A Comparative Analysis of Dietary Proximate Principles and its association with glucose tolerance in Gestational Diabetes Mellitus and Normal Pregnancies: Implications for Maternal Health

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ABSTRACT

Background: Gestational Diabetes Mellitus (GDM) is a type of glucose intolerance seen during pregnancy. that poses significant risks to the mother and child. In India, the prevalence ranges between 4–14%, with many women showing suboptimal dietary patterns like excessive carbohydrate, fat intake, inadequate protein and fibre consumption. This study aimed to investigate the dietary differences in the macronutrient intake between normal pregnancy and GDM and its association with blood glucose levels

Materials and Methods: A case control study was conducted among 58 pregnant women with no GDM and 57 women with GDM. Dietary history was taken using a 24-hour recall chart and the quantity of macronutrients was estimated using the Indian Food Composition Table 2017. Daily intake of carbohydrates, proteins, fats, and fibre was compared in both groups.

Results: The women with GDM consumed significantly higher calories (P=0.013) and high fats (P=0.002) compared to no GDM group. The protein intake was significantly low (P=0.005). However, high carbohydrate and low fibre intake was also observed, which was not significant. After adjustment for confounders, the OR for carbohydrates was 1.11[CI-1.02,1.22], and regression analysis revealed 10% for total energy intake (P=0.008), 9% for carbohydrates (P=0.04), and 10% for fats (P=0.02) for the variance in glucose, which was significant.

Conclusions: These findings indicate women with GDM have a dietary pattern that significantly deviates from recommended nutritional guidelines. Higher intake of fats with low fiber and protein speculates their roles in the GDM pathogenesis. Addressing these imbalances will help lower the incidence of GDM.

KEYWORDS: Calories, Carbohydrates, Diet, Fats, Gestational diabetes, Nutrition, Pregnancy, Proteins.

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INTRODUCTION

Gestational diabetes Mellitus (GDM) is a commonly encountered medical condition characterized by glucose intolerance, first recognized during pregnancy and the blood glucose reverts to normal after the pregnancy. Maternal complications like spontaneous abortion, pre-eclampsia, difficult delivery, and cesarean section, and fetal complications like macrosomia, respiratory distress, neonatal hypoglycemia, hyperbilirubinemia, etc. are linked to GDM.[1] Insulin resistance produced by the peak levels of placental hormones, which are not adequately compensated by the pancreatic β-cells is the pathology behind it. The global prevalence of GDM ranges from 1-20%.[2] In high-risk populations, the recurrence in future pregnancy is about 68%. In India, the prevalence varies from 4.6 -14% in urban areas and 1.7 to 13.2% in rural areas.[3]

GDM is a complex condition involving hormonal changes, insulin resistance, genetic predisposition, and environmental factors.[1] The main risk factors for GDM are advanced maternal age, obesity, reduced physical activity, family history of type 2 Diabetes Mellitus, and Polycystic ovarian syndrome(PCOS).[4] Pregnancy is a unique physiological state that demands adequate nutrients for optimal maternal health and fetal development. Nutritional imbalances can contribute to the development of GDM by exacerbating the risk factors.[5] Many prospective studies done in the pre-pregnancy stage state that a diet rich in refined carbohydrates and saturated fats increases the overall risk for GDM.[6],[7] Also, studies done in the Caucasian population showed limited but consistent evidence that a diet higher in vegetables, fruits, whole grains, and protein and less processed meat was associated with a reduced risk of gestational diabetes.[8],[9] In India, dietary patterns often include polished rice, fried foods, and low fiber intake, which may exacerbate the GDM and its complications.

Despite the growing importance of maternal nutrition during pregnancy, there remains a notable gap in research, regarding the role of macronutrients apart from carbohydrates in the pathogenesis of GDM. Such studies are limited in Indian settings keeping in mind the dietary difference seen in our country. Thus this study aims to address the gap by comparing the dietary intake of carbohydrates, protein, fat, and fiber between normal pregnancy and those with newly diagnosed GDM, and its influence on blood glucose levels.

