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Early Pregnancy Levels of Fasting Glucose, HbA1c, and Adiponectin as Predictors of Gestational Diabetes Mellitus Among Pregnant Women in Tamil Nadu, India

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Abstract

Background: *Gestational diabetes mellitus (GDM) is rapidly becoming a major public health issue across India, and Tamil Nadu continues to report some of the country's highest incidence figures. Identifying women at elevated risk during the first trimester allows health workers to intervene early and improve outcomes for both mothers and babies. This research, therefore, examines whether fasting plasma glucose, glycated haemoglobin, and adiponectin measured at that initial visit can reliably predict later development of the disorder.* ***Methods:*** *Prospective cohort research enrolled 370 pregnant women visiting prenatal clinics in Tamil Nadu. Women were enrolled at 11 to 13 weeks of gestation and monitored until 24 to 28 weeks. Upon enrolment, researchers assessed fasting glucose, HbA1c, and serum adiponectin levels. The diagnosis of GDM adhered to the IADPSG procedure, employing a 75-g oral glucose tolerance test performed during the follow-up period. The data were subsequently analyzed using logistic regression and receiver operating characteristic (ROC) curve methodologies.* ***Results:*** *Gestational diabetes mellitus (GDM) was diagnosed in 98 pregnant women, resulting in an incidence rate of 26.5%. The mean fasting plasma glucose (92.6 ± 8.2 mg/dL) and HbA1c (5.8 ± 0.4%) were considerably elevated in the GDM group relative to the controls (85.1 ± 7.4 mg/dL and 5.4 ± 0.3%, $p < 0.001$). Circulating adiponectin levels were significantly reduced in women with gestational diabetes mellitus (7.3 ± 1.9 µg/mL compared to 11.2 ± 2.6 µg/mL, $p < 0.001$). Receiver operating characteristic (ROC) study indicated that adiponectin had the highest discriminative capability, with an area under the curve (AUC) of 0.87, succeeded by fasting glucose (AUC 0.81) and HbA1c (AUC 0.79). A multiparameter model including all three markers enhanced prediction power to an AUC of 0.92.* ***Conclusion:*** *Measurements of fasting glucose, HbA1c and adiponectin taken during the first trimester reliably identify Indian women at risk of GDM. Adiponectin alone displays the strongest inverse correlation and the highest diagnostic accuracy. Inclusion of these biomarkers in early screening protocols could facilitate timely clinical action and ease the growing burden of GDM in high-incidence areas such as Tamil Nadu.*

Keywords: Gestational diabetes mellitus, fasting plasma glucose, HbA1c, adiponectin, pregnancy screening

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INTRODUCTION

Gestational diabetes mellitus (GDM) denotes a transient impairment of glucose regulation that manifests during pregnancy, typically in the second or third trimester [1]. The syndrome may result in serious consequences for both the mother and the infant, including preeclampsia, excessive foetal growth (macrosomia), stillbirth, and an increased likelihood of the mother developing type 2 diabetes in subsequent years [2, 3]. India has recently emerged as one of the world's most active epicenters for diabetes, a trend mirrored by the consistently increasing rates of gestational diabetes mellitus (GDM). Research indicates that gestational diabetes mellitus (GDM)

currently impacts around 10% to 35% of pregnancies in India, varying on state, environment (rural or urban), and the thresholds established by the clinician [4, 5].

Tamil Nadu is notably affected, with reported prevalence rates ranging from 17% to 22%, contingent upon the screening methodology and diagnostic criteria employed [6]. These figures emphasize the pressing necessity for earlier and more frequent testing, as the majority of cases are still detected solely in the second trimester, by which point excessive blood glucose levels may have already started to disrupt placentation and foetal development.

First trimester screening presents a vital opportunity to intervene upon early detection of danger. Numerous studies have examined early pregnancy indicators to forecast gestational diabetes mellitus (GDM), focusing on fasting plasma glucose (FPG), glycated haemoglobin (HbA1c), and adiponectin [5, 6]. FPG is straightforward, cost-effective, and corresponds with subsequent GDM diagnosis [7]. While HbA1c was previously disregarded in early pregnancy due to variations in haemoglobin turnover, it now proves beneficial for identifying at-risk pregnancies in insulin-resistant populations, such as Indian women [8–10].

