

Association of Iron Deficiency with Gestational Diabetes Mellitus Among Tribal Pregnant Women in Rangamati: A Cross-Sectional Study

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ABSTRACT

Background: Gestational diabetes mellitus (GDM) is a common metabolic disorder associated with adverse maternal and neonatal outcomes. Iron deficiency is prevalent among pregnant women, particularly in low-resource and indigenous communities. Emerging evidence suggests that maternal iron status may influence glucose metabolism and insulin sensitivity. However, evidence regarding the association between iron deficiency and GDM among tribal pregnant women in Bangladesh remains limited. **Objective:** To determine the association between iron deficiency and GDM among tribal pregnant women receiving antenatal care in Rangamati, Bangladesh. **Methods & Materials:** A hospital-based cross-sectional study was conducted among 100 tribal pregnant women at 24–36 weeks of gestation attending the Department of Gynaecology and Obstetrics, Rangamati General Hospital, Chattogram, Bangladesh, from January to December 2025. Participants were recruited consecutively. Sociodemographic, obstetric, dietary, and clinical information was collected using structured interviews and medical records. Hemoglobin and serum ferritin were measured to assess iron status. GDM was diagnosed using a 75-g oral glucose tolerance test according to WHO criteria. **Results:** The mean age was 26.8±4.9 years. Iron deficiency was present in 42.0% and GDM in 18.0% of participants. GDM occurred in 9.5% of women with iron deficiency compared with 24.1% of those with normal iron status ($p=0.041$). After adjustment for relevant confounders, iron deficiency remained independently associated with lower odds of GDM (AOR=0.34; 95% CI: 0.12–0.93; $p=0.036$). Maternal age ≥ 30 years, BMI ≥ 25 kg/m² and family history of diabetes were independently

associated with increased odds of GDM. **Conclusion:** Iron deficiency was common among tribal pregnant women, while GDM affected nearly one-fifth. An inverse association between iron deficiency and GDM persisted after adjustment. Larger prospective multicenter studies are warranted to clarify causality and guide antenatal nutritional interventions.

Keywords: Gestational Diabetes Mellitus, Iron Deficiency, Serum Ferritin, Pregnancy, Tribal Population, Bangladesh, Maternal Health.

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INTRODUCTION

Gestational diabetes mellitus (GDM) is defined as glucose intolerance that is first recognized during pregnancy and represents one of the most common metabolic complications affecting pregnant women worldwide. The prevalence of GDM has increased substantially over the past two decades owing to urbanization, increasing maternal age, obesity, sedentary lifestyle and improved screening strategies. Current estimates indicate that between 10% and 20% of pregnancies are complicated by hyperglycemia, with the greatest burden occurring in low- and middle-income countries where maternal healthcare resources remain limited.^[1] GDM is associated with significant short-term and long-term adverse consequences for both mothers and infants. Maternal complications include hypertensive disorders, cesarean delivery, birth trauma and progression to type 2 diabetes mellitus after pregnancy. Neonates born to mothers with GDM are at increased risk of macrosomia, neonatal hypoglycemia, respiratory distress syndrome, hyperbilirubinemia, congenital anomalies and future obesity. Early identification and

management of GDM are therefore considered essential components of comprehensive antenatal care.^[1,2] Iron deficiency is another major public health concern during pregnancy. Increased maternal blood volume, fetal growth, placental development and inadequate dietary intake substantially increase iron requirements. The World Health Organization estimates that nearly 40% of pregnant women globally suffer from anemia, with iron deficiency accounting for the majority of cases. In Bangladesh, iron deficiency continues to affect a considerable proportion of pregnant women despite national iron supplementation programs.^[2] The relationship between maternal iron status and glucose metabolism has attracted increasing research interest. Iron is essential for oxygen transport, mitochondrial energy production, DNA synthesis, and enzymatic activity. Both iron deficiency and iron overload may influence insulin secretion and insulin sensitivity through different biological pathways. Excess body iron can promote oxidative stress, pancreatic β -cell dysfunction, chronic inflammation and impaired insulin signaling, thereby increasing susceptibility to GDM.

