Dietary fat quantity and quality in early pregnancy and risk of gestational diabetes mellitus in Chinese women: a prospective cohort study

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Abstract

We aimed to examine the association between the quantity and quality of dietary fat in early pregnancy and gestational diabetes mellitus (GDM) risk. In total, 1477 singleton pregnant women were included from Sichuan Provincial Hospital for Women and Children, Southwest China. Dietary information was collected by a 3-d 24-h dietary recall. GDM was diagnosed based on the results of a 75-g, 2-h oral glucose tolerance test at 24–28 gestational weeks. Log-binomial models were used to estimate relative risks (RR) and 95% CI. The results showed that total fat intake was positively associated with GDM risk (Q4 v. Q1: RR = 1.40; 95% CI 1.11, 1.76; P-trend = 0.001). This association was also observed for the intakes of animal fat and vegetable fat. After stratified by total fat intake (< 30%E v. ≥ 30%), the higher animal fat intake was associated with higher GDM risk in the high-fat group, but the moderate animal fat intake was associated with reduced risk of GDM (T2 v. T1: RR = 0.65; 95% CI 0.45, 0.96) in the normal-fat group. Vegetable fat intake was positively associated with GDM risk in the high-fat group but not in the normal-fat group. No association between fatty acids intakes and GDM risk was found. In conclusion, total fat, animal and vegetable fat intakes were positively associated with GDM risk, respectively. Whereas when total fat intake was not excessive, higher intakes of animal and vegetable fat were likely irrelevant with increased GDM risk, even the moderate animal fat intake could be linked to lower GDM risk.

Key words: Dietary intake: Fatty acids: Fat: Gestational diabetes mellitus

Gestational diabetes mellitus (GDM), a common pregnancy complication, is characterised by hyperglycaemia during pregnancy. In recent decades, the prevalence of GDM has become an imminent health concern globally(1). According to the International Diabetes Federation(2), GDM occurs in approximately 16-7% of the population globally in 2021. The China Nutrition and Health Surveys from 2010 to 2013 showed that the prevalence of GDM reached 22.2%(3). GDM has been related to substantial short- and long-term adverse health outcomes, such as adverse pregnancy outcomes(4,5) (macrosomia, caesarean section and pre-eclampsia) and an increased risk of developing several metabolic diseases later in life among both women(6) and their offspring(7). Thus, the early identification of modifiable risk factors for GDM is critical to prevent GDM and its related adverse outcomes.

Dietary factors, as modifiable risk factors, have been associated with GDM risk(8). Dietary fat, as one of the most important parts of the diet, deserves sustained attention. Previous studies suggested that total fat intake during pregnancy was associated with GDM risk, but the findings have been inconsistent(9–15). For instance, some studies(12,13,15) have shown that a diet high in fat and low in carbohydrates during pregnancy poses a risk for developing GDM and impaired glucose tolerance. However, two American cohort studies did not identify an association between total fat intake and GDM risk pre-pregnancy or during the first trimester(16). In Asia, a positive association between total fat intake and GDM risk was observed in three case-control studies(17–19) but was not observed in one cohort study(14). Therefore, the association between total fat intake during pregnancy and GDM risk requires further research.

In addition to the quantity, the quality (source and composition) of fat is also important; nevertheless, few studies have concentrated on the relationship between the quality of fat and GDM risk. Only two studies(10,14) concerned the source of fat, one(10) of which showed that fat from animal products was positively associated with GDM risk, and neither study observed an association between vegetable fat intake and GDM risk. Studies concentrating on the composition of fat are also sparse. Dietary fat is composed of fatty acids, some of which are bioactive and play a vital role in glucose homoeostasis. Increased plasma NEFA may...
contribute to insulin resistance\(^{20}\), and women with GDM have a distinctive fatty acid profile\(^{21}\). However, only three available studies\(^{9,10,14}\) investigated dietary fatty acid intake and GDM risk, which suggested MUFA may be positively associated with GDM risk, while \(n\)-3 PUFA and \(\alpha\)-linolenic acid may be negatively associated. However, the above studies were focussed on pre-pregnancy or the second trimester. Thus far, the associations between animal fat, vegetable fat, fatty acid intake and GDM risk during the first trimester remain to be further studied.

