**Abstract**

**Objective:** To identify peri-conceptional diet patterns among women in Bangalore, and examine their associations with risk of gestational diabetes mellitus.

**Design:** BANGLES, started in June 2016, was a prospective observational study, in which women were recruited at 5-16 weeks’ gestation. Peri-conceptional diet was recalled at recruitment, using a validated 224-item food frequency questionnaire. GDM was assessed by a 75-gram oral glucose tolerance test at 24-28 weeks’ gestation, applying WHO 2013 criteria. Diet patterns were identified using principal component analysis and diet pattern-GDM associations were examined using multivariate logistic regression, adjusting for ‘*a prior*i’ confounders.

**Setting:** Antenatal clinics of two hospitals, Bangalore, South India

**Participants:** 785 pregnant women of varied socio-economic status

**Results:** GDM prevalence was 22%. Three diet patterns were identified: a) High-diversity, urban (HDU) characterised by diverse, home-cooked and processed foods was associated with older, more affluent, better-educated and urban women; b) Rice-fried snacks-chicken-sweets (RFCS), characterised by low diet-diversity, was associated with younger, less-educated, and lower income, rural and joint families; c) Healthy, traditional vegetarian (HTV), characterised by home-cooked-vegetarian and non-processed foods was associated with less-educated, more affluent, and rural and joint families. The HDU pattern was associated with a lower GDM risk (aOR: 0.80 per SD, 95% CI: 0.64, 0.99, p=0.04) after adjusting for confounders. BMI was strongly related to GDM risk and possibly mediated diet-GDM associations.

**Conclusions:** The findings support global recommendations to encourage women to attain a healthy pre-pregnancy BMI and increase diet-diversity. Both healthy and unhealthy foods in the patterns indicate low-awareness about healthy foods and a need for public-education.

**Key words:** peri-conceptional, diet patterns, prospective study, gestational diabetes mellitus and India.

**INTRODUCTION**

Gestational diabetes mellitus (GDM) is an important public health problem in India, affecting about 20 percent of the pregnancies (1). GDM causes short and long-term adverse health consequences for mothers and their children. Short-term problems include a higher risk of caesarean deliveries in the mother and preterm birth, macrosomia and congenital heart abnormalities for the fetus (2). Long-term consequences of GDM include an increased maternal risk of type 2 diabetes mellitus (T2DM), and intrauterine programming of insulin resistance in the offspring that increases their risk of obesity, T2DM and cardiovascular disease in later life (2). While diet before and during pregnancy is increasingly being recognised as an important modifiable risk factor to prevent GDM (3), diet during the peri-conceptional period may be critical to prevent GDM, since, although GDM is usually detected in late pregnancy, the source of metabolic dysfunction is established much before, probably during the peri-conceptional period (6 months around conception including the period of oocyte growth, fertilization and embryogenesis) (4 & 5). Diet patterns best capture the totality of the ‘diet’ exposure, the combinations and quantities in which foods and nutrients are consumed and overcome the limitations of single food and nutrient approaches (3). Evidence linking peri-conceptional diet patterns and GDM in high-income countries in the West have found healthy or prudent patterns, with higher intakes of whole grains, fruits and vegetables, to be associated with a lower GDM risk; and an unhealthy or ‘Western’ diet pattern with higher intakes of refined grains, fried and fast food, high sugar, red and processed meat to be associated with a higher risk (3). However, definitions of ‘healthy’ patterns across the globe are heterogeneous and challenging to interpret (6). Currently, a knowledge gap exists about culture-specific healthful diet patterns to prevent GDM in India. Foods in Indian and Western diets are different, although ultra-processed food intake is rising in India (7). Most global interventions have focussed on calorie and fat restriction to reduce gestational weight gain (GWG) and macrosomia to prevent GDM (8). These strategies are less applicable to India as they may decrease birth weight (8); and increase the burden of GDM and T2DM (9) according to the DOHaD (Developmental Origins of Health and Disease) hypothesis. The BAngalore Nutrition Gestational diabetes LifEstyle Study (BANGLES) aimed to identify peri-conceptional diet patterns in South India and examine their association with GDM risk.

**METHODS**

**Study location and design:** Bangalore, the capital of Karnataka state (South India), has a population of 8.5 million.BANGLES was a prospective observational study, in which 785 women were recruited from the antenatal clinics of two hospitals in Bangalore at 5-16 weeks of gestation (**figure a**). One hospital mainly caters to women from middle- and high-income groups, while the other caters to women from the highest income group. Inclusion criteria included: i) a singleton pregnancy; ii) <17 weeks’ gestation; iii) no previous history of diabetes; and iv) an intent to stay in Bangalore until at least 28 weeks’ gestation (to ensure follow-up to ascertain GDM). A consecutive recruitment process was followed in both hospitals, between June 2016 and October 2017.

**Dietary exposure**

The exposure was the woman’s diet in the peri-conception period. Most women discover that they are pregnant between 2-4 weeks after conception so at recruitment, we asked them to think back to what they were eating during the month before they knew they were pregnant. We recruited women between 5 and 17 weeks of pregnancy and asked them to recall their diet in the month before they know they were pregnant. Based on this, the interval from conception to recruitment ranged from 2 to 6 months. A 224-item FFQ (**supplementary sections 1 & 2)** was administered by trained nutritionists at recruitment (5-16 weeks’ gestation). The FFQ was developed from the 136-item Mysore Parthenon Study’s FFQ (MP-FFQ), used for children in Mysore (10).Bangalore and Mysore in Karnataka are only 150 km apart, and the foods eaten in both places are similar. We undertook pilot work to adapt the MP-FFQ for pregnant women and to capture new-age foods, for example, ready-to-eat breakfast cereals, that were not widely consumed when the MP-FFQ was designed. Using 500 24-hour recalls among pregnant women in both the study centres, frequently consumed foods were identified and food-items appearing >5 times (and not already on the MP-FFQ) were added to the BANGLES FFQ. Seasonal foods were grouped separately and the women were asked how often they consumed them when in season. The FFQ was organised into sections of similar foods types to facilitate data collection (e.g. fruit, beverages). These steps created the 224-item BANGLES FFQ (**supplementary section 3)**. Dietary data were collected using an FFQ kit with familiar household vessels. The nutritionists collecting the data were fluent in local languages, and used an atlas with photographs and food models. Foods that women reported eating but were not on the FFQ were recorded as ‘other foods’ in a separate section of the FFQ. These were later merged into existing FFQ items with similar nutrient composition. The BANGLES FFQ was validated using a combination of methods (**supplementary section 4)**.

