World Journal of Pharmaceutical Science and Research
www.wjpsronline.com
Research Article
ISSN: 2583-6579
SJIF Impact Factor: 5.111
Year - 2025
Volume: 4; Issue: 3
Page: 1547-1557

ANTHROPOMETRY, MORBIDITY & MORTALITY AMONG THE INFANTS OF DIABETIC MOTHERS IN A TERTIARY CARE CENTER

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Article Received: 22 May 2025 | | ***Article Revised: 12 June 2025*** | | ***Article Accepted: 03 July 2025***

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DOI: https://doi.org/10.5281/zenodo.15879764

How to cite this Article: Dr. Ankita Mishra, Dr. Suryakanta Swain, Dr. Srihari Umasankar Bramha, Dr. Subhalaxmi Sahoo, Dr. Ayush Behera (2025) ANTHROPOMETRY, MORBIDITY & MORTALITY AMONG THE INFANTS OF DIABETIC MOTHERS IN A TERTIARY CARE CENTER. World Journal of Pharmaceutical Science and Research, 4(3), 1547-1557. https://doi.org/10.5281/zenodo.15879764

ABSTRACT

Background: Diabetes mellitus in pregnancy, encompassing both gestational and pregestational diabetes, poses significant risks to fetal growth and neonatal outcomes. Infants of diabetic mothers (IDMs) are at increased risk of macrosomia, metabolic complications, and disproportionate anthropometric growth patterns. **Objective:** To evaluate and compare the anthropometric profiles and early neonatal outcomes of infants born to diabetic mothers with those born to non-diabetic mothers in a tertiary care setting. **Methods:** This was a cross-sectional observational study conducted at Government Theni Medical College and Hospital over a 12-month period. A total of 316 neonates were enrolled, including 79 IDMs and 237 controls. Anthropometric measurements including birth weight, length, head and chest circumference were recorded. The Ponderal Index (PI) was calculated. IDMs were monitored for hypoglycemia, hypocalcemia, polycythemia, and congenital anomalies. Statistical analysis was performed using SPSS version 16.0. **Results:** IDMs had significantly higher mean birth weight (3.09 ± 0.59 kg vs. 2.89 ± 0.42 kg) and PI (2.69 ± 0.33 vs. 2.45 ± 0.25; p = 0.003) compared to controls. The incidence of large for gestational age (LGA) infants was higher in the diabetic group (22.8%) versus controls (5.9%). Hypoglycemia was observed in 35.4% of IDMs, while 7.6% developed hypocalcemia. Cesarean delivery was more frequent among diabetic mothers (88.6%). **Conclusion:** Maternal diabetes significantly influences neonatal anthropometry and increases the risk of early metabolic complications. Routine antenatal screening, stringent glycemic control, and close neonatal monitoring are essential to optimize outcomes in diabetic pregnancies.

KEYWORDS: Infants of diabetic mothers, Ponderal Index, macrosomia, neonatal hypoglycemia, gestational diabetes mellitus, anthropometry.

INTRODUCTION

Diabetes mellitus (DM) is a major public health concern and one of the most prevalent medical disorders encountered during pregnancy. Its association with adverse maternal and perinatal outcomes has been well documented. The condition, when present during gestation, can be broadly classified into pregestational diabetes mellitus (PGDM)—which includes both type 1 and type 2 diabetes—and gestational diabetes mellitus (GDM), which is defined as glucose intolerance first recognized during pregnancy. While PGDM exposes the fetus to maternal hyperglycemia throughout pregnancy, GDM usually becomes apparent during the second or third trimester and may go undetected if not screened appropriately. The rise in the global prevalence of diabetes, including among women of reproductive age, has led to a parallel increase in the incidence of diabetes during pregnancy. This trend is particularly alarming in countries like India, which is often described as the "diabetes capital of the world."

The prevalence of GDM in India has been estimated at around 16.55%, significantly higher than in most Western countries where rates typically range between 6% and 7%.[1] Such high prevalence underscores the urgent need for effective screening strategies, early diagnosis, and proper antenatal management. GDM accounts for the majority (approximately 85%) of cases of diabetes during pregnancy, with PGDM accounting for the rest. Importantly, both forms of diabetes are associated with a wide range of complications that can compromise maternal well-being and affect fetal growth, neonatal adaptation, and long-term metabolic health.

