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Associations between quality of dietary intake during pregnancy and gestational diabetes mellitus : a prospective cohort study

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Short Report

Keywords: diet quality, diet balance index·, pregnancy diet, gestational diabetes mellitus

Posted Date: September 2nd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10651962/v1

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Additional Declarations: Competing interest reported. The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Abstract

Background

The global rise in gestational diabetes mellitus (GDM) prevalence is imposing substantial health and economic burdens. Diet is a modifiable risk factor, recent research has shifted toward exploring holistic dietary patterns and their associations with disease. While a priori dietary indices are used to assess dietary quality, their application remains limited by the current understanding of diet-disease relationships.

Purpose

We investigated the association between diet quality and the risk of GDM.

Methods

In this prospective study of 1,220 early-pregnant women, dietary intake was evaluated via FFQ. Logistic regression analyses were then performed to explore the link between dietary quality and GDM.

Results

Among participants, 312 (25.6%) were diagnosed with GDM. After full covariate adjustment, those in the highest quartile (Q4) of HBS and DQD had a higher risk of GDM than those in Q1, with ORs of 1.67 (95% CI: 1.11–2.51) and 1.75 (95% CI: 1.18–2.59), respectively. No significant association was found for LBS.

Conclusions

These findings indicate that lower dietary quality could potentially be a risk factor for GDM in mothers, thereby supporting the existing dietary guidelines.

Introduction

Gestational diabetes mellitus (GDM) is a condition abnormal glucose tolerance that first presents during pregnancy[1].. As the most common metabolic disease during pregnancy, GDM has become an increasingly serious public health issue in recent years[2]. In China alone, approximately 2.9 million pregnant women are affected by GDM every year, which imposes a heavy burden on maternal and child health as well as the socio-economic situation. Research shows that GDM has notable health consequences for both mothers and offspring. It not only increases the risk of complications such as preterm birth and preeclampsia in pregnant women, but may also lead to excessive fetal growth

resulting in macrosomia, and raises the incidence of neonatal hypoglycemia, respiratory distress syndrome, and even death[3, 4]. More importantly, women with a history of GDM have nearly a tenfold higher risk of developing type 2 diabetes in the future[5]. Given its high incidence and numerous adverse consequences, early identification and management of GDM is crucial for reducing risks to both the mother and her offspring.

Diet, as a modifiable risk factor for gestational diabetes mellitus (GDM), provides a key entry point for early prevention[6, 7]. Therefore, it is very important to assess the dietary of pregnant women during pregnancy. Traditional dietary analysis methods often based on single or a few nutrients have obvious limitations and are difficult to fully reflect the overall relationship between dietary patterns and the risk of GDM. It overlooks the complex synergistic or antagonistic interactions among various nutrients in food. Therefore, nutritional research is shifting towards using overall dietary patterns to explore their association with diseases, providing more valuable insights into the dietary risks of GDM.

Dietary patterns, defined as the longitudinal integration of dietary behaviors, encapsulate the structural complexity of food matrices and their cumulative physiological impact, serving as a comprehensive proxy for lifestyle-related metabolic risk. While established indices—such as the Healthy Eating Index (HEI)[8] and the Mediterranean Diet Score (MDS)[9]—effectively capture the dietary landscapes of Western populations, their applicability to diverse culinary cultures remains limited. In China, the Diet Balance Index (DBI) has emerged as a tailored tool to evaluate the unique 'double burden' of undernutrition and overnutrition[10]. Studies have shown that high-quality diets can help prevent gestational diabetes mellitus (GDM), yet most research linking maternal dietary indices to GDM has focused on Western populations [7, 11, 12]. There is a critical knowledge gap regarding the predictive value of region-specific dietary indices, such as the DBI, for GDM risk within non-Western populations, particularly in the context of the rapidly transitioning Chinese diet.