**Principal component analysis**

PCA is a widely used statistical technique in diet patterns research. It identifies foods that are consumed together by individuals and produces new variables (components) that are independent linear combinations of the dietary variables accounting for maximum variance (9). Weekly frequency of intake of foods were selected as the input variables in order to make study findings more relatable to all settings globally (units and quantified weights of foods can be different across settings based on how a food is cooked).

**Food-group input variables for the PCA:** Food-groups to be used as PCA input variables were constructed using a mix of ***a priori and some a posteriori methods***. The **a** ***priori method*** was based on prior knowledge of foods with similar nutrient composition. E.g. Different types of nuts and seeds including almonds, cashew nuts, pistachios, groundnuts, walnuts, sunflower seeds, pumpkin seeds, flax seeds, and chia seeds were grouped together (**rationale for food-grouping in supplementary section 5).**

The a ***posteriori method*** includedfurther modifications to the *a priori* food-groups to determine the final food-groups as input variables for the PCA and included the following steps:

**1) A PCA of 205 individual FFQ food items** to identify foods that characterise a particular diet pattern. This information may be lost when a PCA is done on pre-grouped foods. Foods with high factor loadings (factor loading >0.2) in each pattern, that stand out in a particular pattern, were retained as separate input variables in the final PCA. For example, the factor loading for chapathi in pattern 1 was 0.38, and banana (yelakki) had a factor loading of 0.26 in pattern 2. These were considered discriminating foods for patterns 1 and 2 **(supplementary section 6)**.

**b) Identification of commonly consumed foods:** Foods that were consumed ≥5 days/ week were grouped as separate input variables. For example, rice, ragi ball, chapathi, banana etc. This was done to prevent commonly consumed foods from diluting the discriminating power of the diet patterns. For instance, bananas were frequently consumed by most women and hence were assigned as a separate food-group. Other fruits were consumed less frequently and not by all the women, so were more discriminatory. If bananas and other fruit were all grouped together, the PCA would not discriminate between the women in terms of their fruit intake because the universal consumption of bananas would mean that the factor loading for fruit would be close to zero.

**c) Consideration of culture-based preferences of women:** While interviewing the women, we formed a strong impression that they tended to make dietary choices based on their cultural inclination, preferences and affordability, more than on nutritional considerations. From a nutrition perspective, brown bread and chapathi are both made of wholegrain wheat, are a good source of fibre and have similar calorie-content. Keeping this in mind, western**-**cereal-products (breads, buns, noodles) were grouped separately from the traditional-Indian-wheat**-**breads (chapathi, paratha).

This combination of ***a priori*** and ***a posteri*** methods created 68 food-groups as input variables. We used an unrotated PCA to derive the diet patterns since some evidence indicates that rotation can lead to loss of pattern discrimination (11 & 12). A cut-off of 0.2 was used for the factor loadings based on the interpretability of the diet patterns. Naming of diet patterns was done using a qualitative method based on the foods that were associated with the pattern (11). Each component represented a particular diet pattern. Pattern scores were calculated for each woman by multiplying the weekly frequency of consumption of items from the food-group with the coefficient for that food-group. These values were then summed for all 68 food-groups to provide scores that represent the woman’s adherence to a particular pattern. Pattern z-scores were then calculated with a mean (SD) of 0 (1).

**Gestational diabetes:** At 24–28 weeks’ gestation, participants underwent a 2-hour 75-gram oral glucose tolerance test (OGTT) after an overnight fast. Venous plasma glucose concentrations at baseline, and 1 and 2 hours after the glucose load, were measured using the hexokinase method. A diagnosis of GDM (based on WHO 2013 criteria) was made if any one of the following values was met or exceeded: 0 hr (fasting): ≥5.1 mmol/L / 92 mg/dl; 1 hour: ≥10.0 mmol/L or 180 mg/dl; and 2 hours: ≥8.5 mmol/L or 153 mg/dl (13). The majority of women (n=677) completed the OGTT but 35 women had, on the instruction of their obstetrician, a 50-gram glucose challenge test (GCT) in which GDM is diagnosed from a single blood glucose value (>140mg/dl) 1 hour after a 50-gram glucose drink. All women managed as GDM by their obstetrician (139 diagnosed by 75-gram OGTT and 18 diagnosed by 50-gram GCT, totally 157) were included in the analysis as cases.

**Co-variates**: At recruitment, we collected information on factors that may be associated with diet and/or GDM risk, based on published literature. Height was measured to the nearest 0.1 cm using a Harpenden pocket stadiometer. Weight was measured to the nearest 100 g using a calibrated, electronic digital weighing scale. Health information included gravidity, history of polycystic ovarian syndrome (PCOS) or hypothyroidism and a family history of type 2 diabetes (T2DM) among first degree relatives. Socio-economic status (SES) was assessed using the Standard of Living Index (SLI) from the National Family Health Survey 2 (NFHS 2) (14). This creates a score based on household assets, amenities, and the quality of the woman’s home, with a higher score representing higher SES. The participant’s education, occupation, and family income were recorded. Education level was classified into 4 groups, from no schooling to post-graduate degree. Occupation was classified based on Kuppuswamy’s scale (15), and the International Standard Classification of Occupations (ISCO-08) (16). Physical Activity was assessed using the WHO International Physical Activity Questionnaire (IPAQ) short version (17). BMI was categorised into underweight (BMI <18.5 kg/m2), normal weight (BMI 18.5-25.0 kg/m2), overweight (BMI 25.01-30.0 kg/m2) and obesity (BMI >30.0 kg/m2). Rural or urban areas of residence were classified using their postal codes in the Census directory, in which the Government of India defines ‘urban’ areas as having a population of >5000, a density of at least 400 people per-square kilometre and where the majority are engaged in non-agricultural activities (18).

**Statistical analysis:**

Diet patterns:From the PCA of 68 food-groups, the first three components were retained in the analysis based on the break in the scree plot (**supplementary section 7**). **Table 2** shows the factor loadings for the first three components without rotation. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for the PCA was 0.73 indicating the adequacy of our sample size for PCA. The first three components explained 18.6 percent of variance in the sample.

Statistical rationale of the overall analysis: All analysis was done using SPSS version 25. Data are presented as number and percentage (for categorical variables), mean and standard deviation (for normally distributed continuous variables), and median and interquartile range (for skewed continuous variables). Three distinct peri-conceptional diet patterns were derived using the 68 food-group PCA and these were the dietary exposures. Logistic regression was used to test associations between the women’s diet pattern scores and GDM as a binary outcome, firstly in an unadjusted univariate model, secondly adjusted for potential *a priori* confounders identified from the literature (the woman’s age, gravidity, history of PCOS and hypothyroidism, family history of T2DM, urban/rural residence, nuclear/ joint family type, physical activity, SLI score, education level and use of supplements including folic acid, iron, calcium-vitamin D, B12, and energy-protein supplements), and thirdly adjusted for all the above plus BMI. An additional sensitivity analysis was carried out among women with a 75-gram OGTT only, because a 75-gram OGTT is considered a more robust GDM screening method (13), and to explore if excluding cases diagnosed by other methods would change any observed findings. All *p* values presented were two-tailed and *p* < 0.05 was considered statistically significant.