Different source of fats (animal/vegetable fat) and fatty acids are positively correlated with total fat intake, and their associations with outcome may change at different levels of total fat intake. For instance, one clinical trial\(^{22}\) found that substituting MUFA for SFA in the diet improves insulin sensitivity but not in individuals with a high fat intake (\(> 37\%\)). Therefore, the influence of the total fat consumption should be taken into consideration when investigating the relationship of the quality of fat with GDM risk.

The present study hypothesised that (1) total fat intake in early pregnancy is positively associated with the risk of GDM and (2) the intakes of animal fat and MUFA are positively associated with the risk of GDM, but these associations disappear in lower total fat intake group. Therefore, using data from a prospective cohort study in China, we aimed to examine the association between the quantity and quality of fat during the first trimester and GDM risk.

**Methods**

**Study population**

Participants were drawn from a population-based prospective cohort study conducted in Sichuan Provincial Hospital for Women and Children, Southwest China. From February to July 2017, we recruited 1673 healthy women who met the following inclusion criteria: singleton pregnancy, gestational age ranging from 6 to 14 weeks and no chronic metabolic diseases (diabetes, hypertension and hyperlipidaemia). The study was approved by the Ethics Committee of Sichuan University. All participants provided written informed consent when recruited for the study.

The sample size was calculated based on the GDM incidence from previous research\(^{23}\) about high-fat and low-carbohydrate diet and GDM risk (\(\alpha = 0.05\) (two-sided), \(1-\beta = 0.90\)). The minimum sample size required was 576 participants. We assumed a 20 % dropout rate, resulting in a final included sample size of 720 participants. At recruitment, a total of 1673 participants were invited to join the study; we excluded participants with unfinished dietary surveys (\(n = 8\)). We also excluded participants with a history of GDM (\(n = 40\)) because these diagnoses could result in dietary changes in the subsequent pregnancy. Furthermore, we excluded women who had implausible energy intake (< 2092 or > 41644 kJ/d)\(^{24}\) (\(n = 20\)) or missing data on the diagnosis of GDM (\(n = 128\)) (Fig. 1). The final analysis included 1477 women.

**Assessment of dietary intake**

Dietary information was assessed by 24-h dietary recalls for three consecutive days, including two weekdays and one weekend day. Information on all types and amounts of food consumed by the participants in the past 24 h was collected by specialised investigators via face-to-face interviews at recruitment (6–14 gestational weeks). To reduce measurement error, standard serving bowls, cups, spoons and illustrative food pictures of various portion sizes\(^{25}\) were displayed to help the participants estimate their food intake intakes of food. Specialised investigators collected the next 2 d of dietary information through telephone interviews.

Cooking oil intake was calculated as the sum of energy from food and cooking oil consumed by pregnant women multiplied by the ratio of daily cooking oil intake (41.8 g) for the energy of a standard person (2250 kcal/d) used in the data of the China Nutrition and Health Surveys from 2010 to 2013\(^{26}\). In this method, the estimate of cooking oil intake is closest to the consumption weighed for three consecutive days\(^{27}\). Information regarding the types of cooking oil (animal oil or vegetable oil) mainly consumed in the past month was also collected.

Estimates of the intake of nutrients (including intakes of fat and fatty acids) were calculated mainly using the Chinese Food Composition Tables\(^{28}\), which are expanded and updated on an ongoing basis and supplemented with the United States Department of Agriculture Nutrient database. The intake of macronutrients was computed as the percentages of total energy intake by the nutrient density method, and other nutrient intakes were adjusted for total energy intake by the residual method\(^{24}\). The \(n\)-3 PUFA/\(n\)-6 PUFA ratio and the PUFA/SFA ratio were calculated.

**Ascertainment of gestational diabetes mellitus**

Between 24 and 28 weeks of gestation, the participants were routinely screened by the 75-g, 2-h oral glucose tolerance test to diagnose GDM. According to the diagnostic criteria of the International Association of Diabetes Pregnancy Study Group...
Dietary fat and gestational diabetes mellitus

Of the 1477 women evaluated, 530 (35.9%) cases of GDM were diagnosed. The mean age of the participants was 28.0 (SD 4.0) years, and the mean pre-pregnancy BMI was 21.0 (SD 2.8) kg/m². The median total fat intake was 32.7 (interquartile range 28.9–36.9)%E, which is above the recommended fat intake during early pregnancy in China (20–30)%E. The intake of animal fat and vegetable fat was 11.0 (interquartile range 7.3–15.1)%E and 9.8 (interquartile range 8.9–23.4)%E, respectively. The large majority (98.1%) mainly consumed vegetable oil in the past month.