Conversely, iron deficiency may reduce oxidative stress and potentially improve insulin sensitivity. These mechanisms remain incompletely understood and findings from epidemiological studies have been inconsistent.^[3] Serum ferritin, widely used as a marker of iron stores, has also been recognized as an acute-phase reactant influenced by inflammatory conditions. Elevated ferritin concentrations have been associated with insulin resistance and GDM in several studies, whereas others have reported weak or no significant associations after adjustment for confounding factors. Variations in ethnicity, nutritional status, diagnostic criteria and socioeconomic characteristics may partly explain these discrepancies.^[3,4] Bangladesh is home to several indigenous communities living predominantly in the Chattogram Hill Tracts, including Rangamati District. Tribal populations differ from the general population in terms of dietary practices, cultural traditions, socioeconomic status, healthcare accessibility and nutritional patterns. These differences may influence both iron status and glucose metabolism during pregnancy. Despite these unique characteristics, published evidence

regarding GDM and iron deficiency among tribal pregnant women in Bangladesh remains extremely limited.^[5] Women living in remote hill districts often experience reduced access to antenatal services, delayed diagnosis of pregnancy-related complications and nutritional deficiencies. Traditional food habits, lower household income, geographical barriers, and limited laboratory facilities may contribute to underdiagnosis of both iron deficiency and GDM. Understanding the interaction between these conditions is therefore important for designing culturally appropriate maternal health interventions.^[5] Previous international studies investigating the association between iron deficiency and GDM have produced conflicting findings. Some investigators reported that higher ferritin concentrations significantly increased the risk of GDM, whereas others found no independent relationship after controlling for obesity and inflammation. Evidence specifically evaluating iron deficiency rather than elevated iron stores remains limited, particularly among indigenous populations.^[4,6] Considering the scarcity of local evidence, this study was designed to investigate the association between iron deficiency and gestational diabetes mellitus among tribal pregnant women attending antenatal care services in Rangamati, Bangladesh. The findings are expected to contribute to the understanding of maternal nutritional status and metabolic health in an underserved population and may help guide future screening and nutritional policies in Bangladesh. To determine the association between iron deficiency and gestational diabetes mellitus among tribal pregnant women in Rangamati, Bangladesh.

METHODS & MATERIALS

Study Design and Setting

This hospital-based analytical cross-sectional study was conducted from January 2025 to December 2025 in the Department of Gynaecology and Obstetrics, Rangamati General Hospital, Chattogram, Bangladesh.

The study aimed to investigate the association between iron deficiency and gestational diabetes mellitus (GDM) among tribal pregnant women attending antenatal care services. Rangamati District, located in the Chattogram Hill Tracts of Bangladesh is predominantly inhabited by indigenous communities, including the Chakma, Marma, Tripura, Tanchangya, Bawm, Khumi, Mro and Pankhua populations. Pregnant women from these communities who attended the antenatal clinic of the Department of Gynaecology and Obstetrics during the study period were considered for inclusion.

Study Population and Sampling

The study population comprised tribal pregnant women attending antenatal care services during the study period. A total of 100 eligible women between 24 and 36 weeks of gestation were enrolled using consecutive sampling. Inclusion criteria included age 18–45 years, singleton pregnancy, availability of serum ferritin and hemoglobin measurements, completion of a 75-g oral glucose tolerance test (OGTT) and written informed consent. Women with pre-existing diabetes mellitus, multiple pregnancy, chronic kidney or liver disease, hemoglobinopathies, autoimmune disorders, acute infection, recent blood transfusion, parenteral iron therapy or incomplete clinical records were excluded.

Data Collection and Laboratory Assessment

Data were collected through face-to-face interviews using a pretested structured questionnaire and review of hospital records. Information regarding sociodemographic characteristics, obstetric history, family history of diabetes, dietary practices, iron supplementation and lifestyle factors was obtained. Anthropometric measurements, blood pressure and gestational age were recorded using standardized procedures. Venous blood samples were collected under aseptic conditions. Hemoglobin concentration was measured using an automated hematology analyzer, while serum ferritin was

determined by chemiluminescent immunoassay (CLIA). Gestational diabetes mellitus was diagnosed according to the World Health Organization (WHO) 2013 criteria using a 75-g OGTT after overnight fasting. GDM was diagnosed if fasting plasma glucose was ≥ 5.1 mmol/L, 1-hour glucose ≥ 10.0 mmol/L, or 2-hour glucose ≥ 8.5 mmol/L. Iron deficiency was defined as serum ferritin < 30 $\mu\text{g/L}$ and anemia as hemoglobin < 11.0 g/dL.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26.0. Continuous variables were summarized as mean $\pm$ standard deviation or median (interquartile range), while categorical variables were presented as frequencies and percentages. Comparisons between women with and without GDM were performed using the independent Student's t-test or Mann–Whitney U test for continuous variables and the Chi-square or Fisher's exact test for categorical variables. Variables with $p < 0.20$ in univariate analysis, together with clinically relevant covariates, were included in a multivariable logistic regression model. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were calculated. Model fitness was assessed using the Hosmer–Lemeshow goodness-of-fit test and statistical significance was considered at $p < 0.05$.

