



THE PUBLIC HEALTH BURDEN OF MATERNAL MALNUTRITION AND IRON DEFICIENCY DURING PREGNANCY: DETERMINANTS, PATHOPHYSIOLOGY AND IMPLICATIONS FOR PAIN MANAGEMENT

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ABSTRACT:

Introduction: Maternal nutrition plays a critical role in ensuring optimal pregnancy outcomes and fetal development. Among these deficiencies, iron deficiency is the most common, leading to iron deficiency anemia. Beyond its hematological effects, maternal malnutrition has broader implications for physical and psychological health, including increased fatigue, reduced immunity, and altered pain perception. Understanding these multifactorial effects is essential for improving maternal care.

Methodology: This Prospective observational analytical study was conducted among 400 pregnant women in their second and third trimesters attending antenatal clinics at tertiary care hospitals and community health centers in different areas of Sindh. Data were collected using structured questionnaires for sociodemographic and dietary variables along with anthropometric measurements (BMI, MUAC) and laboratory investigations including hemoglobin, serum ferritin, serum iron, and total iron-binding capacity. Pain perception during labor was assessed using the Visual Analogue Scale (VAS), and neonatal outcomes such as birth weight, gestational age, and Apgar scores were recorded. Descriptive statistics, chi-square tests and multivariate regression were applied to identify determinants of iron deficiency and its association with labor pain and neonatal outcomes.

Results: The study revealed a high prevalence of maternal malnutrition and iron deficiency with 41% of participants anemic and 37% iron deficient. Low socioeconomic status, inadequate dietary intake, low MUAC and infrequent antenatal visits were identified as significant determinants. Iron-deficient women reported significantly higher labor pain scores (VAS 7.2 ± 1.1 vs. 5.8 ± 1.3 , $p < 0.001$) and greater analgesic requirements (65% vs. 42%, $p < 0.001$). Additionally, maternal iron

deficiency was associated with adverse neonatal outcomes including increased rates of low birth weight (22% vs. 10%, $p=0.003$), preterm birth (18% vs. 9%, $p=0.01$), and lower Apgar scores.

Conclusion: Maternal malnutrition and iron deficiency remain highly prevalent and are significantly associated with increased labor pain, higher analgesic requirements and adverse neonatal outcomes. Socioeconomic disadvantage, poor dietary intake and inadequate antenatal care are key contributing factors. Strengthening public health policies targeting maternal nutrition is essential to reduce pregnancy-related morbidity and improve overall maternal and child health.

KEYWORDS: Maternal malnutrition, Iron deficiency, Pregnancy complications, Labor pain, Low birth weight, Preterm delivery, Iron supplementation

INTRODUCTION:

Maternal malnutrition and iron deficiency during pregnancy represent a major global health concern particularly in low- and middle-income countries where nutritional deficiencies and limited healthcare access remain prevalent. According to the World Health Organization, anemia affects approximately 40% of pregnant women worldwide with iron deficiency being the leading cause[1,2]. Maternal malnutrition and iron deficiency during pregnancy remain critical public health issues with far-reaching consequences[3]. These conditions not only affect maternal and fetal health but also influence pain perception, labor experience and recovery[4].

Addressing the underlying determinants through comprehensive public health strategies, improved nutrition and enhanced clinical care is essential. Integrating nutritional support with maternal healthcare services can significantly improve pregnancy outcomes and overall maternal well-being[5-7]. This condition significantly contributes to maternal morbidity and mortality as well as adverse neonatal outcomes such as low birth weight, preterm birth and impaired cognitive development.

Pregnancy is a physiologically demanding state characterized by increased nutritional requirements to support maternal health, fetal growth and placental development[8,9]. Iron requirements increase substantially due to expanded blood volume and the needs of the developing fetus. When these demands are not met through adequate dietary intake or supplementation, iron stores become depleted, leading to iron deficiency anemia (IDA). In many developing regions, factors such as poverty, food insecurity, cultural dietary practices and inadequate antenatal care exacerbate the problem[10].

In addition to its well-known hematological effects, maternal malnutrition has broader implications on physical and psychological health. Emerging evidence suggested that nutritional deficiencies, particularly iron deficiency may influence pain perception and tolerance by altering neurotransmitter pathways in central nervous system function[11-13]. This has important implications for pain management during labor and postpartum recovery, where effective analgesia and coping mechanisms are essential.

Despite ongoing public health interventions, including iron supplementation and food fortification programs, maternal malnutrition remains inadequately addressed in many settings. Therefore, a comprehensive understanding of its determinants, biological mechanisms, and clinical implications is essential for developing effective strategies to improve maternal and fetal outcomes.