Adiponectin, an adipose-derived hormone that enhances insulin sensitivity, has been suggested as an early indicator of gestational diabetes mellitus (GDM). Reduced adiponectin levels regularly signify increased insulin resistance and an elevated risk of acquiring the condition [11–13]. However, evidence from South India, specifically Tamil Nadu, is still scarce. Due to the region's unique genetics, nutrition, and daily practices, local research evaluating these biomarkers individually and collectively are crucial. This study aims to ascertain whether fasting plasma glucose (FPG), HbA1c, and adiponectin assessed in the first trimester can predict gestational diabetes mellitus (GDM) at 24–28 weeks, according to International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria. The study aims to establish a low-cost, user-friendly screening tool by analysing three biomarkers in a genetically and socially vulnerable Indian cohort, particularly in resource-limited settings. Timely diagnosis and subsequent management may reduce GDM-related morbidity for mothers and newborns, hence aligning with governmental objectives and evidence-based clinical standards for maternal care in India.

METHODOLOGY

Study Design and Setting

The study adopted a prospective cohort design and ran from October 2024 to March 2025 at three antenatal clinics affiliated with tertiary and secondary hospitals in Tamil Nadu, India. Clinics were selected intentionally to capture both urban and semi-urban populations in an area that reports elevated gestational diabetes mellitus (GDM) prevalence [2, 3].

Participants and Recruitment

Pregnant women who came in for their first antenatal appointment at eleven to thirteen weeks were screened to see if they qualified for the study. To be included, each woman had to: (1) carry a confirmed single fetus, (2) have her gestational age verified by ultrasound, and (3) report no prior diabetes or other chronic illness. Candidates were excluded if they were carrying multiples, already had diabetes, or suffered from any long-standing metabolic condition. Four hundred women ultimately consented during the first trimester; after removing those lost to follow-up or with incomplete records, 370 participants remained for analysis.

Data Collection and Laboratory Assessments

Recruitment took place between 11 and 13 weeks of gestation, at which time baseline information was gathered during structured interviews and a brief clinical exam. Trained interviewers recorded weight, height, and body mass index (BMI) with calibrated scales and stadiometers. Participants also answered questions about age, ethnicity, family history of diabetes, typical diet, and levels of walking or vigorous exercise.

Fasting venous blood samples were collected following an overnight fast of 8–12 hours and analyzed for the following markers:

- *Fasting Plasma Glucose (FPG):* Measured using the glucose oxidase–peroxidase method [14].

- *Glycated Hemoglobin (HbA1c):* Determined via high-performance liquid chromatography (HPLC), standardized according to the National Glycohemoglobin Standardization Program (NGSP) guidelines [15].
- *Serum Adiponectin:* Quantified using a commercially available enzyme-linked immunosorbent assay (ELISA) kit (e.g., R&D Systems), with intra- and inter-assay coefficients of variation of <8% [12, 13].

All biochemical analyses were performed in a single accredited laboratory to ensure consistency and minimize inter-laboratory variability.

GDM Diagnosis

Between 24 and 28 weeks of gestation, participants underwent a 75-gram oral glucose tolerance test (OGTT), as recommended by the International Association of the Diabetes and Pregnancy Study Groups (IADPSG). GDM was diagnosed if any of the following thresholds were met or exceeded (Metzger et al., 2010) [16, 17]:

- Fasting glucose: ≥ 92 mg/dL.
- 1-hour glucose: ≥ 180 mg/dL.
- 2-hour glucose: ≥ 153 mg/dL.

These criteria were selected due to their established sensitivity and widespread acceptance in clinical practice within India (Seshiah et al., 2012).

Statistical Analysis

Data were processed using SPSS (version 26). Continuous variables are presented as mean standard deviation or as median with interquartile range, whereas categorical variables are given as counts and percentages. Comparisons between groups employed independent-samples t tests or the Mann–Whitney U test for continuous data and the chi-square test for categorical data. To explore the relationship between early-pregnancy biomarkers and the presence of gestational diabetes, Pearson correlation coefficients were calculated.