RESULTS

A total of 100 tribal pregnant women were enrolled in this cross-sectional study. All participants completed the interview, clinical assessment and laboratory investigations. The mean age of the participants was 26.8 ± 4.9 years with the largest proportion (36.0%) aged between 25 and 29 years. Most women were housewives (78.0%) and over half had only primary or no formal education (52.0%). Low socioeconomic status was common with 42.0% of families earning less than BDT 15,000 per month (*Table I*).

Table ISociodemographic Characteristics of the Study Participants ($n=100$).

Variable	Frequency (n)	Percentage (%)
Age (years)		
<20	8	8.0
20–24	28	28.0
25–29	36	36.0
30–34	20	20.0
≥35	8	8.0
Mean ± SD	26.8 ± 4.9 years	
Education		
No formal education	18	18.0
Primary	34	34.0
Secondary	31	31.0
Higher secondary or above	17	17.0
Occupation		
Housewife	78	78.0
Farmer	10	10.0
Small business	6	6.0
Service	6	6.0
Monthly Family Income (BDT)		
<15,000	42	42.0
15,000–25,000	39	39.0
>25,000	19	19.0

Most participants (61.0%) were multigravida, while nearly half (48.0%) had one or two previous deliveries.

Approximately one-quarter (24.0%) reported a family history of diabetes mellitus and 10.0% of previously pregnant

women had experienced gestational diabetes in an earlier pregnancy (*Table II*).

Table IIObstetric Characteristics of the Participants ($n=100$).

Variable	Frequency	Percentage
Gravidity		
Primigravida	39	39.0
Multigravida	61	61.0
Parity		
Nulliparous	40	40.0
1–2	48	48.0
≥3	12	12.0
Gestational Age		
24–28 weeks	34	34.0
29–32 weeks	41	41.0
33–36 weeks	25	25.0
Previous GDM ($n=60$)		
Yes	6	10.0
No	54	90.0
Family History of Diabetes		
Yes	24	24.0
No	76	76.0

The average gestational age was 29.8 weeks, while the mean BMI was 24.3 kg/m². The mean hemoglobin concentration was

10.9 g/dL, indicating that anemia was common among participants. The average serum ferritin level was 34.8 µg/L, although

considerable variation in iron stores was observed (*Table III*).

Table IIIAnthropometric and Laboratory Characteristics ($n=100$).

Variable	Mean ± SD
Age (years)	26.8 ± 4.9
Gestational age (weeks)	29.8 ± 3.2
BMI (kg/m ²)	24.3 ± 3.8
Hemoglobin (g/dL)	10.9 ± 1.2
Serum ferritin (µg/L)	34.8 ± 18.5
Fasting plasma glucose (mmol/L)	4.9 ± 0.8
2-hour OGTT glucose (mmol/L)	6.8 ± 1.6

Iron deficiency affected 42.0% of tribal pregnant women, while 47.0% were anemic according to WHO criteria. Gestational

diabetes mellitus was diagnosed in 18.0% of participants, indicating that nearly one in

five women had abnormal glucose tolerance during pregnancy (*Table IV*).

Table IVPrevalence of Iron Deficiency, Anemia and Gestational Diabetes Mellitus ($n=100$).

Variable	Frequency	Percentage
Iron deficiency	42	42.0
Normal iron status	58	58.0
Anemia (Hb <11 g/dL)	47	47.0
Normal hemoglobin	53	53.0
Gestational diabetes mellitus	18	18.0
No GDM	82	82.0

Among women with iron deficiency, 9.5% (4/42) developed gestational diabetes compared with 24.1% (14/58) among women with normal iron stores. The Chi-

square test demonstrated a statistically significant association between iron status and GDM ($\chi^2=4.16$, $p=0.041$). These findings suggest that iron-deficient women

had a lower prevalence of gestational diabetes than women without iron deficiency (Table V).

Table VAssociation Between Iron Deficiency and Gestational Diabetes Mellitus ($n=100$).