Results

Baseline characteristics

Of the 1477 women evaluated, 530 (35.9%) cases of GDM were diagnosed. The mean age of the participants was 28.0 (SD 4.0) years, and the mean pre-pregnancy BMI was 21.0 (SD 2.8) kg/m². The median total fat intake was 32.7 (interquartile range 28.9–36.9)%E, which is above the recommended fat intake during early pregnancy in China (20–30)%E. The intake of animal fat and vegetable fat was 11.0 (interquartile range 7.3–15.1)%E and 9.8 (interquartile range 8.9–23.4)%E, respectively. The large majority (98.1%) mainly consumed vegetable oil in the past month.
Women with a higher total fat intake were more often primiparous and consumed more protein, eggs, meat, dairy products, nuts, fish and legumes and less carbohydrates, grains and tubers (tubers mainly included potatoes, sweet potatoes and cassava) (Tables 1 and 2). The baseline characteristics and dietary intakes of the participants according to quartiles of animal fat or vegetable fat are presented in online Supplementary Tables S1–S4.

The correlation coefficients of the energy-adjusted intake of specific types of fat were as follows: 0.74 between total fat intake and animal fat intake; 0.81 between total fat intake and vegetable fat intake and 0.96 between total fat intake and MUFA intake (all $P < 0.05$) (online Supplementary Table S5).

### Association between fat and gestational diabetes mellitus risk

Higher intakes of total fat, animal fat and vegetable fat were significantly associated with GDM risk in the fully adjusted models, including both dietary and non-dietary covariates (Table 3). The multivariable-adjusted RR of GDM from the lowest to the highest quartiles of total fat were 1.00 (reference), 1.14 (95% CI 0.92, 1.41), 1.33 (95% CI 1.09, 1.63) and 1.28 (95% CI 1.03, 1.59) ($P = 0.026$ for trend) after adjusting for the same dietary, socio-demographic, lifestyle factors and additional vegetable fat intake (model 2). The multivariable-adjusted RR of GDM from the lowest to the highest quartiles of vegetable fat were 1.00 (reference), 1.16 (95% CI 0.93, 1.43), 1.31 (95% CI 1.07, 1.60) and 1.24 (95% CI 0.995, 1.54) ($P = 0.048$ for trend) in model 2.

To eliminate the influence of the other macronutrients, additional adjustments for carbohydrates, dietary glycaemic load, proteins and animal protein were modelled, respectively. The effect sizes between fat intake (total fat, animal fat and vegetable fat) and GDM risk were increased after adjusting for carbohydrate and dietary glycaemic load but did not change apparently after additionally adjusting for protein or animal protein. Therefore, we only displayed the results after additionally adjusting for glycaemic load (model 3) in Table 3, and other results are displayed in online Supplementary Table S6.

We did not observe a significant association between intakes of SFA, MUFA, PUFA, n-3 PUFA, n-6 PUFA, specific fatty acids and GDM risk in the fully adjusted model (model 2) (Table 4 and online Supplementary Table S7).

These substitution models revealed replacing 5% of the energy from carbohydrates with total fat increased the risk of GDM by 6.8% and replacing 3% of the energy from carbohydrates with animal fat increased the risk of GDM by 4.5%. However, replacing 3% of the energy from carbohydrates with vegetable fat was not associated with GDM risk (online Supplementary Table S8).
### Table 2. Dietary intakes of participants according to quartiles of the total fat
(Median values and interquartile ranges)