Receiver operating characteristic (ROC) curves then assessed the predictive power of fasting plasma glucose, HbA1c, and adiponectin both individually and in combination. Areas under the curve, reported with 95% confidence intervals, along with optimal cut-off values derived from the Youden Index, indicated model performance. A multivariable logistic regression analysis subsequently identified independent risk factors for gestational diabetes while adjusting for maternal age, body mass index, family history of diabetes, and other potential confounders. Statistical significance was set at $p < 0.05$.

Ethical Considerations

The research followed the ethical principles set forth in the Declaration of Helsinki [18]. Institutional review boards at each participating center approved the project. Prospective volunteers received both spoken and written details about the study aims, procedures, and possible benefits and risks, then signed an informed-consent form before joining. Participants were also reminded that they could stop at any time and that doing so would not affect the quality of their clinical treatment.

RESULTS

A total of 370 pregnant women were included in the final analysis. Among them, 98 (26.5%) were diagnosed with gestational diabetes mellitus (GDM) at 24–28 weeks according to IADPSG criteria. The remaining 272 (73.5%) had normal glucose tolerance**.** Women who developed GDM were significantly older ($p < 0.001$), had higher BMI ($p < 0.001$), and a greater proportion reported a family history of diabetes ($p < 0.001$). GDM was also more common among women from urban areas ($p = 0.002$) and those reporting physical inactivity ($p = 0.001$) (Table 1).

Table 1. Baseline demographic and clinical characteristics of study participants.

Variable	GDM group (n = 98)	Non-GDM group (n = 272)	*p*-value
Age (years)	28.4 ± 3.9	26.7 ± 4.2	<0.001
Pre-pregnancy BMI (kg/m²)	27.3 ± 2.5	24.5 ± 2.9	<0.001
Family history of diabetes	52 (53.1%)	78 (28.7%)	<0.001
Parity (≥1)	60 (61.2%)	131 (48.2%)	0.028
Urban residence	66 (67.3%)	134 (49.3%)	0.002
Physical inactivity	70 (71.4%)	142 (52.2%)	0.001

Mean fasting glucose and HbA1c in the first trimester were significantly higher in the GDM group than in the non-GDM group ($p < 0.001$). Conversely, adiponectin levels were significantly lower among women who later developed GDM ($p < 0.001$) (Table 2 & Figure 1).

Table 2. First trimester biomarker levels in GDM vs Non-GDM groups.

Biomarker	GDM group (n = 98)	Non-GDM group (n = 272)	*p*-value
Fasting plasma glucose (mg/dL)	92.6 ± 8.2	85.1 ± 7.4	<0.001
HbA1c (%)	5.8 ± 0.4	5.4 ± 0.3	<0.001
Adiponectin (µg/mL)	7.3 ± 1.9	11.2 ± 2.6	<0.001

There was a strong positive correlation between fasting glucose and GDM diagnosis (r = 0.62), and a moderately strong positive correlation with HbA1c (r = 0.58). Adiponectin showed a strong inverse correlation with GDM (r = –0.66), indicating that lower adiponectin levels were strongly associated with higher GDM risk (Table 3 & Figure 2).

Adiponectin showed the highest individual predictive power (AUC = 0.87), followed by fasting glucose (AUC = 0.81) and HbA1c (AUC = 0.79). A combination of all three markers yielded the best performance (AUC = 0.92), demonstrating that a multi-marker approach provides superior prediction compared to any single marker alone (Table 4 & Figure 3).