**RESULTS**

**Study population characteristics**

A total of 785 women took part in the study and 714 were assessed for GDM. GDM was diagnosed in 157 (21.9%). **Table 1** describes the women’s characteristics. Overall, their mean age was 26.7 years and median BMI 23.8 kg/m2,with one-third overweight or obese (BMI>25 kg/m2). Sixty-seven percent ofparticipants were primigravid, 33% reported a family history of T2DM, 68% were educated to at least graduate level and 71% were homemakers. Median monthly family income was INR 30,000 (approximately GBP 300). 68% lived in urban areas. Many women had low levels of physical activity – nearly half reported not doing any weekly light walking.Women who developed GDM were older, had a higher BMI, were more likely to be urban, multigravid, living in a nuclear household, and to have a family history of T2DM. Of all the characteristics, higher BMI was the strongest predictor of GDM.

**Peri-conceptional diet patterns**

**Constituents of the three diet patterns**

**Table 2** shows the three diet patterns identified: i) the high-diversity, urban (HDU) pattern, characterised by consumption of a high-diversity diet (many foods in every food-group having higher positive factor loadings) of expensive, home-cooked, processed, healthy and unhealthy foods including whole-grains, fruits, vegetables, dairy, nuts, seeds, egg, poultry, meat, fast-food and sweets. The main staple was chapathi (whole-wheat pancake); ii) the-rice-fried snacks-chicken-sugar pattern (RFCS), characterised by low diet-diversity (labelled low-diversity due to fewer foods consumed in this pattern), with frequent intakes of a white rice dishes (the staple cereal for this pattern), chicken dishes, shop bought and homemade fried snacks and a high sugar intake in tea, coffee and sweets. The main fruit was banana; iii) the healthy-traditional-vegetarian-pattern (HTV), characterised by frequent intake of vegetarian, healthy, home-cooked, traditional dishes including millets (ragi-ball, rotis made of finger-millet/ragi, sorghum/jowar and /pearl millet/bajra) as the staple cereal, fermented dairy products (curds & buttermilk), tender coconut water and a moderate variety of fruits (apple, pomegranate and sweetlime), pulses and legumes, cooked greens, raw vegetables including traditional salads (kosambiri), dried fruits and nuts. This pattern was devoid of any non-vegetarian and unhealthy foods such as processed fried and fast foods and sweets. The median frequency of intake of key foods characteristic of each diet pattern showed convincing trends across quintiles of the diet pattern scores (**supplementary section 8**).

**Validation of the three diet patterns**

There are no ‘rules’ by which to construct food-groups in PCA; it is to some extent subjective to a researcher’s perspectives (11 & 12). It has been argued that food-grouping in PCA is arbitrary and that this may affect the results (11). We therefore compared the components obtained from all 205 foods with those obtained from the reduced number of 68 food-groups. The figure in **supplementary section 9** shows that there were strong correlations between the first three components or diet patterns derived by both methods, suggesting that despite the subjectivity of the methods, this did not lead to much difference in the results.

**Associations between population characteristics and women’s diet patterns scores**

The HDU pattern was associated with higher diet-diversity, and with women being educated to graduate level or above, having higher incomes and SLI, and urban residence. Also they were older, and more likely to be multigravid, have a diagnosis of PCOS and/or hypothyroidism and a family history of T2DM. The RFCS pattern was associated with lower education and income and being Hindu, educated to the level of high school and less, living in a joint and rural household and having a low daily screen time (<4 hours). The HTV pattern was associated with a lower BMI, the Hindu and Jain religions, a higher SLI, rural residence and living in a joint family (**table 3**). Higher SES was associated with higher scores for the high diet-diversity patterns (HDU & HTV) and lower SES was associated with higher scores for the low diet-diversity (RFCS) pattern.

**Associations between diet patterns and BMI**

Higher scores on the HDU (β: -0.42, 95% CI: -0.806, -0.038, p=0.03), RFCS (β: -0.62, 95% CI: -1.04, -0.20, p=0.004) and HTV (β: -0.64, 95% CI: -1.01, -0.28, p=0.001) diet patterns were associated with a lower BMI, after adjusting for *a priori* confounders.

**Association between diet patterns and gestational diabetes mellitus**

**Table 4** shows the three regression models. Model 1 was the univariate model. Model 2 was adjusted for all the ‘*a priori*’ confounders based on previous literature, with and without adjustment for BMI, that included all 714 women who completed glucose tolerance (35 women who had a GCT, and 2 women with fasting and postprandial blood glucose tests). Model 3 was a sensitivity analysis consisting of the 677 women who had 75-gram OGTT results only. Higher scores of the high-diversity urban (HDU) pattern were associated with a significantly lower risk of GDM (aOR: 0.80, 95% CI: 0.64, 0.99, p=0.04 in model 2). When BMI was added to all the models, the HDU pattern-GDM association weakened, suggesting that the association may be partly mediated by BMI. There was no evidence that the other two diet patterns were related to GDM risk.

**DISCUSSION**

**Study summary:** Three peri-conceptional diet patterns were derived using PCA, namely, the high-diversity (HDU) urban pattern, the rice-fried snacks-chicken-sweets (RFCS) pattern and the healthy traditional vegetarian (HTV) pattern. Pattern 3 comprised mainly healthy foods, while patterns 1 and 2 contained both ‘healthy’ and ‘unhealthy’ foods. The high-diversity urban pattern was associated with a lower GDM risk after adjusting for confounders. BMI was the strongest risk factor for GDM and adjusting for BMI attenuated associations between all diet patterns and GDM.

