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THE ROLE OF PRENATAL NUTRITION IN PREVENTING GASTROINTESTINAL DISORDERS IN NEWBORNS: A BIOCHEMICAL ASSESSMENT

Prof. Ruchu Kuthiala[1*], Dr. Dhananjay Dilip Deshmukh[2], Dr. Nitin Jain[3], Dr. Gajendra Singh[4], Dr. Vaibhav S. Adhao[5], Dr. Venugopal Reddy. I[6]

[1*]Head of Department, School of Science, Nutrition and Psychology, PCET's Pimpri Chinchwad University, Pune, Email Id: clinicalnutruchu@gmail.com, ORCID ID: 0000-0002-1089-9289
[2]Associate Professor & HOD in the Balrog Department at Dronacharya Ayurvedic Educational Institute & Hospital, Saharanpur, Uttar Pradesh, India, Email Id: dhananjaydeshmukh03@gmail.com
[3]Degree Mch, Senior Consultant, Specialization in Pediatric Surgery, Amrita School of Medicine, Amrita Vishwavidyapeetham, Faridabad, Haryana, India, Email Id: nitjai53@gmail.com, ORCID ID: 0000-0002-9751-3106
[4]PhD Public Health, IIHMR University, Jaipur, Rajasthan, Email Id: talk2me@doctor.com, ORCID ID: 0000-0003-3945-5101
[5]Professor, Department of Pharmaceutical Quality Assurance, Dr. Rajendra Gode College of Pharmacy, Malkapur, District -Buldana, Maharashtra-443101, India, Email Id: adhao.vaibhav@gmail.com, ORCID ID: 0000-0001-7664-4038
[6]Consultant Pediatrician, Department of Pediatrics, Longevia Clinics, Bangalore-560048, India, Email Id: drivgr@gmail.com, Orcid Id: 0000-0002-2272-0004

ABSTRACT

Background: Prenatal nutrition plays an important role in fetal growth and early gastrointestinal (GI) development. However, limited evidence is available on the variations in maternal nutrient intake during pregnancy translate into specific gastrointestinal outcomes in newborns.

Objective: To examine the association between prenatal nutritional intake and gastrointestinal disorders in newborns, and to identify biochemical markers that may mediate this relationship.

Methods: This observational analytical study included 240 mother–infant pairs from a tertiary maternity hospital. Maternal nutrition was assessed using a food frequency questionnaire and 24-hour recall. Maternal blood and cord blood samples were analysed for nutrient levels, inflammation markers, and gut integrity indicators. Neonatal GI disorders were diagnosed from clinical records. Logistic regression and mediation analysis were used to evaluate associations.

Results: Most mothers were aged 25–30 years and were from middle- or low-income households. While many had a normal BMI, anaemia was common. Newborns showed generally healthy birth outcomes, including normal gestational age, birth weight, and Apgar scores. However, a considerable proportion of mothers had inadequate intake of protein, iron, and vitamin D. Infants born to mothers with these deficiencies were more likely to develop GI disorders. Cord blood findings showed elevated markers of intestinal stress and inflammation among affected neonates, suggesting that poor maternal nutrition may influence GI vulnerability before birth.

Conclusion: Poor prenatal nutrition, particularly low iron, protein, and vitamin D, increases the risk of gastrointestinal disorders in newborns. Early screening and improved maternal nutrition may help prevent GI problems in infants.

KEYWORDS: prenatal nutrition, neonatal health, gastrointestinal disorders, biochemical markers, cord blood