While numerous studies have investigated the association between dietary patterns and gestational diabetes mellitus (GDM), research focusing on the relationship between a priori-defined dietary indices and GDM risk remains limited. Moreover, evidence specific to Chinese populations is particularly scarce. Given that dietary habits are strongly influenced by cultural and geographical factors, the adoption of locally validated dietary assessment tools is essential. Therefore, this study aims to examine the relationship between dietary quality during early pregnancy and the risk of developing GDM among Chinese women.

Methods

Study design

This prospective cohort study was conducted between October 2022 to June 2024 at Long-gang Women's and Children's Hospital in Shenzhen, China. The study procedures were approved by the Ethics Review Committee of Long-gang District Maternity & Child Healthcare Hospital in Shenzhen City

(LGFYYXLLL-2022-018), and informed consent was obtained from all participants during the enrollment process.

Study population

Pregnant women who were at a gestational age of 6–13^{+6} weeks and had their initial antenatal visit at the obstetrics clinic were randomly selected to participate. Only women who had been residents of Shenzhen for at least 2 years were included to ensure convenient follow-up. The study focused on women with singleton pregnancies between the ages of 18–45. Participants with pre-existing diabetes mellitus (n = 14), a history of GDM (n = 37), polycystic ovary syndrome (n = 32), implausible daily energy intake (< 500 or > 3500 kcal/day; n = 19), or pre-existing mental health disorders (n = 0) were excluded. Ultimately, a total of 1220 women were eligible for analysis. The detailed enrollment and stepwise exclusion of all study participants are systematically presented in Fig. 1.

Dietary assessment

A face-to-face interview was conducted with all participants by a trained investigator during their routine prenatal visits in early pregnancy. A validated Food Frequency Questionnaire (FFQ) specifically designed for Chinese pregnant women was used to assess their daily dietary intake during this early stage of pregnancy[13]. Participants were asked to recall the frequency and portion sizes of the various food types they had consumed in the past 4 weeks. Additionally, to assist participants in accurately estimating their usual consumption, we provided them with food models featuring standard portion sizes. The dietary data obtained were then categorized and summarized based on the Chinese dietary guidelines and subsequently used to calculate the DBI-P.

Dietary Balance Index-Pregnancy

The DBI-P is based on the 2016 DBI-16 and customized with reference to the Dietary Guidelines for Chinese Maternal and Child Populations (2016), making it an effective tool for the comprehensive assessment of pregnant women's dietary habits. The DBI-P evaluates food consumption across several categories, including: (1) cereal; (2) animal food (meat, poultry, seafood, eggs); (3) dairy products, soybeans and nuts; (4) vegetables and fruits; (5) empty calorie foods (cooking oils, alcoholic beverages); (6) condiments (added sugar, salt); (7) diet variety; and (8) drinking water.

The DBI-P includes three evaluation indicators to assess diet quality, where higher scores denote poorer diet quality and more significant issues. High Bound Score (HBS): This indicator reflects excessive dietary intake. The HBS score is calculated as the sum of positive scores for all food groups and ranges from 0 to 44. A score of 0 indicates no excessive intake, 1–7 suggests a fairly suitable intake, 8–14 indicates mild excessive intake, 15–20 represents moderate excessive intake, and 21–34 denotes severe excessive intake. Low Bound Score (LBS): This indicator represents inadequate dietary intake.

The LBS score, ranging from 0 to 72, is the sum of absolute negative scores for all food groups. A score of 0 signifies no inadequate intake, 1–17 suggests a fairly suitable intake, 18–33 indicates mild inadequacy, 34–50 represents moderate inadequacy, and 51–83 indicates severe inadequacy. Diet Quality Distance (DQD): The DQD score is the sum of the absolute values of both positive and negative scores from all indicators, with a range of 0 to 96. A score of 0 denotes a balanced intake, 1–18 suggests a fairly balanced diet, 19–36 indicates mild imbalance, 37–55 signifies moderate imbalance, and 56–91 reflects severe imbalance. For specific details and scoring criteria, please refer to Supplementary Table 1.

