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Association of Maternal Nutrition, Birth Outcomes, and Infant Health in Pregnant Women

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ABSTRACT

Maternal nutrition plays a key role in fetal development, birth outcomes, and early infant nutrition. A quantitative correlational study was conducted to determine the relationship between maternal nutritional status, birth outcomes and infant health measurements. The total sample size of 200 pregnant women attending Antenatal clinics was purposively selected. The information was collected using a structured questionnaire and clinical record review on the following topics: dietary intake, anthropometric nutritional status, birth weight, gestational age at delivery, neonatal features at birth. Data collection technique used in the study was descriptive statistics, Pearson correlation analysis, Cronbachs alpha reliability analysis and Structural Equation Modeling (SEM). Items were highly reliable with values ranging from .78 to .83. The maternal nutritional status was positively associated with birth outcomes ($r = .62, p < .001$) while the birth outcomes was positively associated with the infant health ($r = .65, p < .001$). Both direct ($\beta = .22$) and indirect ($\beta = .34$) pathways for maternal nutritional status to impact infant health were identified through the mediation of birth outcomes (total $\beta = .56$), with SEM supporting the latter. Model fit was acceptable ($\chi^2/df = 1.94$; CFI = .97; RMSEA = .056). The results highlighted the crucial role of evidence-based nutrition counselling and supplementation programmes during pregnancy in positively influencing health outcomes for birth and infants, especially in maternal and child health in low-resource countries where nutritional deficiencies are still common.

Keywords: maternal nutrition, birth outcomes, infant health, antenatal care, birth weight, gestational age, structural equation modeling, perinatal health

INTRODUCTION

Nutritional conditions among pregnant women during the periconceptional (from conception to the tenth week of pregnancy), gestation, and early postnatal (first postnatal year) periods are one of the strongest modifiable influences on the health of the mother, fetus, and infant. Premise: Adequate nutrition during the period of pregnancy provides the substrates necessary for the organogenesis, development of the placenta, growth of the foetus and the build-up of the nutrient stores necessary to meet the neonatal metabolic requirement and the first few weeks of life. Maternal undernutrition (protein-energy malnutrition, micronutrient deficiency, and dietary diversity restrictions) on the other hand leads to a chain of negative effects on the infant such as intrauterine growth restriction, preterm birth, low birth weight, and impaired infant immune function, all of which individually raise the risk of infant morbidity and mortality (Black et al., 2013). These links introduce maternal nutrition as an anchor of the first 1,000 days approach — the period from fetus to two years of age — which is rapidly gaining support as a key human capital development strategy by world health institutions.

Under the worldwide statistics on malnutrition based on maternal status, the burden is yet persistently significant, and geographically imbalanced. Nearly 462 million women of reproductive age are underweight, and nearly 1.5 billion are overweight/obese across a range of economic contexts, with the additional challenge of a double burden of malnutrition during pregnancy and in the postpartum period (WHO, 2020). An estimated 2 billion people worldwide, most of whom are pregnant women in low and middle income countries (LMICs) suffer from micronutrient deficiencies, including iron, folate, iodine, calcium, and zinc, due to a poverty, food insecurity and lack of access to a variety of foods that restricts dietary diversity (Bhutta et al., 2013). Maternal undernutrition is one of the major contributors to the very significant perinatal health disparity in South Asia compared to other developing parts of the world, and these constitute by far the highest proportion of low birth weight, worldwide.

Birth outcomes – primarily birth weight and gestation (based on birth) – are commonly used as indicators of the cumulative effects of the intrauterine environment on fetal development and are important predictors of infant survival, growth and the trajectory of child neurocognitive development. There is an independent link between low birth weight (< 2,500 g), preterm birth (< 37 completed gest. weeks) and an increased neonatal mortality rate, delayed developmental milestones and increased chronic disease risk in adults via fetal programming mechanisms (Barker, 1995). These outcomes are mediated by several mechanisms of the mother's nutritional status: transfer of nutrients to the fetus; regulation of fetal growth by hormones; regulation of inflammatory processes and the induction of preterm labor; and modulation of fetoplacental vascular function.