INTRODUCTION

Prenatal nutrition is crucial in the development of fetuses and the provision of physiological basis on which ideal gastrointestinal (GI) functioning can be achieved after birth. Maternal nutrition is sufficient to promote intestinal epithelial growth, enhance mucosal immunity and increase the digestive capacity, thus decreasing the risk of early gastrointestinal disturbances. According to literature on the foundational neonatal nutrition, maternal dietary imbalance can have a negative impact on the intestinal physiology of the infants and on metabolic adjustment in the early postnatal period [1]. GI tract grows steadily during gestation period and structural, enzymatic and immunological maturation of the organs require adequate and regular nutrient supply [2]. Malnutrition has been a top cause of neonatal gastrointestinal weakness. The lack of key nutrients, along with the insufficiency of caloric intake or lack of nutrient diversity can undermine the integrity of intestinal barriers, the protective mechanisms, and the ability to transport the nutrients. Such alterations predetermine infants to malabsorption and inflammatory gastrointestinal reactions [3]. GI diseases (neonatal) like cholestatic jaundice also exhibit the role of immaturity of both digestive and hepatobiliary systems that might need early identification and nutrition-focused management strategies [4]. One of the most prevalent GI disturbances in infancy is functional gastrointestinal disorders (FGIDs) which are now clearly characterized by the Rome IV criteria [5]. Also, perinatal risk factors like prematurity and exposure to neonatal antibiotics change the microbial colonization dramatically and predispose to early gastrointestinal malfunction [6]. This growing body of evidence indicates that prenatal nutrition can be used as a preventive measure early in life to reduce gastrointestinal complications in neonates. However, the mechanisms by which nutrient disorders cause GI susceptibility are not well comprehended.

The several studies have highlighted the significance of maternal nutrition to the health of the neonates, there are still many gaps in the research which impede the thorough comprehension of the effects of maternal nutrition on the gastrointestinal outcomes. Some of the nutritional interventions that are targeted to prevent severe neonatal GI disorders such as the necrotizing enterocolitis are mainly based on the postnatal feeding measures, but not the maternal dietary considerations during pregnancy [7]. The research on the experimental animals including maternal L-glutamine supplementation demonstrates the bettering of intestinal functions in the offspring [8], they have not been sufficiently applied to human prenatal care.

Surveys of nutritional deficiencies and toxicities outline systemic impacts of inadequate dietary food intake [9], but the underlying mechanistic relationships between nutritional status during the prenatal period and neonatal gut indicators are scarcely discussed. Equally, although it is known that metabolic bone disease of prematurity develops due to nutrient deficiency [10], gastrointestinal effects of similar deficiencies were not given the same scientific consideration. Despite the fact that the basic literature elucidates the intricate elements of neonatal GI physiology [11], there is a lack of association between maternal nutrition patterns and these physiological cognizances. The studies on prenatal and neonatal bone structure continually show the significance of maternal nutrition to the formation of structures [12], whereas the parallels between prenatal nutrition and the gastrointestinal biochemical measurements are scarcely investigated. Trials comparing maternal vitamin D supplementation provide an effect on the pregnancy and birth results [13], although its impact on GI-specific neonatal outcomes is poorly elucidated. Pediatric investigations into the impact of total parenteral nutrition on gut microbiota have shown significant impacts [14], but nothing comparing prenatal nutrient exposures. The nutritional models of chronic diseases emphasize personalized dietary evaluation [15], although personalized dietary evaluation seldom incorporates maternal biochemical indicators of predisposition to neonatal GI susceptibility. To ensure GI-targeted biochemical screening, standardized processes of prenatal nutrition care focus on dietary evaluation and laboratory monitoring [16], although they are often deprived of biochemical screening. All these gaps prove the necessity of an integrative evaluation between maternal diet, maternal biochemical markers and neonatal gastrointestinal outcomes. There is also an emerging evidence that nutritional exposures can be altered to stabilize the gut microbes during the perinatal period, and lower the risk of gastrointestinal disease during early life [17]. The literature on maternal-child health has and continues to identify prenatal nutrition as one of the key factors of neonatal adaptation, growth and organ system resilience, including the digestive system [18]. Detailed texts in maternity care support this knowledge and focus on the fact that maternal nutrition patterns in the course of pregnancy have a direct impact on the development of fetal organs, immune systems, and the maintenance of physiological stability in infants [19]. Collectively, these sources indicate the necessity of a study that relates prenatal dietary consumption, biochemical outcomes and neonatal GI outcomes in a system of analysis. In this way, it will be feasible to pinpoint certain nutrient-related pathways that affect the newborn GI health, come up with evidence-based prenatal nutrition guidelines and early detection approaches, which can unlock the door to infants at the increased risk of gastrointestinal disorders.

Research Objectives

1. To evaluate the association between prenatal nutritional intake and the incidence of gastrointestinal disorders in newborns.
2. To assess biochemical indicators that mediate the relationship between maternal prenatal nutrition and neonatal gastrointestinal outcomes.