Maternal hyperglycemia, especially when poorly controlled, adversely affects fetal development through a well-understood pathophysiological cascade. According to the widely accepted Pedersen Hypothesis, maternal glucose readily crosses the placenta, while insulin does not. As a result, maternal hyperglycemia leads to fetal hyperglycemia, which in turn stimulates the fetal pancreas to produce excessive amounts of insulin (fetal hyperinsulinemia). Insulin acts as a growth hormone in the fetus, promoting lipogenesis and deposition of glycogen, particularly in the liver, heart, and adipose tissue. This often results in disproportionate fetal growth, or macrosomia, which is typically characterized by increased weight with normal or near-normal length and head circumference.

Macrosomia is a key clinical feature among infants of diabetic mothers (IDMs), and it carries important implications. It increases the likelihood of birth complications such as shoulder dystocia, perineal trauma, and the need for operative delivery, including cesarean section. Furthermore, disproportionate growth, which can be evaluated using anthropometric indices such as the Ponderal Index (PI), is often associated with perinatal metabolic derangements. These include hypoglycemia, hypocalcemia, polycythemia, hyperbilirubinemia, and respiratory complications such as respiratory distress syndrome (RDS). These conditions may require immediate medical attention and NICU admission, placing a burden on healthcare resources and increasing emotional and financial stress for families.

While the effects of maternal diabetes on fetal growth and neonatal outcomes have been extensively studied in high-income countries, there is limited region-specific data available from India, particularly in resource-limited settings and rural populations. Existing studies often vary in methodology, diagnostic criteria, and healthcare infrastructure, which limits their generalizability. Moreover, social, cultural, and economic factors unique to Indian settings, such as delayed diagnosis due to lack of universal screening and reduced access to tertiary care during pregnancy, may significantly influence both maternal and neonatal outcomes. Hence, there is a critical need to generate robust, locally relevant data to better understand the burden of disease and to inform evidence-based antenatal and neonatal care.

Anthropometric parameters such as birth weight, length, head circumference, chest circumference, and the derived Ponderal Index serve as simple, yet powerful, tools to assess intrauterine growth and predict neonatal risk. The PI, calculated as weight in grams divided by length in centimeters cubed (×100), helps identify disproportionate growth and can be a useful indicator of the fetus's exposure to a hyperglycemic intrauterine environment. Discrepancies in measurements such as reduced head–chest circumference difference or an increased PI may be early markers of underlying metabolic alterations, including insulin-mediated growth patterns.

In addition to anthropometry, a significant proportion of IDMs develop metabolic complications during the early neonatal period. Hypoglycemia, occurring in up to 50% of IDMs, is a consequence of fetal hyperinsulinemia and can manifest within the first few hours of life. If not identified and managed promptly, it may result in neurodevelopmental impairment. Other complications such as hypocalcemia, polycythemia, and hyperbilirubinemia also occur more frequently in these infants due to altered maternal-fetal nutrient exchange and hormonal imbalances. Respiratory distress due to delayed surfactant production and increased risk of congenital anomalies, particularly involving the cardiovascular and central nervous systems, further add to the complexity of clinical management in this vulnerable population.

Given the increasing prevalence of diabetes in pregnancy and the consequent rise in neonates at risk, there is an urgent need for systematic studies examining the spectrum of anthropometric and metabolic alterations in IDMs. Furthermore, by comparing neonates born to diabetic and non-diabetic mothers within the same institution and healthcare setting, meaningful insights can be gained into the relative risks, patterns of growth, and burden of neonatal complications.

The present study was undertaken at a tertiary care institution in South India to evaluate the anthropometric profile, morbidity, and mortality among infants born to diabetic mothers. The primary objective was to compare the Ponderal Index of neonates born to mothers with diabetes mellitus to those of neonates born to non-diabetic mothers. Secondary objectives included the assessment of the frequency and types of neonatal complications, including hypoglycemia, hypocalcemia, hyperbilirubinemia, and congenital anomalies, among the infants of diabetic mothers. Through this study, we aim to provide a comprehensive evaluation of the impact of maternal diabetes on neonatal outcomes and contribute region-specific evidence that can help guide clinical practices, screening strategies, and healthcare policies in India and other similar low-resource settings.

