

Original Article

First-trimester two-hour post-challenge glucose and HbA1c as early predictors of gestational diabetes mellitus: A prospective cohort study

Rose Khandelwal,¹ Aruna Nigam¹ & Supriya Chaubey¹

¹Department of Obstetrics and Gynaecology, Hamdard Institute of Medical Sciences & Research, Jamia Hamdard University, Delhi, India

Received June 28, 2025; Accepted October 15, 2025; Published February 28, 2026

Background and objectives: Traditional gestational diabetes mellitus (GDM) screening at 24–28 wk occurs after foetal exposure to maternal hyperglycemia during critical developmental windows. Our objective was to investigate whether first-trimester glycaemic parameters within currently accepted normal ranges could predict subsequent GDM development.

Methods: In this prospective cohort (May 2023–December 2024), 270 women with singleton pregnancies were enrolled at 8–12 wk gestation with normal glycaemic values (FPG <92 mg/dL, 1-h <180 mg/dL, 2-h <153 mg/dL, HbA1c <5.9%). All underwent a 75 g OGTT and HbA1c testing in the first trimester and repeat OGTT at 24–28 wk for GDM diagnosis (IADPSG criteria).

Results: GDM prevalence was 15.9%. Women who developed GDM had significantly higher first-trimester 2-h post-challenge glucose [116.7±15.4 vs. 99.0±16.6 mg/dL (6.5±0.9 vs. 5.5±0.9 mmol/L), $P<0.001$] and HbA1c [5.30±0.30% vs. 4.90±0.37% (34±3.3 vs. 30±4.0 mmol/mol), $P<0.001$] compared to those who maintained normal glucose tolerance. ROC analysis identified optimal cut-offs: 2-h glucose ≥ 112 mg/dL (6.2 mmol/L) (sensitivity 79.1%, specificity 81.9%, AUC 0.799) and HbA1c $\geq 5.4\%$ (36 mmol/mol) (sensitivity 60.5%, specificity 88.4%, AUC 0.805). A combined model incorporating 2-h glucose, HbA1c, and family history achieved the highest performance (AUC 0.866, sensitivity 69.8%, specificity 89.0%, diagnostic accuracy 85.9%). Newborns of GDM mothers had significantly higher birth weights (3366.4±399.0g vs. 2935.8±427.0g, $P<0.001$).

Interpretation and conclusions: First-trimester 2-h glucose ≥ 112 mg/dL and HbA1c $\geq 5.4\%$, even within normal ranges, effectively predict GDM. Combined assessment improves predictive accuracy, supporting early first-trimester risk stratification and timely intervention to enhance maternal and neonatal outcomes.

Keywords 2-h post-challenge glucose; Early prediction; First trimester screening; Gestational diabetes mellitus; HbA1c

Screening for gestational diabetes mellitus (GDM) at 24–28 wk misses early foetal exposure to maternal hyperglycaemia, which can begin around 10–11 wk and trigger metabolic alterations such as the ‘foetal glucose steal phenomenon’.¹ Studies indicate that foetal weight and abdominal circumference begin to diverge prior to the usual 24–28 wk GDM diagnosis period. Li *et al*² showed that maternal glycaemic status influences foetal growth trajectories as early as 16–20 wk, with measurable differences in growth patterns occurring well before conventional screening. Similarly, Boghossian *et al*³ observed that excessive foetal abdominal circumference growth between 20–28 wk often precedes GDM diagnosis, with additive

effects from maternal obesity. Sarathi *et al*⁴ reported increased foetal adiposity in South Asian women with GDM as early as 20 wk, supporting the ‘thin-fat’ baby phenotype preceding GDM. These findings highlight that current screening timelines may overlook crucial windows for early intervention during foetal organogenesis and growth programming. Women with GDM have a higher risk of fetomaternal complications as well as long term consequences.⁵

The landmark Hyperglycemia and Adverse Pregnancy Outcome (HAPO) study⁶ revealed a continuous association between maternal glucose concentrations and adverse perinatal outcomes,

How to cite this article: Khandelwal R, Nigam A, Chaubey S. First-trimester two-hour post-challenge glucose and HbA1c as early predictors of gestational diabetes mellitus: A prospective cohort study. *Indian J Med Res.* 2026;163:49-54. DOI: 10.25259/IJMR_1666_2025.

forming the basis for current screening strategies. An optimal screening method should detect both existing GDM cases and women at elevated risk of developing the condition. Considering the heightened foetal susceptibility during early gestation and the potential benefits of timely intervention, establishing reliable first-trimester predictors of GDM has become a key area of research focus.