Assessment of outcomes

The primary outcome of this study was the clinical incidence of GDM. In accordance with the WHO criteria, all participants underwent a standardized 75-g oral glucose tolerance test (OGTT) between 24 and 28 weeks of gestation. GDM was diagnosed if one or more of the following venous plasma glucose thresholds were exceeded: a fasting glucose level of 5.1 mmol/L (92 mg/dL), a 1-hour post-load level of 10.0 mmol/L (180 mg/dL), or a 2-hour post-load level of 8.5 mmol/L (153 mg/dL). To ensure diagnostic consistency, blood samples were collected via venipuncture after an overnight fast of at least 8 hours. Trained clinical staff, blinded to the participants' dietary index scores, performed the assessments to minimize potential ascertainment bias.

Covariates

To account for potential confounding factors, various socio-demographic characteristics and lifestyle information were collected during the early stages of pregnancy. These included maternal age, pre-pregnancy body mass index, education level, reproductive history (parity), family history of diabetes, Vomiting, abnormal pregnancy-labor history, passive smoking, and physical activity level.

Among these variables, pre-pregnancy body mass index (BMI) was calculated based on weight and height. Family income was classified into four levels: <5000 RMB/person, 5000 ~ 10,000 RMB/person, 10,000 ~ 20,000 RMB/person, and > 20,000 RMB/person. Education was allocated into four categories: college or lower, technical/high school, university education, and graduate degree. Physical activity level was divided into inadequate (< 600 MET-min/w), low (600–3999 MET-min/w), and medium or high (≥ 4000 MET-min/w) levels, determined using the previously validated International Physical Activity Questionnaire.[17]

Statistical analysis

Descriptive statistics were used to express normally distributed measures as (mean ± standard deviation). Between-group comparisons for these measures were conducted using t-tests and ANOVA. Categorical variables were described using frequencies and percentages (n, %), and between-group

comparisons were performed using the chi-square test. To analyze the correlations between the three indicators in the DBI-P and GDM, logistic regression analysis was employed.

The statistical analysis involved two models. When modeling dietary index as a continuous variable, restricted cubic splines (RCS) were used to investigate the potential nonlinearity of the relationship between dietary quality and GDM. The HBS model included three knots located at the 10th, 50th, and 90th quantile. The DQD model had five knots located at the 5th, 27.5th, 50th, 72.5th, and 95th percentiles. Scores outside the 5th and 95th percentiles were excluded from the analysis.

R software (version 4.2.2) and SPSS software version 22.0 (SPSS, Inc.) were used for all statistical analyses. All tests were two-tailed, and a *P*-value of < 0.05 was considered statistically significant.

Result

Characteristics of the study population

Among the total 1220 participants, 312 (25.6%) had GDM (mean age 29.9±4.2 years; pre-pregnancy BMI 21.4±3.0 kg/m²). Compared to non-GDM women, those with GDM were significantly older, had higher BMI, more passive smoking exposure, and distinct family income distribution; they also showed greater physical activity and higher education levels (all P<0.05). Baseline characteristics across LBS, HBS, and DQD quintiles are detailed in Supplementary Table 2.

Evaluation of Food Group Intake and Dietary Quality

Table 2 presents an assessment of food group intake and dietary quality among the participants. Overall, 94% of pregnant women had some dietary imbalance, with under-consumption more common than over-consumption. About 72% showed low or moderate under-consumption, and 50% had low or moderate excess intake. Inadequate intake was most striking for cereals (91.6%), eggs (87.1%), and seafood (67.9%), while meat insufficiency affected 28.7%. Conversely, overconsumption of salt (74.6%) and oil (49.0%) was prevalent, with positive scores in 89% and 45% of participants, respectively (Figure 2).

Association of GDM with Dietary Quality Indicators

The results of the logistic regression analyses examining the association between key indicators of DBI-P and GDM risk are presented in Table 3. Both HBS and DQD scores exhibited a positive association with GDM risk in all crude and multivariable-adjusted models.

