Title:

**Higher maternal dietary protein intake is associated with a higher risk for gestational diabetes mellitus in a multi-ethnic Asian cohort1-4**

Author names and affiliations:

Wei Wei Pang1, Marjorelee Colega2, Shirong Cai1, Yiong Huak Chan3, Natarajan Padmapriya1, Ling-Wei Chen4, Shu-E Soh2, Wee Meng Han5, Kok Hian Tan6, Yung Seng Lee2,4,7, Seang-Mei Saw8, Peter D Gluckman2,9, Keith M Godfrey10,11, Yap-Seng Chong1,2, \*Rob M van Dam8,12, \*Mary FF Chong2,8.

\*co-last authors

1Department of Obstetrics and Gynaecology, Yong Loo Lin School of Medicine, National University of Singapore, National University Health System, Singapore

2Singapore Institute for Clinical Sciences (SICS), Agency for Science, Technology and Research

3Department of Biostatistics, Yong Loo Lin School of Medicine, National University of Singapore, Singapore

4Department of Paediatrics, Yong Loo Lin School of Medicine, National University of Singapore, Singapore

5Department of Nutrition and Dietetics, KK Women's and Children's Hospital, Singapore

6Department of Maternal Fetal Medicine, KK Women’s and Children’s Hospital, Singapore

7Khoo Teck Puat-National University Children’s Medical Institute, National University Health System, Singapore

8Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore

9Liggins Institute, University of Auckland, Auckland 1142, New Zealand

10Medical Research Council Lifecourse Epidemiology Unit, Southampton

11NIHR Southampton Biomedical Research Centre, University of Southampton and University Hospital Southampton NHS Foundation Trust

12Department of Medicine, Yong Loo Lin School of Medicine, National University of Singapore and National University Health System, Singapore

Corresponding authors:

**Author 1**

Wei Wei Pang

Address: Department of Obstetrics & Gynaecology, National University of Singapore,

Tahir Foundation Building, 12 Science Drive 2, #12-03, Singapore 117549.

Phone: +65 6601 1963

Fax: +65 6779 4753

Email: [obgpww@nus.edu.sg](mailto:obgpww@nus.edu.sg)

**Author 2**

Mary Foong-Fong Chong

Address: Saw Swee Hock School of Public Health, Tahir Foundation Building, National University of Singapore, 12 Science Dr 2, #09-01Q, Singapore 117549.

Phone: +65 6516 4969

Fax: +65 6779 1489

Email: [ephmcff@nus.edu.sg](mailto:ephmcff@nus.edu.sg)

Authors’ last names:

Pang, Colega, Cai, Chan, Padmapriya, Chen, Soh, Han, Tan, Lee, Saw, Gluckman, Godfrey, Chong, van Dam, Chong.

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3 Supplemental Figure 1 and Supplemental Tables 1-8 are available from the “Online Supporting Material” link in the online posting of the article and from the same link in the online table of contents at jn.nutrition.org.

4 Abbreviations used: GDM, gestational diabetes mellitus; GUSTO, Growing Up in Singapore Toward healthy Outcomes; T2DM, type 2 diabetes mellitus; OGTT, oral glucose tolerance testing; SSB, Sugar-sweetened beverage.

**ABSTRACT**

**Background:** Dietary protein may affect glucose metabolism through several mechanisms, but results from studies on dietary protein intake and risk of gestational diabetes mellitus (GDM) have been inconsistent.

**Objective:** We examined the cross-sectional associations of dietary protein intake from different food sources during pregnancy with the risk for GDM in a multi-ethnic Asian population.

**Methods:** We included980 participants with singleton pregnancies from Growing Up in Singapore Toward healthy Outcomes (GUSTO) cohort. Protein intakes were ascertained from 24hr dietary recall and 3-day-food diary at 26–28 weeks’ gestation. GDM was defined as fasting glucose ≥7.0 mmol/L and/or 2-hour post-load glucose ≥7.8 mmol/L at 26-28 weeks’ gestation. We evaluated the association of dietary protein intake with GDM risk by substituting carbohydrate with protein in an isocaloric model using multivariable logistic regression analysis.

**Results:** Theprevalence ofGDM was17.9% among our participants. After adjustment for potential confounders, a higher total dietary protein intake was associated with a higher risk for GDM; the odds ratio (OR) comparing the highest versus the lowest quartile of intake was 2.15 (95% CI 1.27-3.62; *P*-trend= 0.016). Higher intakes of animal protein (OR 2.87; 95% CI 1.58-5.20; *P*-trend=0.001) and vegetable protein (OR 1.78; 95% CI 0.99-3.20; *P*-trend=0.009) were both associated with a higher risk for GDM. Among the animal protein sources, higher intakes of seafood protein (OR 2.17; 95% CI 1.26-3.72; *P*-trend=0.023) and dairy protein (OR 1.87; 95% CI 1.11-3.15; *P*-trend=0.017) were significantly associated with a higher GDM risk.

**Conclusions:** Higher intakes of both animal and vegetable protein were associated with higher risk for GDM in Asian women.

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**KEYWORDS**

Dietary protein; gestational diabetes mellitus; Asian; animal protein; vegetable protein

**INTRODUCTION**

Gestational diabetes mellitus (GDM), characterized by glucose intolerance with first recognition during pregnancy, is a complication associated with adverse pregnancy and perinatal outcomes. Besides an increased risk of delivering macrosomic babies (1), infants born to mothers with GDM are predisposed to obesity and developing metabolic syndrome in childhood (2). In addition, women with GDM are seven-fold more likely to develop type 2 diabetes mellitus (T2DM) later in life (3). Hence it is important to identify opportunities to prevent GDM through modifiable risk factors such as diet.

Many studies have examined the association of carbohydrate and fat intake with GDM (4-7), but less is known about the role of dietary protein intake and GDM. Dietary protein and amino acids are important modulators of glucose metabolism (8, 9)(8), with human and animal studies both showing that a high-protein diet is accompanied by increased insulin resistance and increased gluconeogenesis (10). Currently, most of what is known about the association between protein intake and GDM is inferred from studies examining protein intake and T2DM. In some (11, 12) but not all (13) cohort studies, higher protein intake was associated with a higher risk of T2DM. A higher consumption of animal protein, but not vegetable protein, was also associated with a higher risk of T2DM (11, 14).

One study in U.S. nurses specifically examined dietary protein intake in relation to risk of GDM (15). The authors reported that the risk of GDM was associated with the source of protein intake: higher animal protein intake was associated with a higher GDM risk, but higher vegetable protein intake was associated with a lower risk for GDM. Similar to the results for T2DM (16, 17), higher intake of red meat was associated with a higher risk of GDM (15). In contrast, a ‘protein-rich’ dietary pattern, characterized largely by high intakes of animal protein sources, was not associated with risk for GDM in a Chinese population (18). Studies in Mediterranean countries (19) and the U.S. (20) demonstrated that protein-dense foods, such as red meat and dairy, were also not associated with the risk for GDM.

The current literature on the role of dietary protein intake in the development of GDM is thus limited and inconsistent. Using data from a multi-ethnic Asian population where diets are different to those of the Western population and the prevalence of GDM is high (21, 22), we examined the association of dietary protein intake, as well as major dietary protein sources, during pregnancy with the risk of developing GDM.

**SUBJECTS AND METHODS**

Study Design and Population

The GUSTO (Growing Up in Singapore Toward healthy Outcomes) study, described in detail previously (23), is a birth cohort study which recruited 1247 pregnant women between the ages of 18 to 46yrs, from 2009 and 2010 in either KK Women’s and Children’s Hospital (KKH) or National University Hospital (NUH) in Singapore. Eligible subjects were of Chinese, Malay or Indian ethnicity with homogenous parental ethnic background and intended to deliver either at NUH or KKH. Women who were on chemotherapy, psychotropic drugs or those with type 1 diabetes were excluded. Ethical approval for the GUSTO study was given by the National Healthcare Group Domain Specific Review Board (NHG DSRB) and the Sing Health Centralised Institutional Review Board (CIRB). Written informed consent was provided by all participants.

For the current investigation, GUSTO participants were excluded if they did not undergo oral glucose tolerance testing (OGTT) at 26-28weeks’ gestation, had multiple births or underwent IVF treatment. Women were also excluded if their 24hr dietary recall data was incomplete or if their reported energy intake was unrealistic (i.e., <800kcal/day) (24). Hence, a total of 980 participants remained eligible for analysis (**Supplemental Figure 1**).

Maternal dietary assessment

Participants were asked to report on their food and beverage intakes using a 24hr recall and a 3-day food diary at 26–28 weeks’ gestation as previously described (24). In brief, the 24hr dietary recall was administered by trained staff in accordance to the 5-stage, multiple-pass interviewing technique (25). This was conducted prior to GDM diagnosis provided at the subsequent antenatal visit (see section on outcome assessment). To assist women in quantifying their food intake, pictures of food with various portion sizes as well as standardized household measuring utensils were presented. Additional details such as brands of food products and preparation methods were also documented. With guidance from staff, participants also filled out the 3-day food diary at home during the following week. The diaries were collected at the next clinic visit. Nutrient analysis software (Dietplan, Forestfield Software) was used to analyse nutrients in the dietary records. A database of locally available foods was primarily used to derive the food composition of the dietary records (26). For mixed dishes not found in the local database, nutrient content were derived from recipes using the nutrient software. Nutrient information of other food items not found in the database were obtained from either food labels or the USDA national nutrient database (NDL/FNLC Food composition database, 2011). Heme iron content was calculated using the mean percentage of heme iron in foods derived from published sources (27, 28). Nutrient information derived from 24hr recalls were used as the source of dietary data in our statistical analyses as only a smaller subset of participants with results on OGTT, also completed and returned 3-day food diaries (n=607). Sensitivity analyses were conducted on the subset that completed and returned the 3-day food diaries.

Assessment of other covariates

At the recruitment visit (<14 weeks gestation), interviewer-administered questionnaires were used to capture demographic data, socio-economic status, family medical history, as well as maternal obstetric and medical history, which included any previous GDM diagnosis (*i.e.,* any diagnosis of GDM from prior pregnancies). Maternal pre-pregnancy BMI was derived from self-reported pre-pregnancy weight and standing height measured using a stadiometer (SECA model 213, SECA Corp.). Information on smoking, alcohol consumption and physical activity level during pregnancy were collected using standardized interviewer-administered questionnaires at the time of blood collection at 26-28weeks’ clinic visit. The energy expended on physical activity was calculated as described previously (29). Gestational weight gain z-scores up to 26 weeks were derived using the method of Hutcheon *et al.* (2013) from serial pregnancy weight measurements taken from the clinical obstetric record (30).