Several studies have examined early pregnancy glycaemic markers as predictors of GDM, but findings remain inconsistent. The TOBOGM trial showed that initiating treatment for GDM before 20 wk of gestation led to reduction in adverse neonatal outcomes, reduced NICU admissions and shortened hospital stay compared with starting treatment later in pregnancy.^{7,8} These findings from the largest randomized controlled trial of early GDM treatment provide strong evidence supporting the clinical utility of first-trimester screening and intervention strategies.

We aimed to investigate whether first-trimester glycaemic parameters—specifically 2-h post-challenge glucose [110–153 mg/dL (6.1–8.5 mmol/L)] and HbA1c [5.3–5.9% (34–41 mmol/mol)]—within currently accepted normal ranges could predict subsequent GDM development. Our hypothesis was that subtle alterations in these parameters, even within currently accepted normal ranges, might signal increased risk for GDM development and adverse pregnancy outcomes.

Methods

Study design and participants: This prospective cohort study was conducted at department of Obstetrics and Gynaecology, Hamdard Institute of Medical Sciences & Research, Jamia Hamdard University, Delhi, India between May 2023 and December 2024. The study received approval from the Institutional Ethics Committee.

Eligible participants included pregnant women with singleton pregnancies attending antenatal care at 8–12 wk of gestation with fasting blood glucose (FBG) <92 mg/dL (5.1 mmol/L), 1-hour post-challenge glucose <180 mg/dL (10.0 mmol/L), and 2-h post-challenge glucose <153 mg/dL (8.5 mmol/L), HbA1c <5.9% (41 mmol/mol). Exclusion criteria were pre-existing type 2 diabetes mellitus, deranged OGTT at first visit, multiple pregnancies, autoimmune diseases, current tuberculosis, and steroid therapy.

All eligible participants were provided detailed information about the study, and written informed consent was obtained prior to enrolment. Sample size

was calculated based on the reported GDM incidence of 19.2% from Bahl *et al*⁹, with 5% significance 90% power, and correlation value = 0.20 (based on a pilot study). This yielded a required sample of 259 participants. Considering a potential 20% loss to follow up, we aimed to recruit 300 participants.

Procedures: At 8–12 wk, baseline demographics, BMI, and medical/obstetric history were recorded. A 75 g OGTT with HbA1c was performed, and participants were followed with routine antenatal visits (**Supplementary Figure**).

Another 75 g OGTT was repeated at 24–28 wk, and GDM was diagnosed per IADPSG criteria (fasting \geq 92 mg/dL, 1 h \geq 180 mg/dL, or 2 h \geq 153 mg/dL). Participants were followed until delivery, with documentation of antenatal complications, mode of delivery, and neonatal outcomes (birth weight, APGAR scores, complications). Birth weight was classified as <2500 g (low birth weight) or \geq 2500 g, and percentiles were determined using gestational age-adjusted growth charts.

OGTT procedure: A standardised 75 g oral glucose tolerance test was administered. After an overnight fast of at least eight hours, participants ingested 75 g of anhydrous glucose dissolved in 250–300 mL of water within 5 min. Venous blood samples were drawn at three intervals—fasting (0 min), 1 h (60 min), and 2 h (120 min) post-glucose intake. During the test, participants remained seated and refrained from eating or drinking anything other than water.

Sample collection and processing: Blood samples were collected in fluoride-oxalate tubes for glucose and EDTA tubes for HbA1c, processed within 2 h, and stored at 2–8 °C. Plasma was separated after centrifugation (3000 rpm, 10 min) and analyzed within 4 h in an accredited laboratory using standardized methods to minimize assay variability. Plasma glucose was measured using the glucose oxidase method on an automated analyzer. HbA1c was measured using high-performance liquid chromatography (HPLC) with standardized calibration.

Outcomes: The primary objectives were to determine the association between first-trimester (8–12 wk) 2-h post-challenge glucose values [between 110–153 mg/dL (6.1–8.5 mmol/L)] and HbA1c values [between 5.3–5.9% (34–41 mmol/mol)] with the development of GDM in the second trimester.