**Characteristic foods of the diet patterns and their associations with the socio-economic factors:** The HDU pattern included a diversity of vegetarian and non-vegetarian home-cooked-traditional dishes with fruits and vegetables as well as urban processed shop bought foods, available in urban Bangalore. This pattern showed higher intakes of milk, tender coconut water, soups and fresh fruit and sugarcane and juices as well as flavoured sweetened beverages. Various fruits including banana, apple, pomegranate, sweet lime, chickoo, green grapes, guava, papaya, pear, pineapple, mixed-fruit salad and avocado, and nuts, seeds and dried fruits from almonds to flax seeds to figs were consumed. Dairy products and seasonal foods including mango and strawberry were consumed. Whole-wheat chapathi was the staple cereal-based food and traditional breakfast dishes (upma & dosa), and Western-style wheat products (bun, bread & noodles) and ready to eat breakfast cereals (cornflakes and muesli) were consumed. Various cooked vegetable sides including roots, tubers, lady’s finger and gourds, green leafy sides including drumstick, cabbage and cauliflower and raw vegetables and greens from cucumber to lettuce were consumed. Poultry, fish, meat, seafood and egg also featured here. Pickles, tomato ketchup, fried snacks from chips, samosa and Manchurian (batter-fried cauliflower) and fast food including pizzas and burgers and chocolates, cakes and biscuits were eaten. This pattern was associated with older, more affluent, more educated and urban women. Expensive foods including nuts (INR 1500/GBP 14.68 per kilogram), a diversity of seasonal and non-seasonal fruits (e.g. pomegranates cost INR 128/GBP 1.25 per kilogram and ripe mangoes cost around INR 100/GBP 0.99 per fruit in all seasons) (19) and chicken and mutton costing INR 350 and 500 (GBP 3.43 & 4.89) per kilogram respectively (20) were consumed **(figure b)**.

The RFCS pattern was characterised by low diet-diversity, with a focus on rice, fried snacks, chicken dishes and sweets. Beverages included tea, coffee, and buttermilk, and the main fruit eaten was banana. More frequent intakes of rice dishes with lentils, greens and spices, traditional dishes of greens and chicken (biriyani and curry), pickles, fried snacks, home-made sweets and added sugar in tea and coffee were observed. This pattern was associated with younger, thinner, less educated women from lower-income, rural and joint families. Women adhering to this pattern were younger, thinner, multigravid, without PCOS, thyroid problems or a family history of T2DM. Non-expensive foods including bananas, ragi ball, white rice and fried savoury snacks in the pattern resonate with the lower SES. In government-led-subsidised-ration-shops, low quality rice is as cheap as INR 2/GBP 0.01 per kilogram (21) sufficient for a family of four for a week. If a family has mostly rice, dal, basic vegetables (including potato, tomato and onion) and bananas, similar to this diet pattern, their monthly household food budget would be less than INR 5000/GBP 48.5.

The HTV pattern was characterised by a diverse intake of healthy traditional and vegetarian home-cooked foods. More frequent intakes of milk, fermented dairy products (buttermilk), tender coconut water, a moderate variety of fruits (apple, pomegranate and sweetlime) and dried-fruits (figs, dates and raisins) and nuts and seeds were observed. Staple cereal preparations included millets such as ragi ball, whole pulse and lentil preparations, rice with greens and curds, raw vegetables, kosambiri, curd, and ghee (clarified butter) and seasonal fruits were frequently consumed. Lower consumption of western-type bread, non-vegetarian dishes, fried and fast food and sweets was noted. This pattern could be interpreted as the ‘Vegetarian-Indian equivalent’ of the Mediterranean diet pattern in a western setting. Nutrient-wise, this pattern was high in diet-diversity and nutrients including fibre, vitamins, minerals and antioxidants; food-wise, the pattern was rich in wholegrains, legumes and lentils, nuts, seeds, fresh fruit and dried fruit, raw vegetables, yogurt, milk and green leafy vegetables. This pattern was associated with a lower BMI, the Hindu and Jain religions, a higher SLI, rural residence and living in a joint family.

**Comparing diet pattern-GDM findings with the literature:** Globally, the results of diet pattern studies are inconsistent across different regions due to the heterogeneity of diets. A reason for most Asian and Indian studies not finding the clearly distinct healthy and unhealthy diet patterns seen in Western studies could be due to low-awareness among people in Asia/India about healthy and unhealthy foods (6 & 10). The GUSTO study found that a ‘vegetable-fruit-rice’ based diet pattern was associated with higher fasting blood sugar levels and a ‘seafood-noodle based diet’ was inversely associated with GDM risk (22). These results were attributed to noodles having a lower glycaemic index than white rice (22). Similarly, in our study, women who adhered to the high-diversity urban pattern, consumed chapathi more frequently than white rice. Studies in other upper middle-income countries such as Brazil (23) found three diet patterns, the traditional, western and mixed patterns, but found no difference in GDM risk. Similarly, Sedaghat et al. in Iran identified prudent and western diet patterns but found no association between the prudent pattern and GDM risk (24). Global characteristics of healthy diet pattern studies are higher consumption whole-grains, fruits and vegetables and nuts and seeds; and lower consumption of refined grains, red & processed meat, fried food such as fries & fast food such as pizza and burgers, sweets, desserts & sugar sweetened beverages (3, 5 & 6).

**Potential mechanisms of the HDU diet pattern-GDM association:** Women with GDM have pre-pregnancy β-cell dysfunction and insulin resistance (1); and adherence to healthful dietary components in the peri-conceptional period may be helpful in lowering GDM risk, by abating some metabolic pre-dispositions to GDM (25). The HDU pattern included a high intake of a variety of wholegrains, fruit, vegetables, greens, nuts and seeds, dried fruits and dairy. It is biologically plausible that eating these foods leads to ingestion of key macro and micronutrients including fibre, polyphenols, vitamins, minerals and unsaturated fatty acids, thus enabling a gradual and controlled blood glucose rise and lesser adiposity (3). Women adhering to the HDU pattern possibly swapped white rice to whole-wheat chapathi. White rice has a high glycemic index and its intake in Asian populations has been associated with a higher T2DM risk (25).Unhealthy food intake including biscuits and cakes may be limited, for instance, women in the highest quintile of the HDU diet pattern had a median frequency of intake of biscuits and cakes of two per week. While meat intake is rising in India (26), its annual intake is still low (5 kg/ capita) compared to developed countries (120 kgs./ capita) (27). No Indian study has linked meat intake to higher T2DM or GDM risk, and unprocessed meat has not been associated with a higher GDM risk globally. Unexpectedly, the other diet patterns were not associated with GDM risk, the healthy HTV pattern was not associated with a lower GDM risk. Similar to our findings, other global studies have also not found any association between traditional/ prudent diet patterns that are healthy and GDM risk (23 & 24). Diet patterns studies in India have not captured clearly healthy/prudent diet pattern versus unhealthy diet patterns, where modern versus traditional diet patterns have been reported and religion/SES are the main determinants of diet (10).

**BMI as a mediator:** Lower scores on the HDU diet pattern were associated with a higher BMI and adding BMI to the regression analysis relating the HDU pattern to GDM diminished the association, suggesting that it may be partly mediated by BMI.