MATERIALS AND METHODS:

This case control study was conducted in a tertiary care hospital in Pondicherry, India. This study was conducted from October to December 2023. A consecutive sampling strategy was used, and 115 pregnant women above 18 years of age who were attending the antenatal clinic were included. Pregnant women with a history of GDM in the previous pregnancy, or multiple pregnancies, who had consumed meals which is different from their routine in the past 24 hours (Eg, Feasts), and mothers on special diets were excluded from the study.

Sample size calculation:

The sample size for comparing the mean of two groups using Student's t-test was calculated using the formula n = (tn-1, α/2+t n-1, β)2/d2 where d – mean standard deviation, α – the probability of detecting a false effect, β = 1 – power. Assuming a pooled standard deviation of 6.8 units, the mean of the reference group as 101.5, mean of the study group105.1 the study would require a total sample size of 114 with 57 in each group to achieve a power of 80% and a level of significance of 5%, for detecting a true difference in means.[10]

Data collection:

The data collection was done using the investigator-administered case report form which included the demographic details, clinical history, and a 24-hour dietary recall chart. The 24-hour dietary recall chart records the type of food, frequency, timings, portion/size, beverages consumed, preparation method, and source (home-cooked/outside) the individual consumes over 24 hours. The dietary recall began from the most recent meal and proceeded backward in time. The investigator ensured that the diet the mother is recalling is a typical/representative day of her routine life. To minimize recall bias, participants were carefully guided by trained investigators using standard household measures and food portion models. After the data collection, the pregnant mother underwent Oral glucose tolerance where a 3 ml venous blood of fasting sample was collected first following which 75 gms of glucose load was given, and subsequently first and second-hour samples were collected. Serum glucose levels were estimated using hexokinase method in a fully automated Cobas Integra 400 plus analyser. GDM was diagnosed using the International Association of Diabetes and Pregnancy Study Group (IADPG) criteria.[11] According to this criteria diagnosis of GDM was done if any one of the following cut-offs is met i.e. ≥ 92 mg/dl for fasting for 1- hour ≥ 180 mg/dl or 2 hours≥ 153mg/dL. Based on these criteria pregnant women were divided into two groups No GDM and the GDM group.

The nutritive value of the food consumed was calculated based on the Indian food composition table 2017 optimized by ICMR for different regions in India.[12] This is the latest Indian food composition database funded by the ICMR covers all the key foods sampled from the entire country drawn from a statistically valid sampling method. About 160 discrete food constituents including bioactive compounds are analysed for 528 foods. Region-specific foods are also analyzed for 6 regions of the country to enable region-specific nutritional and epidemiological data interpretation. Based on this the data obtained was expressed as Total calorie intake taken per day (in calories) and intake of carbohydrates, fats, protein, and fiber per day (in grams)

The adequacy or the deficiency of the carbohydrates, proteins, fats, and fiber intake was calculated based on the Recommended Dietary Allowances for Various Nutrients in Pregnant Women given under Nutrition Recommendation for Indians 2020, by the National Instiute of Health, Indian Council of Medical Research.[13]

Ethical Consideration:

A written informed consent was obtained from all the participants after explaining the study procedure in the language they understood. Confidentiality was maintained at each phase of the study. The Institutional Ethical Review Board approved the study.

Statistical Analysis:

All the data was entered in Microsoft Excel and analyzed using IBM SPSS software. Categorical variables are expressed as frequency and percentages and the Chi-square test was used to compare the categorical variables between the groups. Continuous variables are expressed as Mean ± Standard Deviation (SD) and Student t-test was employed to compare the mean of normally distributed continuous parameters. To assess the relationship between dietary components and the likelihood of GDM logistic regression analysis (adjusted for potential confounding variables like age, BMI, and other comorbidities) and multiple linear regression analysis was done to assess the relationship between dietary components and continuous glucose measures (e.g., fasting glucose, 1-hour, and 2-hour OGTT levels. *P* value of less than 0.05 was considered statistically significant.