MATERIALS AND METHODS

Study Design and Setting

This was an observational cross-sectional study conducted in the Departments of Obstetrics and Paediatrics (Neonatology Unit) at Hitech Medical College and Hospital, Bhubaneswar, a tertiary care teaching hospital in Capital city Bhubaneswar. The study was carried out over a period of 12 months, from September 2023to August 2024.

Study Population

The study included all live-born neonates delivered to mothers diagnosed with either gestational diabetes mellitus (GDM) or pregestational diabetes mellitus (PGDM) during the study period. The diagnosis of GDM or PGDM was established based on standard ADA and DIPSI guidelines. For comparative purposes, neonates born to non-diabetic mothers during the same time frame were included as controls.

Inclusion Criteria

- All live-born infants of diabetic mothers (both GDM and PGDM)
- Gestational age ≥28 weeks

Exclusion Criteria

- Neonates born before 28 weeks of gestation.
- Multiple gestations.
- Neonates who died within the first 24 hours of life.
- Mothers with co-existing medical conditions such as hypothyroidism or hypertension.

Control Selection

For each infant of a diabetic mother (IDM) enrolled in the study, the next 5th, 10th, and 15th babies born to non-diabetic mothers were selected as controls to ensure randomization and eliminate selection bias.

Data Collection Procedure

After obtaining informed written consent from the parents, data were collected using a structured proforma. Maternal data including age, gravidity, type and duration of diabetes, treatment history, antenatal complications, and mode of delivery were collected from hospital records.

At birth, each neonate underwent a thorough clinical examination to assess gestational age, anthropometric parameters, and the presence of congenital anomalies. The following anthropometric measurements were recorded after 24 hours of life:

- Birth Weight**:** Measured using an electronic weighing scale to the nearest 10 grams.
- Crown–Heel Length**:** Measured to the nearest 0.1 cm using an infantometer.
- Head Circumference**:** Measured at the level of the occipital protuberance and supraorbital ridges using a non-stretchable measuring tape.
- Chest Circumference**:** Measured at the level of the nipples during quiet respiration.

From these measurements, the Ponderal Index (PI) was calculated using the formula:

$$\mathbf{PI = (Weight\ in\ grams \times 100) / (Length\ in\ cm)^3}$$

Investigations and Monitoring

All infants of diabetic mothers underwent the following investigations:

- **Blood Glucose:** Measured at 1, 2, 3, 6, 12, 24, 36, and 48 hours of life. Hypoglycemia was defined as a blood glucose level <40 mg/dL.
- **Hematocrit:** Measured at 1 and 24 hours. Polycythemia was defined as a venous hematocrit >65%.
- **Serum Calcium:** Measured between 24–72 hours of life. Hypocalcemia was defined as total serum calcium <7 mg/dL.
- **Serum Bilirubin:** Measured on day 4–5 or earlier if clinically indicated. Hyperbilirubinemia was assessed based on AAP nomograms.
- **Echocardiography:** Performed between 24–72 hours of life to detect congenital heart defects.

Outcome Measures

The primary outcome was the comparison of Ponderal Index between neonates born to diabetic and non-diabetic mothers. Secondary outcomes included the incidence of metabolic complications (hypoglycemia, hypocalcemia), hematologic abnormalities (polycythemia), congenital anomalies, and neonatal morbidity and mortality.