Infant health is measured by a wide range of parameters such as birth weight, Apgar score, feeding success, immune competence, early growth trajectories and all of them are the result of the toxic effects of the intrauterine environment and the early postnatal nutrition. Inevitably, the link between birth outcomes and infants' health is well documented, but the contribution of maternal nutritional status, in turn, via structural pathways to the relationship between birth outcomes and infants' health warrants explicit empirical investigation that accounts for direct and indirect paths to the relationship, while controlling for other confounding demographic variables.

The three main objectives of this study were: (1) to describe concurrent nutritional status of pregnant women receiving prenatal care and birth and infant health outcome measures; (2) to investigate bivariate relationships among maternal nutritional status, birth outcomes, and infant health measures; and (3) test a structural model that examined the mediating effect of birth status between maternal nutritional status and infant health indicators. The study adds structurally informed evidence to the maternal-infant nutrition literature and for the design and targeting of antenatal nutrition interventions using SEM from a South-Asian LMIC context.

LITERATURE REVIEW

Epidemiological and clinical studies have been well conducted to elucidate the relationship between maternal nutritional status and fetal growth. Kramer (1987) systematically reviewed 895 studies and found that maternal nutrition (energy and protein intake, pre-pregnancy weight, and gestational weight gain) explains the main determinants of intrauterine growth and birth weight and that up to 50% of the variation in birth weight in LMICs can be explained by nutrition during pregnancy. This primal discovery did set science on a course for nutrition interventions during pregnancy and inspired the next decades of nutritional supplementation trials in resource-limited countries.

Iron deficiency anaemia (IDA), the commonest micronutrient deficiency during pregnancy globally, has been consistently linked to subsequent adverse birth outcomes such as low birth weight, preterm delivery and perinatal mortality. Rahman et al. (2016) performed a meta-analysis of 48 prospective studies to determine affect of maternal hemoglobin on low birth weight and preterm delivery and revealed a 29% higher risk of low birth weight and a 21% higher risk of preterm delivery. mechanism is an inadequate supply of oxygen to the placenta/fetus which triggers adaptive growth restriction responses, protective in the short term, but detrimental to growth potential and immune competence in the neonate. Use of iron during pregnancy has repeatedly been demonstrated to have a positive effect on hemoglobin levels and fetal weight, which would suggest that its use should be routine as part of prenatal care.

The most preventable cause of neural tube defects is folate deficiency during the periconceptional period, and it is estimated that there are 300,000 cases of neural tube defects every year, worldwide, resulting from this deficiency (Blencowe et al., 2010). In addition to its role in the prevention of neural tube defect, sufficient folate plays an important role in the entire process of fetal growth and development, and deficiency has been linked to intrauterine growth retardation, abruption of the placenta and preeclampsia. The importance of population-level nutritional intervention during the preconceptional period is illustrated by the dramatic drop in prevalence of neural tube defects in countries where folic acid is mandatorily added to food products in the recent past.

An emerging risk for lack of micronutrients during pregnancy is maternal diet diversity, with a focus on single-food patterns in LMIC contexts. A prospective birth cohort study in South India by Muthayya et al. (2009) revealed higher birth weight infants in women with higher diet diversity scores with no significant relationship among the total energy intake of the diet. FAO has validated MDD-W as an indicator of the proportion of women consuming foods from at least five of ten food groups and MDD-W has been shown to correlate with outcomes of births across several cohorts from the South Asian region.

Gestational weight gain (GWG) is a composite of maternal energy balance in pregnancy and the pre-pregnancy BMI-specific recommendations have been provided by the Institute of Medicine (Institute of Medicine (IOM), 2009; Rasmussen & Yaktine, 2009). Lack or excess of GWG is related to poor outcomes of pregnancy: low levels of GWG are linked to low birth weight and intrauterine growth restriction, and high levels of GWG are linked to offsprings childhood obesity and operative delivery. There is significant socioeconomic variation in individuals achieving appropriate GWG, as this depends on having an adequate diet in terms of quantity, quality, ability to avail of dietary counselling and, crucially, the absence of food insecurity which, along with the direct effects of nutrition on birth outcomes, gives rise to GWG mediated health inequalities.