2. MATERIALS AND METHODS

2.1 Study Design

The observational analytical design was used in this study to assess the relationship between prenatal intake of nutrients and gastrointestinal outcomes among newborns. The design enabled the natural difference in maternal nutrition to be evaluated to be measured without any form of intervention. The information was gathered prospectively by using the data on pregnant women in the regular antenatal check-ups, and maternal as well as infant data were documented between recruitment and birth up to the initial neonatal follow-up. This technique allowed investigating both direct relationships and mediators of the biochemical nature affecting the health of the neonatal gastrointestinal.

2.2 Study Setting and Population

The research was done at a hospital with tertiary level in a maternity hospital. Two hundred and forty mother-infant pairs were recruited. The pregnant women aged 25-30 weeks of gestation were approached to participate. The women were not to have metabolic diseases, preexisting gastrointestinal diseases or nutrient absorption conditions. Infants with birth defects or incomplete documentation were also not allowed. The final analysis comprised only qualified pairs who have gone through all biochemical tests.

2.3 Data Collection Procedures

The data of mother were measured by use of structured interviews and validated dietary assessment measures. The nutrient intake was measured by using a food frequency questionnaire and 24-hour dietary recall. The third trimester maternal blood samples were used to test the micronutrient status, inflammatory factors, and metabolic factors. During delivery, cord blood samples were collected to assess the biochemical parameters related to gastrointestinal integrity in the newborn including gut permeability, oxidative stress and inflammation. Clinical assessment and hospital records provided data based on neonatal birth weight, gestational age, feeding patterns and recorded gastrointestinal conditions.

2.4 Variables and Measurements

Prenatal nutritional intake was the dependent variable with the principal independent variable and it was assessed using nutritional questionnaires and classified according to the recommended intakes. The dependent variable was the instance of gastrointestinal disorders in newborns in medical records. The potential mediators of the relationship between prenatal nutrition and gastrointestinal outcomes were biochemical indicators--maternal and neonatal. Other factors like maternal age, parity, socioeconomic status, Pregnancy BMI, exposure to antibiotics and mode of delivery were also factored in to control confounding factors. All laboratory tests were conducted in recognized laboratories with standard methods of assays.

2.5 Statistical Analysis

The data analysis was done through descriptive and inferential statistics. Continuous variables were given in the form of means and standard deviations, whereas categorical variables were given in the form of frequencies, percentages. Multivariate logistic regression models were developed to determine the relationships between prenatal intake of nutrients and the development of neonatal gastrointestinal disorders with control of confounding factors. Among biochemical markers, mediation analysis was done to test the indirect impact of maternal nutrition on the relationship between maternal nutrition and neonatal gastrointestinal outcomes. To determine statistical significance, p less than 0.05 was considered significant and statistical software packages were updated in order to make results accurate and reproducible.

2.6 Ethical Considerations

The institutional research ethics committee gave its ethical approval before the start of the study. All participating mothers were informed by giving a written consent to take part in the study after they were thoroughly explained about the procedures, benefits, and risks of the study. The participants were assured that their choice to take or refuse the participation was not going to affect the quality of the clinical care they received. The collected data were anonymized, and kept in a secure place and processed according to the principles of ethical research and data protection regulations.

3. RESULTS

3.1 Maternal Characteristics

The number of pregnant women enrolled in the study was 240. The median maternal age was 27.4 +- 4.3 years and most of them (49.2%) were within the age bracket of 25-30 (Table 1). Almost half of the women (47.9%) had middle socioeconomic status, and 32.1% were low-income households. On the maternal health status, 60.8% of respondents had a normal BMI, 24.2% of respondents were overweight and 15% of respondents were obese. Anaemia occurred in 35% of the respondents. Obstetric analysis revealed that 57.5% and 42.5 % of mothers were primiparous and multiparous respectively. Most of them (71.7%) had 4 antenatal visits, which is also an indication of adequate maternal care coverage.

Table 1. Maternal Characteristics Presented as Frequency and Percentage

Category	Parameter	n (%)
Demographic Profile	Age 18–24 years	72 (30.0%)
	Age 25–30 years	118 (49.2%)
	Age >30 years	50 (20.8%)
	Low socioeconomic status	77 (32.1%)
	Middle socioeconomic status	115 (47.9%)
	High socioeconomic status	48 (20.0%)
Maternal Health Status	Normal BMI	146 (60.8%)
	Overweight	58 (24.2%)
	Obese	36 (15.0%)
	Anemia present	84 (35.0%)
Obstetric Information	Primiparous	138 (57.5%)
	Multiparous	102 (42.5%)
	<4 antenatal visits	68 (28.3%)
	≥4 antenatal visits	172 (71.7%)

3.2 Distribution of Maternal Nutrient Intake

The dietary analysis of maternal food indicated high levels of nutritional deficiency. Mothers had a low level of adequacy in the recommended protein levels with only 58% meeting the requirements and only 44% meeting the adequacy of iron Figure 1. Calcium adequacy was achieved in 61% of participants, folate in 72% and vitamin D adequacy was the lowest with only 39%. Such findings bring to focus the prevalence of micronutrient deficiency in pregnancy.