Outcome assessment

GDM was ascertained by testing pregnant women’s blood glucose levels at the clinic visit conducted at 26–28 weeks’ gestation. Blood glucose levels were measured at (i) fasting and (ii) 2-hour post a 75g oral glucose tolerance test administered following an overnight fasting (8 to 10 hours). Women were diagnosed with GDM if fasting glucose was ≥7.0 mmol/L and/or 2-hour post-glucose was ≥7.8 mmol/L according to the 1999 World Health Organization (WHO) standard criteria for diagnosis of GDM (31, 32). Women were informed of their GDM status by their attending doctor in the subsequent antenatal visit.

Statistical Analyses

As total energy intake is correlated with most nutrients, macronutrient intake was expressed as a percentage of total energy intake using the nutrient-density method, and other nutrients were energy adjusted using the residual method (33). Dietary protein intake was categorized into quartiles to account for potential nonlinear associations, with lowest category used as the reference category in all models. For protein intake from red meat, poultry, seafood, egg, and from beans, participants were divided into 4 categories, where ‘no dietary intake’ was the lowest category, with remaining participants divided into tertiles of protein intakes. Protein intakes were also computed as 5% energy units and 2% energy units to compare the association with GDM for protein from different sources.

Characteristics and dietary intakes of the study population according to protein intake are described using proportions or means and standard deviations, with differences tested using χ2 test and linear regression. Multivariable logistic regression models were used to estimate odds ratios (ORs) for risk of developing GDM associated with maternal protein intake. Based on previous studies, models were adjusted for maternal age, education attainment, parity, ethnicity, pre-pregnancy BMI, family history of diabetes mellitus, previous history of GDM, smoking status during pregnancy, alcohol consumption during pregnancy and physical activity during pregnancy (15, 34).

The association of dietary protein intake with risk of GDM was evaluated using the substitution model (33). For this, carbohydrate was substituted with protein in an isocaloric model by simultaneously including the percentages of energy from protein and fat, total energy intake, and all other potential confounders in the model. The effect estimate from this model can be interpreted as the effect of increasing intake of protein at the expense of carbohydrate while keeping calories constant. Similarly, when estimating the effects of a major protein source (e.g., animal protein), carbohydrate was substituted with the protein source by simultaneously modeling all other protein sources (% total energy) with total energy and other confounding factors. The associations with increasing protein intake were examined at the expense of carbohydrate, instead of fat, as this appeared the most suitable macronutrient to replace protein as reflected by the lower intake of carbohydrate among participants with higher protein intakes.

To account for covariates with missing data (**Supplemental Figure 1**), where the proportion missing ranged from 0.1%-6.6%, missing values were imputed with the mode value for categorical variables, or median values for continuous variables. For pre-pregnancy BMI, BMI was imputed using BMI derived from first pregnancy study visit (<14 weeks gestation) which showed a high correlation with pre-pregnancy BMI (r=0.965).

Several sensitivity analyses were performed. Firstly, the associations between dietary protein intake and the risk of GDM were assessed when models were further adjusted for (a) maternal dietary fiber intake, saturated fat intake, heme iron intake and SSB consumption, and (b) gestational weight gain. Secondly, the effects of substituting carbohydrate with protein intake ascertained from 3 day food records were estimated in a smaller subset of participants (n=607). Thirdly, statistical analyses were performed using (a) non-imputed data by excluding all participants with missing data, and (b) data imputed by multiple imputation. Fourth, the effect of substituting fat, instead of carbohydrate, with protein in an isocaloric model was estimated by simultaneously including the percentages of energy from protein and carbohydrate, total energy intake, and all other potential confounders in the model. As some women had blood glucose testing outside of, and prior to, the 26-28wk study visit, sensitivity analyses excluding these women were also performed. Lastly, the associations between dietary protein intake and the risk of GDM were assessed when models were adjusted for covariates which were significantly associated with total protein intake in univariate analyses. Potential effect modification by maternal age and ethnicity on the association of maternal protein intake and the risk for GDM was evaluated by inclusion of multiplicative interaction terms into the multivariable models.

All statistical analyses were performed using SPSS version 20.0 (IBM). *P* < 0.05 was considered statistically significant.

**RESULTS**

Baseline characteristics

Among the 980 participants included in our analyses, 175 (17.9%) had GDM at 26-28 weeks’ of pregnancy. Older women and those of Chinese ethnicity, tended to consume more dietary protein during pregnancy than younger women and those of Malay and Indian ethnicity respectively. With regard to dietary intakes, total dietary protein intake was associated with lower intakes of carbohydrates, saturated fat, dietary fiber, sugar-sweetened beverage and coffee or tea (**Table 1**).

Pregnancy dietary protein intake and the risk of GDM

The median intake of total dietary protein were 11.4% and 19.9% of energy in the lowest and the highest quartile, respectively. Animal protein accounted for the majority (59.3%) of total protein intake. After adjustment for age, ethnicity, BMI, and other potential non-dietary and dietary confounders, substituting energy from carbohydrates with total protein was significantly associated with a higher GDM risk (OR 2.15; 95% CI 1.27-3.62 for highest vs. lowest quartile; *P-*trend=0.016) (**Table 2**). Both animal and vegetable protein intakes were associated with higher GDM risk, with multivariable-adjusted ORs (95% CI) for GDM comparing highest with lowest quartile of 2.87 (1.58-5.20) for animal protein intake (*P-*trend=0.001), and 1.78 (0.99-3.20) for vegetable protein intake (*P*-trend= 0.009). Similarly, when protein intakes were expressed as 5% energy units, both animal and vegetable protein intakes were associated with significantly higher GDM risks; multivariable ORs (95% CI) of 1.38 (1.10-1.73) and 1.90 (1.14-3.16) for animal and vegetable protein intakes, respectively.

Among the major protein sources, higher protein intakes from seafood and dairy were significantly associated with higher risks for GDM; multivariable-adjusted ORs (95% CI) of GDM for highest vs. lowest levels of intake were 2.17 (1.26-3.72) for seafood protein (*P*-trend=0.023) and 1.87 (1.11-3.15) for dairy protein (*P*-trend=0.017) (**Table 3**). Higher intake of protein from other sources such as red meat, poultry and beans were also associated with a higher GDM risk but these associations were not statistically significant (Table 3).

Ethnicity did not significantly modify the associations between pregnancy dietary protein intake and GDM risk (*P*-interaction of 0.14). Effect modification by maternal age was borderline significant (*P*-interaction of 0.08) – the associations of dietary protein intake and GDM risk post stratification are shown in **Supplemental Table 1**. Relative to younger women (<35 yrs), the direct association between intake of dietary protein, particularly animal protein, and risk of developing GDM was stronger in older women (≥35 yrs). However, the direction of association was the same regardless of maternal age.

Several sensitivity analyses were conducted to evaluate whether the associations between protein intakes and risk for GDM were robust. Firstly, the association of dietary protein intakes with the risk for GDM remained similar with additional adjustments for dietary fiber, saturated fat, heme iron and SSB (**Supplemental Table 2**). Results also remained consistent with further adjustment for gestational weight gain (**Supplemental Table 3**). Thirdly, the associations were similar when missing covariates were not imputed (**Supplemental Table 4**), or imputed using multiple imputation **(Supplemental Table 5)**. Fourth, when analysis was repeated on a smaller subset of participants who had dietary data collected using 3 day diet records (*n*=607), a higher total dietary protein intake remained significantly associated with a higher risk of GDM (**Supplemental Table 6**). Fifth, substituting protein at the expense of fat yielded similar results as substituting protein at the expense of carbohydrate (**Supplemental Table 7**). Lastly, the removal of participants with prior blood glucose testing conducted outside of the study resulted in attenuated, albeit similar, associations between protein intake and risk for GDM (**Supplemental Table 8**).

**DISCUSSION**

In our multi-ethnic Asian population with a high prevalence of GDM (21), we observed that high protein intake at the expense of carbohydrate or fat was associated with a higher risk for GDM. This association was driven by both animal and vegetable protein intake. Among specific food sources of protein, high protein intake from seafood and dairy were associated with higher risks of GDM.

Similar to previous studies on T2DM (11, 12), we observed that higher total protein intake was associated with a higher risk for GDM. This association was independent of pre-pregnancy BMI, and the intake levels of saturated fat, dietary fiber, heme iron and SSB. Dietary protein and amino acid intake can modulate glucose metabolism through various mechanisms, such as by interfering with insulin’s ability to increase peripheral glucose uptake (10), with long-term consumption of high protein diets shown to increase fasting glucose level, increase gluconeogenesis and impair the suppression of hepatic glucose output by insulin (35).

We observed that higher intake of protein from animal sources was associated with a higher risk of developing GDM. This is consistent with results from U.S. nurses (15), even though the average animal protein intake of our population was considerably lower, with median protein intakes of 4.2% and 14.3% of energy in the lowest and the highest quartile, respectively, compared to 10.0% and 18.6% of energy in the lowest and the highest quintile in Nurses’ Health Study II.

We also observed that higher intake of vegetable protein was associated with a higher risk for GDM in our population. Despite similar levels of average vegetable protein intake, our result is in contrast to the findings from the cohort of U.S. nurses in which higher vegetable protein intake was associated with a lower GDM risk (15). Our result is also inconsistent with studies on T2DM conducted in Western populations which have reported no association between vegetable protein intake and T2DM (13, 14, 36). Further exploration of vegetable protein sources did not reveal the association of any particular vegetable protein source with a higher risk of GDM, suggesting that vegetable protein per se may be associated with GDM risk in our population. Reasons for the inconsistency of our results for vegetable protein with those published previously are unclear, but may be due to differing dietary patterns in our Asian population as compared with Western populations (34, 37, 38). These differences in dietary patterns may have resulted in different inter-correlations of foods and nutrients and possibly enabled us to better distinguish vegetable protein intake from co-consumption of healthy food components.

