

Exploring Risk Factors of Child Growth Faltering: A Narrative Review and Regional Regression Study in South and Southeast Asia

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ABSTRACT

Child growth faltering remains a pressing global health issue, particularly in South and Southeast Asia, where stunting and undernutrition rates persist despite economic development. This study combines a narrative review with a quantitative analysis to investigate the most influential risk factors contributing to impaired growth in early childhood. Drawing from literature published between 2008 and 2023, the review highlights key intervention strategies such as exclusive breastfeeding promotion, improved sanitation, and community-based education. In parallel, a multiple linear regression analysis using recent regional health datasets (2020–2021) was conducted to assess the predictive power of six malnutrition-related variables on child growth rate. Among them, suboptimal breastfeeding emerged as the most significant negative predictor ($\beta = -0.196$, $p = 0.003$), even when controlling for other factors such as micronutrient deficiencies, low birthweight, and poor sanitation. The findings underscore the critical importance of early-life nutrition and maternal practices and suggest that culturally sensitive, community-level approaches remain essential for effective and sustainable intervention. Strengthening local health systems to support targeted, education-based strategies may be key to reducing long-term developmental inequality in the region.

Keywords: Child Growth Faltering; Suboptimal Breastfeeding; Stunting; South and Southeast Asia; Regression Analysis; Community-Based Nutrition

INTRODUCTION

The first one thousand days of every life determine all lives. In this period, the body and especially large parts of the central nervous system develop, and our metabolism is established. Undernutrition in this critical

period hampers growth and affects learning capability and health later in life (1). Stunting, which measures hampered longitudinal growth, has been associated with a wide range of developmental outcomes, and stunting at age two has been identified to be “the best predictor of human capital” (2). Globally, 155 million children were affected by stunting in 2016, of which more than half live in Asia (3). Approximately half of the stunted children worldwide belong to the lowest income quintile, which lives in extreme poverty (4).

In developing countries, malnutrition contributes to nearly half of all deaths in children under the age of five. Moreover, insufficient nutrition early in life is not

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only associated with higher morbidity and mortality but also leads to increased health care costs and human suffering. Poor nutrition early in life is also associated with faltered growth that results in children not reaching their full developmental potential. In stunted children, cognitive, motor, and socioemotional development is impaired, which leads to impeded learning capacity, poorer performance in school. Shorter stature is furthermore associated with lower work capacity and productivity. There is also evidence that early childhood malnutrition is linked to higher chances of obesity and cardiovascular diseases later in life. In the future, this might put the health systems of poor countries under further pressure (1).

Maternal and childhood malnutrition is immediately caused by inadequate dietary intake and diseases. Underlying causes include food-insecure households, inadequate care, and an unhealthy household environment, coupled with a lack of health services. These conditions are often related to poverty and a lack of not only financial but also human, physical, social, and natural capital. Of course, the broader socio-economic and political context play important roles here, and war or violent conflicts also severely aggravate nutritional outcomes (5, 6, 7).

Lower productivity and a higher morbidity and mortality contribute to an intergenerational vicious cycle of malnutrition, disease, and poverty that limits the long-term formation of social capital in societies (8). When getting pregnant, short and malnourished mothers are at a higher risk of complications during labor and have higher chances of giving birth to a lighter and smaller baby, which in turn also has intergenerational effects (1).

Evidence that nutrition in a critical ‘window of opportunity’ from conception to the second birthday of a child is critical for the development of a child is solid (9). Around six months of age – around the time of weaning from breastmilk – children fall behind their potential growth trajectories, and stunting prevalence increases in every region (9). Therefore, this paper will focus on analyzing the effects of various programs during this crucial time window.

The review explores key malnutrition risk factors in South and Southeast Asia through both literature and a statistical analysis of child growth faltering. To complement this narrative assessment, a quantitative approach was used to investigate how specific malnutrition-related factors, such as suboptimal breastfeeding, micronutrient deficiencies, and sanitation, are statistically associated with early childhood growth.