**Study strengths and limitations:** BANGLES is the first Indian study investigating diet pattern-GDM associations. The cohort design incorporated temporality with dietary data collection during early pregnancy, before GDM diagnosis. Excluding women with any type of prior diabetes or GDM ensured that the participants had not changed their diets for health reasons before the diet assessment. Trained nutritionists collected dietary data face-to-face and using a validated FFQ which minimised potential errors in exposure measurement (28). Recall bias was minimised as much as possible using tools (food atlas and food models) to make the recall process easier for the participants. All the FFQs were administered in a standardised manner and recall bias is less likely to affect the study as neither the participant nor interviewer were aware of the outcome. Hence, we expect the recall bias would be random and distributed equally across the GDM and non-GDM women. Using frequency of intake as a dietary exposure over quantified amounts makes the findings generalizable to settings elsewhere in the world. Statistical modelling addressed confounding by adjusting for a range of *a priori* confounders. A limitation of the study was that women were recruited in early pregnancy and were asked to recall their diet around the time of conception. Furthermore, the interval between conception and recruitment varied between women (from 2-6 months). We acknowledge that this could introduce recall bias. It was not feasible to recruit women pre-conceptionally, as large numbers of women would be required in order to obtain sufficient pregnancies. Another limitation was that our sample did not include the very poorest sections of society (annual income of <INR 10,000/ GBP 97), but despite this there was a wide variation in socio-economic status. Gestational weight gain could not be measured in the study.

**Conclusion and public-health implications:** BANGLES identified three characteristic peri-conceptional diet patterns among women from rural and urban Bangalore. The HDU pattern was associated with lower GDM risk. One single healthy diet pattern may not be relevant in India (4) where food, culture and attitudes are very diverse across the country. Future work could use pooled-data to study diet patterns across India, which may enable future researchers and policymakers to design culturally relevant food-based policies and interventions to prevent GDM.

Our findings have potential public-health policy implications. The fact that higher BMI was the strongest risk factor for GDM means that future Indian health programmes need to emphasise that attaining a healthy BMI before and during pregnancy in the context of ‘pre-conception health’ to prevent GDM is important, and this is consistent with previous evidence (4, 29 & 30). The HDU pattern-lower GDM association, was consistent with national and global diet recommendations to increase diet-diversity for optimal health (31 & 32). The HDU and RFCS patterns consisting of both healthy and unhealthy foods may indicate low-awareness about micronutrient-rich foods and the need to invest in public-education. National surveys also show that a majority of Indians have sub-optimal diets with excess cereals and not enough micronutrient-rich foods including fruits, vegetables, legumes, milk, poultry, meat and fish, which can be improved by public education (31). Higher SES was positively associated with diet-diversity (HDU & HTV), which highlights the need for national policies to make wholegrains, fruits, vegetables, dairy and poultry foods more affordable (4, 19 & 32).

While the new Indian dietary guidelines define ‘a diverse-diet as a balanced diet’ (31), it may not be practically achievable across all SES levels in a population of 1.3 billion. Achieving the suggested ‘balanced diet’ recommendations, may cost a minimum of INR 15,000/month (GBP 148) for a family of four. This is possible for people of higher SES, challenging for those of middle SES and nearly impossible for those of lower SES (a majority). In this scenario, low-cost novel food-based evidence should be explored; the SARAS study showed that culturally-appropriate, micronutrient-rich snacks (samosas with greens, fruit and milk) costing INR 5 (4 pence) per-woman-per-day, given pre-conceptionally can prevent GDM (33). This amounts to INR 2250 (GBP 22) per reproductive-aged woman for 450 days (6 months of pre-conception and 9 months of pregnancy) - feasible within national-policy budgets (34).

**Evidence before this study:** Studies in high income countries suggest thathealthy diet patterns (higher intake of whole-grains, fruits and vegetables) are associated with a lower risk of GDM; and unhealthy diet patterns (higher intake of refined grains, fried and fast food, high sugar, red and processed meat) with a higher risk. Definitions of healthy/unhealthy diet patterns are heterogeneous across the globe. Evidence from low and middle income countries is sparse.

**Added value of this study:** BANGLES is the first prospective study to investigate diet pattern-GDM associations in India. Three distinct peri-conceptional diet patterns were identified that were associated with socio-economic characteristics. BMI was strongly related to GDM risk and possibly mediated diet-GDM associations. The HDU pattern-lower GDM association was consistent with national and global recommendations to increase diet-diversity.

**Implications of available evidence:** First, most diet patterns were not clearly healthy or unhealthy, this may indicate low-awareness among Indian women about healthy vs unhealthy foods. Hence, investing in public education about healthy foods is critical. Second,there cannot be a ‘universal healthy diet pattern’ for public health recommendations, in a large, diverse country like India. Future work could use pooled data to study an array of diet patterns across India. Third, global evidence suggests that ‘diet diversity’ is important for preventing non-communicable diseases. Higher SES in our study and others was associated with greater diet-diversity and national policies should aim to make micronutrient-rich foods including wholegrains, fruits, vegetables, dairy, nuts and poultry more affordable.