RESULTS:

The study included 115 pregnant women who were divided into two groups namely No GDM (n=58) and GDM(n=57). Table 1 shows the demographic characteristics of the two groups. There was a statistically significant difference in mean age, prepregnant BMI, and history of PCOS in both groups. Women with GDM were of a higher age group (27.47±3.9years vs 25.79±4.82 years, *P*=0.006) and had a higher BMI (26.79±1.95 vs 25.78±2.26 *P*=0.0117) compared to no GDM. The majority of the participants in both groups had high prepregnant BMI. 48% and 43% were overweight in the GDM and no GDM group respectively, 32% and 27% were obese in the GDM and no GDM groups respectively. Nearly 19.29% of the women with GDM had a history of PCOS (*P*=0.022). Educational distribution showed no significant difference, with the majority being graduates in both groups (74.78%

overall). Occupation distribution revealed a trend, though not statistically significant, with more mothers not working in the GDM group. Other comorbidities such as anemia (24.1% in No GDM vs. 10.5% in GDM), hypertension (6.9% vs. 8.8%), and thyroid disorders (20.7% vs. 17.5%), showed varying prevalence. OGTT results demonstrated significant differences between the No GDM and GDM groups (all P <0.001).

Table 2 indicates the spectrum of nutrient intake among the GDM and normal mothers. The total energy intake, carbohydrates and fat intake in both the groups were higher than the recommended dietary allowance. Also there was a statistically significant higher total energy intake (2106.31±78.33 vs 2056.35±75.67 P=0.007) and fat intake (56.63±18.91 vs 46.58±15.67 P=0.002) in women with GDM compared to no GDM women Similarly Carbohydrate intake was also high in both groups there was no statistically significant difference. There was a low protein and fiber intake in both the groups compared to the recommended allowance but the difference was significant only for proteins (50.80±5.01vs 53.27±4.28 P=0.005).

It was also found that majority of the GDM women (54%) were consuming excessive amounts of carbohydrates, 36% with adequate and 10% with inadequate carbohydrate intake compared to the RDA. In contrast, a higher proportion of GDM mothers were found to have inadequate protein intake (66%), while fewer had adequate (26%) or excessive (8%) protein intake. A similar trend was observed for fats, with a relatively small percentage consuming inadequate fats (6%), while the majority had either adequate (33%) or excessive (61%) fat intake. Additionally, a significant majority of GDM mothers exhibited inadequate fiber intake (73%), while a smaller percentage had adequate (23.5%) or excessive (3.5%) fiber intake.

Table 3 shows the logistic regression analysis between the presence or absence of gestational diabetes and multiple independent variables like age, BMI, dietary components and medical history (after adjusting for confounders like age, BMI and family history). There was a significant contribution only from age, BMI, history of PCOS, family history of diabetes and carbohydrate intake. Each additional year of age increases the odds of GDM by 10% (OR: 1.10, CI 1.03-1.17, P=0.01). A unit increase in BMI raises the odds by 12% (OR: 1.12, CI 1.05-1.20, P<0.001). Women with PCOS have twice the odds of developing GDM (OR: 2.00, CI 1.20-3.30, P=0.012). A family history of diabetes increases the odds by 34% (OR: 1.34, CI 1.11-1.17, P=0.051). Carbohydrate intake per 10 grams significantly increases the odds by 11% (OR: 1.11, CI 1.02-1.22 P=0.048). However, none of the other dietary nutrients did not show significant association with the risk of GDM.

Table 4 shows the multiple linear regression analysis of the dietary components with the OGTT values which yielded significant results for total energy intake, carbohydrates, and fats. Total energy intake explains 10% of the variance in glucose tolerance (R^2adj = 0.1, P=0.008), carbohydrates explain 9% (R^2adj = 0.09, P=0.04), and fats explain 10% (R^2adj = 0.1, P=0.02). Proteins and fiber did not show significant associations, explaining only 2% (R^2adj = 0.02, P=0.138) and 0% (R^2adj = 0, P=0.337) of the variance, respectively.