METHODS AND MATERIALS

Search strategies

In light of these complex challenges, combined evidence synthesis was employed with exploratory statistical modeling to better understand key predictors. Literature was identified through targeted searches in PubMed, WHO, and UNICEF databases, as well as global health policy reports published between 2008 and 2023. Priority was given to peer-reviewed articles and authoritative institutional reports addressing nutritional outcomes in children under five years of age.

Studies were included if they discussed interventions relevant to the first 1,000 days of life, including exclusive breastfeeding, sanitation and hygiene, culturally tailored nutrition education, therapeutic foods, and locally grounded implementation strategies. As a narrative review, the objective was to provide a thematic synthesis rather than a systematic or meta-analytic summary.

To complement the conceptual discussion, an exploratory quantitative analysis was conducted using publicly available datasets from the Global Burden of Disease (GBD) study. This analysis aimed to examine the statistical association between child growth rate and malnutrition-related risk factors, including suboptimal breastfeeding, micronutrient deficiencies (vitamin A, iron, and zinc), low birthweight, and unsafe sanitation. Country-level data from 12 countries in South and Southeast Asia (10) were included.

Regional Profile

For the reasons stated above, tackling neonatal and early child malnutrition will positively impact individuals and societies in the short and long term. Interventions in early child nutrition were evaluated as being a cost-effective approach when compared with other health interventions (11). Improving nutrition in children narrows societal inequity because it empowers children’s and families’ developmental potential and their chances to escape poverty. The investment in neonatal and childhood nutrition is an investment in human capital, on which further interventions in other sectors can build on. This paper focuses on South and Southeast Asia since the absolute numbers of stunted children remains highest within that part of the globe and because investment in child nutrition in this region was estimated to be most cost-effective (12).

There is massive potential for economic return on investment (ROI) for in nutrition interventions in this region. Specifically, for every dollar spent on nutrition

programs, there is an ROI of \$48 in Indonesia, \$44 in the Philippines, and \$36 in Vietnam (12). Countries like Indonesia, Cambodia, and Timor-Leste lead developing nations in poor nutrition outcomes, specifically in number of children experiencing wasting and stunted growth (7). India has seen incredible improvements in nutrition outcomes, although with still much more to be done. India and Bangladesh already maintain a strong community health worker structure, which can be accelerated to improved nutritional interventions. South and Southeast Asia were chosen for their relative political stability, existing community health worker (CHW) systems, and because the region is home to the highest number of stunted children worldwide (13).

Although the prevalence of malnutrition is only slightly lower in Sub-Saharan Africa, this region was not chosen due to significant challenges such as political instability, weaker health infrastructure, and variability in reliable data availability, in comparison to the established community health worker networks in Southeast Asia (13). Given the disproportionately high prevalence of stunting and wasting, combined with the presence of functional community health networks and increasing public health engagement, Southeast Asia stands out as a strategically viable and urgently needed focus area for early childhood nutrition interventions.

A Closer Look: South and Southeast Asia

To operationalize this regional focus, a representative sample of twelve countries within South and Southeast Asia was examined to assess risk factors and current infrastructure. South and Southeast Asia bear a disproportionate burden of early childhood malnutrition. As of 2017, the region accounted for over half (56%) of the world's stunted children, with approximately one in three children under five stunted in Southern Asia and one in four in Southeast Asia (3). Countries included in this regional analysis are Bangladesh, India, Myanmar, Indonesia, Thailand, the Philippines, Vietnam, Laos, Brunei, Malaysia, Cambodia, and Timor-Leste.

Despite gradual improvements in economic and health indicators, the prevalence of stunting and wasting has remained persistently high across much of the region (Maternal and Young Child Nutrition Security Initiative in Asia). Public health infrastructure has strengthened in several countries through expanded government funding, improved health surveillance systems, and the institutionalization of community health workers. In countries like India and Bangladesh, CHWs already play an active role in maternal and child health programs,

offering a foundation upon which nutrition-specific interventions can be scaled.