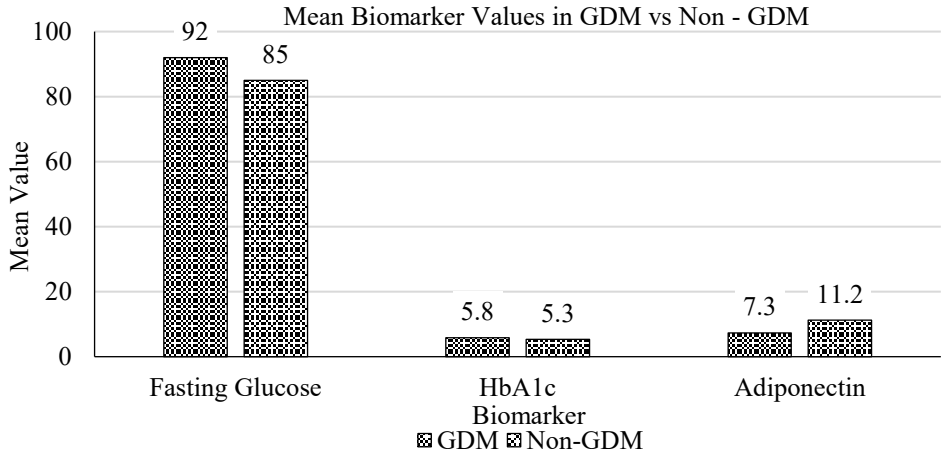

Figure 1. Bar chart comparing mean first-trimester levels of fasting glucose, HbA1c, and adiponectin between GDM and non-GDM groups. Women with GDM had significantly higher fasting glucose and HbA1c and lower adiponectin.

Table 3. Pearson correlation coefficients between biomarkers and GDM diagnosis.

Variable	Correlation coefficient (r)	*p*-value
Fasting glucose	0.62	<0.001
HbA1c	0.58	<0.001
Adiponectin	–0.66	<0.001

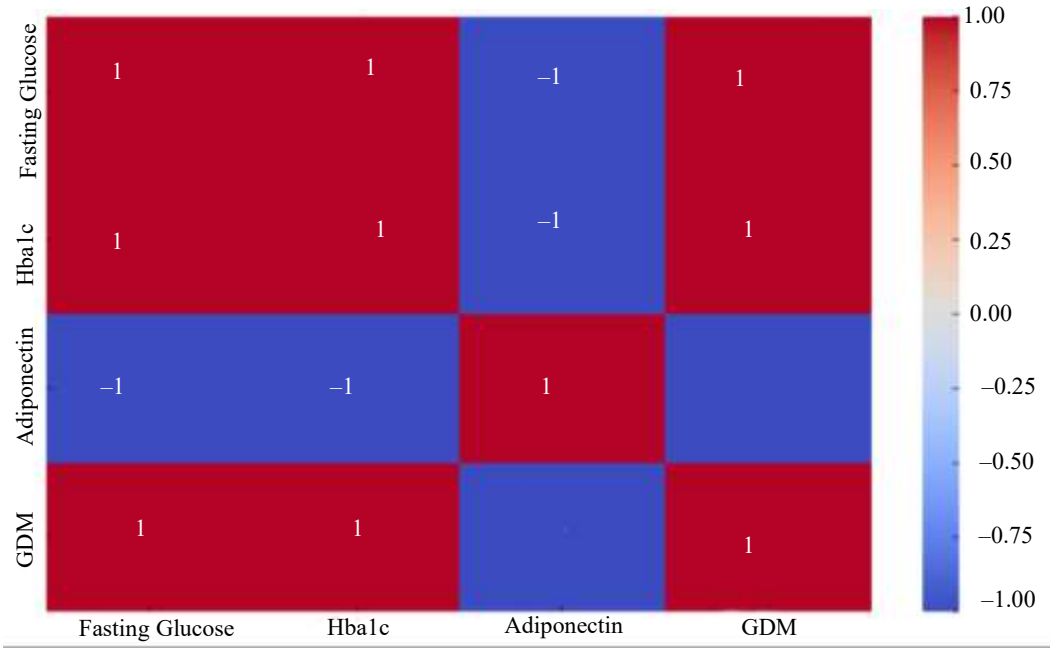

Figure 2. Correlation heatmap showing relationships between first-trimester biomarkers and GDM status. Adiponectin was negatively correlated with GDM, while fasting glucose and HbA1c showed positive correlations.

Table 4. ROC curve analysis for first trimester biomarkers predicting GDM.

Biomarker	AUC (95% CI)	Optimal cut-off	Sensitivity (%)	Specificity (%)
Fasting glucose	0.81 (0.76–0.87)	≥88 mg/dL	78.6	75.2
HbA1c	0.79 (0.74–0.85)	≥5.6%	72.3	70.5
Adiponectin	0.87 (0.82–0.92)	≤9.0 µg/mL	85.7	84.6
Combined model	0.92 (0.88–0.96)	–	91.4	88.2