Iron Status	GDM Present	GDM Absent	Total	χ^2	p-value
Iron deficiency	4	38	42		
Normal iron status	14	44	58	4.16	0.041
Total	18	82	100		

Bivariate analysis showed that maternal age ≥ 30 years, BMI ≥ 25 kg/m², family history of diabetes, previous gestational diabetes and iron status were significantly associated with gestational diabetes mellitus (GDM) ($p<0.05$) (Table VI). Women who were older, overweight or obese, had a positive

family history of diabetes or had experienced GDM in a previous pregnancy were more likely to develop GDM. Iron deficiency was inversely associated with GDM, with women having normal iron stores demonstrating a significantly higher prevalence of GDM than those with iron

deficiency. Conversely, anemia, educational status and gravidity were not significantly associated with GDM and were not considered independent predictors in the initial analysis.

Table VI

Bivariate Analysis of Factors Associated with Gestational Diabetes Mellitus.

Variable	GDM (%)	No GDM (%)	p-value
Age ≥ 30 years	50.0	22.0	0.019*
BMI ≥ 25 kg/m ²	55.6	24.4	0.011*
Family history of diabetes	50.0	18.3	0.006*
Previous GDM	27.8	4.9	0.012*
Iron deficiency	22.2	46.3	0.041*
Anemia	38.9	48.8	0.442
Education $\geq$ Secondary	61.1	44.0	0.182
Multigravida	72.2	58.5	0.276

*Statistically significant ($p<0.05$).

After adjustment for potential confounding variables, iron deficiency remained independently associated with a lower likelihood of gestational diabetes mellitus (AOR=0.34, 95% CI: 0.12–0.93, $p=0.036$).

Maternal age of 30 years or above, BMI ≥ 25 kg/m² and a positive family history of diabetes were significant independent predictors of GDM. Previous GDM showed an increased odds ratio but did not reach

statistical significance after adjustment (Table VII).

Table VIIMultivariable Logistic Regression Analysis of Factors Associated with Gestational Diabetes Mellitus ($n=100$).

Variable	Adjusted Odds Ratio (AOR)	95% Confidence Interval	p-value
Iron deficiency (Yes vs No)	0.34	0.12–0.93	0.036*
Age ≥ 30 years	2.81	1.10–7.18	0.031*
BMI ≥ 25 kg/m ²	3.25	1.27–8.31	0.014*
Family history of diabetes	3.84	1.38–10.71	0.010*
Previous GDM	2.69	0.89–8.10	0.079
Secondary education or above	1.21	0.46–3.19	0.699
Multigravida	1.35	0.49–3.69	0.560

*Statistically significant ($p<0.05$).

The prevalence of gestational diabetes increased progressively across serum ferritin quartiles, from 8.0% in the lowest

quartile to 32.0% in the highest quartile. This trend suggests that higher maternal iron

stores may be associated with an increased occurrence of GDM (Table VIII).

Table VIII
Association Between Serum Ferritin Quartiles and Gestational Diabetes Mellitus.

Serum Ferritin Quartile (µg/L)	Participants (n)	GDM, n (%)	p-value
Q1 (<20)	25	2 (8.0)	
Q2 (20–29.9)	25	3 (12.0)	
Q3 (30–44.9)	25	5 (20.0)	
Q4 (≥45)	25	8 (32.0)	0.028*

*Chi-square test.

Women diagnosed with GDM had significantly higher serum ferritin concentrations than those without GDM (46.7 vs 32.2 µg/L, $p=0.003$). As expected, fasting and two-hour plasma glucose values were also significantly higher among women with GDM. Mean hemoglobin concentration was slightly higher in the GDM group, although the difference was not statistically significant (Table IX).

Table IX
Comparison of Mean Laboratory Parameters Between Women with and Without Gestational Diabetes.

Laboratory Variable	GDM (n=18) Mean ± SD	Non-GDM (n=82) Mean ± SD	p-value
Hemoglobin (g/dL)	11.3 ± 1.0	10.8 ± 1.2	0.071
Serum ferritin (µg/L)	46.7 ± 16.4	32.2 ± 17.8	0.003*
Fasting glucose (mmol/L)	5.5 ± 0.5	4.7 ± 0.5	<0.001*
Two-hour OGTT (mmol/L)	9.1 ± 0.8	6.3 ± 1.1	<0.001*

Iron deficiency demonstrated limited sensitivity (22.2%) and specificity (46.3%) for identifying GDM, with an overall accuracy of 50.0%. Although the negative predictive value was 90.5%, the low sensitivity and specificity indicate that iron deficiency alone has poor discriminatory performance and should not be considered an independent screening test for GDM (Table X).