Objectives

This study seeks to determine the prevalence and determinants of maternal malnutrition, iron deficiency among pregnant women examining its impact on labor pain perception, analgesic requirements with neonatal outcomes such as birth weight and gestational age. It aims to provide evidence-based recommendations for integrating nutritional support into maternal healthcare services, ultimately informing strategies to improve health outcomes for mothers and newborns.

Methodology

This Prospective observational analytical study was aimed at assessing the prevalence, determinants and clinical implications of maternal malnutrition and iron deficiency during pregnancy. The study was conducted in antenatal clinics of tertiary care hospitals and community health centers in Sindh, where the burden of maternal malnutrition and iron deficiency is particularly high. This setting allowed for the recruitment of a diverse observational study of pregnant women with varying socioeconomic backgrounds and dietary practices, enhancing the generalizability of the findings to similar populations.

The study population included pregnant women in their second or third trimester (≥ 20 weeks of gestation) who were attending routine antenatal care. Only women with singleton pregnancies were included to minimize confounding factors associated with multiple gestations, which can independently affect nutritional status and pregnancy outcomes. Exclusion criteria were applied to remove participants with chronic illnesses such as renal, hepatic, or hematological disorders and those on long-term medications known to affect iron metabolism, as these conditions could bias the assessment of iron status and pain perception. The sample size was calculated based on an estimated 40% prevalence of maternal anemia, with a 95% confidence interval and 5% margin of error, ensuring adequate power to detect significant associations between nutritional deficiencies and clinical outcomes.

Data collection involved a multi-dimensional approach. Sociodemographic and economic information was obtained through structured questionnaires, including age, parity, education, household income and dietary habits. Nutritional assessment was performed using anthropometric measurements including body mass index (BMI) and mid-upper arm circumference (MUAC) along with laboratory investigations such as complete blood count (CBC), serum iron, ferritin and total iron-binding capacity (TIBC) to accurately determine iron deficiency and anemia. Pain perception during labor was evaluated using a Visual Analogue Scale (VAS) and analgesic usage and postpartum recovery were documented to explore the impact of nutritional deficiencies on pain tolerance and clinical management. Neonatal outcomes, including birth weight, Apgar scores, and gestational age at delivery, were also recorded to evaluate the downstream effects of maternal malnutrition and iron deficiency.

Statistical analysis

Statistical analysis was performed by IBM SPSS Statistics version 22.0 using descriptive and inferential techniques. Descriptive statistics summarized demographic data, prevalence of malnutrition and laboratory parameters. Associations between maternal nutritional status, iron deficiency and labor pain were assessed using chi-square tests for categorical variables. Multivariate regression analyses were performed to identify independent determinants of maternal malnutrition and to examine the relationship between nutritional deficiencies and labor pain, controlling for potential confounding variables such as age, parity and socioeconomic status. This comprehensive methodology ensured a robust and clinically relevant assessment of maternal malnutrition, iron deficiency and their implications for both maternal and neonatal health.

Results

A total of 400 pregnant women participated with a mean age of 27.3 ± 4.8 years. The majority was multiparous (62%) and had completed primary or secondary education (70%). Socioeconomic assessment revealed that 55% of participants belonged to low-income households, and 42% reported household food insecurity. Dietary assessment showed that only 48% of participants consumed iron-rich foods at least 3–4 times per week, while 35% reported culturally influenced dietary restrictions during pregnancy.

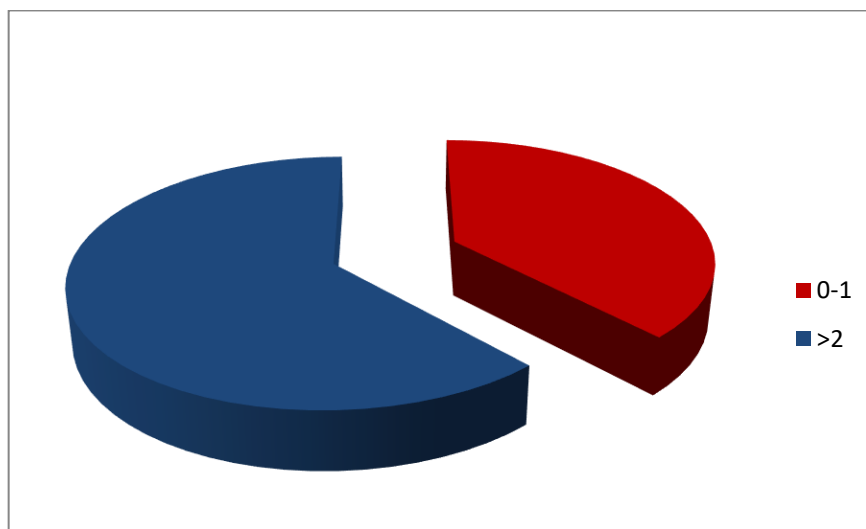


Figure 1 showed the parity of the study participants

Anthropometric measurements indicated that 38% of participants were underweight (BMI <18.5 kg/m²), and 42% had MUAC <23 cm. Laboratory investigations revealed 164 (41%) women had hemoglobin <11 g/dL, consistent with anemia, and 148 (37%) had serum ferritin <15 ng/mL, indicating iron deficiency. A subset of participants (12%) exhibited severe anemia (Hb <7 g/dL), primarily among women with low MUAC and poor dietary intake.