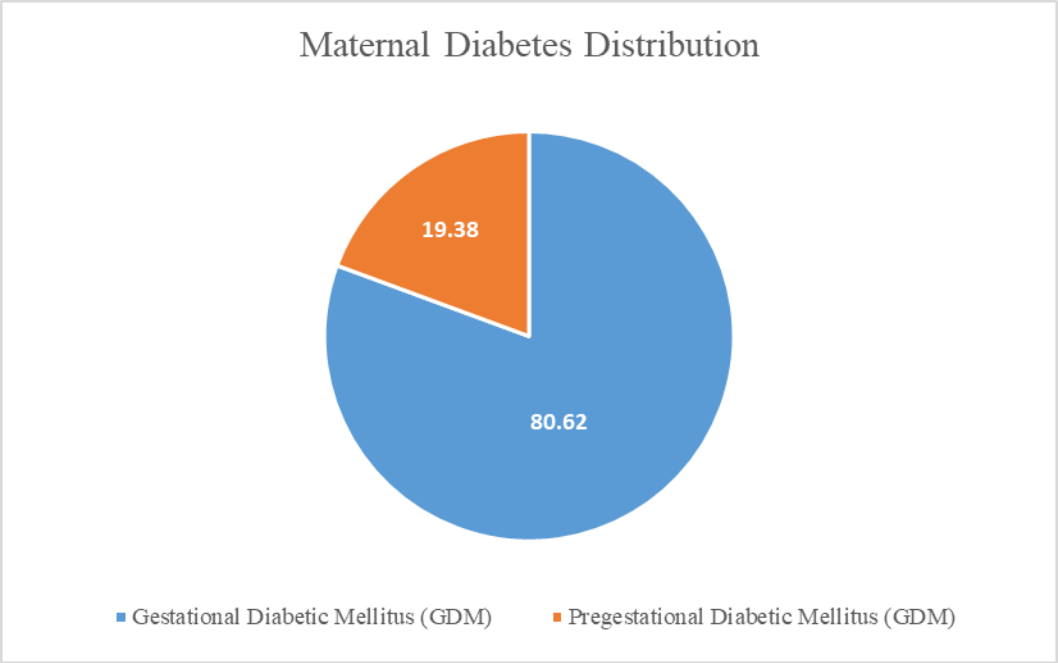
Statistical Analysis

Data were analyzed using SPSS version 23.0. Continuous variables were presented as mean ± standard deviation (SD) and compared using the unpaired t-test or Mann–Whitney U test, depending on distribution. Categorical variables were expressed as frequencies and percentages, and comparisons were made using the Chi-square test. A p-value <0.05 was considered statistically significant.

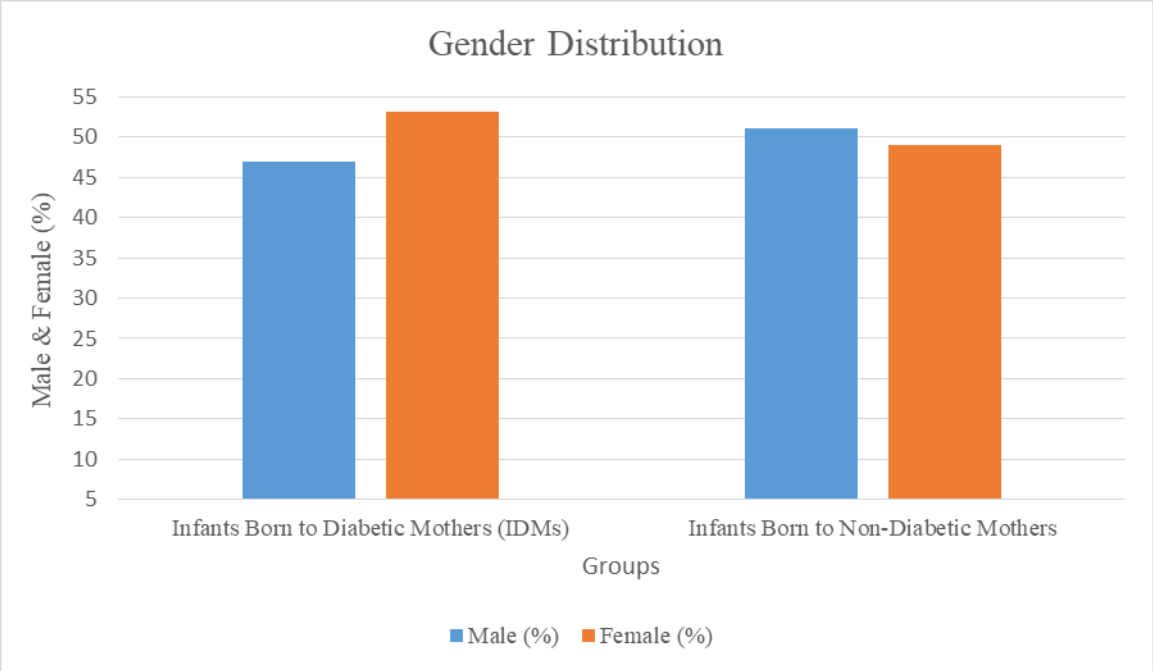
RESULTS

A total of 316 neonates were included in this cross-sectional observational study. Of these, 79 neonates were born to mothers with diabetes mellitus (either gestational or pregestational) and were categorized as infants of diabetic mothers (IDMs), while the remaining 237 neonates born to non-diabetic mothers served as the control group.

