*							
Quintile 1	542	1.00		<0.01	1.00		0.01
Quintile 2	376	0.78	0.68-0.89		0.76	0.66-0.89	
Quintile 3	373	0.83	0.72-0.95		0.86	0.74-1.00	
Quintile 4	315	0.74	0.63-0.86		0.71	0.60-0.84	
Quintile 5	363	0.83	0.71-0.98		0.82	0.69-0.98	
Red meat							
Quintile 1	499	1.00		0. 06	1.00		0.08
Quintile 2	413	0.92	0.81-1.05		0.92	0.80-1.07	
Quintile 3	360	0.84	0.73-0.97		0.88	0.75-1.03	
Quintile 4	313	0.78	0.67-0.91		0.75	0.63-0.88	
Quintile 5	384	0.94	0.80-1.10		0.94	0.79-1.12	
Poultry							
Quintile 1	559	1.00		<0.001	1.00		0.001
Quintile 2	379	0.74	0.64-0.84		0.71	0.62-0.83	
Quintile 3	377	0.80	0.70-0.91		0.78	0.67-0.91	
Quintile 4	310	0. 69	0.60-0.80		0.68	0.58-0.79	
Quintile 5	344	0.78	0.67-0.90		0.79	0.67-0.92	

RR1 Adjusted for age, kcals/day, BMI, WHR, smoking, alcohol consumption, physical activity, vegetable intake, income level, education level, occupation status, hypertension, and chronic disease.

RR2 Adjusted for age, kcals/day, BMI, WHR, smoking, alcohol consumption, physical activity, vegetable intake, income level, education level, occupation status, and hypertension.

Table 3: Frequency of processed meat consumption and risk of type 2 diabetes

	All Participants N=70609				Chronic disease at baseline excluded N=64191		
	Cases	**RR1**	**95% CI**	**P trend**	**RR2**	**95% CI**	**P trend**
Total Processed Meat							
No	249	1.00		0.04	1.00		0.02
Yes	1720	1.15	1.01-1.32		1.21	1.03-1.41	
Frequency							
Never	249	1.00		0.67	1.00		0.38
<once per month	838	1.20	1.04-1.38		1.25	1.06-1.47	
≥once per month	882	1.10	0.95-1.27		1.18	0.99-1.37	
Types of product							
None	249	1.00		0.23	1.00		0.15
One type	716	1.15	0.99-1.33		1.22	1.03-1.44	
Two Types	628	1.15	0.99-1.34		1.17	0.99-1.39	
Three Types	376	1.14	0.96-1.34		1.23	1.02-1.48	
Smoked Meat /Bacon							
Never	1339	1.00		0.72	1.00		0.80
<once per month	488	1.02	0.92-1.14		1.01	0.90-1.14	
≥once per month	142	0.93	0.78-1.11		0.95	0.79-1.16	
Salted/Processed Meat							
Never	364	1.00		0.39	1.00		0.23
<once per month	1194	1.20	1.06-1.35		1.25	1.09-1.43	
≥once per month	411	1.07	0.93-1.24		1.13	0..93-1.32	
Chinese Sausage							
Never	1104	1.00		0.70	1.00		0.88
<once per month	707	1.02	0.93-1.12		1.02	0.93-1.12	
≥once per month	158	0.93	0.79-1.10		0.93	0.79-1.10	

RR1 Adjusted for age, kcals/day, BMI, WHR, smoking, alcohol consumption, physical activity, vegetable intake, income level, education level, occupation status, hypertension, and chronic disease.

RR2 Adjusted for age, kcals/day, BMI, WHR, smoking, alcohol consumption, physical activity, vegetable intake, income level, education level, occupation status, and hypertension.

Table 4: Joint effect of meat intake and obesity categories (WHO International) and type 2 DM risk*

	BMI<25		BMI =25-30		BMI>=30	
Total Meat**	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
Low	1.00		1.79	1.50-2.14	2.72	2.165-3.44
Medium	0.70	0.58-0.84	1.59	1.32-1.85	2.44	1.96-3.03
High	0.71	0.58-0.91	1.67	1.32-1.99	3.22	2.46-4.20
P interaction 0.05						
Red Meat	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
Low	1.00		1.78	1.48-2.14	2.85	2.25-3.62
Medium	0.77	0.64-0.93	1.69	1.42-2.00	2.65	2.13-3.29
High	0.79	0.64-0.99	1.83	1.49-2.24	3.34	2.56-4.37
P interaction 0.16						
Poultry	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
Low	1.00		1.80	1.51-2.14	3.04	2.44-3.80
Medium	0.61	0.51-0.73	1.47	1.24-1.74	2.13	1.71-2.66
High	0.77	0.63-0.95	1.50	1.23-1.83	2.91	2.22-3.81
P interaction 0.07						
Processed Meat	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
Never	1.00		1.67	1.28-2.20	2.14	1.44-3.18
<once per month	1.01	0.80-1.28	2.11	1.68-2.65	3.30	2.53-4.29
≥once per month	0.87	0.69-1.11	1.92	1.53-2.40	3.46	2.67-4.48
P interaction 0.08						

*Adjusted for age, kcals/day, WHR, smoking, alcohol consumption, physical activity, vegetable intake, income level, education level, occupation status, hypertension, and chronic disease.

**Total Meat: :unprocessed meat (red meat and poultry combined)