<table>
<thead>
<tr>
<th></th>
<th>All participants (n)</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>IQR</td>
<td>Median</td>
<td>IQR</td>
<td>Median</td>
</tr>
<tr>
<td>Total energy (kcal/d)</td>
<td>1797.0</td>
<td>1489.5–2135.6</td>
<td>1720.7</td>
<td>1377.6–2082.0</td>
<td>1764.6</td>
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<tr>
<td>Protein (%E)</td>
<td>12.1</td>
<td>10.7–13.9</td>
<td>10.8</td>
<td>9.7–12.4</td>
<td>11.9</td>
</tr>
<tr>
<td>Carbohydrate (%E)</td>
<td>57.7</td>
<td>50.1–60.6</td>
<td>64.3</td>
<td>61.9–67.2</td>
<td>58.2</td>
</tr>
<tr>
<td>Dietary fibre* (g/d)</td>
<td>11.8</td>
<td>9.4–15.0</td>
<td>12.4</td>
<td>10.1–16.1</td>
<td>11.6</td>
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<tr>
<td>Dietary glycaemic load*</td>
<td>150.6</td>
<td>131.0–170.2</td>
<td>177.1</td>
<td>161.1–194.2</td>
<td>159.9</td>
</tr>
<tr>
<td>Carbohydrate (%E)</td>
<td>55.6</td>
<td>44.8–66.9</td>
<td>56.4</td>
<td>46.1–64.2</td>
<td>57.4</td>
</tr>
<tr>
<td>Dietary fibre* (g/d)</td>
<td>11.5</td>
<td>9.4–15.0</td>
<td>12.2</td>
<td>10.1–16.1</td>
<td>11.5</td>
</tr>
<tr>
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<td>57.4</td>
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<tr>
<td>Dietary fibre* (g/d)</td>
<td>11.5</td>
<td>9.4–15.0</td>
<td>12.2</td>
<td>10.1–16.1</td>
<td>11.5</td>
</tr>
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<td>177.1</td>
<td>161.1–194.2</td>
<td>159.9</td>
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<tr>
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<td>56.4</td>
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<td>57.4</td>
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<tr>
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<td>12.2</td>
<td>10.1–16.1</td>
<td>11.5</td>
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<td>10.1–16.1</td>
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<td>177.1</td>
<td>161.1–194.2</td>
<td>159.9</td>
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</table>

%E, percentage of energy intake; IQR, interquartile range.

* Dietary variables were adjusted for total energy intake by the residual method.

## Discussion

We found that higher intakes of total fat, animal fat, and vegetable fat were associated with a higher incidence of GDM. After performing stratified analyses, a higher intake of vegetable fat was associated with a higher risk of GDM, and a moderate intake of animal fat was associated with a significantly increased risk of GDM. No association between fatty acid intake and GDM risk was found.

These findings suggest that total fat intake, and especially animal fat, may be more strongly related to GDM risk than previously thought. A high-fat diet can increase the expression of fatty acid synthase, leading to increased fat synthesis in adipose tissue. In addition, high-fat diets may also increase the risk of insulin resistance, which can lead to insulin resistance and glucose intolerance.

The results of our study are consistent with previous findings [34, 35]. Our study also adds new insights into the relationship between dietary fat intake and GDM risk. The results of this study suggest that a high-fat diet, especially animal fat, may be a risk factor for GDM.

## Conclusion

In conclusion, our study provides evidence that dietary fat intake, especially animal fat, may be a risk factor for GDM. These findings highlight the importance of dietary fat intake in the management of GDM.

**References**


Table 3. Relative risks (RR) of gestational diabetes mellitus (GDM) according to quartiles of total fat, animal fat and vegetable fat (% E) during early pregnancy (Risk ratios and 95% confidence intervals)