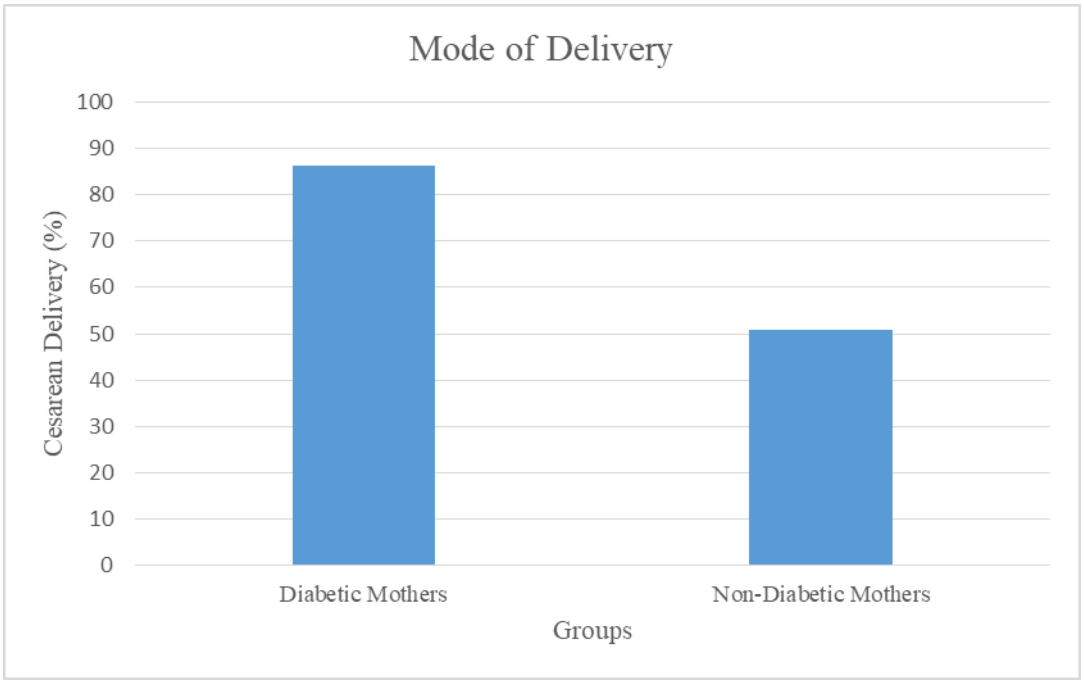
Among the 79 diabetic mothers, 63 (80.62%) had Gestational Diabetes Mellitus (GDM) and 16 (19.38%) had Pregestational Diabetes Mellitus (PGDM). This highlights the predominance of GDM as the most common type of diabetes encountered in pregnancy in the present study.



Gender-wise analysis revealed no statistically significant difference in sex distribution between the two groups. Among IDMs, 39 (49.4%) were males and 40 (50.6%) were females. In the control group, 128 (54%) were males and 109 (46%) were females ($p = 0.535$), indicating that maternal diabetes did not influence fetal sex ratio.