Statistical analysis: Data were analysed using SPSS v26.0 (IBM Corp., Armonk, NY, USA). Continuous

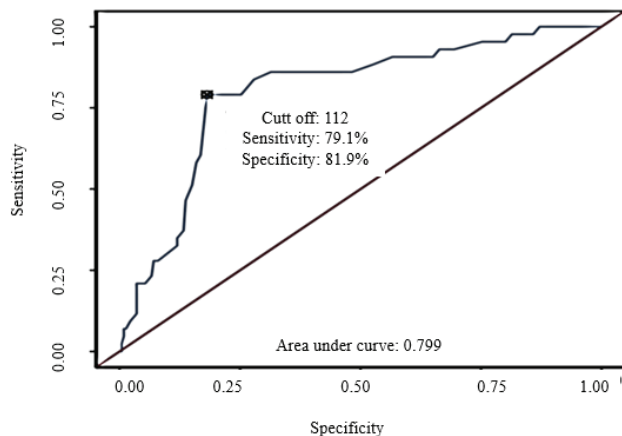


Fig. 1. ROC curve analysis for first-trimester 2-h glucose values as a predictor of GDM.

variables were expressed as mean \pm SD or median (IQR) and compared with t-tests or Mann-Whitney U tests, as appropriate. Categorical variables were presented as frequencies (%) and analysed with chi-square or Fisher's exact tests. Receiver operating characteristic (ROC) curve analysis assessed the ability of first-trimester glycaemic markers to predict GDM. The area under the curve (AUC) with 95% confidence intervals was calculated, and optimal cut-off points were identified using Youden's index (sensitivity + specificity - 1). AUC values were classified as: 0.5–0.7 (poor), 0.7–0.8 (fair), 0.8–0.9 (good), and >0.9 (excellent) discrimination. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were computed for each threshold. Spearman's correlation was used to evaluate the relationship between continuous variables with non-normal distribution. Logistic regression was performed to develop combined predictive models incorporating multiple first-trimester parameters. *P* value <0.05 was considered statistically significant.

Results

Participant characteristics: The mean age of 270 enrolled women was 27.5 ± 4.1 years, with most participants ($n=120, 44.4\%$) between 26–30 years of age. Most women ($n=161, 59.6\%$) were primigravida. The mean pre-pregnancy BMI was 23.7 ± 3.4 kg/m², with 58.5% of participants categorized as overweight or obese according to Asian-specific BMI classifications. A family history of diabetes was present in 23.0% ($n=62$) of participants, with 11.1% ($n=30$) reporting maternal diabetes, 8.9% ($n=24$) paternal diabetes, and 3% ($n=8$) both parents with diabetes.

Of 270, GDM was diagnosed in 43 women (15.9%, 95% CI: 11.9%–21.0%) during follow up at 24–28 wk.

Women who developed GDM had significantly higher pre-pregnancy BMI compared to those who maintained normal glucose tolerance (25.6 ± 2.8 vs. 23.4 ± 3.4 kg/m², $P < 0.001$). ROC analysis identified an optimal BMI cut-off of ≥ 24.8 kg/m² for predicting GDM (sensitivity 69.8%, specificity 70.5%, AUC 0.725).

First-trimester fasting blood glucose: First-trimester fasting glucose levels showed significant differences between women who later developed GDM and those who maintained normal glucose tolerance. Women who subsequently developed GDM had higher first-trimester fasting glucose values [83.5 ± 7.6 mg/dL (4.6 ± 0.4 mmol/L)] compared to those who did not develop GDM [80.9 ± 6.1 mg/dL (4.5 ± 0.3 mmol/L), $P = 0.003$, Mann Whitney U test]. Results of ROC curve analysis demonstrated modest discriminatory ability with an AUC of 0.64 (95% CI: 0.539–0.742, $P = 0.003$). An optimal cut-off of ≥ 86 mg/dL (4.8 mmol/L) provided 60.5% sensitivity and 73.6% specificity for predicting GDM. The positive predictive value was 30.2%, while the negative predictive value was 90.8%, resulting in an overall diagnostic accuracy of 71.5%.