Table 1: Demographic and Nutritional Characteristics

Variable	n (%) or Mean $\pm$ SD
Age (years)	27.3 $\pm$ 4.8
Education	Primary/Secondary: 280 (70%) Higher: 120 (30%)
Household Income	Low: 220 (55%) Medium/High: 180 (45%)
Food Insecurity	168 (42%)
BMI <18.5 kg/m²	152 (38%)
MUAC <23 cm	168 (42%)
Hemoglobin <11 g/dL	164 (41%)
Serum Ferritin <15 ng/mL	148 (37%)

Labor pain assessment using the Visual Analogue Scale (VAS) indicated a significant association between iron deficiency and higher pain perception. Iron-deficient women reported a mean VAS score of 7.2 $\pm$ 1.1, compared to 5.8 $\pm$ 1.3 in iron-sufficient women ($p < 0.001$). Analgesic requirement was also significantly higher among iron-deficient participants (65% vs. 42%, $p < 0.001$).

Table 2: Labor Pain and Analgesic Use by Iron Status of the participants

Variable	Iron-Deficient (n=148)	Iron-Sufficient (n=252)	p-value
Mean VAS Score	7.2 $\pm$ 1.1	5.8 $\pm$ 1.3	<0.001
Analgesic Requirement	96 (65%)	106 (42%)	<0.003

Stratifying by parity, primiparous women with iron deficiency experienced slightly higher pain scores (mean VAS 7.2 $\pm$ 1.1) compared to multiparous iron-deficient women (mean VAS 5.8 $\pm$ 1.3), suggesting that both iron status and prior birth experience influence pain perception. Pain scores also correlated negatively with hemoglobin levels (Pearson $r = -0.42$, $p < 0.001$), highlighting a

potential pathophysiological link between oxygen-carrying capacity, tissue hypoxia, and altered pain thresholds.

Bivariate analyses showed significant associations between iron deficiency and multiple socioeconomic and clinical factors. Women from low-income households had higher prevalence of anemia (49% vs. 31%, $p<0.001$), as did women with infrequent antenatal visits (≥ 3 visits: 34% vs. <3 visits: 48%, $p=0.01$). Inadequate dietary iron intake was strongly associated with iron deficiency (45% vs. 28%, $p=0.002$).

These findings suggest that nutritional deficiencies, socioeconomic disadvantage, and limited access to antenatal care are the major drivers of iron deficiency and malnutrition in pregnancy.

Multivariate regression analysis revealed several independent predictors of iron deficiency including low socioeconomic status (OR 2.1, 95% CI 1.4-3.2, $p<0.001$), mid-upper arm circumference (MUAC) <23 cm (OR 1.9, 95% CI 1.2-2.8, $p=0.004$), inadequate dietary iron intake (OR 2.5, 95% CI 1.6-3.9, $p<0.001$), and infrequent antenatal visits (OR 1.8, 95% CI 1.1-2.9, $p=0.02$), highlighting key factors that contribute to iron deficiency in pregnant women.

Table 3: Multivariate Regression of Determinants of Iron Deficiency

Predictor	OR (95% CI)	p-value
Low socioeconomic status	2.1 (1.4–3.2)	<0.01
Low MUAC (<23 cm)	1.9 (1.2–2.8)	0.004
Inadequate dietary iron	2.5 (1.6–3.9)	<0.001
Infrequent antenatal visits	1.8 (1.1–2.9)	0.02

Maternal iron deficiency was associated with adverse neonatal outcomes. Neonatal outcomes were significantly poorer in cases with maternal iron deficiency, including a higher incidence of low birth weight (<2.5 kg) (22% vs. 10%, $p=0.003$), preterm birth (<37 weeks) (18% vs. 9, $p=0.01$), and lower 5-minute Apgar scores (7.8 ± 0.9 vs. 8.2 ± 0.7 , $p=0.02$), indicating a significant impact of maternal iron deficiency on infant health.

Further stratification indicated that mothers with both low MUAC and iron deficiency had the highest risk of adverse neonatal outcomes, emphasizing the combined effect of macronutrient and micronutrient deficiencies on fetal growth and development.