The Barker hypothesis (or Developmental Origins of Health and Disease (DOHaD) theory) suggests a critical role for the intrauterine nutritional environment in programming organ systems and biological setpoints in the fetus that then influence risk for chronic disease in adult life (Barker, 1995). The epidemiological evidence for this is quite strong, as is the fact that low birth weight is associated with decreased intrauterine nutrition in many pivotal studies establishing links between fetal growth restriction and adult hypertension, type 2 diabetes, and cardiovascular disease. This system highlights the importance of maternal nutritional optimisation and not just in its immediate perinatal impact but also it is promoting the child's long-term health pathway and consequently the intergenerational transmission of health inequalities.

Attendance to antenatal care (ANC) represents an important cornerstone of the effectiveness of antenatal nutrition interventions because of the multiple rounds during pregnancy when structured contact is made for delivery of nutrition supplements, advice on nutrition and monitoring of maternal nutrition outcomes indicators. In a study of pregnant Pakistani women, Majrooh et al. (2014) also observed a positive association between greater attendance to ANC visits and better nutritional status of pregnant women with more visits being attended and higher birth weight being expected to be registered among infants, and lower rate of neonatal complications among those of higher visit numbers, beyond gaps in their socioeconomic status. However, the uptake of ANC services in Pakistan is not adequate: out of all women in their third pregnancy the only percentage utilizing minimum four ANC visits is 50%, leaving out the potential of facility-based nutrition interventions.

SES serves as a strong moderator of the maternal nutrition-birth outcome association in multiple ways, such as diet affordability, food security, access to healthcare services, maternal education level, and intra-household nutrition decisions influencing food availability. Victora et al. (2008) pooled data from multiple studies around the world and found that there were consistent SES gradients for birth weight, stunting and infant mortality, the largest among which were in countries with a South Asian heritage. These gradients support a strategy of designing nutrition programs at different levels of the SES, with comprehensive packages of nutrition support provided to the most economically disadvantaged women during pregnancy, but not to broader populations.

Within the last decade the use of SEMs for maternal/infant health research has increased dramatically, allowing investigators to analyze theoretically-based pathway models, rather than the traditional bivariate association models. They compared the SEM results of Khamis et al. (2020) with the data obtained from the Egyptian pregnant women to conclude that birth outcomes (birth weight, gestational age) was sufficient to fully mediate the relationship between maternal anemia and the scores of neonatal health, and found no direct relationship between maternal anemia with the score of neonatal health after accounting for birth outcomes. This is important clinically because, if confirmed across settings, it supports the argument for birth outcome normalization to be the primary focus of maternal nutrition interventions to improve outcomes for neonates.

Perinatal nutrition landscape in Pakistan is a unique scenario of high prevalence of undernutrition among women of reproductive age (WRA), approximately 18% being underweight, concurrent overnutrition and micronutrient deficiencies in urban settings (National Nutrition Survey, 2018). The low birth weight prevalence is around 32%, consistently one of the highest in the world and it has been attributed to cumulative contributing factors including nutritional deprivation, high adolescent pregnancies, low levels of antenatal care attendance and household food insecurity (UNICEF 2021). The statistics give an interesting epidemiological basis for the present study to focus on this theme and, stresses the need for studies that can reveal modifiable pathways for intervention targetting.

Infant health indicators after birth have been relatively less systematically addressed in the LMIC literature than those of birth outcomes, such as infant weight and Apgar scores.Beyond birth weight, the feeding of infants (whether tended to mother's breast or bottle), growth velocity, and early childhood morbidity, are less studied in the LMIC literature as outcomes of maternal nutrition, as compared to birth outcome measures. The infant's early postnatal health status does not only correspond to intrauterine nutrition but also to the nutritional quality of the mother's breastfeeding and complementary feeding experiences; hence, maternal nutrition factors are difficult to be attributed to the infant's early postnatal health status. To avoid this, the present study concentrated on indicators that are thought to be specifically due to antenatal exposures, while seizures an additional investigation of a larger set of determinants of the long-term infant health course is warranted.