First-trimester 1-h post-challenge glucose: Women who subsequently developed GDM had substantially higher first trimester 1-h glucose values [mean: 125.2 ± 18.9 mg/dL (7.0 ± 1.0 mmol/L)] compared to those who maintained normal glucose tolerance [mean: 108.2 ± 18.3 mg/dL (6.0 ± 1.0 mmol/L)] ($P < 0.001$). ROC curve analysis demonstrated that first-trimester 1-hour glucose had fair discriminatory ability in predicting subsequent GDM development, with an AUC of 0.75 (95% CI: 0.675–0.826, $P < 0.001$). An optimal cut-off of ≥ 118 mg/dL (6.6 mmol/L) provided a sensitivity of 72.1% and specificity of 71.8% for predicting GDM. The positive predictive value was 32.6%, while the negative predictive value was 93.1%, resulting in an overall diagnostic accuracy of 71.9%.

First-trimester 2-h post-challenge glucose: First-trimester 2-h post-challenge glucose levels demonstrated pronounced differences between women who later developed GDM and those who maintained normal glucose tolerance. Women who subsequently developed GDM had significantly higher 2-hour glucose values [116.7 ± 15.4 mg/dL (6.5 ± 0.9 mmol/L)] compared to those who did not develop GDM [99.0 ± 16.6 mg/dL (5.5 ± 0.9 mmol/L), $P < 0.001$].

ROC curve analysis (**Fig. 1**) demonstrated that first-trimester 2-h glucose had good discriminatory ability in predicting subsequent GDM development, with an area under the curve of 0.799 (95% CI: 0.727–0.871, $P < 0.001$). An optimal cut-off of ≥ 112 mg/dL (6.2

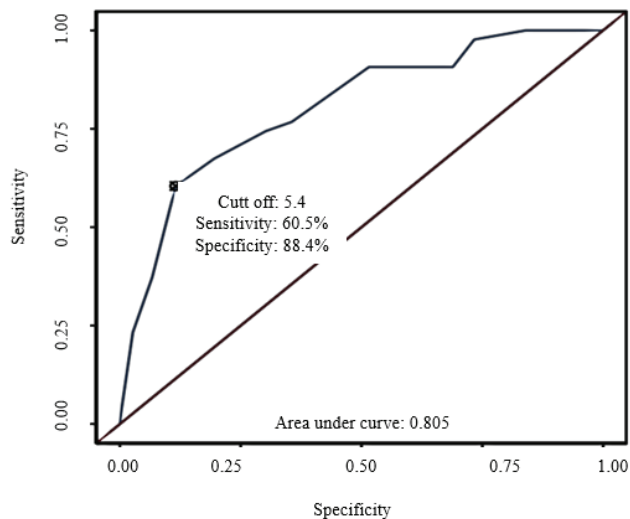


Fig. 2. ROC curve analysis for HbA1c glucose as a predictor of GDM.

mmol/L) provided a sensitivity of 79.1% and specificity of 81.9% for predicting GDM. The positive predictive value was 45.3%, while the negative predictive value was 95.4%, resulting in an overall diagnostic accuracy of 81.4%.

First-trimester HbA1c: Women who later developed GDM had markedly higher first trimester HbA1c values [mean: $5.30 \pm 0.30\%$ (34 ± 3.3 mmol/mol)] compared to those who did not develop GDM (mean: $4.90 \pm 0.37\%$ (30 ± 4.0 mmol/mol), $P < 0.001$). ROC analysis revealed an AUC of 0.805 (95% CI: 0.732-0.877, $P < 0.001$) with an optimal cut-off of $\geq 5.4\%$ (36 mmol/mol) yielding 60.5% sensitivity and 88.4% specificity (**Fig. 2**). The high specificity (88.4%) of HbA1c $\geq 5.4\%$ (36 mmol/mol) indicates that elevated values are relatively uncommon among women who do not develop GDM. However, the moderate positive predictive value (50.0%) reflects the relatively low GDM prevalence in this cohort (15.9%), meaning that only half of women with HbA1c $\geq 5.4\%$ will subsequently develop GDM. The high negative predictive value (92.1%) indicates effective rule-out capacity when values are below 5.4%.