Compared to participants in the first quartile (Q1) of HBS, those in the fourth quartile had a 0.69-fold increased risk of developing GDM after multivariable adjustment (model 1) (95% CI: 1.14,2.51). This association remained significant even after full adjustment for covariates (model 2), with an odds ratio (OR) of 1.67 (95% CI: 1.11,2.51). The restricted cubic splines analysis indicated that HBS scores were linearly associated with the hazard ratio (HR) of GDM, after adjusting for covariates (P for nonlinearity =

0.2) (Fig. 3(A)). Similarly, a positive association was observed between DQD and GDM. In model 1, after adjusting for age and pre-pregnancy BMI, the highest quartile of DQD was significantly associated with increased odds of GDM (OR: 1.60; 95% CI: 1.10, 2.33; P=0.013). In fully adjusted models, the adjusted ORs for GDM from Q1 to Q4 of the DQD score were 1 (reference), 1.80 (95% CI: 1.16, 2.78), 1.47 (95% CI: 0.97, 2.23), and 1.75 (95% CI: 1.18, 2.59). However, the DQD scores did not exhibit a linear association with the HR of GDM after adjusting for other covariates, as visually depicted in Figure 3(B) using spline analyses (P for nonlinearity = 0.014) (Fig. 3(B)). Furthermore, no significant association was found between LBS scores and GDM risk.

Discussion

In this prospective cohort study, we conducted a investigation into the relationship between early pregnancy diet quality and GDM risk among Chinese women. Our findings reveal a strikingly high GDM prevalence of 25.6%, which significantly exceeds the national pooled prevalence of 14.8% and the 2024 regional statistics for Southern China[14, 15]. This discrepancy suggests that the rapid urbanization and distinct "high-oil, high-salt" dietary transition in Tier-1 cities like Shenzhen have created a unique metabolic profile for resident gravidae[15]. Furthermore, recent global trend analyses suggest that the post-pandemic shift toward sedentary lifestyles and processed-food reliance may have further escalated GDM incidence in metropolitan areas[16]. Our multivariable models demonstrated that while individual nutrient inadequacies (LBS) were widespread, it was the overall structural imbalance (DQD) and dietary excess (HBS) that acted as the primary drivers of gestational hyperglycemia.

In our study, despite the fact that over 85% of participants showed insufficient intake of cereals, eggs, and seafood, no significant correlation was found between higher LBS scores and GDM risk. While several studies have identified low intake of whole grains and marine-derived omega-3 fatty acids as independent risk factors for GDM, the results of our study may be attributed to two factors. First, the "urban nutritional profile" of Shenzhen gravidae may involve compensatory intake of other protein sources, which buffers the immediate metabolic impact of specific seafood or egg deficiencies. Second, in the presence of overall energy sufficiency—a characteristic of this middle-to-high-income population—isolated inadequacies (LBS) may not reach the pathogenic threshold required to disrupt maternal glycemic control in the first trimester. Biologically, this reflects the robust compensatory capacity of maternal β-cells during early pregnancy, which preserves glucose homeostasis despite suboptimal intake of protective food groups, provided that total energy availability remains high[17, 18].

In contrast to the null LBS findings, both the Diet Quality Distance (DQD) and High Bound Score (HBS) were significantly associated with increased GDM risk (OR = 1.75 and 1.67, respectively). The DQD captures holistic deviation from dietary guidelines suggests that GDM risk may escalate abruptly once cumulative dietary disorganization exceeds a specific threshold. This phenomenon may be attributed to the combined effects of excessive intake and concurrent deficiencies, which collectively impair insulin sensitivity through multiple pathways, including increased oxidative stress and low-grade systemic inflammation[19, 20].