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**TABLES**

**Table 1: Population characteristics among GDM and non-GDM women (n=714\*)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Population characteristics (continuous variables)** | **Mean (SD) 1/ Median (IQR) 2** | **GDM** **N=157** | **Non-GDM** **N=557** | **p** † |
| Age (years) 1 | 26.7 (4.3) | 27.6 (4.6) | 26.4 (4.1) | 0.005 |
| Early pregnancy weight (Kg) 2 | 57.0 (50.0, 66.0) | 61.8 (53.6, 71.4) | 56.1(49.0, 64.5) | <0.001 |
| BMI based on early pregnancy weight (Kg/m²) 2 | 23.8 (20.4, 26.5) | 25.0 (22.1, 28.2) | 22.0 (19.9, 25.9) | <0.001 |
| Total family monthly income\* (INR) 2  | 30,000.0 (15,000.0, 60,000.0) | 33,500.0 (18000.0, 68750.0) | 30,000.0 (15,000.0, 60,000.0) | 0.68 |
| Standard of Living Index (SLI) score 1 | 38.0 (33.0, 43.0) | 38.0 (33.0, 42.0) | 38.0 (33.0, 42.0) | 0.87 |
| **Population characteristics (categorical variables)** | **N (%)** | **GDM** **N=157** | **Non-GDM****N=557** | **p** † |
| **Categories of BMI\*** |
| <18.50 (underweight) (reference) | 67 (9.4) | 6 (3.9) | 61 (11.3) | Ref |
| 18.5 - 24.9 (normal) | 379 (53.1) | 71 (46.1) | 308 (57.2) | 0.05 |
| 25 - 29.9 (overweight) | 186 (26.1) | 57 (37.0) | 129 (24.0) | 0.001 |
| >30 (obese) | 60 (8.4) | 20 (13.0) | 40 (7.4) | 0.001 |
| **Number of previous pregnancies** |
| None  | 378 (52.9) | 72 (45.9) | 306 (54.9) | Ref |
| At least one | 336 (47.1) | 85 (54.1) | 251 (45.1) | 0.04 |
| **Family history of T2DM among first-degree relatives a**  |
| No  | 481 (67.4) | 93 (59.2) | 388 (69.7) | Ref |
| Yes | 233 (32.6) | 64 (40.8) | 169 (30.3) | 0.01 |
| **History of Polycystic Ovarian**  **Syndrome (PCOS)\*** |
| No  | 638 (89.5) | 138 (88.5) | 500 (89.8) | Ref |
| Yes | 75 (10.5) | 18 (11.5) | 57 (10.2) | 0.64 |
| **Hypothyroidism diagnosis\*** |
| No  | 583 (81.9) | 122 (78.2) | 461 (82.9) | Ref |
| Yes | 129 (18.1) | 34 (21.8) | 95 (17.1) | 0.18 |
| **Physical activity** |  |  |  |  |
| No light walking | 322 (45.1) | 72 (46.5) | 250 (45.1) | Ref |
| Light walking (1-150 minutes/ week) | 247 (34.6) | 54 (34.8) | 193 (34.8) | 0.88 |
| Light walking (>150 minutes/ week)  | 145 (20.3) | 29 (18.7) | 111 (20.0) | 0.69 |
| **Religion\*** |
| Hindu  | 556 (77.9) | 119 (75.8) | 437 (78.5) | Ref |
| Christian | 101 (14.1) | 26 (16.6) | 75 (13.5) | 0.33 |
| Muslim | 39 (5.5) | 9 (5.7) | 30 (5.4) | 0.81 |
| Jain | 9 (1.3) | 1 (0.6) | 8 (1.4) | 0.47 |
| **Participant’s education level**  |
| High school or less  | 105 (14.7) | 22 (14.0) | 83 (14.9) | Ref |
| Pre–university college  | 123 (17.2) | 24 (15.3) | 99 (17.8) | 0.79 |
| Graduate  | 285 (39.9) | 68 (43.3) | 217 (39.0) | 0.55 |
| Post graduate or professional degree  | 201 (28.2) | 43 (27.4) | 158 (28.4) | 0.93 |
| **Participant’s current occupation** |
| High-level professional  | 69 (8.8) | 8 (5.1) | 55 (9.9) | Ref |
| Mid-level professional | 71 (9.0) | 18 (11.5) | 44 (7.9) | 0.03 |
| Highly skilled or technically trained occupation | 57 (7.3) | 13 (8.3) | 41 (7.4) | 0.12 |
| Skilled occupation | 18 (2.3) | 1 (0.6) | 15 (2.7) | 0.50 |
| Semi-skilled occupation | 9 (1.1) | 3 (1.9) | 6 (1.1) | 0.12 |
| Unskilled occupation | 4 (0.5) | 0 (0.0) | 4 (0.7) | 0.10 |
| Homemaker | 557 (71.0) | 111 (70.7) | 382 (68.6) | 0.08 |
| Student | 69 (8.8) | 3 (1.9) | 10 (1.8) | 0.34 |
| **Residence** |
| Urban  | 487 (68.2) | 118 (75.6) | 369 (67.7) | Ref |
| Rural | 214 (30.0) | 38 (24.4) | 176 (32.3) | 0.05 |
| **Family type** |
| Nuclear | 557 (78.0) | 94 (59.9) | 287 (51.5) | Ref |
| Joint | 157 (22.0) | 63 (40.1) | 94 (48.5) | 0.06 |
| Abbreviations: INR-Indian National Rupees; a First-degree relatives refer to father, mother and siblings. \* Missing data: BMI=23, PCOS=1, Hypothyroidism=2, religion=9, Participant’s  husband’s occupation=14, Total family monthly income=148, area of residence =13.† p-values reported from univariate logistic regression analysis of population  characteristics as predictors of GDM. |