Combined predictive models: We developed several combined models incorporating different first-trimester parameters to enhance predictive performance. The combination of 2-h post-challenge glucose, HbA1c, and family history achieved the highest overall diagnostic accuracy (85.9%) with excellent specificity (89.0%), moderate sensitivity (69.8%), and the highest positive predictive value (54.5%) among all models tested (AUC 0.866, 95% CI: 0.812-0.919, $P < 0.001$).

The model incorporating 2-h post-challenge glucose, HbA1c, and pre-pregnancy BMI also demonstrated strong performance (AUC 0.864, 95% CI: 0.814-0.914, $P < 0.001$), with good sensitivity (83.7%) and specificity (74.4%), resulting in a diagnostic accuracy of 75.9%. Models incorporating 2-h post-challenge glucose consistently outperformed those using fasting or 1-hour values, reinforcing the significance of delayed post-challenge hyperglycemia as an early marker of metabolic dysfunction.

Pregnancy outcomes: Newborns of mothers with GDM had substantially higher birth weights (3366.4 ± 399.0 g vs. 2935.8 ± 427.0 g, $P < 0.001$) and birth weight percentiles (median: 70th vs. 36th percentile, $P < 0.001$) compared to those born to mothers without GDM. Strikingly, no infants (0%) born to mothers with GDM had low birth weight (< 2500 g), compared to 15.0% of infants born to mothers without GDM ($P = 0.007$).

Family history of diabetes showed a strong association with GDM development ($P < 0.001$). Among women who developed GDM, 62.8% ($n = 27$) had a positive family history (maternal, paternal, or both parents), compared to only 15.4% ($n = 35$) of women who maintained normal glucose tolerance. The presence of both parents with diabetes was a particularly strong predictor, present in 16.3% ($n = 16.3$) of GDM cases but only 0.4% ($n = 1$) of non-GDM cases.

Discussion

Our study demonstrates that first-trimester 2-hour post-challenge glucose and HbA1c, even within currently accepted normal ranges, can effectively predict subsequent GDM development. Optimal cut-offs [2-h glucose ≥ 112 mg/dL (6.2 mmol/L) and HbA1c $\geq 5.4\%$ (36 mmol/mol)] showed good discriminatory ability. Combined models incorporating these parameters with family history or pre-pregnancy BMI achieved superior predictive performance.

The superior predictive capacity of 2-h post-challenge glucose versus fasting glucose indicates that early metabolic dysfunction in GDM primarily involves postprandial glucose intolerance, reflecting initial beta-cell dysfunction or insulin resistance, consistent with GDM pathophysiology.¹⁰ Our 2-h glucose cut-off (≥ 112 mg/dL) closely aligns with Seshiah *et al*¹¹ threshold (> 110 mg/dL) for Early Gestational Glucose Intolerance, grounded in foetal physiology.¹¹ This convergence reinforces the biological relevance of early postprandial glucose assessment.

The high specificity (88.4%) of first-trimester HbA1c at our optimal cut-off [$\geq 5.4\%$ (36 mmol/mol)] indicates

शोध-संदेश

यह अध्ययन गर्भावस्था के दौरान होने वाले मधुमेह (GDM) की शीघ्र पहचान पर केंद्रित है। पारम्परिक जाँच 24–28 सप्ताह में की जाती है, जब तक भ्रूण पहले ही मातृ उच्च रक्त शर्करा के संपर्क में आ चुका होता है। शोध का उद्देश्य यह जानना था कि गर्भवस्था की पहली तिमाही में सामान्य सीमा के भीतर रहने वाले ग्लाइसेमिक मान भविष्य में GDM के विकास का पूर्वानुमान लगा सकते हैं या नहीं। अध्ययन में पाया गया कि पहली तिमाही में 2-घंटे का ग्लूकोज स्तर 112 mg/dL और HbA1c 5.4%, से यदि अधिक हो, तो ये GDM की प्रभावी भविष्यवाणी कर सकते हैं। दोनों मानकों का संयुक्त आकलन पूर्वानुमान की सटीकता को और बढ़ाता है, जिससे गर्भावस्था की शुरुआत में ही जोखिम वाले महिलाओं की पहचान कर समय पर हस्तक्षेप संभव हो सकता है और मातृ एवं नवजात स्वास्थ्य परिणामों में सुधार किए जा सकते हैं।