Furthermore, our results revealed that HBS was significantly and positively associated with GDM risk. HBS primarily reflects excessive dietary intake, with over-consumption of cooking oils (49.0% of participants) and sodium (74.6%) being its main characteristics. This aligns with previous findings that high-fat and high-salt dietary patterns in the general population are closely associated with increased insulin resistance[21, 22]. From a mechanistic perspective, chronic excessive intake of lipids leads to elevated circulating free fatty acids, which directly interfere with the insulin signaling cascade (e.g., phosphorylation of IRS-1)[23]. Additionally, high sodium intake has been linked to increased endogenous glucose production and impaired glucose tolerance in longitudinal studies[24]. Collectively, these findings suggest that in modern urban settings, the metabolic challenge posed by “over-nutrition” (HBS) exerts a more direct and potent pathogenic effect on maternal glycemic control than “under-nutrition” (LBS).

Although there is a lack of clinical trial data specifically examining the impact of improving diet quality, as measured by predefined indices, on GDM incidence or risk factors, substantial evidence supports the positive effects of healthy dietary patterns such as the DASH diet, the Mediterranean diet,and the dietary recommendations outlined in the Dietary Guidelines for Americans on preventing and treating GDM[25, 26]. Based on our findings, it appears that instead of following a specific diet, prioritizing overall diet quality may play a crucial role in preventing GDM. Therefore, assessing and enhancing dietary quality can be considered an additional strategy for reducing the risk of GDM at a population level.

While the precise mechanisms by which dietary quality influences the risk of GDM are not fully understood, several hypotheses have been proposed. Firstly, poor dietary quality characterized by inadequate intake of vegetables, fruits, cereals, and soybeans may result in a deficiency of antioxidant micronutrients (such as proteins, vitamins, minerals, and beta-carotene), which have been shown to play a role in reducing oxidative stress associated with a higher risk of diabetes[27]. A small-scale studies have explored this hypothesis and found that higher intake of micronutrients potentially reduces the risk of GDM[28]. Secondly, although the relationship between cooking oil consumption and diabetes risk has yielded inconsistent results in previous studies, cooking oil remains a primary source of fat intake in many diets. A high-fat diet has been shown to downregulate certain proteins involved in insulin secretion stimulated by glucose, leading to impaired insulin secretion[29]. This effect can be particularly burdensome during pregnancy when mothers experience physiological increases in insulin resistance[30]. Additionally, multiple studies have demonstrated a positive association between red meat consumption and the risk of GDM[31]. Meat and poultry are rich in saturated fats, heme iron, and advanced glycation end products, which collectively contribute to the development of diabetes mellitus, increased insulin resistance, and beta-cell death[32]. It is important to note that these hypotheses provide some insights into the potential links between dietary factors and GDM risk, but further research is needed to establish a clearer understanding of these relationships.

Limitations

There are also some limitations in our study that should be considered. Firstly, the dietary information was self-reported by the participants, which introduces the possibility of misclassification bias. Nevertheless, it is worth noting that the food frequency questionnaire (FFQ) used in our study has been validated and shown to be reproducible. Secondly, our study only focused on pregnant women in southern China, which may limit the generalizability of our findings to other geographical locations and cultural contexts. Therefore, it is essential to further validate our results through larger prospective studies and randomized clinical trials in different populations.

Conclusion

In conclusion, our study demonstrates that dietary quality in early pregnancy is a critical determinant of GDM risk. While dietary imbalances are near-universal (94%), GDM risk is predominantly driven by overall structural disorganization (DQD) and nutritional excess (HBS), rather than isolated inadequacies (LBS). The rampant over-consumption of cooking oils and salt, coupled with the lack of cereals and seafood, creates a pro-diabetogenic metabolic environment. Clinical strategies should shift from general supplementation toward a targeted "mitigation of excess" approach, specifically prioritizing the reduction of oil and salt intake in the first trimester.

Declarations

Ethics approval and consent to participate

This research was approved by the Ethics Review Committee of Longgang District Maternity & Child Healthcare Hospital in Shenzhen City (LGFYYXLLL-2022-018). All clinical data were used in accordance with relevant ethical guidelines, and each participant provided written informed consent. This study was conducted in accordance with the principles of the Declaration of Helsinki.