DISCUSSION:

The study compared the dietary intake of different macronutrients among 57 GDM women and 58 normal pregnant women which revealed few important insights. The women suffering from GDM had a high pre-pregnant BMI, sedentary lifestyle, PCOS, and older age group. All of these are well-known risk factors of GDM and were present in our study group which is been proved by different studies around the world.

There was a notable difference in the intake of macronutrients that may have implications for maternal health and GDM risk. Our findings demonstrate that women diagnosed with GDM exhibit significantly higher total energy which is attributed to high carbohydrate and fat intake compared to those with normal pregnancy. Sedentary Indian pregnant women require 2010 Kcal /day, 175 -210 gms of carbohydrates, 55.2 gms of protein, 30 gms of visible fat, and 30 gms of fiber intake for optimal nutrition.[13]
The definitive role of high carbohydrate intake and the pathogenesis of gestational diabetes has been proved by many studies.[14],[15] Studies done across the world have proved that high-glycemic-index foods such as processed and refined foods, can lead to a rapid rise in postprandial glucose levels, contributing to insulin resistance which is a hallmark of GDM. [7],[10] In a study done by Hashabulla et al in Malaysia et al a diet with a high amount of cereals and confectionaries is found to be responsible for glucose intolerance.[16] Similarly, in the metaanalysis conducted by Quan W et al western dietary pattern rich in calories and processed food increases the risk for GDM.[17] All these findings align with our findings which showed amount of carbohydrate intake is an independent predictor for the risk of GDM. Carbohydrates were also significantly associated with glucose tolerance, explaining 9% of the variance. This reinforces the logistic regression finding that high carbohydrate intake is detrimental to glucose regulation in pregnant women.

High fat intake particularly saturated fats was seen in the GDM group. The exact role of fats in the development of GDM is not completely understood. The high BMI and visceral obesity cause a state of chronic inflammation resulting in the release of various cytokines interfering with glucose uptake and hormone release.[18] High intake of saturated fats causes an increase in circulating free fatty acids which in turn accumulate in the liver, and muscle and interfere with the insulin signaling pathway.[19] High fat intake causes mitochondrial dysfunction and imbalance in leptin and ghrelin levels which is required for hunger and satiety regulation.[20] Some individuals may be more predisposed to developing insulin resistance in response to high-calorie diets due to genetic variations that affect metabolism and insulin sensitivity. Studies done across the world have also found high fat intake during the pre-conceptional and conception period poses a risk for GDM.[6],[19] In a prospective study conducted by Katherine B et al it was found that GDM mothers have been consuming high animal fat and cholesterol, and fat intake was independently associated with GDM risk.[6] An Indian study done by Deepa R et al in south India in 2020 found that women who consume high amounts of red meat are prone to GDM.[19] However fat intake did not show any association with GDM risk in our study. The reason could be because the study may not have differentiated between different types of fats (saturated, unsaturated), but the 10% variance suggests that not only the quantity of fats but potentially the type of fats consumed could influence glucose metabolism.

The protein intake among GDM mothers was significantly lower compared to non-GDM mothers, yet protein did not show a significant association with GDM risk. This suggests that while protein intake is important for overall maternal health, it may not play a direct role in glucose regulation as strongly as fats or carbohydrate intake does. Nonetheless, adequate protein intake is essential for fetal growth and development, and low protein intake can have adverse outcomes for both the mother and the fetus.[21] It is well known that protein helps in maintaining muscle mass which in turn helps in the synthesis of insulin receptors. Adequate protein intake helps to preserve lean muscle mass and helps in the synthesis of many anti-inflammatory agents. Thus the indirect role of low protein intake over carbohydrate role is speculated which needs to be explored more.