<table>
<thead>
<tr>
<th>Quartile</th>
<th>RR</th>
<th>95% CI</th>
<th>RR</th>
<th>95% CI</th>
<th>RR</th>
<th>95% CI</th>
<th>P&lt;sub&gt;for trend&lt;/sub&gt;</th>
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</thead>
<tbody>
<tr>
<td>Total fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (%E/d)</td>
<td>25.9</td>
<td>30.9</td>
<td>34.6</td>
<td>39.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>17.2–28.9</td>
<td>28.9–32.6</td>
<td>32.6–36.9</td>
<td>36.9–59.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDM cases/pregnancies (n)</td>
<td>113/369</td>
<td>117/369</td>
<td>149/370</td>
<td>151/369</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1*</td>
<td>1.00</td>
<td>0.97</td>
<td>0.78, 1.20</td>
<td>1.24</td>
<td>1.02, 1.51</td>
<td>1.27</td>
<td>1.04, 1.55</td>
</tr>
<tr>
<td>Model 2†</td>
<td>1.00</td>
<td>0.96</td>
<td>0.77, 1.19</td>
<td>1.21</td>
<td>0.99, 1.48</td>
<td>1.24</td>
<td>1.01, 1.51</td>
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<tr>
<td>Model 3‡</td>
<td>1.00</td>
<td>0.999</td>
<td>0.80, 1.24</td>
<td>1.31</td>
<td>1.07, 1.61</td>
<td>1.40</td>
<td>1.11, 1.76</td>
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<tr>
<td>Animal fat</td>
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<td>Median (%TE/d)</td>
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<td>9.2</td>
<td>12.7</td>
<td>18.5</td>
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<tr>
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<td>1.09, 1.63</td>
<td>1.28</td>
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<tr>
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<td>1.16</td>
<td>0.96, 1.47</td>
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<tr>
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<td>21.9</td>
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<tr>
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<td>0.93, 1.43</td>
<td>1.31</td>
<td>1.07, 1.60</td>
<td>1.24</td>
<td>0.99, 1.54</td>
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<tr>
<td>Model 3‡</td>
<td>1.00</td>
<td>1.16</td>
<td>0.94, 1.44</td>
<td>1.33</td>
<td>1.08, 1.62</td>
<td>1.30</td>
<td>1.04, 1.63</td>
</tr>
</tbody>
</table>

* Adjusted for maternal age (≥ 24, 25–29, 30–34 or ≥ 35 years), pre-pregnancy BMI (< 18.5, 18.5–23.9 or ≥ 24.0 kg/m²), educational level (≤ 12, 13–15 and ≥ 16 years), family history of diabetes (yes, no), parity (primiparity or multiparity), alcohol drinking status (yes, no), physical activity (MET h/week) and gestational weight gain before GDM diagnosis (kg).
† Model 1 plus total energy intake (kJ/d), dietary fibre (g/d) and other fats or fatty acids as listed in the table.
‡ Model 2 plus glycaemic load.

Fig. 2. The relation between total fat intake (E%) and gestational diabetes mellitus (GDM) adjusted for maternal age, pre-pregnancy BMI, educational level, family history of diabetes, parity, alcohol drinking status, physical activity, gestational weight gain before GDM diagnosis, total energy intake, dietary fibre and glycaemic load. In the figure, the solid line indicates the estimated risk of death, and the dotted lines represent point-wise 95% CI.
of a high-fat diet as an independent risk factor for type 2 diabetes mellitus (T2DM) in women. Similar to GDM, T2DM also results from a mixture of insulin resistance and dysfunctional insulin secretion. However, another Chinese pregnant women cohort study\textsuperscript{14} elucidated no significant association between total fat intake in the first trimester and GDM risk, which was not consistent with our results. In the former study, dietary information was collected by a FFQ, and the main source of fat was animal food; while we gathered dietary information by 3-d dietary recalls, the fat in our study mainly came from vegetables. Considering that fats from different sources might be differently associated with the risk of T2DM\textsuperscript{39}, the aforementioned points could explain the inconsistent results to some extent.
To eliminate the influence of the other macronutrients, we exploredly took carbohydrates, dietary glycaemic load, protein and animal protein into the model separately (online Supplementary Table S6). The association between total fat intake and GDM risk was increased after adjusting for carbohydrate and dietary glycaemic load, and then we included glycaemic load in the final model. This finding suggested that the observed association may have been partially masked by carbohydrates. It is universally recognised that the dietary glycaemic load may contribute to the onset and progression of diabetes, and a lower glycaemic load is likely to reduce the risk of GDM. A high-fat diet, accompanied by a lower glycaemic load, may offset a part of the hazardous effect of high fat intake. The protein content of the diet tends to remain fairly consistent compared with carbohydrates and fat. Additionally, the effect of proteins, such as carbohydrates, on glucose is not very distinct. This may be why we did not observe apparent changes after additionally adjusting for protein or animal protein.