Higher intake of red meat was associated with higher T2DM and GDM risks in previous studies (7, 15). Although protein from red meat was associated with a higher risk of GDM in our study, this association was not significant. One possible reason for this may be that red meat was a smaller source of animal protein in our Asian population as compared with Western populations. Data from the National Health and Nutrition Examination Surveys (NHANES) conducted in 2003-2004 showed that red meat made up 58% of meat intake in the U.S., followed by poultry (32%) and fish (10%) (39). In our population, red meat made up 29% of meat intake, with seafood making up the largest proportion at 43%, and poultry 28%.

Our results showed that higher protein intake from seafood, which included all types of fish and shellfish, was associated with a higher risk for GDM, in contrast to the findings from the cohort of U.S. nurses which showed no association (15). Results from epidemiologic studies examining the relationship between fish or seafood intake and T2DM have been inconclusive (40-42). Meta-analyses on this topic were also inconsistent (43-45), which may be related to geographical differences (44) and type of fish/seafood consumed (43). As seafood protein is the largest component of protein intake in our population, its association with GDM risk may be a reflection of the association between protein intake per se and GDM in our population.

In addition to protein from seafood, we found that higher dairy protein intake was also associated with a higher risk for GDM. Dairy protein in our cohort was derived from low- and full-fat milk, yoghurt and cheese, as well as formula milk, milk-based malt drinks and cultured yoghurt drinks. The association between protein from dairy and GDM risk remained significant even after further adjustments for possible confounders such as saturated fat intake. This result is in contrast with previous studies in which dairy consumption was generally associated with a lower risk of T2DM (46-51), and not with risk for GDM (15). However, to our knowledge, none of the epidemiologic studies have specifically examined protein from dairy in relation to risk of diabetes. Further research is needed to examine if the association between dairy and GDM risk in our population is due to dairy protein itself or other components of dairy.

Strengths of this study include the multi-ethnic nature of our Asian population and detailed information on potential confounders. Additionally, a study in Asia can provide additional insights into the association between dietary protein intake and the risk of GDM due to the different inter-correlations between dietary components and confounding factors in general. There are also limitations to this study. Maternal diet was assessed using one 24hr dietary recall which may not be reflective of mother's diet during pregnancy. We repeated the analyses on a subset of participants (n=607) who had dietary data collected using 3 day diet records and observed similar association between total protein intake and GDM risk. The association between GDM risk and the intake of protein subtypes from 3 day diet record could not be determined as these data were not available. However, the stronger associations for the 3 day diet records as compared with the 24hr recall estimates suggest that greater within-person variation for the latter may have weakened the observed associations. Second, we cannot fully rule out reverse causation. However, the dietary intakes in this study could not have been affected by knowledge of the OGTT results as women were only informed of GDM diagnosis after the dietary assessments were performed. Third, even though we controlled for confounding by known risk factors of GDM, we cannot completely exclude the possibility of residual confounding owing to the observational nature of the study.

In conclusion, findings from our Asian study population suggest that higher intake of dietary protein, from both animal and vegetable sources during pregnancy is associated with a higher risk of developing GDM. In contrast to previous studies in Western populations where red meat is a major source of protein, our results indicate that a variety of food sources of protein are associated with GDM risk. Therefore, our results support the hypothesis that high protein intake per se, rather than other components of high protein foods such as heme iron or saturated fats, increases the risk of GDM.

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SMS, PDG, KMG, YSC, YSL and KHT designed and led the GUSTO study; MFFC and RMvD designed research; MC and NP conducted research and provided essential materials; SC, LWC, SES and WMH provided essential materials; WWP analyzed data and wrote the paper; RMvD, YHC and MFFC guided the statistical analyses; and MFFC and RMvD reviewed the manuscript for important intellectual content. WWP, MFFC and RMvD had primary responsibility for the final content. All authors read and approved the final manuscript.

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TABLE 1

Participant characteristics and dietary intake at 26-28 weeks of gestation by quartiles of protein intake in the GUSTO study (*n* =980)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Total protein intake (%E) | | | | | | | | | | | | | | | | | |  | | | |
|  | **Q1**  **(*n*=245)** | | | | **Q2**  **(*n*=245)** | | | | | **Q3**  **(*n*=245)** | | | | | **Q4**  **(*n*=245)** | | | | ***P-*trend** | | | |
| **Characteristics1** | **Median (%E) = 11.4** | | | | **Median (%E) = 14.3** | | | | | **Median (%E) = 16.5** | | | | | **Median (%E) = 19.9** | | | |  | | | |
| Maternal age (years) | 30.2 | ± | | 5.1 | 29.9 | ± | | 4.9 | | 31.0 | ± | | 5.3 | | 30.9 | ± | | 5.3 | | 0.028 | | | |
| Pre-pregnancy weight2 (kg) | 56.1 | ± | | 11.6 | 57.0 | ± | | 11.6 | | 56.0 | ± | | 10.4 | | 56.1 | ± | | 11.2 | | 0.75 | | | |
| Pre-pregnancy BMI2 (kg/m2) | 22.6 | ± | | 4.6 | 22.6 | ± | | 4.3 | | 22.4 | ± | | 3.8 | | 22.5 | ± | | 4.3 | | 0.58 | | | |
| Physical activity during pregnancy2 (MET hr/week) | 36.4 | ± | | 65.6 | 33.1 | ± | | 45.5 | | 27.9 | ± | | 38.0 | | 32.0 | ± | | 47.4 | | 0.21 | | | |
| Ethnicity, *n (%)* |  | | | |  | | | | |  | | | | |  | | | | | | | <0.0014 |
| Chinese | 101 | | (41.2) | | 132 | | (53.9) | | 145 | | | (59.2) | | 169 | | | (69.0) | | | | |  |
| Malay | 80 | | (32.7) | | 61 | | (24.9) | | 63 | | | (25.7) | | 54 | | | (22.0) | | | | |  |
| Indian | 64 | | (26.1) | | 52 | | (21.2) | | 37 | | | (15.1) | | 22 | | | (9.0) | | | | |  |
| Maternal education level2, *n (%)* |  | |  | |  | |  | |  | | |  | |  | | |  | | | | | 0.124 |
| No education/ Primary/secondary | 80 | | (33.5) | | 68 | | (28.2) | | 74 | | | (30.2) | | 71 | | | (29.3) | | | | |  |
| Technical College | 34 | | (14.2) | | 28 | | (11.6) | | 26 | | | (10.6) | | 17 | | | (7.0) | | | | |  |
| Pre-university | 49 | | (20.5) | | 56 | | (23.2) | | 71 | | | (29.0) | | 70 | | | (28.9) | | | | |  |
| University | 76 | | (31.8) | | 89 | | (36.9) | | 74 | | | (30.2) | | 84 | | | (34.7) | | | | |  |
| Primiparous2, *n (%)* | 104 | | (42.4) | | 97 | | (39.6) | | 113 | | | (46.1) | | 109 | | | (44.7) | | | | | 0.494,5 |
| Family history of diabetes2, *n (%)* | 82 | | (35.0) | | 74 | | (30.8) | | 72 | | | (29.8) | | 76 | | | (31.7) | | | | | 0.644,6 |
| Previous GDM2, *n (%)* | 5 | | (2.1) | | 8 | | (3.3) | | 8 | | | (3.3) | | 15 | | | (6.2) | | | | | 0.114,7 |
| Smoking status2, *n (%)* |  | |  | |  | |  | |  | | |  | |  | | |  | | | | | 0.254 |
| Never smoker | 201 | | (82.4) | | 214 | | (87.3) | | 213 | | | (86.9) | | 217 | | | (88.9) | | | | |  |
| Former smoker | 37 | | (15.2) | | 25 | | (10.2) | | 23 | | | (9.4) | | 23 | | | (9.4) | | | | |  |
| Current smoker | 6 | | (2.5) | | 6 | | (2.4) | | 9 | | | (3.7) | | 4 | | | (1.6) | | | | |  |
| Consumed alcohol during pregnancy2, *n (%)* | 1 | | (0.4) | | 7 | | (2.9) | | 8 | | | (3.3) | | 2 | | | (0.9) | | | | | 0.0414,8 |
| Dietary intake |  | | | |  | | | | |  | | | | |  | | | |  | | | |
| Energy (kcal/d) | 1958 | ± | | 632 | 1913 | ± | | 573 | | 1887 | ± | | 534 | | 1835 | ± | | 539 | | 0.015 | | | |
| Carbohydrate (%E) | 56.7 | ± | | 8.1 | 53.6 | ± | | 7.6 | | 50.5 | ± | | 7.7 | | 45.8 | ± | | 7.7 | | <0.001 | | | |
| Fat (%E) | 32.2 | ± | | 7.8 | 32.2 | ± | | 7.6 | | 32.8 | ± | | 7.6 | | 33.4 | ± | | 7.3 | | 0.049 | | | |
| Saturated fat (%E) | 13.7 | ± | | 4.4 | 13.1 | ± | | 4.0 | | 12.9 | ± | | 3.7 | | 12.6 | ± | | 3.7 | | 0.004 | | | |
| Protein (%E) | 11.1 | ± | | 1.4 | 14.2 | ± | | 0.8 | | 16.6 | ± | | 0.7 | | 20.7 | ± | | 2.9 | | <0.001 | | | |
| Animal protein (%E) | 4.6 | ± | | 2.3 | 7.7 | ± | | 2.2 | | 10.2 | ± | | 2.3 | | 14.6 | ± | | 3.6 | | <0.001 | | | |
| Protein from poultry (%E) | 1.0 | ± | | 1.5 | 2.0 | ± | | 2.3 | | 2.9 | ± | | 3.0 | | 4.5 | ± | | 4.5 | | <0.001 | | | |
| Protein from seafood (%E) | 1.1 | ± | | 1.5 | 1.9 | ± | | 2.2 | | 2.5 | ± | | 2.6 | | 4.7 | ± | | 4.6 | | <0.001 | | | |
| Protein from red meat (%E) | 0.9 | ± | | 1.4 | 1.4 | ± | | 1.9 | | 2.0 | ± | | 2.3 | | 2.7 | ± | | 3.2 | | <0.001 | | | |
| Protein from dairy (%E) | 1.2 | ± | | 1.1 | 1.6 | ± | | 1.5 | | 1.9 | ± | | 1.7 | | 1.9 | ± | | 1.6 | | <0.001 | | | |
| Protein from egg (%E) | 0.5 | ± | | 0.8 | 0.8 | ± | | 1.1 | | 0.9 | ± | | 1.1 | | 0.8 | ± | | 1.1 | | 0.001 | | | |
| Vegetable protein (%E) | 6.5 | ± | | 1.9 | 6.5 | ± | | 2.0 | | 6.5 | ± | | 2.2 | | 6.2 | ± | | 2.1 | | 0.11 | | | |
| Protein from rice, noodles, desserts (%E) | 4.5 | ± | | 1.5 | 4.3 | ± | | 1.4 | | 4.2 | ± | | 1.5 | | 3.8 | ± | | 1.2 | | <0.001 | | | |
| Protein from beans (%E) | 0.8 | ± | | 1.2 | 0.9 | ± | | 1.3 | | 1.0 | ± | | 1.4 | | 1.1 | ± | | 1.4 | | 0.008 | | | |
| Protein from other vegetable sources (%E) | 1.3 | ± | | 1.2 | 1.3 | ± | | 0.9 | | 1.3 | ± | | 1.0 | | 1.4 | ± | | 1.1 | | 0.38 | | | |
| Dietary fibre3 (g/d) | 17.4 | ± | | 9.4 | 17.1 | ± | | 8.4 | | 16.4 | ± | | 8.8 | | 15.5 | ± | | 5.6 | | 0.007 | | | |
| Dietary Iron3 (mg/d) | 11.3 | ± | | 6.3 | 13.5 | ± | | 10.6 | | 13.1 | ± | | 5.3 | | 15.5 | ± | | 8.6 | | <0.001 | | | |
| Heme3 (mg/d) | 0.5 | ± | | 1.0 | 0.9 | ± | | 1.9 | | 0.9 | ± | | 0.7 | | 1.3 | ± | | 1.2 | | <0.001 | | | |
| Non-heme3 (mg/d) | 10.9 | ± | | 5.7 | 12.7 | ± | | 9.0 | | 12.2 | ± | | 5.2 | | 14.2 | ± | | 8.3 | | <0.001 | | | |
| SSB, ≥ 250 mL/day, *n (%)* | 76 | (31.0) | | | 58 | (23.7) | | | | 64 | (26.1) | | | | 48 | (19.6) | | | | | 0.0304,9 | | | |
| Coffee or tea, ≥ 150 mL/day, *n (%)* | 68 | (27.8) | | | 80 | (32.7) | | | | 58 | (23.7) | | | | 49 | (20.0) | | | | | 0.0104,10 | | | |