Moreover, the region demonstrates relatively stable demographic trends, and rising health literacy among younger, more educated populations presents an opportunity to enhance demand for early childhood nutrition services. Taken together, these structural and societal characteristics make South and Southeast Asia a promising focal point for targeted community-based malnutrition interventions.

Statistical Analysis

Pearson correlation coefficients were first computed to assess the direction and strength of bivariate relationships between variables. To explore multivariate associations, a multiple linear regression model was constructed with child growth rate as the dependent variable (14). Statistical assumptions, such as linearity, normality of residuals, and multicollinearity, were evaluated. Variance Inflation Factors (VIFs) and correlation matrices were used to assess multicollinearity among predictors (15). All statistical analyses were conducted using GraphPad Prism (v10.1), Microsoft Excel (2024), and R version 4.3.2 in RStudio.

RESULTS

To illustrate the burden of malnutrition over time, trends were first visualized in neonatal and child deaths attributed to key nutrition-related risk factors. Most factors showed a gradual decline, reflecting regional improvements in neonatal care and nutritional access across South and Southeast Asia. However, deaths linked to low birth weight and short gestation, iron deficiency, and zinc deficiency continued to rise, indicating unresolved gaps in maternal and early childhood health. Notably, while the child growth rate itself showed a decreasing trend in Figure 1, the proportion of deaths associated with growth faltering remains substantial, underscoring the urgent need for targeted intervention.

Following the trend analysis of key risk factors, Pearson correlation was conducted to further examine the relationships among them. Figure 2 presents a Pearson correlation matrix illustrating the bivariate relationships between child growth rate and several malnutrition-related risk factors, including suboptimal breastfeeding, vitamin A deficiency, iron deficiency, zinc deficiency, low birthweight, and unsafe sanitation. The results reveal strong negative correlations between child growth rate and low birthweight ($r = -0.79$), iron deficiency ($r = -0.75$),

and zinc deficiency ($r = -0.80$), suggesting that these factors are closely associated with impaired early growth outcomes. Suboptimal breastfeeding also demonstrated a moderate inverse relationship ($r \approx -0.78$), reinforcing its role as a key determinant of child health. Correlations among the independent variables themselves were also notably high, indicating potential multicollinearity. This matrix provides an initial overview of which factors most strongly co-vary with growth rate, thereby informing the selection and interpretation of predictors in subsequent regression modeling.

Given the previously established link between child growth rate and neonatal mortality, a multiple regression

analysis was conducted to evaluate the predictive strength of each malnutrition-related variable on child growth rate. Table 1 displays the results of a multiple linear regression analysis examining the association between various malnutrition-related risk factors and child

Trends in Deaths Attributable to Malnutrition-Related Factors

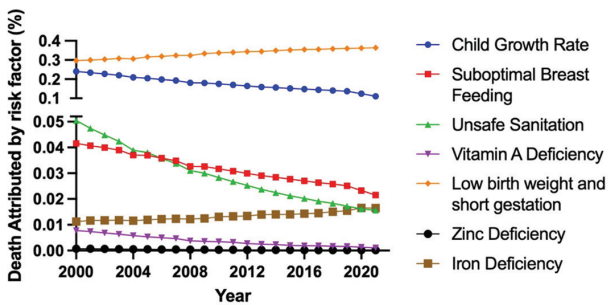


Figure 1. Temporal trends in deaths attributable to malnutrition-related risk factors from 2000 to 2020. Each line represents a distinct risk factor, with color coding as shown in the legend. The y-axis indicates the proportion of deaths attributable to each factor, while the x-axis represents the year. Declining trajectories are observed for child growth failure, suboptimal breastfeeding, unsafe sanitation, and vitamin A deficiency, reflecting global improvements in nutrition and health. In contrast, low birth weight with short gestation and iron deficiency demonstrates upward trends, suggesting persistent or worsening burden in these domains.