In the present study, a higher intake of animal fat was associated with an increased risk of GDM, but the association remained only in the high-fat group after stratification by the percentage of energy from fat. The Nurses’ Health Study II also observed adverse effects of pre-pregnancy high animal fat intake on GDM risk. In addition, a study in Korea with women having a history of GDM found that participants with high animal fat intake were more likely to develop T2DM. However, these two studies did not exclude the influence of total fat intake on the association between animal fat intake and GDM or T2DM risk. In our study, the influence of total fat intake was partly excluded by the stratified analyses, and we observed that high intake of animal fat increased GDM risk in the high-fat group, and moderate intake of animal fat reduced GDM risk by 38% in the normal-fat group. Our findings indicated that moderate animal fat intake during pregnancy may be protective against GDM when total fat intake is not excessive, and pregnant women with excessive intake of total fat should preferably reduce animal fat intake. However, due to the small sample size in the normal-fat group, the results may be unstable. Therefore, this is a point that necessitates further examination in the future.

We also observed a positive association between vegetable fat intake and GDM risk, but it disappeared in the normal-fat group. However, most studies did not show an association between vegetable intake and GDM risk; Moreover, a review suggested that vegetable fat might be beneficial regarding T2DM prevention. In our cohort, total fat intake was highly correlated with vegetable fat intake. Therefore, the association between intake of vegetable fat and GDM risk in the high-fat group can be attributed to the high correlation with total fat intake. Moreover, the replacement of 3% of energy from carbohydrates with vegetable fat or from animal fat with vegetable fat was not associated with an increased risk of GDM. Thus, high vegetable fat intake during pregnancy may not be an independent risk factor for GDM.

We identified no association between fatty acids intake and GDM risk. However, in the high-fat group, participants with
higher intake of MUFA had a higher likelihood of having GDM, which is not significant after Bonferroni correction ($P = 0.031 > 0.017$). The Nurses’ Health Study II observed the adverse effects of higher MUFA intake on GDM risk. However, evidence regarding the association between MUFA intake and diabetes risk is inconsistent. The precise pathological mechanisms underlying the association between MUFA and glucose homeostasis and diabetes risks are still unclear. In this cohort, the association between intake of MUFA and GDM risk in the high-fat group can still be partly attributed to the high correlation ($r = 0.96$) with total fat intake. The correlation between MUFA intake and GDM risk remains to be further studied at different total intake levels. In terms of specific fatty acids, a randomised controlled trial with twenty-eight participants found that palmitic and oleic acids in the diet were related to β-cell function and insulin sensitivity. Another prospective nested case–control study observed that myristic and palmitic and linoleic acids in plasma were correlated with insulin resistance or insulin secretion, such as indices of dietary fat quality for CVD.

The strengths of our study include the following: First, we observed the positive association between total fat intake and GDM risk and then reduced its influence by stratification in the following analysis, which has not been done in existing studies. Using this approach, we found higher animal fat intake raised the probability of developing GDM but not when total fat intake under the upper limit, which may be more instructive than those simply indicating that higher total fat, animal fat intakes may increase GDM risk. Second, this is the first prospective cohort study to investigate the association between specific fatty acids intakes and GDM risk in China. Third, dietary information was assessed in the first trimester before the diagnosis of GDM in our study, which can enable earlier prevention of GDM. Nevertheless, some limitations of our study should be acknowledged. First, baseline glycaemia was not collected in our study, which would help to detect unknown diabetes or impaired fasting glucose condition. However, according to the Report on Chinese Residents’ Nutrition and Chronic Disease Status in 2020, the prevalence of diabetes among women aged 18–44 years in China was $5\%$ in 2018. In our research, most participants are under age 30, and their prevalence of diabetes may be lower. Therefore, the missing of baseline glycaemia would not affect the results significantly. Second, we did not calculate the intake of trans-fatty acids due to a lack of data on trans-fatty acids in the updated Chinese Food Composition Tables. High intake of trans-fatty acids may increase the risk for T2DM, thus, future studies are suggested to take this into account. Third, as in other observational studies, measurement errors or residual confounding cannot be entirely eliminated, although trained interviewers used the estimation tools to help participants minimise recall bias. Finally, our study population was composed of Chinese pregnant women; therefore, it cannot be extended to other ethnic populations. Our results need further verification in future larger prospective studies and randomised clinical trials.

In conclusion, total fat, animal and vegetable fat intakes were positively associated with GDM risk, respectively. Whereas when total fat intake was not excessive, higher intakes of animal and vegetable fat were likely irrelevant with increased GDM risk, even the moderate animal fat intake could be linked to lower GDM risk. Our findings suggest that compared with quality, the quantity of dietary fat is the priority for nutritional interventions to prevent GDM.

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**Supplementary material**

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114522002422

**References**

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