**Table 2: PCA of 68 food-groups showing factor loadings of the first 3 diet patterns (n=785)**

|  | **Pattern 1** | **Pattern 2** | **Pattern 3****HTV**  |
| --- | --- | --- | --- |
| **HDU**  | **RFCS** |
| **Beverages:** |
| Tea and coffee | 0.04 | 0.33 | -0.20 |
| Cows milk | 0.21 | -0.16 | 0.25 |
| Fermented dairy products  | 0.06 | 0.27 | 0.34 |
| Flavoured nutrient enriched sweetened supplements | 0.17 | -0.13 | 0.15 |
| Flavoured sweetened beverages | 0.38 | 0.12 | -0.10 |
| Therapeutic beverages  | 0.25 | 0.10 | 0.22 |
| Soups | 0.20 | 0.16 | -0.02 |
| Fresh fruit juices | 0.31 | -0.04 | 0.14 |
| **Fruits:** |
| Other fruits  | 0.41 | -0.08 | 0.19 |
| Banana (yelakki and robusta) | 0.31 | 0.26 | 0.12 |
| Apple | 0.28 | 0.11 | 0.28 |
| Pomegranate | 0.33 | 0.12 | 0.26 |
| Sweetlime | 0.21 | 0.12 | 0.27 |
| **Dried fruits, nuts and seeds:** |
| Dried fruits (figs, prunes & apricots) | 0.30 | -0.14 | 0.26 |
| Dates and raisins | 0.42 | 0.07 | 0.39 |
| Other nuts and seeds  | 0.49 | -0.07 | 0.38 |
| Almonds | 0.51 | -0.16 | 0.28 |
| **Rice and wheat foods:** |
| Plain boiled white rice | -0.24 | 0.59 | 0.01 |
| Spice seasoned preparations  | 0.09 | 0.50 | 0.13 |
| Unpolished rice  | 0.00 | -0.14 | 0.03 |
| Rice with dal/sambhar | -0.08 | 0.44 | 0.07 |
| Idly | 0.20 | 0.02 | -0.21 |
| Rice and greens preparation  | -0.02 | 0.42 | 0.26 |
| Curd rice  | 0.11 | 0.03 | 0.23 |
| Cereal preparations (upma etc.) | 0.27 | -0.09 | 0.14 |
| Dosa and masala dosa | 0.27 | 0.04 | -0.25 |
| Fried cereal dishes (poori & Parantha) | 0.34 | -0.16 | -0.10 |
| Fried pulse preparations (vada) | 0.30 | 0.00 | -0.19 |
| Chapathi | 0.34 | -0.47 | 0.02 |
| Processed shop bought western-style breads and extruded cereals (pasta, noodles etc.) | 0.39 | 0.03 | -0.22 |
| Rice roti & kadabu | 0.14 | 0.07 | 0.16 |
| **Ready to eat breakfast cereals:** |
| Ready to eat breakfast cereals | 0.28 | -0.31 | 0.08 |
| **Ragi foods:** |
| Millet preparations (jowar/ragi roti, dosa, malt & vermicelli) | 0.13 | 0.13 | 0.23 |
| Ragi ball | -0.27 | 0.53 | 0.28 |
| **Pulse and vegetable sides:** |
| Traditional whole and split pulse preparations | 0.06 | 0.26 | 0.22 |
| Roots and tuber palyas (potato, carrot & beetroot/ radish/yam & tapioca) | 0.40 | 0.09 | -0.06 |
| Other vegetables sides (ladys finger, gourds, pumpkin, capsicum, brinjal, beans, mushroom & multiveg. saagu) | 0.54 | -0.06 | 0.03 |
| Traditional style GLV sides (GLV sambhar, GLV palya and drumstick palya) | 0.10 | 0.48 | 0.28 |
| GLV sides (cabbage/knol khol palya and cauliflower palya ) | 0.38 | -0.17 | -0.11 |
| **Raw vegetables and salads:** |
| Raw vegetables (cucumber, tomato, onion, carrot, radish, runner beans and raw greens) | 0.46 | -0.07 | 0.29 |
| Kosambari (traditional South Indian lentil vegetable salad) | 0.11 | 0.10 | 0.36 |
| **Non-vegetarian preparations:** |
| Chicken (fry, curry/sambhar) | 0.24 | 0.25 | -0.39 |
| Chicken biriyani | 0.20 | 0.28 | -0.35 |
| Fish (fry, curry, cutlet, dried fish/dried seafood/prawn, crab & shellfish) | 0.28 | -0.07 | -0.26 |
| Red meat (fry, cutlet, curry, organ meat, keema curry, ham salami bacon & mutton biriyani) | 0.29 | 0.12 | -0.27 |
| Boiled egg | 0.21 | 0.17 | -0.04 |
| Egg preparations (egg biriyani, egg burchi, omelette) | 0.32 | 0.17 | -0.28 |
| **Condiments:** |
| Pickles, papads, chutneys & chutney powders | 0.33 | 0.27 | -0.14 |
| Western condiments (ketchup & instant soups) | 0.29 | -0.22 | -0.14 |
| **Added sugar:** |
| Added sugar (sugar in tea, coffee, milk, fruit juice, jam, honey & jaggery) | 0.17 | 0.30 | -0.07 |
| **Savoury snacks:** |
| Medium calories fried savoury snacks (namkeen & chakli) | 0.27 | 0.27 | -0.16 |
| High calories savoury fried snacks (pakoda/bhajji/samosa) | 0.32 | 0.26 | -0.39 |
| Puff pastry snacks | 0.23 | 0.28 | -0.20 |
| Chats | 0.28 | 0.10 | -0.23 |
| **Sweet snacks:** |
| Chocolate | 0.31 | -0.05 | -0.23 |
| Creamless & cream cake | 0.32 | 0.17 | -0.20 |
| Sweet, cream & salted biscuits | 0.29 | 0.13 | -0.08 |
| Traditional, home-made cereal based sweets (kesaribaath, kheer & holige) | 0.18 | 0.26 | -0.07 |
| Traditional shop bought fried sweet preparation (khoa based sweets - barfi, pedha, jamoon, laddoo, halwa and other sweets) | -0.16 | -0.14 | 0.12 |
| Western style desserts (cheesecakes, custards, puddings) | 0.16 | -0.15 | -0.16 |
| **Fast food:** |
| Fast food (veg and non-veg pizza and burger) | 0.34 | -0.25 | -0.22 |
| **Milk products:** |
| Curd/ yogurt | 0.21 | 0.00 | 0.32 |
| Ghee | 0.24 | -0.03 | -0.12 |
| Butter | 0.26 | 0.00 | 0.26 |
| Cheese and paneer | 0.38 | -0.39 | 0.00 |
| Milkshakes and ice creams | 0.40 | 0.03 | -0.22 |
| **Seasonal foods:** |
| Seasonal fruits | 0.48 | 0.03 | 0.22 |
| Seasonal green beans & peas | 0.15 | 0.17 | 0.11 |
| **Lighter shading: positive factor loadings ≥0.2: Darker shadings: negative factor loadings ≤-0.2** |
| Factor loadings >0.2 for pattern 1, 2 & 3; Factor loadings < -0.2 for pattern 1, 2 & 3 |

**Table 3: Univariate regression analysis of population characteristics as predictors of women’s diet pattern scores (n=785\*)**