Consent for publication

Not applicable.

Declaration of Competing Interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Competing Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This study was supported by the Science and Technology Research Key Program of Chongqing Municipal Education Commission (No. KJQN202500127).

Author Contribution

Study conception and design: Tingyu Luo and Sifen Jiang. Recruitment of patients: Tingyu Luo. Data acquisition: Tingyu Luo. Data analysis and/or interpretation: Tinglan Luo, Lingling Xiong and Yousha Wang. Drafting or revising the article critically for important intellectual content: Li Fang, Fan Li and Shasha Li. Final approval of the article: Li Fang.

Acknowledgments

We want to thank all the individuals who participated in this research.

Data Availability

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Tables

Tables are available in the Supplementary Files section.

Figures

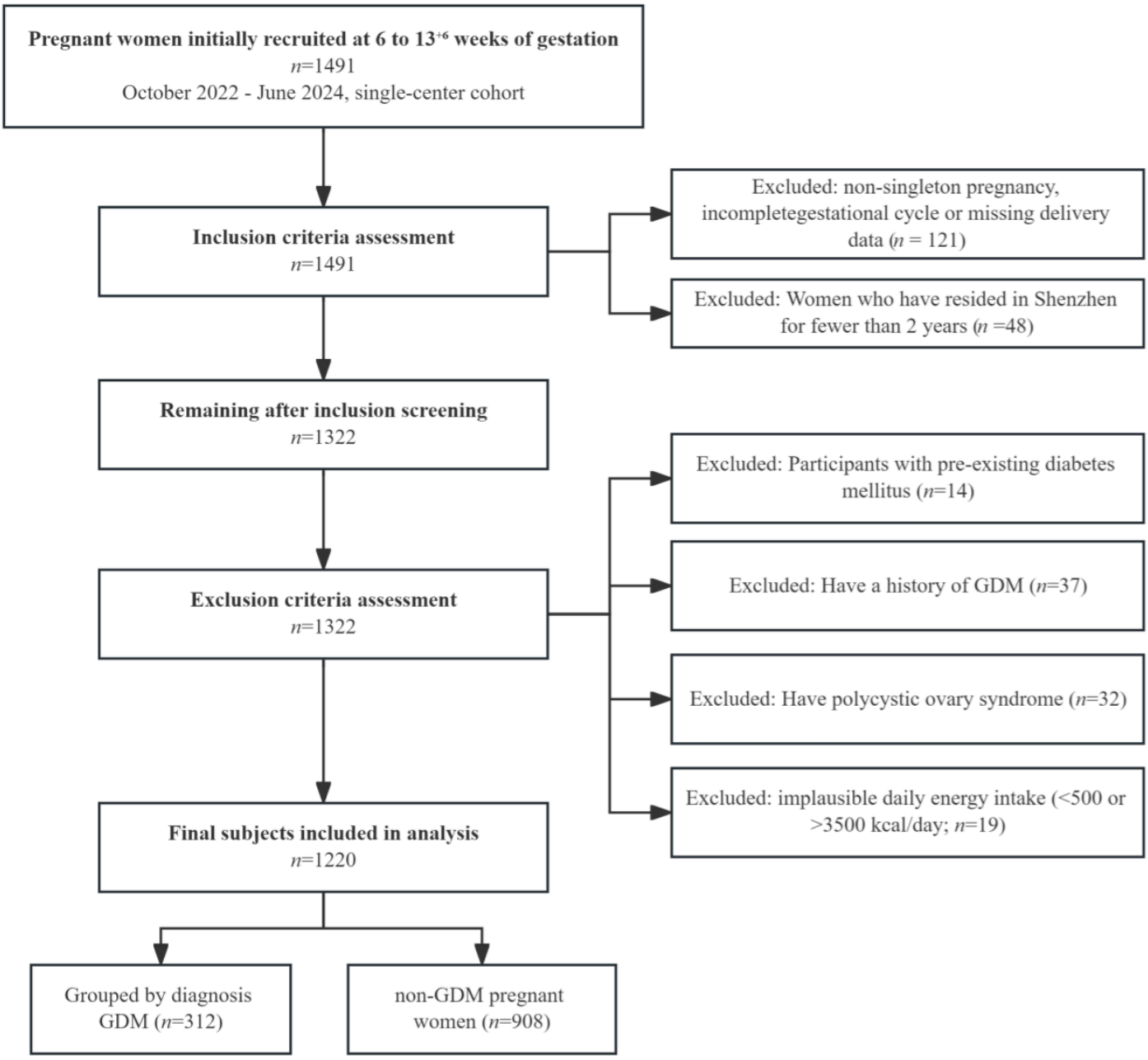


Figure 1

Flowchart of study participant enrollment

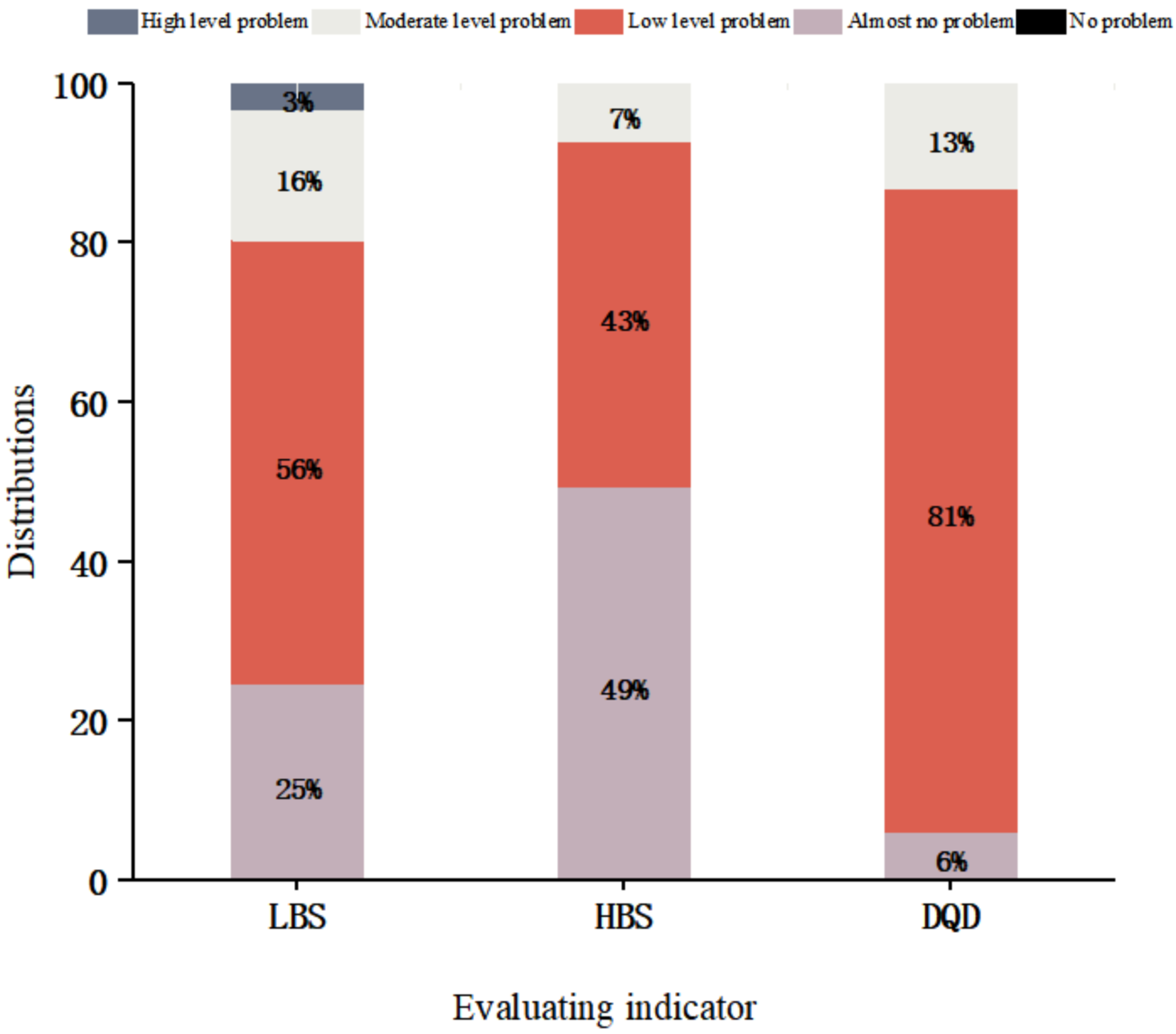


Figure 2

For each indicator, a score of 0 means no problem; a score lss than 20% of the total score means almost no problem; between 20% and 40% of thetoal score means low level problem; betlween 40% and 60% of the total score meanms moderate level problem; and greater than 60% of the total scoremeans high level problem.