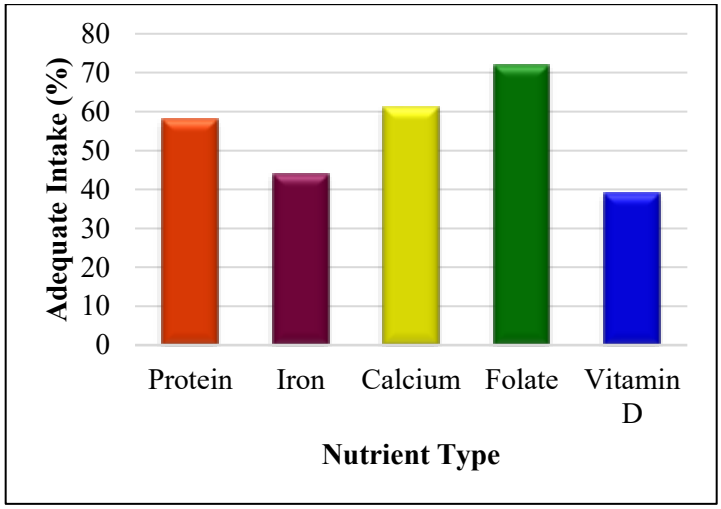

Figure 1. Percentage Distribution of Maternal Nutrient Intake Relative to Recommended Levels

3.3 Neonatal Characteristics

The overall state of neonatal outcomes was healthy birth. The average gestational age at delivery was 38.2 +- 1.4 weeks and the mean birth weight was 2965 +- 415 grams which is appropriate full-term growth (Table 2). The mean birth length was 49.3 +- 2.8 cm and the mean head circumference was 33.8 +- 1.6 cm, which means that there was no urgent neonatal adaptation issues.

Table 2. Neonatal Characteristics Presented as Mean and Standard Deviation

Category	Parameter	Mean ± SD
Birth Profile	Gestational age (weeks)	38.2 ± 1.4
	Birth weight (grams)	2965 ± 415
	Birth length (cm)	49.3 ± 2.8
	Head circumference (cm)	33.8 ± 1.6
Immediate Health	Apgar score (1 minute)	8.1 ± 0.7
	Apgar score (5 minutes)	9.0 ± 0.4

3.4 Incidence of Neonatal Gastrointestinal Disorders

About one-third of newborns of the newborns (28.3%) had at least one gastrointestinal disorder. Among these, 34% were diagnosed with FGIDs, 29% with feeding intolerance, 21% with cholestatic jaundice, and 16% with NEC (Figure 2). Such a distribution indicates that almost one-third of the cohort had early GI difficulties.

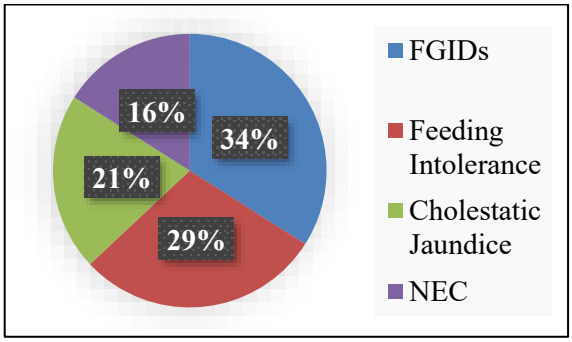

Figure 2. Prevalence of Neonatal Gastrointestinal Disorders

3.5 Maternal and Neonatal Biochemical Indicators

Mother biochemical results were 58.6 +- 12.4 ug/dl serum iron and vitamin D 21.3 +- 6.2 ng/mL, which revealed that a substantial part of the cohort was deficient. Mean CRP was 5.8 +- 2.1mg/L, which indicated borderline cases of inflammatory reactions in certain subjects. Cord blood analysis revealed high levels of gastrointestinal injury and inflammation indicators in infants with GI disorder with an average of I-FABP 287.4 +- 61.5 pg/mL and IL- 6 18.3 +- 6.1 pg/mL as indicated by Table 3. These increased levels of biomarkers suggest intestinal stress and pro-inflammatory diseases related to early GI malfunction.