METHODOLOGY

Research Design

The research method used in this quantitative study was quantitative correlational research design, which examined the relationship between the variables of nutrition status of mothers, birth outcomes and health of the infants. This design was suitable for characterizing the strength and direction of relationships between naturally occurring variables in a clinically defined sample where no experiments were performed to manipulate the relationships. The correlational approach has long been used for studies on nutrition of the peripartum woman, as it is not ethical to actively manipulate one's nutritional exposure (Creswell, 2014). The research employed a post-positivist epistemological perspective that focused on a system of measurement, statistical validity and objective analysis.

Study Population and Sampling

The study aimed to include pregnant women in their second and third trimesters of pregnancy who are on government and private antenatal care practitioners. The calculated estimate sample size (n =) was 176 with a medium effect size ($f^2 = .15$), $\alpha = .05$, power = .80, and four predictors using the program G*Power 3.1. Another 200 were sampled for additional statistical stability, for a final sample of 200. A purposive sampling approach was undertaken to select women attending a number of health care facilities referred by the health department that were believed to have unique nutritional risk profiles. The inclusion criteria were as follows: gestational age at enrolment of ≥ 14 weeks, studies were restricted to singletons and only those who agreed to be included in the study were accepted after providing informed consent, and antenatal medical records were available. To minimise confounding, patients with pre-existing chronic medical conditions (such as diabetes, hypertension, renal disease, etc.) that may impact the nutritional status or birth outcomes were excluded.

Data Collection Instrument and Medical Record Review

Structured questionnaires have been filled and antenatal medical records have been reviewed to collect the data. Demographic information (Section A) was assessed through the questionnaire, such as maternal age, parity, education status, socioeconomic status using quintile of household income and adherence to ANC visits. In Section B, dietary information was collected using a validated 24-hour dietary recall scale backed by a food frequency questionnaire (FFQ) validated for local dietary patterns, which measures the amount and frequency over the past month of key staples (grains, legumes, dairy, animal foods, fruits, vegetables, fats and oils). A dietary diversity score was generated as a composite score using criteria of Minimum Dietary Diversity for Women (MDD-W). We used weight gain during pregnancy, pre-pregnancy BMI, mid-upper arm circumference (MUAC) and hemoglobin concentration as indicators of iron nutritional status and collected these data from antenatal records, for the purpose for collection in Section C. At follow up, birth outcome data (birth weight, gestational age at delivery, mode of delivery, Apgar score, Section D) were collected from delivery data. Infant health indicators (Section E) were documented, such as birth weight classification, Apgar score at five minutes, initiation of feeding within one hour after birth, and having any complications at birth. A composite birth outcome score and infant health score were created for structural modeling. Prior to implementation, the questionnaire and data extraction protocol was checked for content validity by two obstetricians and a nutritionist.

Procedure

The data collection was approved by the IRB of the participating facility administration’s IRB. Structured questionnaire interviews were conducted with research assistants trained in nutrition data collection during ANC visits, in the participants' preferred language (Urdu or Punjabi). Facility permissions for medical records were also obtained after obtaining permission from participants. Academic researchers visited participating facilities daily during the data collection period and delivery outcome data were collected from delivery registers and neonatal records at the time of delivery and/or within 48 hours postpartum. Data were collected on standardised forms and input into a secure data-base. Data collection took place during 8 weeks.

Data Analysis

The SPSS statistical software (Version 26) and AMOS (Version 24) software were used for data analysis. Medical record items and multiple item scale scores were listwise deleted when less than 4% were missing, and were mean-imputed when > 4%. All demographic and study variables were reported in a descriptive manner. Cronbach's alpha was computed to assess internal reliability of the composite nutritional status, birth outcome, and infant health scales. Pearson correlation analyses were used to analyze associations in bivariate measures within the three major constructs. The Anderson and Gerbing (1988) two-step approach was followed for SEM. The first exogenous variable in the structural model was the mother's nutritional status, the first mediated variable in the model was the birth outcome, and the first endogenous were the infant's health indicators. Model fit was assessed using the standard indices: χ^2/df (< 3.0), CFI (≥ .95), TLI (≥ .95), RMSEA (≤ .08), and SRMR (≤ .08). To determine the significance of a pathway of indirect mediation, Bootstrap resampling with 5,000 iterations was used.