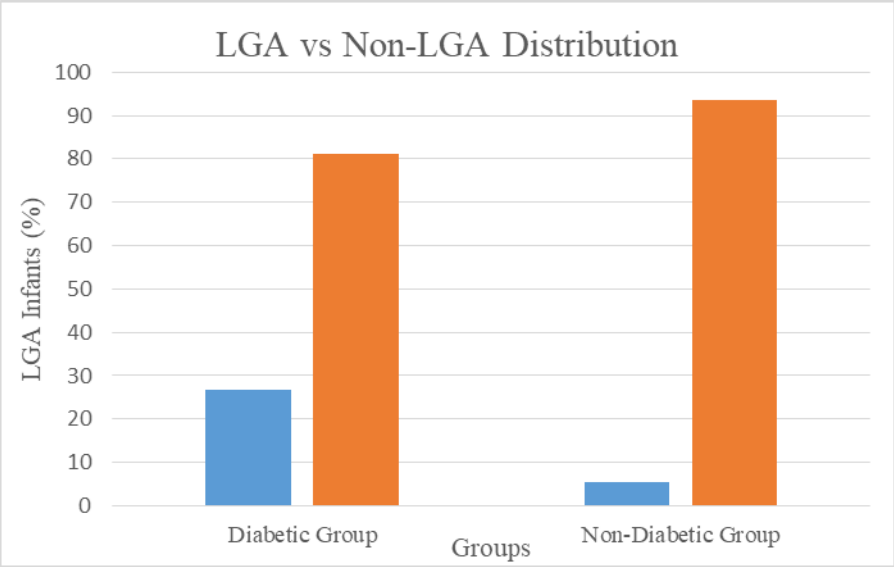


History of previous fetal and neonatal losses was significantly more frequent among diabetic mothers compared to non-diabetic mothers. In the diabetic group, only 49 out of 79 mothers (62%) had no prior adverse obstetric history, whereas 200 out of 237 (84.4%) of non-diabetic mothers reported no losses. The remaining diabetic mothers had varied histories of abortion, intrauterine death (IUD), or neonatal death, indicating a higher background risk of adverse reproductive outcomes in diabetic pregnancies. The incidence of cesarean section (LSCS) was significantly higher among diabetic mothers. Out of 79 IDMs, 70 (88.6%) were delivered via LSCS, whereas only 9 (11.4%) had vaginal deliveries. In contrast, in the control group, 126 (53.2%) underwent LSCS, and 111 (46.8%) had vaginal deliveries. This difference underscores the increased obstetric interventions required in diabetic pregnancies, often due to complications such as fetal macrosomia, polyhydramnios, or preeclampsia.



Birth order analysis showed that the majority of IDMs were either first or second born. Specifically, 24 (30.4%) were first-borns, and 30 (38%) were second-borns. This pattern was comparable to the control group, which had a similar distribution with a predominance of first and second births.

The proportion of infants classified as Large for Gestational Age (LGA**)** was significantly higher among IDMs. In the diabetic group, 18 (22.8%) neonates were LGA, compared to 14 (5.9%) in the non-diabetic group. This confirms the well-established association between maternal hyperglycemia and fetal macrosomia.



Anthropometric Outcomes

The primary objective of the study was to evaluate anthropometric differences, particularly Ponderal Index (PI), between IDMs and non-IDMs.

Sl. No.	Parameter	IDMs (n=79)	Non-IDMs (n=237)	p-value	Interpretation
1	Ponderal Index (PI)	2.69 ± 0.33	2.45 ± 0.25	0.003	**Significant**
2	Birth Weight (kg)	3.09 ± 0.59	2.89 ± 0.42	0.001	**Significant**
3	Length (cm)	48.22 ± 2.8	48.78 ± 1.7	0.036	**Significant**
4	Chest Circumference (cm)	32.28 ± 2.3	30.63 ± 1.8	0.155	Not Significant
5	Head Circumference (cm)	33.01 ± 1.54	32.96 ± 1.25	0.778	Not Significant
6	HC–CC Difference (cm)	0.72 ± 1.5	2.3 ± 1.5	0.001	**Significant**

The mean PI of IDMs was significantly higher than that of non-IDMs ($p = 0.003$), reflecting disproportionate fetal growth, particularly increased fat deposition relative to length. Mean birth weight was also significantly higher in IDMs ($p = 0.001$), while the mean length was slightly lower, further contributing to increased PI. Head–chest circumference difference was significantly reduced in IDMs, reinforcing the observation of disproportionate macrosomia.

However, there were no significant differences in chest circumference or head circumference when considered independently between the two groups.

The study evaluated a range of neonatal complications frequently associated with diabetic pregnancies. Out of 79 IDMs, 28 neonates (35.4%) developed hypoglycemia (defined as blood glucose <40 mg/ dl). The incidence was higher

among LGA infants (44%) compared to non-LGA (32%), although this was not statistically tested. This high incidence reflects the fetal hyperinsulinemic state caused by maternal hyperglycemia.

A total of 6 infants (7.6%) in the diabetic group developed hypocalcemia (serum calcium <7 mg/dL), and it was more frequently observed in LGA neonates (11.1%) than in non-LGA ones (6.5%). 11 infants (13.9%) of diabetic mothers were diagnosed with polycythemia, defined as hematocrit >65%. This is consistent with fetal hypoxia-induced erythropoiesis, a common consequence of poor maternal glycemic control.

