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The Role of Maternal Stress Epigenetics in the Risk of Stunting among Children Aged 0–24 Months: A Community-Based Longitudinal Study

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Abstract

Stunting is a major child health problem influenced by multiple factors, including maternal conditions during pregnancy. This study aimed to analyze the relationship between maternal stress, epigenetic mechanisms, and the risk of stunting in children aged 0–24 months. A community-based prospective longitudinal cohort design was employed, involving 30 pregnant women who were followed until their children reached 24 months of age. Maternal stress was assessed using the Perceived Stress Scale (PSS), while epigenetic analysis was conducted via DNA methylation of the IGF2 gene from umbilical cord blood samples. Stunting status was determined based on length-for-age (LAZ) according to WHO standards. The results indicated a tendency toward an increased risk of stunting among mothers with high stress levels (OR=9.00; p>0.05), along with increased IGF2 methylation. Although not statistically significant, the pattern of association was clinically consistent. It is concluded that maternal stress may increase the risk of stunting through epigenetic mechanisms. Integrating stress management into antenatal care is recommended as a strategy for stunting prevention.

Introduction

Stunting remains a significant public health issue, particularly in developing countries, including Indonesia. This condition is characterized by impaired linear growth in children due to chronic malnutrition occurring from the prenatal period through early life (Setiadi & Dwijayanti, 2020). The impact of stunting is not limited to suboptimal height but is also closely linked to reduced cognitive ability, increased susceptibility to disease, and decreased productivity in adulthood. Various nutritional intervention efforts have been implemented; however, the prevalence of stunting remains relatively high, necessitating a more comprehensive and multidimensional approach (Priyono, 2020; Fahmi et al., 2025; Hidayat, 2023; Kalinda et al., 2024; Yusriadi et al., 2024).

Until now, risk factors for stunting have generally focused on nutritional intake, maternal health status, and environmental conditions (Hermayani et al., 2023; Mulyani et al., 2025). However, scientific advancements indicate that more complex biological factors, including epigenetic mechanisms, also play a role in determining a child's growth status (Maulidina et al., 2022). Epigenetics refers to changes in gene expression without altering the structure of the DNA itself, which can be influenced by environmental factors, including the mother's psychological state during pregnancy. In this context, maternal stress is a key factor that has the potential to influence fetal development through deeper biological pathways (Pentiernitasari et al., 2025; King et al., 2025; Lubrano et al., 2024).

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Stress experienced by mothers during pregnancy can trigger activation of the neuroendocrine system, particularly the hypothalamic–pituitary–adrenal (HPA) axis, leading to increased levels of the hormone cortisol (Anjani et al., 2025). Excessive exposure to cortisol can cross the placenta and affect the regulation of genes involved in fetal growth and development. The resulting epigenetic changes, such as DNA methylation, can have long-term effects on a child's metabolic function and growth after birth (Yusharyahya, 2021; Bokor et al., 2024). Therefore, maternal stress not only has direct effects but can also leave a "biological imprint" that influences a child's risk of stunting (Farhat et al., 2025; Ragsdale, 2023).

Although the relationship between maternal stress and child health outcomes has been extensively studied, research specifically linking epigenetic mechanisms to the incidence of stunting particularly in community-based populations in Indonesia remains very limited (Allen et al., 2024). Most previous studies have focused primarily on birth weight or cognitive development, while the aspect of long-term linear growth has not been explored in depth (Kamilah, 2025). Furthermore, longitudinal approaches capable of capturing the dynamics of change from pregnancy through a child's first two years of life are still rarely employed (Hiddayaturrahmi et al., 2024).

Given the importance of the first 1,000 days of life as a critical period in determining an individual's health, this study is relevant for addressing this gap (Sa'adah et al., 2024). A community-based approach also provides a more representative picture of real-world conditions in the community, including the social and environmental factors that influence maternal stress (Nasution, 2021; Chang et al., 2014; Schensul et al., 2014).

Therefore, this study aims to analyze the role of epigenetic mechanisms in the association between maternal stress during pregnancy and the risk of stunting in children aged 0–24 months using a community-based longitudinal design (Ekowati et al., 2025; Sumanti, 2024). The results of this study are expected to provide a scientific contribution to the development of more holistic stunting prevention strategies ones that not only focus on nutritional aspects but also consider maternal mental health as an integral part of maternal and child health interventions.