that most women without GDM have values below this threshold. However, the moderate positive predictive value (50.0%) means that HbA1c alone has limited utility as a standalone rule-in test in populations with GDM prevalence similar to ours (15.9%). The high negative predictive value (92.1%) suggests its greater utility for ruling out GDM risk when values are below 5.4%. This aligns with findings by Mañé *et al*,¹² who reported that early HbA1c $\geq 5.9\%$ (41 mmol/mol) identified women at higher risk for adverse pregnancy outcomes independent of subsequent GDM diagnosis. Our lower optimal cut-off likely reflects our focus on GDM prediction rather than adverse outcomes directly, and suggests that even mildly elevated HbA1c may signal increased GDM risk when used in combination with other predictors. Our findings align with and extend recent Indian studies examining early pregnancy HbA1c. It has been demonstrated that among pregnant Asian Indian women without GDM, first-trimester HbA1c $\geq 5.5\%$ (37 mmol/mol) was independently associated with preterm birth (adjusted OR 2.10, 95% CI 1.11-3.98), suggesting that even mildly elevated HbA1c carries clinical significance beyond GDM prediction.¹³ Similarly, the landmark multicentre study by Saravanan *et al*,¹⁴ including Indian cohorts, validated early pregnancy HbA1c as a practical first-line screening tool for gestational diabetes across diverse populations in low- and middle-income countries.¹⁴ A recent comprehensive review supports the use of HbA1c thresholds in early pregnancy for identifying women at risk of adverse outcomes.¹⁵ Our optimal cut-off of 5.4% (36 mmol/mol) is lower than the 5.5% (37 mmol/mol) threshold identified by Punnose *et al*¹³ and the 5.9% (41 mmol/mol) threshold reported by Mañé *et al*.¹² This likely reflects our focus on GDM prediction specifically rather than broader adverse outcomes, and suggests that even mildly elevated HbA1c within the currently accepted normal range may signal increased metabolic risk.

The significant association between GDM and increased birth weight, with complete absence of low birth weight infants in GDM pregnancies, highlights the complex relationship between maternal glycaemia

and foetal growth. This finding suggests that while GDM increases macrosomia risk, it may paradoxically protect against growth restriction, possibly reflecting the anabolic effects of foetal hyper insulinemia. This pattern indicates a continuous association between maternal glucose levels and foetal growth across all percentiles, rather than simply increasing the incidence of macrosomia.

Our findings expand on previous research examining early pregnancy glycaemic parameters for GDM prediction. Various other studies also found that first-trimester fasting glucose predicted subsequent GDM, but with lower discriminatory performance compared to our post-challenge glucose and HbA1c results.^{16,17} Few studies have examined combined models incorporating multiple first-trimester parameters. One of the researchers have reported that combining first-trimester HbA1c with maternal characteristics achieved an AUC of 0.76, somewhat lower than our best model (AUC 0.866).¹⁸

Strengths of the study includes prospective design, comprehensive assessment, standardized methodology, follow up until delivery and focus on Indian population. Limitations include single-centre recruitment and moderate sample size.

Clinically, early first-trimester screening using 2-h glucose and HbA1c, combined with maternal factors, could guide targeted interventions and optimize care. Future multicentre studies should validate and refine these models. These findings suggest that early identification of high-risk women could enable timely preventive measures, optimised glycaemic monitoring, and tailored antenatal care, potentially improving maternal and neonatal outcomes.

Author contributions: RK: Literature search, study design, data collection, data analysis and interpretation, manuscript writing; AN: Literature search, figures, study design, data collection, data analysis and interpretation, manuscript writing; SC: Data collection, data analysis, data interpretation, manuscript writing. All authors have read and agree to the final printed version of the manuscript.

Financial support and sponsorship: None.

Conflicts of Interest: None.

Use of Artificial Intelligence (AI)-Assisted Technology for manuscript preparation: The authors confirm that there was no use of AI-assisted technology for assisting in the writing of the manuscript and no images were manipulated using AI.

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For correspondence: Dr Aruna Nigam, Department of Obstetrics and Gynaecology, Hamdard Institute of Medical Sciences & Research, Jamia Hamdard University, Delhi 110 062, India
e-mail: prakasharuna@hotmail.com

Supplementary file(s) available at: https://doi.org/10.25259/IJMR_1666_2025