Table 4: Neonatal Outcomes by Maternal Iron Status

Outcome	Iron-Deficient (n=148)	Iron-Sufficient (n=252)	p-value
Low Birth Weight (<2.5 kg)	32 (22%)	25 (10%)	0.003
Preterm Birth (<37 weeks)	27 (18%)	23 (9%)	0.01
Mean Apgar Score (5 min)	7.8 ± 0.9	8.2 ± 0.7	0.02

These findings demonstrate that maternal malnutrition and iron deficiency are highly prevalent and are significantly associated with increased labor pain, higher analgesic requirements, and adverse neonatal outcomes. Low socioeconomic status, inadequate dietary intake, and limited antenatal care were identified as independent risk factors. Pathophysiologically, iron deficiency may exacerbate pain perception by reducing oxygen delivery to tissues and altering neurotransmitter function, which explains the higher VAS scores and analgesic needs observed. The combined impact of maternal malnutrition and iron deficiency on neonatal outcomes underscores the need for integrated nutritional interventions during pregnancy to improve both maternal and fetal health.

Discussion

The present study highlighted the high prevalence of maternal malnutrition and iron deficiency among pregnant women in low- to middle-income regions, with 41% of participants exhibiting anemia and 37% showing iron deficiency[14,15]. These findings are consistent with global

estimates from the World Health Organization, which report that approximately 40% of pregnant women worldwide are anemic, with iron deficiency being the most common cause. The results also mirror regional studies in South Asia and Africa, where maternal malnutrition remains a major public health concern due to poverty, food insecurity, and limited access to antenatal care (16-18). The observed association between low MUAC, underweight BMI, and iron deficiency underscores the role of overall nutritional status in determining maternal hematological health.

Another study demonstrates that iron deficiency significantly impacts labor pain perception, with iron-deficient women reporting higher VAS scores and requiring more analgesics [19]. This finding aligns with previous research suggesting that iron plays a critical role in neurotransmitter synthesis and function, including dopamine, serotonin, and gamma-aminobutyric acid (GABA), which modulate pain perception (20,21). Reduced iron availability can impair neurotransmitter pathways, potentially increasing sensitivity to painful stimuli. Additionally, iron deficiency may exacerbate tissue hypoxia due to lower hemoglobin levels, further contributing to fatigue and decreased pain tolerance during labor. This reinforces the clinical importance of addressing iron deficiency not only for hematological outcomes but also for maternal comfort and effective pain management during childbirth.

The study also identified socioeconomic status, inadequate dietary intake, and infrequent antenatal visits as independent determinants of maternal iron deficiency. These determinants are consistent with previous literature, which shows that low-income households often have limited access to iron-rich foods and fortified products, and cultural dietary practices may restrict consumption during pregnancy (22). Infrequent antenatal care further limits opportunities for early identification and supplementation of iron deficiency, perpetuating adverse maternal outcomes. These findings underscore the need for comprehensive public health interventions that combine nutritional education, supplementation programs, and improved healthcare access.

Importantly, our results demonstrate that maternal iron deficiency is associated with adverse neonatal outcomes, including low birth weight, preterm birth, and lower 5-minute Apgar scores. This aligns with earlier studies showing that iron deficiency during pregnancy can impair fetal growth and development due to reduced oxygen delivery and nutrient availability (23). The combined impact of maternal malnutrition and iron deficiency highlights the intergenerational consequences of poor maternal nutrition, affecting not only immediate birth outcomes but also long-term infant growth, neurodevelopment, and cognitive function.

Finally, the findings emphasize the critical need for integrated maternal nutrition interventions. Programs such as iron and folic acid supplementation, dietary counseling, and food fortification have been shown to improve maternal hemoglobin levels, reduce labor complications, and improve neonatal outcomes (24). Beyond supplementation, addressing underlying socioeconomic determinants such as poverty, food insecurity, and healthcare access is essential for sustained improvement. Our study reinforces that improving maternal nutrition is not solely a biomedical issue but a multifactorial public health priority, directly influencing maternal well-being, pain management during labor, and neonatal health.

Conclusion

Maternal malnutrition and iron deficiency are significant concerns during pregnancy leading to adverse outcomes for mothers and newborns, such as increased labor pain, low birth weight, and preterm delivery. Factors like poverty, food insecurity and inadequate prenatal care exacerbate these issues. Effective strategies should integrate nutritional support, iron supplementation and education into routine maternal healthcare to mitigate these risks. Addressing iron deficiency can improve hematological status, enhance labor experience, reduce analgesic needs and support postpartum recovery. Prioritizing maternal nutrition in public health policies, especially in resource-limited settings, is crucial to improve health outcomes and reduce pregnancy-related complications and mortality.

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