1Data presented are mean ±SD unless otherwise stated.

2Number of participants with missing data: Pre-pregnancy weight (*n* =65); Pre-pregnancy BMI (*n* =65); Physical Activity during pregnancy (*n* =13); Mother’s education (*n* =13); Parity (*n* =1); Family history of diabetes (*n* =24); Previous GDM (*n* =24); Smoking status (*n* =2) and Alcohol consumption during pregnancy (*n* =23).

3Energy-adjusted using the residual method.

4*P* for differences between groups.

Compared with women who 5were multiparous, 6had no family history of diabetes, 7had no previous GDM, 8did not consume alcohol, 9consumed <250 mL/day, 10consumed <150 mL/day

E: energy; hr: hour; GDM: gestational diabetes mellitus; MET: metabolic equivalent task; SSB: Sugar-sweetened beverage

TABLE 2

Odds ratio (OR) for GDM according to pregnancy intake of dietary protein in the GUSTO study (*n* =980)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *n* | Median intake  (% E) | Model 11 | Model 22 |
| **OR (95% CI)** | **OR (95% CI)** |
| Total protein |  |  |  |  |
| Q1 | 245 | 11.4 | reference | reference |
| Q2 | 245 | 14.3 | 1.71 (1.03, 2.85) | 1.72 (1.02, 2.92) |
| Q3 | 245 | 16.5 | 1.28 (0.75, 2.17) | 1.28 (0.74, 2.21) |
| Q4 | 245 | 19.9 | 2.28 (1.38, 3.77) | 2.15 (1.27, 3.62) |
| Per 5 energy % | 980 |  | 1.43 (1.16, 1.76) | 1.37 (1.10, 1.71) |
| *P*-trend | 980 |  | 0.006 | 0.10 |
| Animal protein |  |  |  |  |
| Q1 | 245 | 4.2 | reference | reference |
| Q2 | 245 | 7.7 | 1.46 (0.88, 2.43) | 1.82 (1.06, 3.14) |
| Q3 | 245 | 10.4 | 1.33 (0.80, 2.24) | 1.79 (1.01, 3.17) |
| Q4 | 245 | 14.3 | 2.04 (1.23, 3.38) | 2.87 (1.58, 5.20) |
| Per 5 energy % | 980 |  | 1.23 (1.02, 1.49) | 1.38 (1.10, 1.73) |
| *P*-trend | 980 |  | 0.012 | 0.001 |
| Vegetable protein |  |  |  |  |
| Q1 | 245 | 4.1 | reference | reference |
| Q2 | 245 | 5.6 | 0.72 (0.43, 1.21) | 0.84 (0.48, 1.48) |
| Q3 | 245 | 6.8 | 1.32 (0.82, 2.11) | 1.69 (0.99, 2.89) |
| Q4 | 245 | 8.7 | 1.24 (0.76, 2.01) | 1.78 (0.99, 3.20) |
| Per 5 energy % | 980 |  | 1.35 (0.89, 2.05) | 1.90 (1.14, 3.16) |
| *P*-trend | 980 |  | 0.12 | 0.009 |

1Model 1: adjusted for maternal age (continuous) and ethnicity (Chinese, Malay, Indian).

2Model 2: model 1 adjustments plus parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), total fat intake (quartiles), total energy intake (quartiles) and mutual adjustment for animal and vegetable protein. CI, confidence interval; E, energy; OR, odds ratio; Q, quartile.

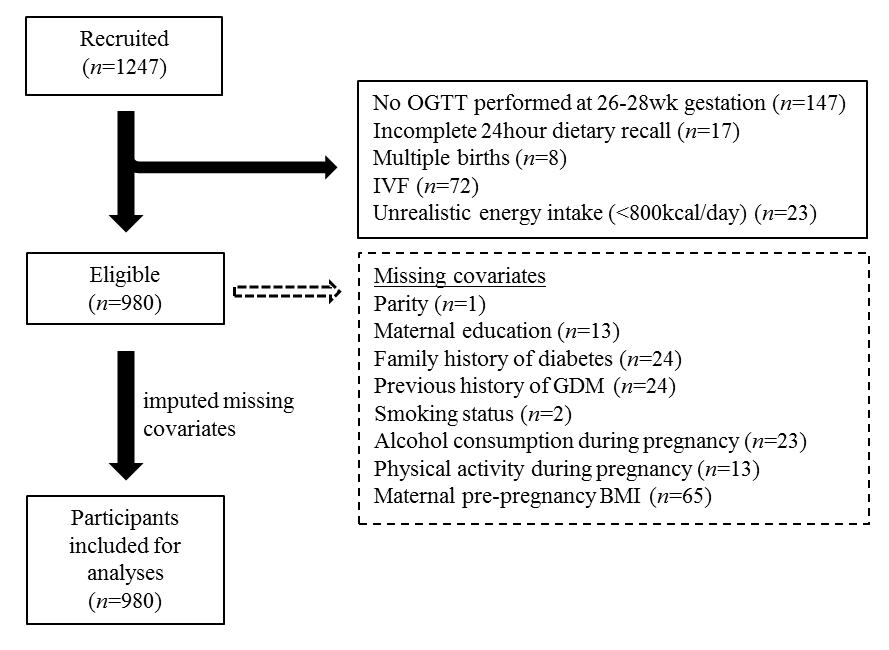
TABLE 3

Odds ratio (OR) for GDM according to pregnancy intake of various sources of dietary protein in the GUSTO study (*n* =980)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *n* | Median intake  (% E) | Model 11 | Model 22 |
| **OR (95% CI)** | **OR (95% CI)** |
| Red meat protein |  |  |  |  |
| No intake | 427 | 0.0 | reference | reference |
| T1 | 184 | 1.0 | 0.96 (0.58, 1.58) | 1.09 (0.64, 1.85) |
| T2 | 185 | 2.3 | 0.92 (0.56, 1.51) | 1.00 (0.58, 1.74) |
| T3 | 184 | 5.2 | 1.11 (0.69, 1.80) | 1.40 (0.81, 2.42) |
| Per 2 energy % | 980 |  | 1.07 (0.93, 1.23) | 1.13 (0.96, 1.33) |
| *P*-trend | 980 |  | 0.76 | 0.31 |
| Poultry protein |  |  |  |  |
| No intake | 340 | 0.0 | reference | reference |
| T1 | 213 | 1.1 | 0.84 (0.52, 1.35) | 0.91 (0.55, 1.51) |
| T2 | 214 | 3.3 | 1.24 (0.80, 1.93) | 1.48 (0.91, 2.41) |
| T3 | 213 | 6.7 | 0.80 (0.49, 1.30) | 1.16 (0.67, 2.02) |
| Per 2 energy % | 980 |  | 1.00 (0.90, 1.11) | 1.09 (0.96, 1.23) |
| *P*-trend | 980 |  | 0.77 | 0.28 |
| Seafood protein |  |  |  |  |
| No intake | 317 | 0.0 | reference | reference |
| T1 | 221 | 1.0 | 1.53 (0.95, 2.46) | 1.66 (1.00, 2.77) |
| T2 | 221 | 2.8 | 1.14 (0.69, 1.89) | 1.23 (0.75, 2.09) |
| T3 | 221 | 6.6 | 1.62 (1.01, 2.59) | 2.17 (1.26, 3.72) |
| Per 2 energy % | 980 |  | 1.07 (0.97, 1.18) | 1.15 (1.03, 1.29) |
| *P*-trend | 980 |  | 0.12 | 0.023 |
| Egg protein |  |  |  |  |
| No intake | 460 | 0.0 | reference | reference |
| T1 | 173 | 0.5 | 0.77 (0.47, 1.27) | 0.83 (0.49, 1.41) |
| T2 | 174 | 1.2 | 1.02 (0.64, 1.63) | 1.15 (0.70, 1.89) |
| T3 | 173 | 2.3 | 1.15 (0.73, 1.80) | 1.28 (0.78, 2.08) |
| Per 2 energy % | 980 |  | 1.05 (0.76, 1.45) | 1.10 (0.77, 1.55) |
| *P*-trend | 980 |  | 0.56 | 0.29 |
| Dairy protein |  |  |  |  |
| Q1 | 245 | 0.0 | reference | reference |
| Q2 | 245 | 0.9 | 1.18 (0.72, 1.94) | 1.21 (0.72, 2.05) |
| Q3 | 245 | 1.8 | 1.25 (0.76, 2.04) | 1.41 (0.83, 2.37) |
| Q4 | 245 | 3.3 | 1.52 (0.94, 2.46) | 1.87 (1.11, 3.15) |
| Per 2 energy % | 980 |  | 1.22 (0.99, 1.50) | 1.36 (1.07, 1.71) |
| *P*-trend | 980 |  | 0.09 | 0.017 |
| Rice, noodles, dessert protein | | |  |  |
| Q1 | 245 | 2.6 | reference | reference |
| Q2 | 245 | 3.7 | 0.60 (0.37, 0.96) | 0.60 (0.36, 1.01) |
| Q3 | 245 | 4.5 | 0.59 (0.36, 0.95) | 0.73 (0.43, 1.25) |
| Q4 | 245 | 5.8 | 1.04 (0.66, 1.65) | 1.45 (0.83, 2.53) |
| Per 2 energy % | 980 |  | 0.99 (0.54, 1.81) | 1.18 (0.87, 1.60) |
| *P*-trend | 980 |  | 0.96 | 0.27 |
| Beans protein | |  |  |  |
| No intake | 375 | 0.0 | reference | reference |
| T1 | 201 | 0.2 | 0.85 (0.52, 1.39) | 0.92 (0.55, 1.54) |
| T2 | 202 | 1.1 | 1.18 (0.75, 1.86) | 1.17 (0.71, 1.90) |
| T3 | 202 | 2.7 | 1.33 (0.85, 2.09) | 1.44 (0.88, 2.35) |
| Per 2 energy % | 980 |  | 1.18 (0.94, 1.49) | 1.27 (0.98, 1.64) |
| *P*-trend | 980 |  | 0.15 | 0.13 |