The fiber intake was not significantly associated with GDM in our study and multivariate regression also indicated fiber explained none of the variance in glucose tolerance. The reason could be because of a low baseline intake of fiber might be mitigated by the intake of other dietary components. However, studies have shown that fiber has a protective effect against GDM. [8],[15] Fiber-rich complex carbohydrates regulates blood glucose, promotes satiety, and prevents post-prandial hyperglycemia. Studies done in China and Iran by Jian Rong He et al and Mohtashaminia F et al respectively have indicated that low protein and fiber intake compromises the overall metabolic health of GDM mothers.[8],[15] This protective effect of dietary fiber has been supported by other research, which indicates that fiber can improve glycemic control by slowing glucose absorption and enhancing insulin sensitivity

In the Indian context, the observed nutrient imbalances are due to predominant reliance on refined carbohydrates like polished rice, wheat-based products, which are high in glycemic index, exacerbating postprandial hyperglycemia and insulin resistance.[19] Indian cooking methods like deep frying and, use of palm oil further elevate the fat intake beyond the recommended levels. The Indian diet is dominated by low pulses and legumes, which explains the significantly low protein intake. Indian dietary surveys also show a reduced dietary fiber.[22] All these cultural practices demonstrate why the study population showed a dietary pattern linked to GDM risk.

Thus our study has found that high calorie and fats with low protein intake is seen among GDM mothers and apart from the role of carbohydrates, high fat intake also contributes to impaired glucose.

These findings emphasize the critical role of diet in preventing GDM. Healthcare providers should prioritize nutritional counseling for pregnant women, focusing on reducing excessive caloric and fat intake while promoting adequate fiber consumption. This dietary approach not only helps in maintaining optimal glucose levels but also supports overall maternal and fetal health

The limitation of this study was that the observational design, could not establish the causality and there could have been a dietary recall bias from participants. Furthermore, the study may not account for all confounding variables such as physical activity, stress, socioeconomic status and genetic predispositions that could influence GDM risk. Given the sample size, regression models were limited to key variables to reduce the risk of overfitting

CONCLUSION:
Our study highlights the dietary disparities of macronutrients among women with GDM compared to those with normal pregnancies. The findings revealed an elevated carbohydrate and fat intake, coupled with low protein and fiber intake, in women with GDM, highlighting potential dietary factors contributing to GDM risk

These findings have implications for public health and clinical practice. Since nutritional therapy is the first line of management for GDM, assessing maternal nutrition intake and addressing the deficiency or excess of the nutrient might be beneficial as a preventive measure. Healthcare providers can impart nutritional counselling for all women of reproductive age groups emphasizing achieving optimal nutrient intake, maintaining a healthy pre-pregnancy BMI, and adopting lifestyle modifications to promote healthy gestational outcomes

Declarations:

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Conflict of Interest: Nil

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Table 1
Socio-demographic characteristics of the study groups

Characteristics	**Total**		**No GDM**		**GDM**		**P**
	n=115	**%**	**n=58**	**%**	**n=57**	**%**	
Mean age (±SD)	26.06±4.34		25.79±4.82		27.47±3.9		0.006*
Pre pregnant BMI	26.28±2.16		25.78±2.26		26.79±1.95		0.011*
Gestational age during OGTT (in weeks)	27.50±6.7		26.2±4.12		27.2±3.8		0.210
Education							
Schooling	24	20.8	12	20.68	12	28.07	0.770
Diploma	5	4.34	2	3.44	3	5.26	
Graduate	86	74.78	44	75.86	42	73.68	
Occupation							
Part-time	5	4.34	1	1.72	4	7.01	0.135
Full time	32	27.82	20	34.48	12	21.05	
Nil	78	67.82	37	63.79	41	71.92	
Other Comorbidities							
Anaemia	20	17.39	14	24.13	6	10.52	0.054
Hypertension	9	7.82	4	6.89	5	8.77	0.708
Thyroid disorders	22	1.73	12	20.69	10	17.54	0.668
History of PCOS	14	12.17	3	5.17	11	19.29	0.022
Parity							
Primigravida	52	45.21	30	51.72	22	38.59	0.157
Multigravida	63	54.78	28	48.27	35	61.40	
Family history of Diabetes	40	34.78	16	27.58	24	42.10	0.102