Table 3. Maternal and Cord Blood Biochemical Marker Levels

Marker	Maternal Level (Mean ± SD)	Cord Blood Level (Mean ± SD)
Serum iron	58.6 ± 12.4	92.1 ± 15.8

(µg/dL)		
Vitamin D (ng/mL)	21.3 ± 6.2	18.7 ± 5.4
CRP (mg/L)	5.8 ± 2.1	—
I-FABP (pg/mL)	—	287.4 ± 61.5
IL-6 (pg/mL)	—	18.3 ± 6.1

3.6 Association and Mediation Pathways

Regression analysis was used to illustrate that low protein consumption predisposed neonatal GI disorders by 2.14 times (95% CI: 1.32-3.47), iron deficiency by 2.68 times (95% CI: 1.57-4.56), and low vitamin D by 1.89 times (95% CI: 1.11-3.23). Poor caloric consumption was marginally important with an odds ratio of 1.43 (Table 4). Overall, it highlights that maternal nutritional deficiencies play a significant role in predicting neonatal gastrointestinal outcomes.

Table 4. Multivariable Regression Analysis of Maternal Nutrition and Neonatal GI Disorders

Maternal Nutritional Factor	Adjusted OR	95% CI	p-value
Low protein intake	2.14	1.32–3.47	0.002
Iron deficiency	2.68	1.57–4.56	<0.001
Low vitamin D	1.89	1.11–3.23	0.018
Inadequate caloric intake	1.43	0.95–2.17	0.081

4. DISCUSSION

This study has shown that there is a clear relationship between prenatal nutritional deficiencies and incidence of gastrointestinal (GI) disorders among newborns. The scale of the clinical issue can be demonstrated by the fact that neonatal GI problems are prevalent among 28.3% of infants. The maternal deficiencies in protein, iron and vitamin D were closely associated with increased risk of neonatal GI disturbances. The regression model revealed that iron deficiency contributed to a higher risk with a coefficient of 2.68 which is a significant finding that requires the regulation of micronutrient consumption during pregnancy. Smart cord blood indicators (1-FABP 287.4 +- 61.5 pg/mL, IL-6 18.3 +- 6.1 pg/mL) were also used to support the fact that intestinal epithelial stress and inflammatory activation occurs in affected neonates. These observations imply that inadequate maternal nutrient consumption can disrupt the development of the fetal intestines through the modulations of the mucosal barrier formation, immune preparedness and enzyme activity. The mediation analysis shows that the associations are partially explained by biochemical markers, which decays the direct nutritional impact (b decreases to 0.29). This underscores that the prenatal nutrition influences the neonatal GI health both directly due to developmental mechanisms and indirectly due to inflammatory or metabolic mechanisms.

Findings of the current research are consistent with the new findings on the interdependence of nutrition, microbiome development, immune control, and fetal programming. The GEMMA study and multi-omics based studies show that prenatal exposures including nutritional patterns can determine early microbiome and metabolome patterns that determine disease risk, including gastrointestinal and immune-mediated diseases [20]. This helps us to conclude that cord blood biomarkers (I-FABP, IL-6) are the mediators between maternal nutrition and neonatal gut outcomes. The close correlation between maternal iron deficiency and GI neonatal issues is also consistent with previous findings that focus on the significance of iron homeostasis in infancy. Hare et al. emphasized that iron metabolism disruption even in iron-sufficient infants can have an adverse effect on neurological and systemic development [21]. It is in line with our finding that iron deficiency impairs the intestinal integrity of the neonatal gut, presumably due to the disruption in the epithelial resilience. The technological advancements in the field of infant nutrition in the recent past only support the role of bioavailability of nutrients in the determination of gastrointestinal health. An example of improved stability and absorption of nutrients by liposome-based delivery systems in infant formula is the fecal effect [22], which demonstrates that, by targeting nutrient-enhancement, there can be beneficial changes in gut functionality. These technological understandings are an indication of the biological feasibility of our data: nutrient availability affects intestinal development as early as the intrauterus period. Prenatal and infant probiotics also have been found to have positive effects on gut microbial balance and GI outcomes. Baldassarre et al. pointed out that maternal probiotics decrease neonatal dysbiosis and can aid mucosal immunity [23], which is similar with our results that show inflammatory imbalance of infants with low maternal nutrient intake. Moreover, maternal immune status is also identified as one of the determinants of newborn immunity. Investigations into HIV-exposed babies demonstrate that there are robust prenatal immunological effects on the early immune development [24]. This is consistent with our biochemical results of IL- 6 rising in the case of neonates with gastrointestinal diseases indicating inflammatory programming dependent on maternal physiological conditions. Lastly, the more general fetal programming literature points to the effects of maternal stress and nutritional deprivation, which influence development patterns of the fetus, neurodevelopment, and organogenesis [25]. These processes underpin the conceptual framework of our research: prenatal nutrition, by means of nutritional adequacy and inflammatory pathways, is one of the factors that cause the early susceptibility of the gastrointestinal system.