1Model 1: adjusted for maternal age (continuous) and ethnicity (Chinese, Malay, Indian).

2Model 2: model 1 adjustments plus parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), total fat intake (quartiles), total energy intake (quartiles) and mutual adjustment for other major dietary protein sources. CI, confidence interval; E, energy; OR, odds ratio; Q, quartile; T, tertile (tertiles among consumers).



SUPPLEMENTAL FIGURE 1. Flowchart of participants included for analysis in the GUSTO (Growing Up in Singapore Towards healthy Outcomes) study, Singapore. BMI: body mass index; GDM: gestational diabetes mellitus; IVF: in vitro fertilization; OGTT: oral glucose tolerance testing; wk: week.

SUPPLEMENTAL TABLE 1

Effect modification of maternal age on the association of dietary protein intake (per 5 energy %) and GDM in the GUSTO study (*n* =980)

|  |  |  |  |
| --- | --- | --- | --- |
|  | *n* | Model 11 | Model 22 |
| **OR (95% CI)** | **OR (95% CI)** |
| Total Protein |  |  |  |
| <35years old | 763 | 1.25 (0.98, 1.60) | 1.23 (0.95, 1.59) |
| ≥35 years old | 217 | 2.27 (1.45, 3.54) | 2.21 (1.34, 3.64) |
| Animal Protein |  |  |  |
| <35years old | 763 | 1.07 (0.86, 1.33) | 1.25 (0.96, 1.63) |
| ≥35 years old | 217 | 1.85 (1.26, 2.72) | 2.17 (1.31, 3.61) |
| Vegetable Protein |  |  |  |
| <35years old | 763 | 1.58 (0.97, 2.56) | 1.99 (1.08, 3.67) |
| ≥35 years old | 217 | 1.15 (0.52, 2.52) | 2.21 (0.83, 5.91) |

1Model 1: adjusted for ethnicity (Chinese, Malay, Indian).

2Model 2: model 1 adjustments plus parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), total fat intake (quartiles), total energy intake (quartiles) and mutual adjustment for animal and vegetable protein. CI, confidence interval; E, energy; OR, odds ratio; Q, quartile.

SUPPLEMENTAL TABLE 2

Odds ratio (OR) for GDM according to pregnancy intake of dietary protein with further adjustments for dietary fiber, saturated fat, heme iron and SSB in the GUSTO study (*n* =980)

|  |  |  |  |
| --- | --- | --- | --- |
|  | *n* | Median intake  (% E) | Model 2a1 |
| **OR (95% CI)** |
| Total protein |  |  |  |
| Q1 | 231 | 11.4 | reference |
| Q2 | 236 | 14.3 | 1.67 (0.97, 2.89) |
| Q3 | 240 | 16.5 | 1.32 (0.74, 2.36) |
| Q4 | 234 | 19.9 | 2.44 (1.34, 4.47) |
| Per 5 energy % | 941 |  | 1.52 (1.17, 1.96) |
| *P*-trend | 941 |  | 0.013 |
| Animal protein2 |  |  |  |
| Q1 | 233 | 4.2 | reference |
| Q2 | 237 | 7.7 | 1.87 (1.05, 3.31) |
| Q3 | 239 | 10.4 | 2.09 (1.12, 3.90) |
| Q4 | 232 | 14.3 | 3.58 (1.80, 7.13) |
| Per 5 energy % | 941 |  | 1.52 (1.18, 1.98) |
| *P*-trend | 941 |  | 0.001 |
| Vegetable protein2 |  |  |  |
| Q1 | 236 | 4.1 | reference |
| Q2 | 236 | 5.6 | 0.81 (0.45, 1.45) |
| Q3 | 231 | 6.8 | 1.70 (0.96, 3.01) |
| Q4 | 238 | 8.7 | 1.62 (0.84, 3.10) |
| Per 5 energy % | 941 |  | 1.63 (0.93, 2.85) |
| *P*-trend | 941 |  | 0.036 |
| Red meat protein3 |  |  |  |
| No intake | 406 | 0.0 | reference |
| T1 | 178 | 1.0 | 1.15 (0.66, 1.98) |
| T2 | 181 | 2.3 | 1.10 (0.61, 1.98) |
| T3 | 176 | 5.2 | 1.66 (0.87, 3.15) |
| Per 2 energy % | 941 |  | 1.21 (1.00, 1.46) |
| *P*-trend | 941 |  | 0.18 |
| Poultry protein3 |  |  |  |
| No intake | 326 | 0.0 | reference |
| T1 | 210 | 1.1 | 0.95 (0.57, 1.59) |
| T2 | 204 | 3.3 | 1.77 (1.04, 2.99) |
| T3 | 201 | 6.7 | 1.38 (0.74, 2.57) |
| Per 2 energy % | 941 |  | 1.14 (0.99, 1.31) |
| *P*-trend | 941 |  | 0.11 |
| Seafood protein3 |  |  |  |
| No intake | 295 | 0.0 | reference |
| T1 | 213 | 1.0 | 1.77 (1.05, 3.00) |
| T2 | 213 | 2.8 | 1.39 (0.80, 2.41) |
| T3 | 220 | 6.6 | 2.41 (1.37, 4.24) |
| Per 2 energy % | 941 |  | 1.19 (1.05, 1.34) |
| *P*-trend | 941 |  | 0.009 |
| Egg protein3 |  |  |  |
| No intake | 439 | 0.0 | reference |
| T1 | 170 | 0.5 | 0.84 (0.48, 1.44) |
| T2 | 167 | 1.2 | 1.21 (0.72, 2.01) |
| T3 | 165 | 2.3 | 1.30 (0.79, 2.14) |
| Per 2 energy % | 941 |  | 1.14 (0.80, 1.62) |
| *P*-trend | 941 |  | 0.25 |
| Dairy protein3 |  |  |  |
| Q1 | 241 | 0.0 | reference |
| Q2 | 229 | 0.9 | 1.23 (0.72, 2.08) |
| Q3 | 234 | 1.8 | 1.43 (0.84, 2.43) |
| Q4 | 237 | 3.3 | 1.82 (1.07, 3.12) |
| Per 2 energy % | 941 |  | 1.34 (1.06, 1.71) |
| *P*-trend | 941 |  | 0.024 |
| Rice, noodles, dessert protein3 | | |  |
| Q1 | 241 | 2.6 | reference |
| Q2 | 234 | 3.7 | 0.60 (0.36, 1.02) |
| Q3 | 231 | 4.5 | 0.76 (0.44, 1.32) |
| Q4 | 235 | 5.8 | 1.55 (0.86, 2.81) |
| Per 2 energy % | 941 |  | 1.17 (0.85, 1.61) |
| *P*-trend | 941 |  | 0.19 |
| Beans protein3 | |  |  |
| No intake | 354 | 0.0 | reference |
| T1 | 195 | 0.2 | 0.94 (0.55, 1.58) |
| T2 | 197 | 1.1 | 1.11 (0.67, 1.85) |
| T3 | 195 | 2.7 | 1.26 (0.75, 2.11) |
| Per 2 energy % | 941 |  | 1.18 (0.90, 1.55) |
| *P*-trend | 941 |  | 0.34 |

1Model 2a: adjusted for maternal age (continuous) and ethnicity (Chinese, Malay, Indian), parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), total fat intake (quartiles), total energy intake (quartiles), dietary fiber intake (quartiles), saturated fat intake (quartiles), heme iron intake (quartiles) and SSB (≥ 1 serving/day, <1 serving/day).

2mutual adjustment for animal and vegetable protein

3mutual adjustment for other major protein sources

CI, confidence interval; E, energy; OR, odds ratio; Q, quartile; T, tertile (tertiles among consumers).