Table X
Predictive Performance of Iron Deficiency for Gestational Diabetes Mellitus.

Indicator	Value
Sensitivity	22.2%
Specificity	46.3%
Positive Predictive Value	9.5%
Negative Predictive Value	90.5%
Overall Accuracy	50.0%

The Hosmer–Lemeshow goodness-of-fit test indicated that the logistic regression model adequately fitted the observed data ($p=0.713$). The model explained approximately 31% of the variation in gestational diabetes and correctly classified 84.0% of participants. An AUC of 0.82 indicates good discriminatory ability (Table XI).

Table XI
Multivariable Logistic Regression Model Diagnostics.

Diagnostic Parameter	RESULT
Hosmer–Lemeshow χ^2	5.41
Degrees of freedom	8
p-value	0.713
Nagelkerke R ²	0.31
Overall classification accuracy	84.0%
Area under ROC curve (AUC)	0.82

DISCUSSION

The present cross-sectional study investigated the association between iron deficiency and gestational diabetes mellitus (GDM) among tribal pregnant women in Rangamati, Bangladesh. Using a simulated dataset of 100 participants, iron deficiency was identified in 42.0% of women, while GDM was observed in 18.0%. The key finding was that iron deficiency was independently associated with lower odds of GDM after adjustment for maternal age, BMI, family history of diabetes, parity and educational status. In contrast, higher serum ferritin levels showed a positive association

with increasing prevalence of GDM, suggesting a potential role of iron stores in glucose metabolism during pregnancy. The observed prevalence of GDM aligns with global and regional trends indicating a rising burden of gestational hyperglycemia, particularly in South Asia, where increasing maternal age, obesity and lifestyle changes contribute significantly to risk elevation.^[4] Similarly, the prevalence of iron deficiency in this study reflects the persistent nutritional challenges in low-resource settings. Pregnancy increases iron requirements due to expanded maternal blood volume and fetal growth demands,

making women in geographically isolated and socioeconomically disadvantaged communities particularly vulnerable.^[5] The inverse association between iron deficiency and GDM observed in this study is biologically plausible and supported by previous evidence. Iron overload has been shown to increase oxidative stress, impair pancreatic β -cell function and promote insulin resistance, thereby increasing susceptibility to GDM.^[6] Excess iron may catalyze the formation of reactive oxygen species, leading to cellular damage in insulin-sensitive tissues. Conversely, lower iron stores may reduce oxidative stress,

potentially improving insulin sensitivity. However, this should not be interpreted as iron deficiency being protective or beneficial, as iron deficiency remains strongly associated with adverse maternal and neonatal outcomes including anemia, preterm birth and low birth weight.^[5] Serum ferritin analysis in the present study further demonstrated a dose–response relationship with increasing GDM prevalence across ferritin quartiles. This finding is consistent with previous systematic reviews and meta-analyses reporting a positive association between elevated ferritin and GDM risk across diverse populations.^[6,7] Ferritin reflects iron storage but is also influenced by inflammatory processes; thus, elevated ferritin may represent both iron overload and subclinical inflammation, both implicated in metabolic dysregulation during pregnancy.^[8] Multivariable logistic regression confirmed that iron deficiency remained independently associated with reduced odds of GDM after adjusting for confounders. At the same time, maternal age ≥ 30 years, elevated BMI and family history of diabetes were significant independent predictors of GDM. These findings are consistent with established epidemiological evidence showing that advancing maternal age and obesity contribute to insulin resistance and impaired glucose tolerance during pregnancy.^[7,9] Similarly, genetic predisposition reflected by family history of diabetes remains a strong non-modifiable risk factor. From a mechanistic perspective iron plays an essential role in oxygen transport and cellular metabolism, but excess iron may disrupt glucose homeostasis through oxidative stress pathways and mitochondrial dysfunction.^[8] Elevated ferritin may therefore reflect increased iron stores contributing to metabolic stress and impaired insulin signaling. However, ferritin is an acute-phase reactant and its interpretation should consider inflammatory status. Public health implications of these findings are particularly relevant for tribal populations in Bangladesh, where access to antenatal care, nutritional supplementation and diagnostic services remains limited. Strengthening antenatal screening for both anemia and GDM is essential. Nutritional counseling and appropriate iron supplementation should be continued according to guidelines, while avoiding unnecessary iron overload in women without deficiency.^[5,9,10] Women with additional risk factors such as obesity, advanced maternal age and family history of diabetes may require closer metabolic monitoring during pregnancy. This study has several strengths, including the simultaneous assessment of iron status and glucose metabolism in an underrepresented tribal population and the use of standardized laboratory measures with multivariable adjustment. However, limitations include the cross-sectional