Abbreviations: HBS, high bound score; LBS, low bound score; DQD, diet quality distance.

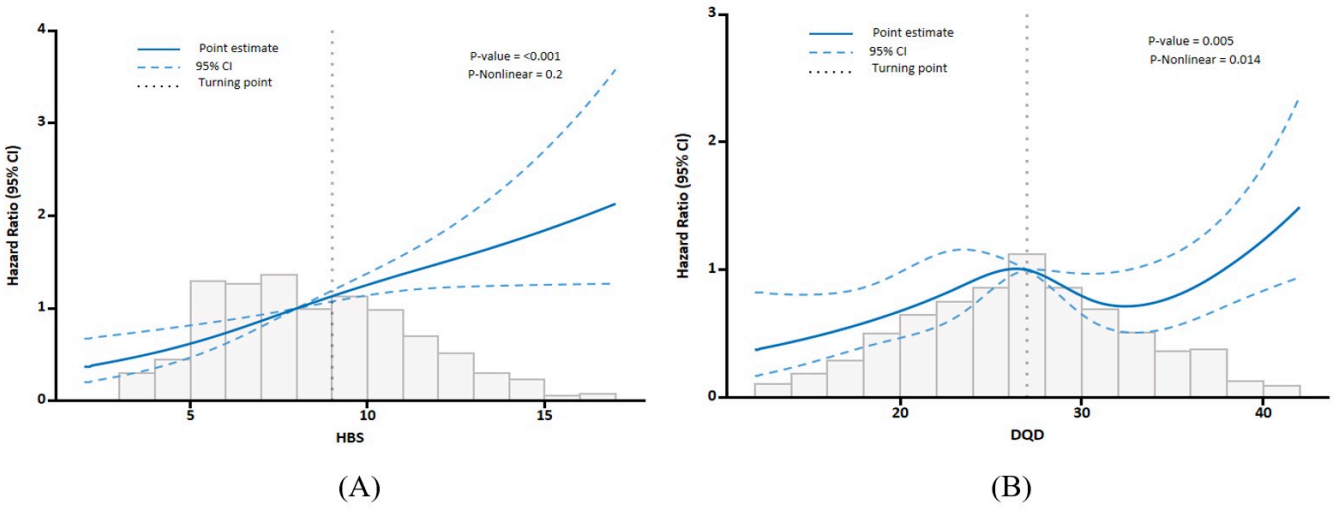


Figure 3

Restricted cubic spline analysis illustrates the shapes of the multivariable association between HBS Score (A) and DQD Score (B) and GDM.

The Cox regression was adjusted for maternal age; pre-pregnancy BMI; total energy; parity; education level; family monthly income; vomiting; abnormal pregnancy-labor history; physical activity; family history of diabetes and exposure to passive smoking; HR, hazard ratio.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table.docx
- SupplementalMaterial.docx