SUPPLEMENTAL TABLE 3

Odds ratio (OR) for GDM according to pregnancy intake of dietary protein with further adjustment for gestational weight gain in the GUSTO study (*n* =941)

|  |  |  |  |
| --- | --- | --- | --- |
|  | *n* | Median intake  (% E) | Model 21 |
| **OR (95% CI)** |
| Total protein |  |  |  |
| Q1 | 231 | 11.4 | reference |
| Q2 | 236 | 14.2 | 1.73 (1.01, 2.98) |
| Q3 | 240 | 16.5 | 1.29 (0.74, 2.26) |
| Q4 | 234 | 19.9 | 2.05 (1.19, 3.52) |
| Per 5 energy % | 941 |  | 1.34 (1.07, 1.69) |
| *P*-trend | 941 |  | 0.034 |
| Animal protein2 |  |  |  |
| Q1 | 233 | 4.2 | reference |
| Q2 | 237 | 7.7 | 1.71 (0.98, 2.99) |
| Q3 | 239 | 10.4 | 1.73 (0.97, 3.11) |
| Q4 | 232 | 14.3 | 2.57 (1.40, 4.75) |
| Per 5 energy % | 941 |  | 1.34 (1.07, 1.69) |
| *P*-trend | 941 |  | 0.005 |
| Vegetable protein2 |  |  |  |
| Q1 | 236 | 4.0 | reference |
| Q2 | 236 | 5.3 | 0.85 (0.48, 1.52) |
| Q3 | 231 | 6.5 | 1.70 (0.98, 2.95) |
| Q4 | 238 | 8.4 | 1.77 (0.97, 3.21) |
| Per 5 energy % | 941 |  | 1.85 (1.11, 3.10) |
| *P*-trend | 941 |  | 0.012 |
| Red meat protein3 |  |  |  |
| No intake | 406 | 0.0 | reference |
| T1 | 178 | 1.0 | 1.10 (0.64, 1.89) |
| T2 | 181 | 2.3 | 0.94 (0.54, 1.64) |
| T3 | 176 | 5.2 | 1.24 (0.71, 2.20) |
| Per 2 energy % | 941 |  | 1.10 (0.94, 1.30) |
| *P*-trend | 941 |  | 0.60 |
| Poultry protein3 |  |  |  |
| No intake | 326 | 0.0 | reference |
| T1 | 210 | 1.0 | 0.88 (0.53, 1.46) |
| T2 | 204 | 3.3 | 1.35 (0.82, 2.23) |
| T3 | 201 | 6.6 | 1.04 (0.58, 1.84) |
| Per 2 energy % | 941 |  | 1.07 (0.94, 1.22) |
| *P*-trend | 941 |  | 0.52 |
| Seafood protein3 |  |  |  |
| No intake | 295 | 0.0 | reference |
| T1 | 213 | 1.0 | 1.75 (1.03, 2.97) |
| T2 | 213 | 2.9 | 1.36 (0.79, 2.36) |
| T3 | 220 | 6.6 | 2.25 (1.29, 3.93) |
| Per 2 energy % | 941 |  | 1.15 (1.03, 1.29) |
| *P*-trend | 941 |  | 0.016 |
| Egg protein3 |  |  |  |
| No intake | 439 | 0.0 | reference |
| T1 | 170 | 0.5 | 0.87 (0.51, 1.48) |
| T2 | 167 | 1.2 | 1.18 (0.71, 1.97) |
| T3 | 165 | 2.3 | 1.27 (0.77, 2.09) |
| Per 2 energy % | 941 |  | 1.05 (0.73, 1.50) |
| *P*-trend | 941 |  | 0.30 |
| Dairy protein3 |  |  |  |
| Q1 | 241 | 0.0 | reference |
| Q2 | 229 | 0.9 | 1.17 (0.68, 2.00) |
| Q3 | 234 | 1.9 | 1.30 (0.76, 2.21) |
| Q4 | 237 | 3.3 | 1.87 (1.10, 3.17) |
| Per 2 energy % | 941 |  | 1.37 (1.08, 1.73) |
| *P*-trend | 941 |  | 0.020 |
| Rice, noodles, dessert protein3 | | |  |
| Q1 | 241 | 2.6 | reference |
| Q2 | 234 | 3.7 | 0.61 (0.36, 1.03) |
| Q3 | 231 | 4.5 | 0.72 (0.42, 1.24) |
| Q4 | 235 | 5.8 | 1.40 (0.79, 2.47) |
| Per 2 energy % | 941 |  | 1.10 (0.81, 1.49) |
| *P*-trend | 941 |  | 0.35 |
| Beans protein3 | |  |  |
| No intake | 354 | 0.0 | reference |
| T1 | 195 | 0.2 | 1.01 (0.60, 1.70) |
| T2 | 197 | 1.1 | 1.22 (0.74, 2.02) |
| T3 | 195 | 2.7 | 1.56 (0.95, 2.56) |
| Per 2 energy % | 941 |  | 1.29 (1.00, 1.67) |
| *P*-trend | 941 |  | 0.07 |

1Model 2: adjusted for maternal age (continuous) and ethnicity (Chinese, Malay, Indian), parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), gestational weight gain z-score to 26 weeks’ gestation (continuous), total fat intake (quartiles)and total energy intake (quartiles).

2mutual adjustment for animal and vegetable protein

3mutual adjustment for other major protein sources

CI, confidence interval; E, energy; OR, odds ratio; Q, quartile; T, tertile (tertiles among consumers).

SUPPLEMENTAL TABLE 4

Odds ratio (OR) for GDM according to pregnancy intake of dietary protein using non-imputed data in the GUSTO study (*n* =880)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *n* | Median intake  (% E) | Model 11 | Model 22 |
| **OR (95% CI)** | **OR (95% CI)** |
| Total protein |  |  |  |  |
| Q1 | 219 | 11.5 | reference | reference |
| Q2 | 225 | 14.2 | 1.66 (0.99, 2.80) | 1.66 (0.97, 2.83) |
| Q3 | 221 | 16.6 | 1.14 (0.66, 1.96) | 1.09 (0.62, 1.92) |
| Q4 | 215 | 19.9 | 2.15 (1.29, 3.60) | 2.00 (1.17, 3.40) |
| Per 5 energy % | 880 |  | 1.43 (1.15, 1.78) | 1.35 (1.07, 1.69) |
| *P*-trend | 880 |  | 0.018 | 0.05 |
| Animal protein3 |  |  |  |  |
| Q1 | 216 | 4.3 | reference | reference |
| Q2 | 231 | 7.7 | 1.36 (0.81, 2.29) | 1.68 (0.96, 2.93) |
| Q3 | 215 | 10.4 | 1.29 (0.75, 2.19) | 1.67 (0.92, 3.02) |
| Q4 | 218 | 14.3 | 1.89 (1.12, 3.20) | 2.59 (1.40, 4.80) |
| Per 5 energy % | 880 |  | 1.22 (1.01, 1.49) | 1.34 (1.06, 1.69) |
| *P*-trend | 880 |  | 0.027 | 0.005 |
| Vegetable protein3 |  |  |  |  |
| Q1 | 223 | 4.0 | reference | reference |
| Q2 | 220 | 5.3 | 0.68 (0.40, 1.16) | 0.84 (0.47, 1.50) |
| Q3 | 217 | 6.5 | 1.24 (0.76, 2.02) | 1.67 (0.96, 2.91) |
| Q4 | 220 | 8.4 | 1.24 (0.75, 2.04) | 1.87 (1.02, 3.44) |
| Per 5 energy % | 880 |  | 1.41 (0.91, 2.18) | 2.04 (1.19, 3.48) |
| *P*-trend | 880 |  | 0.12 | 0.008 |
| Red meat protein4 |  |  |  |  |
| No intake | 388 | 0.0 | reference | reference |
| T1 | 162 | 1.0 | 0.89 (0.53, 1.51) | 1.03 (0.60, 1.80) |
| T2 | 164 | 2.3 | 1.00 (0.60, 1.66) | 1.07 (0.61, 1.87) |
| T3 | 166 | 5.2 | 1.02 (0.62, 1.68) | 1.23 (0.70, 2.17) |
| Per 2 energy % | 880 |  | 1.06 (0.92, 1.23) | 1.11 (0.93, 1.31) |
| *P*-trend | 880 |  | 0.89 | 0.49 |
| Poultry protein4 |  |  |  |  |
| No intake | 311 | 0.0 | reference | reference |
| T1 | 190 | 1.1 | 0.79 (0.48, 1.30) | 0.89 (0.53, 1.52) |
| T2 | 195 | 3.2 | 1.35 (0.85, 2.12) | 1.61 (0.97, 2.68) |
| T3 | 184 | 6.7 | 0.86 (0.52, 1.42) | 1.20 (0.67, 2.13) |
| Per 2 energy % | 880 |  | 1.02 (0.92, 1.14) | 1.10 (0.97, 1.24) |
| *P*-trend | 880 |  | 0.87 | 0.19 |
| Seafood protein4 |  |  |  |  |
| No intake | 287 | 0.0 | reference | reference |
| T1 | 199 | 1.0 | 1.46 (0.90, 2.39) | 1.60 (0.95, 2.70) |
| T2 | 199 | 2.9 | 1.07 (0.64, 1.81) | 1.18 (0.68, 2.04) |
| T3 | 195 | 6.6 | 1.60 (0.98, 2.60) | 2.21 (1.26, 3.88) |
| Per 2 energy % | 880 |  | 1.06 (0.96, 1.18) | 1.14 (1.02, 1.29) |
| *P*-trend | 880 |  | 0.15 | 0.025 |
| Egg protein4 |  |  |  |  |
| No intake | 413 | 0.0 | reference | reference |
| T1 | 154 | 0.5 | 0.69 (0.41, 1.17) | 0.76 (0.44, 1.34) |
| T2 | 153 | 1.2 | 0.93 (0.57, 1.52) | 1.09 (0.65, 1.84) |
| T3 | 160 | 2.3 | 1.11 (0.70, 1.76) | 1.24 (0.75, 2.04) |
| Per 2 energy % | 880 |  | 1.02 (0.73, 1.41) | 1.05 (0.74, 1.49) |
| *P*-trend | 880 |  | 0.75 | 0.40 |
| Dairy protein4 |  |  |  |  |
| Q1 | 220 | 0.0 | reference | reference |
| Q2 | 213 | 0.9 | 1.14 (0.68, 1.91) | 1.21 (0.70, 2.09) |
| Q3 | 221 | 1.8 | 1.31 (0.79, 2.16) | 1.49 (0.87, 2.55) |
| Q4 | 226 | 3.3 | 1.40 (0.85, 2.31) | 1.75 (1.01, 3.02) |
| Per 2 energy % | 880 |  | 1.15 (0.92, 1.44) | 1.27 (0.99, 1.63) |
| *P*-trend | 880 |  | 0.15 | 0.033 |
| Rice, noodles, dessert protein4 | | |  |  |
| Q1 | 217 | 2.6 | reference | reference |
| Q2 | 224 | 3.7 | 0.61 (0.37, 1.00) | 0.61 (0.36, 1.04) |
| Q3 | 221 | 4.5 | 0.56 (0.34, 0.93) | 0.71 (0.41, 1.24) |
| Q4 | 218 | 5.8 | 1.10 (0.68, 1.77) | 1.54 (0.86, 2.76) |
| Per 2 energy % | 880 |  | 1.01 (0.79, 1.31) | 1.22 (0.89, 1.67) |
| *P*-trend | 880 |  | 0.85 | 0.21 |
| Beans protein4 | |  |  |  |
| No intake | 337 | 0.0 | reference | reference |
| T1 | 184 | 0.2 | 0.78 (0.47, 1.30) | 0.84 (0.49, 1.42) |
| T2 | 176 | 1.0 | 1.07 (0.66, 1.72) | 1.13 (0.67, 1.88) |
| T3 | 183 | 2.7 | 1.29 (0.82, 2.04) | 1.45 (0.88, 2.39) |
| Per 2 energy % | 880 |  | 1.19 (0.94, 1.50) | 1.30 (0.99, 1.70) |
| *P*-trend | 880 |  | 0.23 | 0.13 |

1Model 1: adjusted for maternal age (continuous) and ethnicity (Chinese, Malay, Indian).