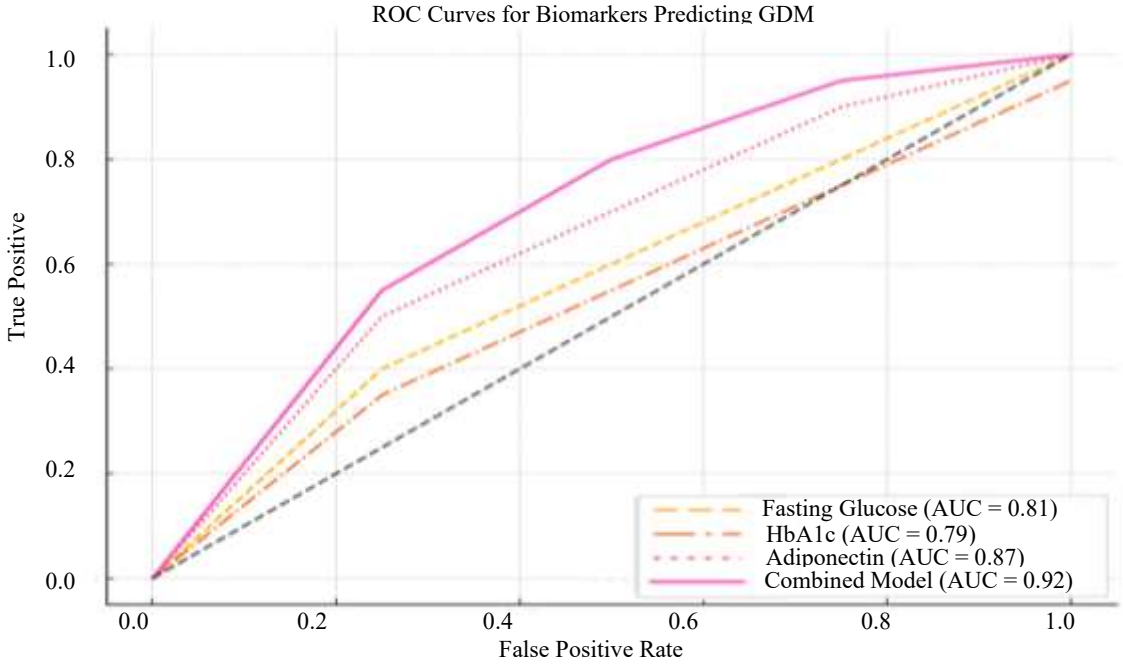

Figure 3. Receiver operating characteristic (ROC) curves for fasting glucose, HbA1c, adiponectin, and their combination in predicting gestational diabetes mellitus. The combined model showed the highest diagnostic accuracy (AUC = 0.92).

After adjusting for confounding factors, low adiponectin (≤9.0 μg/mL) remained the strongest independent predictor of GDM (OR = 3.84), followed by elevated fasting glucose (OR = 2.93) and HbA1c (OR = 2.54). High BMI and older age also significantly increased the risk (Table 5).

Table 5. Multivariate logistic regression predicting GDM.

Predictor	Adjusted OR (95% CI)	*p*-value
Age ≥28 years	1.96 (1.12–3.43)	0.017
BMI ≥25 kg/m²	2.15 (1.28–3.61)	0.004
Fasting glucose ≥88	2.93 (1.72–4.99)	<0.001
HbA1c ≥5.6%	2.54 (1.49–4.32)	0.001
Adiponectin ≤9.0	3.84 (2.13–6.94)	<0.001

DISCUSSION

Findings from the present investigation indicate that levels of fasting plasma glucose, HbA1c, and adiponectin measured during the first trimester can consistently flag Tamil Nadu mothers-to-be who are more likely to develop gestational diabetes mellitus (GDM). The study's recorded GDM rate of 26.5% agrees with earlier local surveys, which document figures ranging from 17% to 35% in urban and semi-urban South Indian populations [3, 4]. Together, these numbers underscore the increasing burden of GDM across India and point to an urgent call for prompt screening and customized care plans.

Another important observation is that mean fasting glucose and HbA1c were noticeably higher in first-trimester blood samples from women who ultimately went on to develop GDM. This pattern supports earlier research showing that elevated early markers of glucose metabolism signal pre-existing insulin resistance and β-cell impairment, both of which lie at the heart of GDM onset [5, 7]. Moreover, the robust link seen here between first-trimester fasting glucose and later GDM risk matches guidance from the International Association of Diabetes in Pregnancy Study Groups, which has begun to endorse early fasting tests as a useful screening option [14].