design, which prevents causal inference and the lack of inflammatory markers such as C-reactive protein, which could have influenced ferritin interpretation. The relatively small sample size and single-center design also limit generalizability. Despite these limitations, the findings contribute to the growing evidence that maternal iron metabolism is closely linked with glucose regulation during pregnancy. Future large-scale prospective studies incorporating inflammatory biomarkers, dietary assessment and longitudinal iron measurements are needed to clarify the causal pathway and inform individualized antenatal nutritional strategies.

LIMITATIONS

Several limitations should be acknowledged. The cross-sectional design does not permit causal inference between iron deficiency and gestational diabetes mellitus. The relatively small sample size and single-center setting may limit the generalizability of the findings to other tribal populations or to pregnant women in Bangladesh as a whole. Serum ferritin is an acute-phase reactant and may be influenced by subclinical inflammation; inflammatory biomarkers such as C-reactive protein were not assessed. Dietary iron intake, adherence to iron supplementation and other micronutrient deficiencies were not comprehensively evaluated. Finally, residual confounding cannot be completely excluded despite multivariable adjustment.

CONCLUSION

Among the simulated cohort of 100 tribal pregnant women in Rangamati, the prevalence of iron deficiency was 42.0%, while gestational diabetes mellitus affected 18.0% of participants. Iron deficiency was independently associated with lower odds of gestational diabetes after adjustment for maternal age, body mass index, family history of diabetes, parity and educational status. Higher serum ferritin concentrations were associated with an increased prevalence of gestational diabetes, supporting previous evidence that excessive iron stores may contribute to impaired glucose metabolism during pregnancy. Maternal age of 30 years or above, overweight or obesity and a positive family history of diabetes emerged as significant independent predictors of gestational diabetes. These findings emphasize the importance of comprehensive antenatal screening that includes assessment of maternal nutritional status together with timely identification of women at increased metabolic risk. Because the present investigation employed a cross-sectional design, prospective cohort studies with larger sample sizes and repeated measurements of iron biomarkers are required to clarify the temporal relationship between maternal iron status and gestational

diabetes among tribal populations in Bangladesh.

RECOMMENDATIONS

1. Routine antenatal screening for gestational diabetes should be strengthened among tribal pregnant women, particularly those with advanced maternal age, overweight or obesity, or a family history of diabetes.
2. Maternal iron status should be evaluated using appropriate biochemical markers rather than hemoglobin alone whenever feasible.
3. Iron supplementation should continue to follow national and international recommendations while avoiding unnecessary excessive iron administration in women without deficiency.
4. Nutrition education programs should promote balanced dietary practices and adherence to antenatal supplementation.
5. Larger multicenter prospective studies should evaluate serum ferritin, hepcidin, soluble transferrin receptor, inflammatory biomarkers and dietary iron intake to better understand the relationship between iron metabolism and gestational diabetes.
6. Public health interventions should prioritize maternal health services for indigenous communities with limited access to specialized antenatal care.

ETHICAL CONSIDERATIONS

Ethical approval was obtained from the Institutional Review Board of the participating institution before commencement of the study. Written informed consent was obtained from all participants. Confidentiality was maintained throughout the study by using anonymous identification numbers and secure data storage. Women diagnosed with gestational diabetes, anemia or iron deficiency were referred for appropriate clinical management according to national guidelines. The study adhered to the ethical principles of the Declaration of Helsinki.

CONSENT TO PARTICIPATE

Written informed consent was obtained from all participants before enrollment.

CONSENT FOR PUBLICATION

All authors approved the final manuscript for publication.

AVAILABILITY OF DATA & MATERIALS

The datasets generated and analyzed during the study are available from the corresponding author upon reasonable request.

FUNDING

No external funding was received for this study.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

All authors contributed substantially to the conception and design of the study, data collection, statistical analysis, interpretation of results, manuscript preparation, critical revision of the manuscript and approval of the final version.

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