Hyperbilirubinemia was documented in 9 (11.4%) IDMs, mostly of mild to moderate severity. All cases were managed successfully with phototherapy, and none required exchange transfusion.

Echocardiographic screening revealed 3 cases (3.8%) of congenital heart anomalies among IDMs, underscoring the importance of routine early cardiac evaluation in this high-risk group.

Sl. No.	Complication	Number of Cases	Percentage (%)
1	Hypoglycemia	28	35.44
2	Hypocalcemia	6	7.6
3	Polycythemia	11	13.9
4	Hyperbilirubinemia	9	11.4
5	Congenital Heart Disease	3	3.8

Neonatal Mortality

Only **one neonatal death** was recorded among the IDMs during the study period. The overall neonatal survival rate was high, likely reflecting improved perinatal care, early diagnosis, and prompt management of complications in the current clinical setting.

DISCUSSION

This study was conducted to assess and compare the anthropometric parameters, morbidity, and immediate outcomes among infants of diabetic mothers (IDMs) versus those born to non-diabetic mothers. Our findings show that infants born to diabetic mothers are significantly more likely to be macrosomic, have higher Ponderal Index (PI), and exhibit greater neonatal complications including hypoglycemia, hypocalcemia, and polycythemia.

The Ponderal Index, which reflects disproportionate growth due to increased adipose tissue deposition relative to linear growth, was significantly higher in IDMs (2.69 ± 0.33) than in the control group (2.45 ± 0.25). These findings reinforce the "hyperinsulinemic macrosomia" hypothesis proposed by Pedersen.[1], where maternal hyperglycemia results in fetal hyperinsulinemia, driving lipogenesis and increased soft tissue growth.A recent Indian study by Deshpande et al. (2020) from Maharashtra corroborates these findings, reporting higher Ponderal Index and birth weight in neonates born to mothers with GDM compared to those born to normoglycemic mothers.[2] Similarly, Goyal et al. (2021), in a prospective study from North India, observed significantly increased PI and abdominal circumference in IDMs, highlighting the importance of monitoring for asymmetric growth.[3] However, some studies from low-resource settings, such as that by Ramachandran et al. (2014), noted only marginal increases in PI among GDM infants, likely due to undernutrition and delayed detection of maternal hyperglycemia.[4]

Our study observed 22.8% incidence of large for gestational age (LGA) neonates among IDMs, markedly higher than the 5.9% seen in controls. Similar figures have been reported in the study by Rajput et al. (2015) from Rohtak, where

LGA incidence was 26% in GDM pregnancies versus 7.2% in non-GDM pregnancies.[5] A multicentric cohort study by Seshiah et al. (2012) from Tamil Nadu also found that LGA was significantly higher in poorly controlled GDM, underlining the importance of tight glycemic control.[6] Contrastingly, a study by Bhat et al. (2019) from Karnataka found a lower prevalence of macrosomia (16%), attributing it to early diagnosis and improved antenatal glucose monitoring protocols.[7]

Our findings also show significantly higher mean birth weights in the IDM group (3.09 ± 0.59 kg) compared to controls (2.89 ± 0.42 kg), consistent with the results of Sharma et al. (2020), who found an average birth weight difference of 0.3 kg between diabetic and non-diabetic pregnancies in a tertiary center in Delhi.[8] Similar findings have been echoed in the studies by Mamatha et al. (2016) from Andhra Pradesh and by Bharati et al. (2021), who showed that infants of poorly controlled GDM mothers weighed significantly more than those of euglycemic mothers.[9,10]

Hypoglycemia was observed in 35.4% of IDMs in our study, which aligns with the findings of Kiran et al. (2021) from Hyderabad, who reported an incidence of 32.6% and emphasized early feeding as a key preventive strategy.[11] Likewise, Nanda et al. (2019) from West Bengal reported hypoglycemia in 38% of IDMs, with a significant association between neonatal hypoglycemia and maternal HbA1c >6.5%.[12]

Hypocalcemia was noted in 7.6% of IDMs in our cohort. This is consistent with the 6–10% range reported in Indian studies by Sudhakar et al. (2018) and Kumar et al. (2016), which highlight the transient suppression of neonatal parathyroid hormone secretion secondary to maternal hyperglycemia.[13,14]