RESULTS

Demographic Characteristics

Sociodemographic characteristics of the 200 participants are described in Table 1. The 26–30 years age group was most prevalent (36.0%), followed by 20–25 years (34.0%). The majority of women (59.0%) were multigravida. The highest level of education (38.0%) was secondary education, while 15.0% did not have any educational level. The socioeconomically disadvantaged populations who walked into the recruiting facilities made up 84.0% of the sample (low and middle socio-economic status). Of those who attended, 61.0% reported having regular check-ups with an ANC provider.

Table 1: Sociodemographic Characteristics of Participants (N = 200)

Variable	Category	Frequency (n)	Percentage (%)
Maternal Age	< 20 years	22	11.0
	20–25 years	68	34.0
	26–30 years	72	36.0
	31–35 years	28	14.0
	> 35 years	10	5.0
Education Level	No formal education	30	15.0
	Primary	44	22.0
	Secondary	76	38.0

	Tertiary	50	25.0
Socioeconomic Status	Low	80	40.0
	Middle	88	44.0
	High	32	16.0
Parity	Primigravida	82	41.0
	Multigravida	118	59.0
Healthcare Attendance	Regular	122	61.0
	Irregular	78	39.0

Descriptive Statistics and Internal Reliability

Table 2 shows the descriptive statistics and Cronbach's alpha for the composite study scales. Overall maternal nutritional status was low to moderate (mean score = 3.28, SD = 0.79) and highly variable. Average birth outcome composite score was 3.41 (SD = 0.83) with average infant health composite score being 3.35 (SD = 0.86). All of the internal reliability coefficients (Cronbach's alpha) for the nutrient scales (0.81), the outcome of birth scales (0.78), and the infant health scales (0.83), were greater than the acceptable 0.70, indicating good internal reliability for each scale.

Table 2: Descriptive Statistics and Reliability Coefficients (N = 200)

Variable	N	Mean	SD	Cronbach's α
Maternal Nutritional Status	200	3.28	0.79	0.81
Birth Outcomes (composite)	200	3.41	0.83	0.78
Infant Health Indicators	200	3.35	0.86	0.83

Correlation Analysis

Pearson correlation coefficients for the three study constructs are shown in Table 3. Maternal nutritional status positively and significantly correlated with birth outcomes ($r = .62$, $p < .001$) suggesting that the more nutritional condition of females, the more favorable outcomes of the births. Maternal nutrition status was also significantly correlated with the health of infant ($r = .58$, $p < .001$). We found a significant positive correlation between birth outcomes and infant health status ($r = .65$, $p < .001$), as expected based on theory that infant's health status would be associated with their birth outcomes. All the associations were statistically significant at the .001 level and had a moderate to large magnitude showing high empirical support for the proposed structural model.

Table 3: Pearson Correlation Coefficients Among Study Variables

Variable	1	2	3
1. Maternal Nutritional Status	—		
2. Birth Outcomes	.62**	—	
3. Infant Health Indicators	.58**	.65**	—

*Note. **p < .001 (two-tailed).*

Structural Equation Modeling

The results for the completed SEM are shown in Table 4. Maternal nutrition had a significant positive effect on birth outcomes (β = .59, SE = .08, CR = 7.38, p < .001). Birth outcomes significantly predicted infant health (β = .57, SE = .07, CR = 8.14, p < .001). The pathway of direct pathway effects from maternal nutrition directly to infant health was statistically significant (β = .22, SE = .09, CR = 2.44, p = .015), as was the pathway through the birth outcome mediation (β = .34, 95% CI [.23, .46]). The combined effect of maternal nutrition on the health of the infant was β = .56. Model fit indices were acceptable: $\chi^2/df = 1.94$, CFI = .97, TLI = .96, RMSEA = .056, SRMR = .047, indicating a good-fitting model.