2Model 2: model 1 adjustments plus parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), total fat intake (quartiles) and total energy intake (quartiles).

3mutual adjustment for animal and vegetable protein

4mutual adjustment for other major protein sources

CI, confidence interval; E, energy; OR, odds ratio; Q, quartile; T, tertile (tertiles among consumers).

SUPPLEMENTAL TABLE 5

Odds ratio (OR) for GDM according to pregnancy intake of dietary protein, with missing data imputed using multiple imputation in the GUSTO study (*n* =980)

|  |  |  |  |
| --- | --- | --- | --- |
|  | *n* | Median intake  (% E) | Model 21 |
| **OR (95% CI)** |
| Total protein |  |  |  |
| Q1 | 245 | 11.4 | reference |
| Q2 | 245 | 14.3 | 1.72 (1.02, 2.92) |
| Q3 | 245 | 16.5 | 1.31 (0.75, 2.26) |
| Q4 | 245 | 19.9 | 2.20 (1.30, 3.71) |
| Per 5 energy % | 980 |  | 1.38 (1.11, 1.72) |
| *P*-trend | 980 |  | 0.012 |
| Animal protein2 |  |  |  |
| Q1 | 245 | 4.2 | reference |
| Q2 | 245 | 7.7 | 1.87 (1.08, 3.23) |
| Q3 | 245 | 10.4 | 1.85 (1.04, 3.28) |
| Q4 | 245 | 14.3 | 2.97 (1.64, 5.40) |
| Per 5 energy % | 980 |  | 1.39 (1.11, 1.74) |
| *P*-trend | 980 |  | 0.001 |
| Vegetable protein2 |  |  |  |
| Q1 | 245 | 4.0 | reference |
| Q2 | 245 | 5.3 | 0.87 (0.50, 1.54) |
| Q3 | 245 | 6.5 | 1.75 (1.02, 2.99) |
| Q4 | 245 | 8.4 | 1.84 (1.02, 3.31) |
| Per 5 energy % | 980 |  | 1.95 (1.17, 3.24) |
| *P*-trend | 980 |  | 0.007 |
| Red meat protein3 |  |  |  |
| No intake | 427 | 0.0 | reference |
| T1 | 184 | 1.0 | 1.09 (0.64, 1.86) |
| T2 | 185 | 2.3 | 1.01 (0.58, 1.74) |
| T3 | 184 | 5.2 | 1.45 (0.84, 2.50) |
| Per 2 energy % | 980 |  | 1.14 (0.97, 1.34) |
| *P*-trend | 980 |  | 0.26 |
| Poultry protein3 |  |  |  |
| No intake | 340 | 0.0 | reference |
| T1 | 213 | 1.1 | 0.90 (0.54, 1.49) |
| T2 | 214 | 3.3 | 1.48 (0.91, 2.42) |
| T3 | 213 | 6.7 | 1.15 (0.66, 2.01) |
| Per 2 energy % | 980 |  | 1.09 (0.96, 1.23) |
| *P*-trend | 980 |  | 0.28 |
| Seafood protein3 |  |  |  |
| No intake | 317 | 0.0 | reference |
| T1 | 221 | 1.0 | 1.71 (1.03, 2.84) |
| T2 | 221 | 2.8 | 1.26 (0.74, 2.14) |
| T3 | 221 | 6.6 | 2.26 (1.32, 3.89) |
| Per 2 energy % | 980 |  | 1.15 (1.03, 1.29) |
| *P*-trend | 980 |  | 0.015 |
| Egg protein3 |  |  |  |
| No intake | 460 | 0.0 | reference |
| T1 | 173 | 0.5 | 0.84 (0.49, 1.43) |
| T2 | 174 | 1.2 | 1.15 (0.70, 1.90) |
| T3 | 173 | 2.3 | 1.31 (0.80, 2.13) |
| Per 2 energy % | 980 |  | 1.12 (0.79, 1.58) |
| *P*-trend | 980 |  | 0.25 |
| Dairy protein3 |  |  |  |
| Q1 | 245 | 0.0 | reference |
| Q2 | 245 | 0.9 | 1.22 (0.72, 2.05) |
| Q3 | 245 | 1.8 | 1.38 (0.82, 2.33) |
| Q4 | 245 | 3.3 | 1.87 (1.11, 3.16) |
| Per 2 energy % | 980 |  | 1.35 (1.07, 1.71) |
| *P*-trend | 980 |  | 0.017 |
| Rice, noodles, dessert protein3 | | |  |
| Q1 | 245 | 2.6 | reference |
| Q2 | 245 | 3.7 | 0.61 (0.36, 1.01) |
| Q3 | 245 | 4.5 | 0.74 (0.44, 1.26) |
| Q4 | 245 | 5.8 | 1.47 (0.84, 2.57) |
| Per 2 energy % | 980 |  | 1.18 (0.87, 1.60) |
| *P*-trend | 980 |  | 0.24 |
| Beans protein3 | |  |  |
| No intake | 375 | 0.0 | reference |
| T1 | 201 | 0.2 | 0.91 (0.54, 1.52) |
| T2 | 202 | 1.1 | 1.21 (0.74, 1.97) |
| T3 | 202 | 2.7 | 1.49 (0.91, 2.42) |
| Per 2 energy % | 980 |  | 1.30 (1.00, 1.67) |
| *P*-trend | 980 |  | 0.09 |

1Model 2: adjusted for maternal age (continuous) and ethnicity (Chinese, Malay, Indian), parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), total fat intake (quartiles) and total energy intake (quartiles).

2mutual adjustment for animal and vegetable protein

3mutual adjustment for other major protein sources

CI, confidence interval; E, energy; OR, odds ratio; Q, quartile; T, tertile (tertiles among consumers).

SUPPLEMENTAL TABLE 6

Odds ratio (OR) for GDM according to pregnancy intake of dietary protein using averaged dietary data from 3 day food diaries in the GUSTO study (*n* =607)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *n* | Median intake  (% E) | Model 11 | Model 22 |
| **OR (95% CI)** | **OR (95% CI)** |
| Total protein |  |  |  |  |
| Q1 | 151 | 13.0 | reference | reference |
| Q2 | 151 | 15.0 | 1.76 (0.82, 3.76) | 1.90 (0.84, 4.29) |
| Q3 | 155 | 16.8 | 1.71 (0.79, 3.72) | 1.86 (0.81, 4.26) |
| Q4 | 150 | 19.7 | 5.87 (2.88, 11.96) | 6.09 (2.81, 13.17) |
| Per 5 energy % | 607 |  | 3.06 (2.09, 4.47) | 3.05 (2.02, 4.61) |
| *P*-trend | 607 |  | <0.001 | <0.001 |

1Model 1: adjusted for maternal age (continuous) and ethnicity (Chinese, Malay, Indian).

2Model 2: model 1 adjustments plus parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), total fat intake (quartiles) and total energy intake (quartiles). CI, confidence interval; E, energy; OR, odds ratio; Q, quartile.

SUPPLEMENTAL TABLE 7

Odds ratio (OR) for GDM according to pregnancy intake of dietary protein where dietary protein is substituted for dietary total fat intake in the GUSTO study (*n* =980)