Polycythemia was not systematically quantified in this study but observed in some LGA neonates. Similar associations have been noted in prior Indian studies where fetal hyperinsulinemia and hypoxia resulted in increased erythropoiesis and subsequent hyperviscosity syndromes.[15]

Our study reported a caesarean delivery rate of 88.6% among diabetic mothers, much higher than in controls. A study from PGIMER, Chandigarh by Gupta et al. (2020) reported a similar high rate (82%) among GDM mothers, primarily due to obstetric indications such as macrosomia, polyhydramnios, and failed induction.[16] However, lower rates have been noted in centers with strict glucose targets and adherence to induction protocols, such as those reported by Seshiah et al. (2014), where GDM-related caesarean rates were under 60%.[6]

CONCLUSION

This study highlights the significant impact of maternal diabetes—both gestational and pregestational—on neonatal anthropometry and early neonatal outcomes. Infants born to diabetic mothers were found to have a higher mean birth weight and Ponderal Index compared to those born to non-diabetic mothers, indicating disproportionate intrauterine growth. The incidence of large for gestational age (LGA) babies was also significantly higher among the diabetic cohort, increasing the risk of delivery complications and postnatal morbidity.

In addition to altered anthropometric parameters, infants of diabetic mothers exhibited a greater prevalence of metabolic complications such as hypoglycemia and hypocalcemia, particularly among those with disproportionate growth. These findings underscore the importance of meticulous antenatal screening, strict glycemic control, and targeted neonatal surveillance.

While advances in obstetric and neonatal care have reduced overall morbidity and mortality in infants of diabetic mothers, this study reaffirms that such pregnancies continue to be high-risk and require multidisciplinary management. Early identification, timely intervention, and sustained maternal education are critical to improving perinatal outcomes in this vulnerable population.

Limitations

This study was conducted at a single tertiary care center, which may limit the generalizability of the findings to broader populations, especially those from rural or primary care settings with limited resources.

The study focused only on immediate neonatal outcomes within the first 72 hours of life. Long-term complications and developmental outcomes, which are particularly relevant in infants of diabetic mothers, were not evaluated.

The degree of maternal glycemic control during pregnancy was not consistently quantified (e.g., serial HbA1c values), which could have helped in correlating metabolic control with neonatal outcomes.

The relatively small number of infants of diabetic mothers (n=79) may limit the statistical power to detect less common complications or sub-group differences (e.g., between GDM and PGDM).

While efforts were made to exclude mothers with co-morbidities like hypertension or hypothyroidism, other maternal factors such as obesity, socioeconomic status, and dietary practices were not adjusted for, which may have influenced neonatal anthropometry.

RECOMMENDATIONS

All pregnant women, especially in high-risk populations like India, should undergo universal screening for gestational diabetes mellitus (GDM) preferably in the first trimester and again at 24–28 weeks, as per DIPSI or IADPSG criteria. Early diagnosis enables timely intervention.

Optimal glycemic control must be maintained throughout pregnancy using diet, insulin, or oral hypoglycemic agents as indicated. Regular monitoring of blood glucose and HbA1c levels is essential to reduce the risk of macrosomia and neonatal metabolic complications.

Serial antenatal ultrasonography should be employed to monitor fetal growth parameters, particularly abdominal circumference and estimated fetal weight, to identify early signs of disproportionate growth and plan delivery accordingly.

Infants of diabetic mothers should be closely monitored for hypoglycemia, hypocalcemia, polycythemia, and hyperbilirubinemia during the first 48–72 hours. Early initiation of breastfeeding or appropriate supplementation should be ensured to prevent hypoglycemic episodes.

Routine measurement of neonatal anthropometric indices such as Ponderal Index and MAC/HC ratio should be considered in high-risk neonates to identify disproportionate growth, which may serve as an early marker for neonatal morbidity.

A coordinated approach involving obstetricians, endocrinologists, dieticians, and neonatologists is essential in the management of diabetic pregnancies to optimize both maternal and neonatal outcomes.

Infants of diabetic mothers should undergo regular developmental and metabolic follow-up, particularly those with macrosomia or metabolic instability, to detect early signs of obesity, insulin resistance, or neurodevelopmental delays.

Public health initiatives should focus on educating women of reproductive age about the risks of diabetes in pregnancy and the importance of preconception glucose control in known diabetics to reduce congenital anomalies and adverse outcomes.

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