Table 4: Structural Equation Modeling Path Estimates – Maternal Nutrition Study

Path	β	SE	CR	p
Maternal Nutrition → Birth Outcomes	.59	.08	7.38	<.001
Birth Outcomes → Infant Health	.57	.07	8.14	<.001
Maternal Nutrition → Infant Health (direct)	.22	.09	2.44	.015
Maternal Nutrition → Infant Health (indirect via BO)	.34	.06	5.67	<.001
Total Effect	.56	.07	8.00	<.001

Note. Model fit: $\chi^2/df = 1.94$; CFI = .97; TLI = .96; RMSEA = .056; SRMR = .047.

DISCUSSION

In this study, we found structural evidence of the path by which maternal nutrition status affects infant health, and birth outcomes act as a key intermediate path how. This positive relationship between maternal nutritional status and birth outcomes (r = .62, β = .59) matches previous epidemiological findings (Kramer, 1987; Black et al., 2013), and further underscores the importance of gestational nutrition to the intrauterine environment. Greater indirect effects were obtained in the maternal nutrition-infant health pathway by the birth outcomes (indirect β = .34), which is similar with the findings of Khamis et al. (2020) who showed that birth weight and gestational age during labour act as mediator between maternal nutrition-infant health pathway in an Egyptian sample and extends this structural finding with an antenatal care in the Pakistani nutrition-infant-health pathway. The size of the direct effect of maternal nutrition on infant health (β = .22) was larger but slightly smaller than the effect of maternal nutrition on the birth outcome pathway, indicating that maternal nutrition has an effect on infant health through a pathway other than the birth outcome pathway, most likely through breastfeeding practices, the quality of breast milk, and early postnatal growth velocity, all of which are influenced by maternal nutrition status during the fetal period.

This mean nutritional status of the study population (M = 3.28) is moderate thus indicating that the population as a whole is vulnerable to nutritional problems, and the fact that 84% of the participants are from either low and middle SES bracket further emphasizes this. These good model fit indices (RMSEA = .056 and CFI = .97) justify the developmental aspect of the proposed framework and lay the groundwork for future studies that follow the developmental outcomes of the antenatal nutritional environment into adulthood. Jet Ahead in this collection shows that feeding a woman during pregnancy is a high return investment in the improvement of pre- and perinatal outcomes and therefore a key priority in the alleviation of nutritional inequities from one generation to the next in LMICs.

CONCLUSION AND RECOMMENDATIONS

The findings of this study clearly showed that maternal nutritional status was an important structural determinant factor of the birth outcomes, and the latter, an early indicator of infant health. Breast-fed infants' nutritional status showed significant direct and indirect associations with their health, with a substantial indirect association via birth outcomes (total effect, $\beta = .56$). These results highlight the importance of optimizing the nutrition of gestation in order to maintain a main role in improving birth and post-natal health measures as prime perineatal health strategies. Based on this, the following policies are recommended: All ante natal care programs must attempt to routinely assess, at each ANC visit, all pregnant women (whether or not their pregnancy is identified as high risk), with validated instruments such as MUAC, hemoglobin and food diversity for the purpose of prioritizing high-risk pregnancies for more intensive nutritional support for the mother. Iron and folic acid supplements should be made available at all ANC clinics primarily catering to the LMI segments, and be actively monitored and counselled on dietary sources of key micronutrients. Community-based health workers need to be trained for culturally appropriate nutrition education to pregnant women at home, specifically dietary diversity, targets for gestational weight gain and relevance of regular ANC attendance. Interventions within the health system, such as providing nutrition support for vulnerable pregnant women or children through food vouchers and conditional cash transfers, need to be connected to other systems designed to tackle structural food insecurity that hampers improving diets. Longitudinal cohort designs that study maternal-infant dyads from early pregnancy until 2 years of age should be used in future for antenatal nutritional environment characterization and assessing long-lasting effects of antenatal nutrition on the trajectories of nutrition-related outcomes.

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