|  |  |  |  |
| --- | --- | --- | --- |
|  | *n* | Median intake  (% E) | Model 21 |
| **OR (95% CI)** |
| Total protein |  |  |  |
| Q1 | 245 | 11.4 | reference |
| Q2 | 245 | 14.3 | 1.75 (1.03, 2.97) |
| Q3 | 245 | 16.5 | 1.31 (0.74, 2.29) |
| Q4 | 245 | 19.9 | 2.14 (1.20, 3.79) |
| Per 5 energy % | 980 |  | 1.38 (1.08, 1.78) |
| *P*-trend | 980 |  | 0.03 |
| Animal protein2 |  |  |  |
| Q1 | 245 | 4.2 | reference |
| Q2 | 245 | 7.7 | 1.84 (1.06, 3.18) |
| Q3 | 245 | 10.4 | 1.80 (0.99, 3.27) |
| Q4 | 245 | 14.3 | 2.85 (1.48, 5.49) |
| Per 5 energy % | 980 |  | 1.36 (1.05, 1.75) |
| *P*-trend | 980 |  | 0.004 |
| Vegetable protein2 |  |  |  |
| Q1 | 245 | 4.1 | reference |
| Q2 | 245 | 5.6 | 0.84 (0.48, 1.47) |
| Q3 | 245 | 6.8 | 1.70 (1.00, 2.89) |
| Q4 | 245 | 8.7 | 1.80 (1.01, 3.19) |
| Per 5 energy % | 980 |  | 1.94 (1.18, 3.19) |
| *P*-trend | 980 |  | 0.007 |
| Red meat protein3 |  |  |  |
| No intake | 427 | 0.0 | reference |
| T1 | 184 | 1.0 | 1.08 (0.63, 1.84) |
| T2 | 185 | 2.3 | 0.98 (0.57, 1.71) |
| T3 | 184 | 5.2 | 1.34 (0.76, 2.36) |
| Per 2 energy % | 980 |  | 1.12 (0.94, 1.33) |
| *P*-trend | 980 |  | 0.67 |
| Poultry protein3 |  |  |  |
| No intake | 340 | 0.0 | reference |
| T1 | 213 | 1.1 | 0.92 (0.56, 1.52) |
| T2 | 214 | 3.3 | 1.43 (0.87, 2.35) |
| T3 | 213 | 6.7 | 1.12 (0.63, 2.01) |
| Per 2 energy % | 980 |  | 1.08 (0.95, 1.24) |
| *P*-trend | 980 |  | 0.30 |
| Seafood protein3 |  |  |  |
| No intake | 317 | 0.0 | reference |
| T1 | 221 | 1.0 | 1.65 (0.99, 2.74) |
| T2 | 221 | 2.8 | 1.27 (0.74, 2.17) |
| T3 | 221 | 6.6 | 2.14 (1.22, 3.75) |
| Per 2 energy % | 980 |  | 1.15 (1.02, 1.30) |
| *P*-trend | 980 |  | 0.034 |
| Egg protein3 |  |  |  |
| No intake | 460 | 0.0 | reference |
| T1 | 173 | 0.5 | 0.83 (0.49, 1.41) |
| T2 | 174 | 1.2 | 1.17 (0.71, 1.93) |
| T3 | 173 | 2.3 | 1.25 (0.76, 2.06) |
| Per 2 energy % | 980 |  | 1.08 (0.75, 1.54) |
| *P*-trend | 980 |  | 0.50 |
| Dairy protein3 |  |  |  |
| Q1 | 245 | 0.0 | reference |
| Q2 | 245 | 0.9 | 1.24 (0.73, 2.09) |
| Q3 | 245 | 1.8 | 1.40 (0.83, 2.36) |
| Q4 | 245 | 3.3 | 1.83 (1.09, 3.09) |
| Per 2 energy % | 980 |  | 1.34 (1.06, 1.69) |
| *P*-trend | 980 |  | 0.042 |
| Rice, noodles, dessert protein3 | | |  |
| Q1 | 245 | 2.6 | reference |
| Q2 | 245 | 3.7 | 0.62 (0.37, 1.03) |
| Q3 | 245 | 4.5 | 0.75 (0.44, 1.27) |
| Q4 | 245 | 5.8 | 1.49 (0.86, 2.58) |
| Per 2 energy % | 980 |  | 1.20 (0.89, 1.61) |
| *P*-trend | 980 |  | 0.16 |
| Beans protein3 | |  |  |
| No intake | 375 | 0.0 | reference |
| T1 | 201 | 0.2 | 0.93 (0.56, 1.55) |
| T2 | 202 | 1.1 | 1.17 (0.72, 1.90) |
| T3 | 202 | 2.7 | 1.45 (0.89, 2.35) |
| Per 2 energy % | 980 |  | 1.27 (0.99, 1.64) |
| *P*-trend | 980 |  | 0.12 |

1Model 2: adjusted for maternal age (continuous) and ethnicity (Chinese, Malay, Indian), parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), total carbohydrate intake (quartiles) and total energy intake (quartiles).

2mutual adjustment for animal and vegetable protein

3mutual adjustment for other major protein sources

CI, confidence interval; E, energy; OR, odds ratio; Q, quartile; T, tertile (tertiles among consumers).

SUPPLEMENTAL TABLE 8

Odds ratio (OR) for GDM according to pregnancy intake of dietary protein among participants who had no OGTT performed prior to the study visit in the GUSTO study (*n* =938)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *n* | Median intake  (% E) | Model 11 | Model 22 |
| **OR (95% CI)** | **OR (95% CI)** |
| Total protein |  |  |  |  |
| Q1 | 238 | 11.4 | reference | reference |
| Q2 | 235 | 14.3 | 1.58 (0.94, 2.66) | 1.58 (0.92, 2.72) |
| Q3 | 236 | 16.5 | 1.21 (0.71, 2.07) | 1.21 (0.69, 2.11) |
| Q4 | 229 | 19.8 | 1.94 (1.15, 3.25) | 1.78 (1.03, 3.06) |
| Per 5 energy % | 938 |  | 1.30 (1.04, 1.63) | 1.25 (0.99, 1.59) |
| *P*-trend | 938 |  | 0.039 | 0.10 |
| Animal protein3 |  |  |  |  |
| Q1 | 237 | 4.2 | reference | reference |
| Q2 | 233 | 7.7 | 1.45 (0.86, 2.44) | 1.69 (0.97, 2.95) |
| Q3 | 236 | 10.4 | 1.28 (0.75, 2.17) | 1.59 (0.89, 2.85) |
| Q4 | 232 | 14.2 | 1.80 (1.06, 3.06) | 2.29 (1.23, 4.24) |
| Per 5 energy % | 938 |  | 1.17 (0.96, 1.42) | 1.26 (1.00, 1.60) |
| *P*-trend | 938 |  | 0.055 | 0.018 |
| Vegetable protein3 |  |  |  |  |
| Q1 | 237 | 4.0 | reference | reference |
| Q2 | 236 | 5.3 | 0.72 (0.42, 1.22) | 0.84 (0.47, 1.49) |
| Q3 | 230 | 6.5 | 1.29 (0.79, 2.10) | 1.65 (0.95, 2.88) |
| Q4 | 235 | 8.4 | 1.07 (0.65, 1.77) | 1.43 (0.78, 2.63) |
| Per 5 energy % | 938 |  | 1.23 (0.80, 1.89) | 1.60 (0.94, 2.71) |
| *P*-trend | 938 |  | 0.34 | 0.07 |
| Red meat protein4 |  |  |  |  |
| No intake | 409 | 0.0 | reference | reference |
| T1 | 171 | 1.0 | 0.81 (0.48, 1.38) | 0.87 (0.49, 1.53) |
| T2 | 181 | 2.3 | 0.79 (0.47, 1.34) | 0.78 (0.44, 1.40) |
| T3 | 177 | 5.2 | 1.06 (0.64, 1.74) | 1.20 (0.68, 2.12) |
| Per 2 energy % | 938 |  | 1.04 (0.89, 1.21) | 1.08 (0.91, 1.29) |
| *P*-trend | 938 |  | 0.95 | 0.70 |
| Poultry protein4 |  |  |  |  |
| No intake | 330 | 0.0 | reference | reference |
| T1 | 198 | 1.1 | 0.80 (0.49, 1.32) | 0.86 (0.51, 1.45) |
| T2 | 204 | 3.3 | 1.20 (0.76, 1.89) | 1.38 (0.83, 2.29) |
| T3 | 206 | 6.7 | 0.70 (0.42, 1.18) | 0.90 (0.50, 1.63) |
| Per 2 energy % | 938 |  | 0.98 (0.88, 1.10) | 1.04 (0.91, 1.18) |
| *P*-trend | 938 |  | 0.49 | 0.78 |
| Seafood protein4 |  |  |  |  |
| No intake | 307 | 0.0 | reference | reference |
| T1 | 214 | 1.0 | 1.40 (0.86, 2.30) | 1.43 (0.84, 2.44) |
| T2 | 205 | 2.9 | 1.12 (0.66, 1.89) | 1.12 (0.65, 1.96) |
| T3 | 212 | 6.6 | 1.59 (0.98, 2.59) | 1.99 (1.14, 3.47) |
| Per 2 energy % | 938 |  | 1.07 (0.97, 1.19) | 1.14 (1.01, 1.28) |
| *P*-trend | 938 |  | 0.12 | 0.049 |
| Egg protein4 |  |  |  |  |
| No intake | 450 | 0.0 | reference | reference |
| T1 | 166 | 0.5 | 0.77 (0.46, 1.29) | 0.81 (0.47, 1.41) |
| T2 | 166 | 1.2 | 0.99 (0.62, 1.61) | 1.11 (0.67, 1.86) |
| T3 | 156 | 2.3 | 0.97 (0.60, 1.59) | 1.07 (0.63, 1.80) |
| Per 2 energy % | 938 |  | 0.96 (0.68, 1.36) | 0.99 (0.68, 1.43) |
| *P*-trend | 938 |  | 0.94 | 0.70 |
| Dairy protein4 |  |  |  |  |
| Q1 | 236 | 0.0 | reference | reference |
| Q2 | 233 | 0.9 | 1.20 (0.71, 2.01) | 1.19 (0.69, 2.05) |
| Q3 | 236 | 1.9 | 1.36 (0.82, 2.26) | 1.45 (0.84, 2.49) |
| Q4 | 233 | 3.3 | 1.50 (0.91, 2.49) | 1.74 (1.00, 3.01) |
| Per 2 energy % | 938 |  | 1.21 (0.97, 1.51) | 1.31 (1.03, 1.68) |
| *P*-trend | 938 |  | 0.10 | 0.037 |
| Rice, noodles, dessert protein4 | | |  |  |
| Q1 | 233 | 2.6 | reference | reference |
| Q2 | 235 | 3.7 | 0.52 (0.31, 0.86) | 0.52 (0.31, 0.89) |
| Q3 | 235 | 4.5 | 0.56 (0.34, 0.92) | 0.67 (0.39, 1.16) |
| Q4 | 235 | 5.9 | 0.99 (0.62, 1.59) | 1.26 (0.70, 2.25) |
| Per 2 energy % | 938 |  | 0.99 (0.53, 1.87) | 1.12 (0.82, 1.54) |
| *P*-trend | 938 |  | 0.92 | 0.54 |
| Beans protein4 | |  |  |  |
| No intake | 360 | 0.0 | reference | reference |
| T1 | 196 | 0.2 | 0.80 (0.48, 1.33) | 0.82 (0.48, 1.40) |
| T2 | 196 | 1.1 | 1.15 (0.72, 1.83) | 1.08 (0.65, 1.79) |
| T3 | 186 | 2.7 | 1.23 (0.77, 1.97) | 1.30 (0.78, 2.16) |
| Per 2 energy % | 938 |  | 1.13 (0.89, 1.44) | 1.20 (0.91, 1.57) |
| *P*-trend | 938 |  | 0.27 | 0.28 |

1Model 1: adjusted for maternal age (continuous) and ethnicity (Chinese, Malay, Indian).

2Model 2: model 1 adjustments plus parity (0, ≥1), maternal education attainment (secondary or below, technical college, pre-university, university), family history of diabetes (yes, no), previous GDM (yes, no), smoking status (never, former, current), alcohol consumption during pregnancy (yes, no), physical activity during pregnancy (continuous), pre-pregnancy BMI (<18.5, 18.5-22.9, 23- <27.5, ≥27.5kg/m2), total fat intake (quartiles) and total energy intake (quartiles).

3mutual adjustment for animal and vegetable protein

4mutual adjustment for other major protein sources

CI, confidence interval; E, energy; OR, odds ratio; Q, quartile; T, tertile (tertiles among consumers).