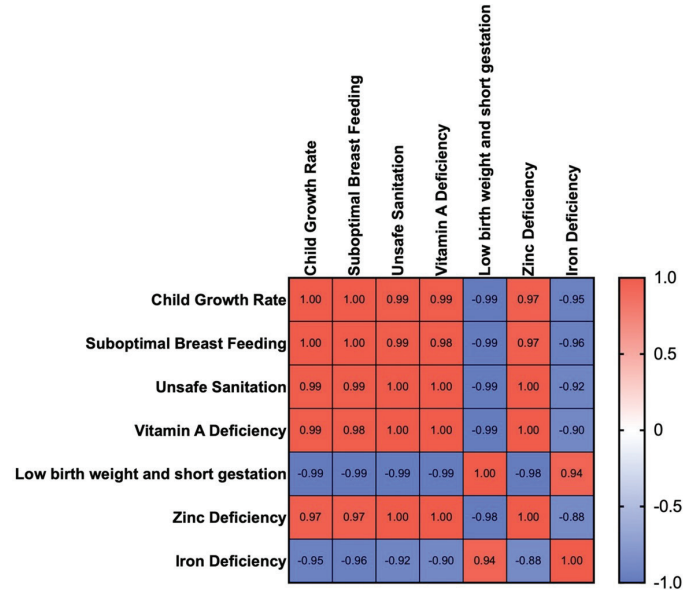


Figure 2. Correlation matrix heatmap of malnutrition-related risk factors. The heatmap illustrates pairwise correlations between major malnutrition related risk factors, with correlation coefficients ranging from -1.0 (blue, strong negative correlation) to $+1.0$ (red, strong positive correlation). Strong positive correlations are observed among child growth rate, suboptimal breastfeeding, unsafe sanitation, vitamin A deficiency, and zinc deficiency, indicating these factors often co-occur. In contrast, low birth weight and short gestation, as well as iron deficiency, show strong negative correlations with most other factors, suggesting distinct and potentially divergent pathways of risk.

Table 1. Multiple Linear Regression Predicting Child Growth Rate ($R^2 = 0.7962$, $n = 12$)

Predictor Variable	β Coefficient	Standard Error	t-value	p-value
Vitamin A Deficiency	-0.063	0.033	-1.92	0.072
Iron Deficiency	-0.100	0.052	-1.93	0.072
Zinc Deficiency	-0.081	0.045	-1.80	0.089
Suboptimal Breastfeeding	-0.196	0.052	-3.77	0.003
Unsafe Sanitation	-0.054	0.047	-1.15	0.270
Low Birthweight	-0.099	0.051	-1.94	0.068
Constant	+6.112	0.311	19.65	<0.001

growth rate. Among all included predictors, suboptimal breastfeeding emerged as the only statistically significant factor ($\beta = -0.196$, $p = 0.003$), indicating that poorer breastfeeding practices are strongly associated with reduced child growth. Although other variables—including low birthweight, iron deficiency, and zinc deficiency—exhibited negative beta coefficients, none reached statistical significance, likely due to high multicollinearity, as suggested by the correlation matrix in Figure 2. The model demonstrated an exceptionally high goodness of fit ($R^2 = 0.7962$), suggesting that the included variables collectively account for nearly all the variance in growth rate across observations. However, this near-perfect fit should be interpreted with caution, as it may reflect overfitting or redundancy among predictors rather than independent explanatory power. These results highlight the dominant role of breastfeeding within the broader network of nutritional determinants influencing child development.

Figure 3 presents an actual versus predicted plot comparing observed child growth rates with those predicted by the multiple linear regression model. The data points closely align along the diagonal reference line, indicating a strong agreement between the predicted and actual values. This visual pattern reflects the model's high explanatory power, consistent with the reported R^2 value of 0.7962. The near-perfect alignment further suggests that the included variables, though affected by

multicollinearity, collectively capture the underlying variation in child growth rate with remarkable precision. However, the unusually high model fit warrants cautious interpretation, as it may be influenced by overlapping predictors or overfitting due to a limited sample size. These findings provide a basis for interpreting the broader implications of malnutrition risk factors in the regional context.