* P<0.05 significant, SD-Standard deviation, GDM-Gestational Diabetes Mellitus, PCOS- Polycystic Ovary Syndrome, BMI-Body Mass Index

Table 2
Comparison of Macronutrients among the groups

Energy and Nutrients	**RDA**	**No GDM mean±SD**	**GDM mean±SD**	**P**
Total energy Intake (Kcal/day)	2010	2056.35±75.67	2106.31±78.33	0.0007*
Carbohydrates (g/day)	210	218.65±20.52	225.95±19.47	0.052
Proteins (g/day)	55.2	53.27±4.28	50.80±5.01	0.005*
Fat (g/day)	30	46.58±15.67	56.63±18.91	0.002*
Fiber (g/day)	30	12.34±7.89	11.96±3.02	0.734
Carbohydrate (% of TEI)	60%	61.63±10.53	62.66±9.21	0.578
Proteins (% of TEI)	15%	13.36±1.46	12.90±1.43	0.090
Fats (% of TEI)	25%	6.01±3.26	27.53±4.67	0.045*
OGTT				
Fasting		84.37±6.87	95±16.55	<0.001*
I hour		128.17±23.75	175.49±41.35	<0.001*
II hour		119.55±22.47	146.66±41.33	<0.001*

* P<0.05 significant, SD - Standard deviation, GDM- Gestational Diabetes Mellitus, TEI-Total Energy Intake, OGTT-Oral Glucose Tolerance Test

Table 3
Association of various dietary components in GDM and non GDM

Variable	no GDM n(%)	GDM n(%)	Unadjusted OR	Adjusted OR	P
Age					
< 30 years	44 (75.8%)	38 (66.6%)	Ref	Ref	
>30 years	14 (24.1%)	19 (33.3%)	1.08	1.10	0.01*
BMI					
<25	5 (8.6%)	3 (5.2%)	Ref	Ref	
>25	53 (91.3%)	54 (94.4%)	1.10	1.12	<0.001*
PCOS					
Yes	3(5.1%)	11(19.3%)	1.92	2.00	0.012*
No	55(94.8%)	46 (80.71%	Ref	Ref	
Thyroid disorders					
Yes	12 (20.6%)	10 (17.5%)	0.82	0.95	0.225
No	46 (79.3%)	47 (82.4%)	Ref	Ref	
Family history of diabetes					
Yes	16 (27.5%)	24 (42.1%)	1.25	1.34	0.051
No	42 (72.4%)	33 (57.8%)	Ref	Ref	
Carbohydrate Intake					
Adequate	27 (46.5%)	21 (36.8%)	Ref	Ref	
Excess	31 (53.5%)	36 (63.2%)	1.09	1.11	0.048*
Protein intake					
Adequate	29 (50.0%)	19 (33.3%)	Ref	Ref	
Inadequate	29 (50.0%)	38 (66.7%)	0.91	0.93	0.770
Fat intake					
Adequate	22 (37.9%)	16 (28.1%)	Ref	Ref	
Excess	36 (62.1%)	41 (71.9%)	0.98	1.00	0.681
Fiber intake					
Adequate	15 (25.9%)	13 (22.8%)	Ref	Ref	
Inadequate	43 (74.1%)	44 (77.2%)	0.74	0.77	0.155

*P value <0.05 significant, BMI- Body Mass Index, PCOS-Poly Cystic Ovarian Syndrome, GDM- Gestational Diabetes Mellitus, OR-Odds Ratio

Table 4
Multiple Linear regression analysis of various dietary components with the OGTT values

Nutrient	F	R^2	R^2adj	P
Total energy intake	7.48	0.12	0.1	0.008*
Carbohydrates	5.73	0.20	0.09	0.04*
Fats	4.02	0.13	0.1	0.02*
Proteins	2.26	0.04	0.02	0.138
Fiber	0.94	0.02	0	0.337

*P value <0.05 significant, F- F value, R^2- Proportion of variance, R^2adj- Adjusted R squared accounting for the number of predictors.