The relevance of this to clinical and public health is significant. First, it highlights the importance of systematic assessment of the nutritional condition of mothers in pregnancy. Testing of iron, vitamin D and protein insufficiency should be included as routine screening during antenatal care programs. Second, personalised nutritional counselling, dietary improvement interventions, and specific supplementation can potentially decrease the neonatal gastrointestinal morbidity. Third, the discovery of I-FABP and IL-6 as mediators provides a chance of early diagnostic evaluation of at-risk neonates. The analysis of cord blood might be an early warning system of GI upheaval and preventive or therapeutic treatment can then be implemented. Fourth, the results advocate the enhancement of the policies of maternal nutrition and the incorporation of nutritional education into the community healthcare system.

The study has a number of limitations even though it is strong. The design makes it difficult to infer causation based on observations. The maternal dietary intake was self-reported, bringing possible recalling or reporting bias. In spite of the inclusion of biochemical markers in order to increase validity, the marker panel was restricted on a small number of indicators. The use of more metabolic, inflammatory, and microbiome-based indicators should be included in future research. The case was carried out in one geographical area limiting the application to other population groups. Moreover, neonatal gastrointestinal disorders are multifactorial; breastfeeding habits, environmental exposures and genetic predisposition were not adequately explained.

It is important that the future studies are based on longitudinal studies that would evaluate the effects of prenatal nutrition on gastrointestinal health and general developmental outcomes. It can be enhanced by multi-omics methods, i.e. combination of genomic, metabolomic, proteomic, and microbiome methods, as shown using systems biology approaches recently. Mother-to-infant randomized controlled trials of targeted maternal supplementation programs of protein, iron, vitamin D, and probiotics can provide better causal data. Predictability will be enhanced by extending biomarker studies to incorporate gut permeability biomarkers, immune cytokines and microbial metabolites. Research on a variety of socioeconomic and ethnic groups is required to increase the international relevance. Also, a study investigating the interactive effect of maternal stress, nutritional patterns, and inflammatory signaling will promote knowledge regarding gastrointestinal vulnerability of prenatal origin.

5. CONCLUSION

The study indicates the paramount role of prenatal nutrition in neonatal gastrointestinal (GI) health and that maternal deficiencies of protein, iron and vitamin D play a significant role in raising the incidence of early GI disorders in newborns. The gastrointestinal issues in this group were reported to be quite high (28.3%) and most especially were functional GI disorders and feeding intolerance, which is a significant burden that can be avoided by providing the mother with better nutrition. The close relationship between iron deficiency and neonatal GI morbidity based on odds ratio of more than two is an indication of the criticality of iron during fetal mucosal development and immune prepareness. Further, the increased cord blood Biomarker I-FABP and IL-6 in the impacted infants displayed the presence of measurable intestinal epithelial stress and inflammatory activation in infants at birth, which established the physiological vulnerability. Mediation analysis also revealed that these biochemical markers were in part to explain the association between maternal nutrient inadequacy and neonatal outcomes, indicating that prenatal nutrition has been shown to have an effect on GI health both directly via developmental and indirectly via inflammatory mechanisms. Taken together, the major findings indicate a strong demand of regular prenatal nutritional screening, specific supplementation of the high-risk mothers, and early newborn biochemical screening in order to detect those infants with increased risks.

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