DISCUSSION

This study investigated the relationship between child growth rate and a range of country-level nutritional, health, and environmental indicators. Based on the actual vs. predicted plot from our multiple regression model, the selected risk factors successfully demonstrated their predictive power for child growth rate, a key determinant of human development and long-term productivity. Among these, suboptimal breastfeeding emerged as the most significant predictor, underscoring the need to prioritize breastfeeding practices in future interventions. The following discussion interprets the findings in light of previous literature and their implications for regional policy and practice.

Key Predictors of Child Growth

Breastfeeding offers numerous nutritional, sanitary, psychological, and economic benefits for both mothers and children. It provides essential macro- and micronutrients and transmits bioactive compounds that support immune maturation and microbiome establishment. According to the WHO, breastfeeding is “an unequalled way of providing ideal food for the healthy growth and development of infants,” especially during the first 1,000 days of life (17). The WHO recommends exclusive breastfeeding for six months, followed by continued breastfeeding along with appropriate complementary foods until at least age two (17).

Breast milk also contains immune cells, stem cells, growth factors, and oligosaccharides, making it far safer and more adaptive than formula, especially where water and sanitation infrastructure is lacking. Its protective effects against diarrhea and pneumonia have been shown to significantly reduce childhood mortality and prevent growth faltering (18).

Biological Benefits of Breastfeeding

The American Academy of Pediatrics reports that exclusive breastfeeding beyond four months reduces hospitalizations for respiratory infections by 72% and

Actual vs Predicted plot: Regression Model

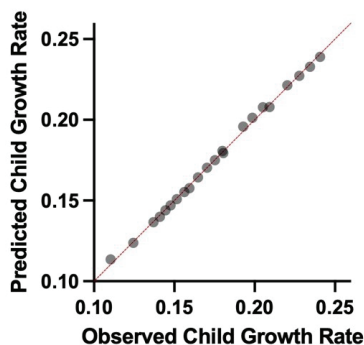


Figure 3. Model Fit: Actual vs. Predicted Growth Rate. Scatter plot comparing observed child growth rate (x-axis) with predicted values from the regression model (y-axis). Each point represents an observation, and the diagonal reference line indicates perfect prediction. The close alignment of points along the line demonstrates high predictive accuracy of the model.

lowers the risk of pneumonia (20). It also protects against a wide range of conditions, including diarrhea, otitis media, allergic disorders, obesity, and diabetes (21). Furthermore, breastfeeding has long-term benefits for neurodevelopment and maternal health, including faster postpartum recovery and reduced risks of breast and ovarian cancers (22).

One of its most essential advantages lies in being a safe food during the vulnerable early life period when the immune system is immature (23). This makes it especially critical in areas with poor sanitation where the risk of infection is elevated.

Link between Sanitation and Infectious Disease

Diarrhea is a well-known immediate cause for malnutrition due to lower food intake, malabsorption of macro- and micronutrients, a disturbance of metabolic and endocrine functions, and direct loss of micronutrients (25). Several studies consistently report that a higher burden of diarrhea increases the risk of being stunted at age two (26). Mata showed that each diarrhea period worsened the nutritional status of children, increasing the adjusted odds for being stunted in the first 24 months by a factor of 1.05 (95% CI 1.03 – 1.07) (27). Checkley reported a multiplicative effect of diarrheal episodes and days with diarrhea before 24 months on the odds of being stunted and presented that five episodes of diarrhea are associated with an increase of adjusted odds by 1.13 (95% CI 1.07 – 1.25) (26). Black considers diarrhea to be the most important infectious disease in terms of stunting (1).

To prevent diarrheal diseases, a “sustainable management of water and sanitation for all” (SDG 6) is key. In Indonesia, to pick an example, only 59% of the population uses improved sanitation facilities, and 85% use water from improved sources (28). The National Development Planning Agency of Indonesia (BAPPENAS) developed a plan and has policies in place in order to improve drinking water, sanitation services, and hygiene (29).