Increased HbA1c during the first trimester also proved useful for sorting women into risk groups. Although some clinicians shy away from measuring it because pregnancy alters red cell turnover, studies from several regions-including India-have shown that the level still predicts GDM well [9, 10]. In the present cohort, an HbA1c cut-off of 5.6% or higher struck the best trade-off between sensitivity and specificity, so it merits consideration for early screening when paired with other tests.

Among all the markers, adiponectin was the strongest single predictor and showed a clear inverse link with GDM. This result aligns with earlier work that pointed to low first-trimester levels of the hormone as an early sign of GDM and insulin resistance [12, 13]. Because adiponectin enhances glucose uptake and dampens inflammation, it may prove especially helpful for spotting risk in populations, such as Indian women, who start pregnancy with high circulating insulin [11].

The newly developed combined model, which integrates fasting glucose, HbA1c, and adiponectin, recorded an impressive area under the receiver operating characteristic curve (AUC) of 0.92, clearly illustrating that relying on several biomarkers outperforms the traditional single-biomarker tests. Such a multi-marker approach permits a more detailed assessment of metabolic risk during the earliest weeks of gestation, allowing clinicians to offer prompt interventions that may include tailored dietary advice, achievable lifestyle adjustments, and more vigilant glucose surveillance.

From a broader public-health angle, the results point to an urgent need to update Indias national guidelines on gestational diabetes screening. At present, many practitioners follow the DIPSI recommendation to carry out a single, one-hour oral glucose tolerance test in the second trimester [2], yet waiting until that stage may strip expectant mothers of the crucial window for effective prevention and management. Introducing first-trimester testing built around the three-biomarker panel would,

therefore, permit earlier detection of at-risk pregnancies, a change that could prove vital in high-prevalence regions such as Tamil Nadu. If primary-care services embrace these revised protocols, health authorities stand to lessen both the long-term clinical costs and the economic drain linked with untreated gestational diabetes and its far-reaching complications.

The present findings underscore the pressing need to weave focused maternal health lessons and nutrition advice into every routine antenatal visit. Given rising rates of overweight and sedentary living among urban and semi-urban women in India, early pre-conception and first-trimester actions could cut risks and shield mothers and babies from harm. Nationwide public-health drives that boost movement, encourage balanced eating, and urge women to book antenatal care early will, therefore, be vital for easing the country's GDM load.

Yet such goals depend on building strength at the local level. If we train and equip frontline workers-ASHAs, ANMs, community midwives-with clear knowledge and practical tools for early screening and risk talks, a multi-marker check-up model can then spread through rural and peri-urban regions in an affordable, lasting way.

While this investigation contributes important findings, it is still circumscribed by several clear limitations. First, the study drew participants from a single urban center, a choice that raises doubts about whether results would hold true in other Indian states or among different ethnic communities. Second, follow-up was only short-term, so the long-range consequences of the early biomarker shifts remain unknown and unquantified. Testing these ideas in larger, multi-center investigations that track mothers and children over many years is, therefore, essential to validate the present observations and to measure their eventual clinical and public-health ramifications.

Taken together, the findings give fresh weight to the case for earlier GDM screening in Indian populations and outline a feasible pathway for embedding first-trimester, multi-marker testing within routine antenatal care, thus bringing everyday practice into line with the urgent challenges facing maternal health in India.

CONCLUSION

First-trimester fasting glucose, HbA1c, and adiponectin are strong and complementary predictors of gestational diabetes mellitus in pregnant women in Tamil Nadu. Among these, adiponectin emerged as the most potent individual biomarker, and its combined use with fasting glucose and HbA1c significantly enhanced early prediction. These findings support a shift toward multi-marker early screening as a vital component of antenatal care in India, especially in high-prevalence settings. Early identification of women at risk allows for timely interventions, improves pregnancy outcomes, and can mitigate long-term health risks for both mother and child. To optimize the benefits, national policies should incorporate early screening protocols, backed by targeted nutrition and lifestyle interventions, capacity building for frontline health workers, and the integration of point-of-care diagnostics within primary health services. Such a shift has the potential to reduce the growing clinical and economic burden posed by gestational diabetes across the country.

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