| **Predictors: Population characteristics** | **N** | **Diet pattern score – Mean (SD)** |
| --- | --- | --- |
| **1** | **2** | **3** |
| **HDU** | **RFCS** | **HTV** |
| **Mean (SD)** | **p** | **Mean (SD)** | **p** | **Mean (SD)** | **p** |
| **Age groups (in years):** |
| < 22 years | 114 | -0.29 (0.97) | <0.001 | 0.37 (0.83) | <0.001 | -0.09 (0.85) | 0.365 |
| 22 - years | 250 | -0.11 (1.00) |  | 0.17 (0.93) |  | -0.02 (0.95) |  |
| 26 - 30 years | 248 | 0.01 (0.89) |  | -0.08 (1.00) |  | -0.01 (0.98) |  |
| >30 years | 173 | 0.34 (1.06) |  | -0.38 (1.03) |  | 0.10 (1.16) |  |
| **Gravida:** |
| Primigravida | 415 | -0.05 (0.99) | 0.060 | -0.06 (1.01) | 0.048 | -0.01 (1.00) | 0.488 |
| Multigravida | 370 | 0.06 (1.00) |  | 0.06 (0.98) |  | 0.01 (0.99) |  |
| **T2DM family history from first degree relatives:** |
| No | 536 | -0.06 (0.95) | 0.007 | 1.10 (0.99) | <0.001 | 0.01(0.96) | 0.366 |
| Yes | 249 | 0.13 (1.07) |  | -0.23 (0.98) |  | -0.03 (1.06) |  |
| **PCOS diagnosis\*:** |
| No | 701 | -0.03 (0.98) | 0.002 | 0.04 (0.98) | <0.001 | -0.02 (0.98) | 0.099 |
| Yes | 83 | 0.33 (1.06) |  | -0.38 (1.04) |  | 0.22 (1.06) |  |
| **Hypothyroid diagnosis\*:** |
| No | 641 | -0.03 (0.97) | 0.002 | 0.04 (0.98) | 0.003 | -0.01 (0.97) | 0.391 |
| Yes | 142 | 0.17 (1.10) |  | -0.21 (1.05) |  | 0.08 (1.10) |  |
| **Religion\*:** |
| Hindu | 607 | -0.08 (0.95) |  | 0.09 (1.00) |  | 0.17 (0.93) |  |
| Christian | 111 | 0.10 (0.98) | 0.060 | -0.23 (0.74) | 0.019 | -0.74 (0.81) | <0.001 |
| Muslim | 47 | 0.56 (1.24) | <0.001 | -0.33 (1.04) | 0.033 | -0.77 (0.96) | <0.001 |
| Jain | 11 | 0.58 (0.71) | 0.027 | -1.58 (0.53) | <0.001 | 0.91 (0.65) | 0.065 |
| **Educational attainment:** |
| High school and less | 117 | -0.15 (1.03) |  | 0.37 (0.94) |  | -0.14 (0.93) |  |
| Intermediate & Pre-university | 137 | -0.25 (0.89) | 0.413 | 0.31 (0.83) | 0.548 | -0.04 (0.85) | 0.584 |
| Graduate | 312 | 0.04 (0.98) | 0.062 | 0.04 (0.97) | 0.001 | -0.05 (0.98) | 0.809 |
| Postgraduate | 219 | 0.17 (1.02) | 0.004 | -0.46 (0.98) | <0.001 | 0.18 (1.11) | 0.070 |
| **Income categories\*:** |
| <25,000 | 289 | -0.27 (0.88) | <0.001 | 0.30 (0.83) | <0.001 | -0.02 (0.84) | 0.117 |
| 25,000 -50,000 | 180 | 0.05 (0.95) |  | -0.001 (0.92) |  | -0.08 (0.93) |  |
| 50,000- 100000 | 109 | 0.15 (1.02) |  | -0.56 (0.94) |  | 0.008 (1.20) |  |
| >100000 | 59 | 0.63 (1.04) |  | -1.01 (0.79) |  | 0.30 (1.25) |  |
| **SLI score:** |
| Low | 1 | -0.10 | 0.003 | 0.26 | 0.776 | -1.65 | <0.001 |
| Medium | 31 | -0.25 (0.87) |  | 0.04 (0.99) |  | -0.19(1.00) |  |
| High | 753 | 0.01 (1.00) |  | -0.002 (1.00) |  | 0.01 (0.99) |  |
| **Area of residence\*:** |
| Urban | 539 | 0.13 (1.01) | <0.001 | -0.22 (0.97) | <0.001 | -0.09 (1.05) | <0.001 |
| Rural | 233 | -0.30 (0.90) |  | 0.51 (0.87) |  | 0.23 (0.82) |  |
| **Family type** |
| Nuclear | 429 | 0.04 (0.96) | 0.120 | -0.14 (0.99) | <0.001 | -0.04 (0.96) | 0.069 |
| Joint | 356 | -0.05 (1.04) |  | 1.17 (0.97) |  | 0.05 (1.03) |  |
| **Levels of light walking:** |
| No walking | 374 | -0.09 (0.98) |  | 0.04 (1.01) |  | 0.001 (0.92) |  |
| Up to 150 minutes/ week | 259 | 0.07 (0.99) | 0.157 | -0.05 (0.98) | 0.283 | -0.04 (1.04) | 0.284 |
| Above 150 minutes/ week | 152 | 0.10 (1.02) |  | -0.02 (0.98) |  | 0.06 (1.10) |  |
| **Screen time:** |
| Below 4 hrs/day | 561 | 0.01 (1.04) | 0.626 | 0.10 (0.99) | <0.001 | 0.05 (1.01) | 0.297 |
| Above 4 hrs/day | 224 | -0.02 (0.88) |  | -0.26 (0.96) |  | 0.01 (0.97) |  |
| \*n missing: PCOS diagnosis=1; Hypothyroid diagnosis=2; Religion=9; Income=148; Area of residence=13.text in grey = reference group in logistic regression analysis. |

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| **Table 4: Association between women’s diet pattern scores and GDM**  |
| **DP scores (SD)**  | **GDM: 0 = no, 1 = yes** |
| **Univariate model 1** | **Multivariate model 2**  | **Multivariate model 3** |
| **-** | **Model** **without BMI** | **Model** **with BMI** | **Model** **without BMI** | **Model** **with BMI** |
| **n=714** | **n=700** | **n=677** | **n=664** | **n=641** |
| **OR** | **95% C.I.** | **p** | **OR** | **95% C.I.** | **p** | **OR** | **95% C.I.** | **p** | **OR** | **95% C.I.** | **p** | **OR** | **95% C.I.** | **p** |
| **HDU** | 0.90 | 0.75, 1.08 | 0.29 | 0.80 | 0.64, 0.99 | 0.04 | 0.84 | 0.67, 1.05 | 0.12 | 0.65 | 0.65, 1.01 | 0.04 | 0.84 | 0.67, 1.05 | 0.12 |
| **RFCS** | 0.87 | 0.72, 1.05 | 0.15 | 0.89 | 0.71, 1.11 | 0.32 | 0.96 | 0.76, 1.21 | 0.75 | 0.76 | 0.76, 1.18 | 0.63 | 1.01 | 0.81, 1.27 | 0.92 |
| **HTV** | 0.93 | 0.77, 1.12 | 0.45 | 0.95 | 0.78, 1.16 | 0.65 | 0.98 | 0.80, 1.21 | 0.90 | 0.80 | 0.80, 1.20 | 0.83 | 1.01 | 0.82, 1.25 | 0.92 |
| **Abbreviations: HDU – High-diversity, urban; RFCS – Rice-fried snacks-chicken-sweets & HTV – Healthy, traditional vegetarian****1**Unadjusted model**2**Model adjusted for *a priori* confounders including woman’s age, gravidity, PCOS status (no/yes), area of residence (urban/ rural), family type (nuclear and joint), family history of T2DM (no/yes), use of nutrient supplements (Calcium-vitamin D, B12, iron, folic acid and energy-protein) and physical activity (weekly light walking) and SES measures (SLI score, education & occupation levels).**3**Model for sensitivity analysis, limited to women who had a full OGTT, adjusted for the data-driven confounders including woman’s age, family history of T2DM (no/yes), area of residence (urban/rural) & family type (nuclear/joint). |

**Legend for figure (a):** \*\* Recruitment included data on diet, general health, socio economic status, physical activity and blood samples; \*\*\* Moved away means participants dropped out due to moving to their native place for delivery before 6 months and change of hospital; GTT = Glucose Tolerance Test; GCT = Glucose Challenge Test; FBS = Fasting Blood Sugar test; PPBS = Post Prandial Blood Sugar test.