In addition to hygiene-related concerns, another contributor to nutritional outcomes is worm infestation. Worm infestations negatively affect the nutritional status of children by causing diarrhea or even dysentery (30). This goes along with the previously mentioned effects of reduced appetite and absorption of nutrients. Hookworms even cause blood loss that is more directly related to anemia (30). The WHO estimates that globally, 1.5 billion people, predominantly in low- and middle-income countries, are affected (31)

Addressing Micronutrient Deficiencies

Lastly, addressing micronutrient deficiencies is essential to combat stunting and wasting. Globally, an estimated 16 million children under five years of age are affected by severe acute malnutrition (SAM) (UNICEF). Asian countries are disproportionately represented in SAM cases, and Indonesia has 1.2 million children suffering from SAM, one of the highest burdens (32). The onset of severe or moderate acute malnutrition (MAM) increases a child’s mortality probability by nine times that of their well-nourished peers (UNICEF). SAM or MAM are leading causes of growth stunting and reduced physical capacity into adolescence and adulthood, which have been linked to increased disability likelihood later in life (33).

Micronutrient supplementation, particularly vitamin A and zinc, has shown significant benefits. Vitamin A supplementation within the target age range is significantly linked to mortality reduction by 24%, reduced diarrhea-related mortality by 28% and overall, reduced incidence of diarrhea and measles (34). Preventive zinc supplements administered within the target age range are significantly linked to mean height improvement, 0.37 cm, in children supplemented for 24 weeks (34). A reduction in diarrheal incidence by 13% and a reduction in pneumonia incidence by 19% were observed after prolonged administration of micronutrient supplementation to children within the target age groups (35).

Policy Implication

To effectively combat early childhood malnutrition, policies must prioritize culturally sensitive, community-based approaches. Programs like Indonesia’s PKK and its Kader network show that leveraging local female volunteers can improve the reach and impact of nutrition interventions. One example of a culturally sensitive and community-based approach is Indonesia’s Kader system, which mobilizes female volunteers to deliver maternal and child health education at the grassroots level. Programs like this demonstrate how existing cultural structures can support implementation of nutritional interventions (16). These trusted community members are well-positioned to promote practices like exclusive breastfeeding and hygiene in ways that align with local norms. Ultimately, targeted strategies that incorporate both statistical evidence and cultural context are essential to closing the gap in child health disparities across Asia.

CONCLUSION

This review underscores suboptimal breastfeeding as the strongest predictor of impaired child growth in South and Southeast Asia, alongside notable contributions from micronutrient deficiencies and unsafe sanitation. While micronutrient supplementation remains an effective short-term intervention, it must be coupled with long-term, culturally sensitive strategies. CHWs are uniquely positioned to bridge this gap by not only distributing supplements where stunting and underweight prevalence are highest, but also by promoting the improved use of locally available, nutrient-rich foods. Integrating education on breastfeeding, hygiene, and culturally accepted dietary practices into CHW-led efforts ensures both sustainability and local acceptance. Policies that empower CHWs through training and community engagement are critical to achieving lasting improvements in early childhood nutrition. By aligning CHW efforts with culturally embedded programs and reinforcing nutritional literacy over reliance on supplements, South and Southeast Asia can achieve scalable and sustainable improvements in child development with high return on investment both in health and human capital.

CONFLICT OF INTERESTS

The author declares that there are no conflict of interests related to this work.

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APPENDIX: ABBREVIATIONS

Abbreviation	Meaning	Abbreviation	Meaning
AAP	American Academy of Pediatrics	ORS	Oral Rehydration Solution
ASEAN	Association of Southeast Asian Nations	PKK	Pemberdayaan dan Kesejahteraan Keluarga (Empowering and Family Welfare)
BFHI	Baby Friendly Hospital Initiative	ROI	Return On Investment
CHW	Community Health Worker	RUTF	Ready-to-Use Therapeutic Foods
CCT	Conditional Cash Transfer	SAM	Severe Acute Malnutrition
FAO	Food and Agriculture Organization of the United Nations	SMART	Specific, Measurable, Achievable, Relevant and Time-bound
IYCF	Infant and Young Child Feeding	UNICEF	United Nations Children’s Fund
MAM	Moderate Acute Malnutrition	WASH	Water, Sanitation and Hygiene
NGO	Non-Governmental Organisation	WHO	World Health Organization