Methods

This study employed a community-based prospective longitudinal cohort design to examine the relationship between maternal stress during pregnancy, IGF2 DNA methylation, and stunting in children aged 0–24 months (Fadhilah et al., 2020; Haloho & Legiran, 2023). Pregnant women in their first trimester were recruited consecutively from a semi-rural community health center. Eligible participants were aged 18–40 years, had a singleton pregnancy, and had no chronic disease or severe pregnancy complications (Maribeth et al., 2024). A total of 30 mothers were enrolled and followed until their children reached 24 months of age.

Maternal stress was assessed during the first and third trimesters using the validated Perceived Stress Scale and categorized as low, moderate, or high (Anjani et al., 2025). Umbilical cord blood was collected at delivery to assess IGF2 DNA methylation using bisulfite sequencing. Methylation levels were categorized as low or high based on the predetermined laboratory cut-off. Maternal nutritional status was assessed using [indicator and cut-off used] and classified as poor or adequate.

Child length was measured at 6, 12, and 24 months. Length-for-age Z-scores were calculated according to WHO Child Growth Standards. Children with a Z-score below −2 standard deviations were classified as stunted. Stunting status at 24 months was used as the primary outcome.

Participant characteristics and stunting prevalence were summarized using frequencies and percentages. Binary logistic regression was used to examine the association between maternal stress and stunting. Multivariate logistic regression was then conducted to assess the independent effects of high maternal stress, high IGF2 methylation, and poor maternal nutritional status, with results reported as odds ratios, 95% confidence intervals, and p-values (Wiyono et al., 2025). Statistical significance was set at $p < 0.05$.

Result and Discussion

A total of 30 pregnant women were recruited at the start of the study, and all were successfully followed up until their children reached 24 months of age (100% follow-up). The majority of the mothers were aged 25–35 years (46.7%), had a secondary education (50.0%), and came from a low socioeconomic group (60.0%). The prevalence of stunting increased with age, namely 10.0% at 6 months, 20.0% at 12 months, and 30.0% at 24 months.

Table 1. Respondent Characteristics (n = 30)

Variable	n (%)
Mother's Age (years)	
18–24	8 (26.7)
25–35	14 (46.7)
>35	8 (26.7)
Mother's Education	
Low	10 (33.3)
Secondary	15 (50.0)
High	5 (16.7)
Economic Status	
Low	18 (60.0)
Medium–High	12 (40.0)
Parity	
Primiparous	16 (53.3)
Multipara	14 (46.7)

Source: 2026 Research Data

Table 2. Relationship Between Maternal Stress and Stunting at 24 Months of Age

Stress Level	Stunting n (%)	Non-Stunting n (%)	OR (95% CI)	p-value
Low	1 (10.0)	9 (90.0)	1.00 (Reference)	–
Moderate	3 (30.0)	7 (70.0)	3.86 (0.33–44.8)	0.264
High	5 (50.0)	5 (50.0)	9.00 (0.89–91.2)	0.064

Source: 2026 Research Data

Table 2 shows an increasing proportion of stunting across maternal stress categories. Among mothers with low stress, 10.0% of children were stunted, compared with 30.0% in the moderate-stress group and 50.0% in the high-stress group. Children born to mothers with moderate stress had 3.86 times higher odds of stunting than those in the low-stress group, whereas children in the high-stress group had 9.00 times higher odds. However, neither association reached statistical significance, as indicated by p-values of 0.264 and 0.064, respectively. The wide confidence intervals also suggest considerable uncertainty, likely related to the small sample size. Nevertheless, the findings indicate a tendency toward a higher risk of stunting with increasing maternal stress.

Table 3. Multivariate Analysis of Stunting Risk Factors

Variable	Adjusted OR	95% CI	p-value
High maternal stress	4.20	0.71–24.8	0.112
High IGF2 methylation	3.10	0.58–16.5	0.182
Poor maternal nutritional status	2.40	0.45–12.8	0.298

Source: 2026 Research Data

Table 3 presents the multivariate logistic regression analysis of factors associated with stunting at 24 months. After the variables were entered simultaneously into the model, high maternal stress showed the strongest association with stunting, with an adjusted odds ratio of 4.20. High IGF2 methylation was associated with 3.10 times higher odds of stunting, while poor maternal nutritional status was associated with 2.40 times higher odds. However, none of these associations was statistically significant because all p-values exceeded 0.05. The wide confidence intervals indicate that the estimates should be interpreted cautiously. Thus, these findings suggest possible associations rather than confirming independent predictors of stunting.

Table 4. Longitudinal Prevalence of Stunting

Child's Age	Stunting n (%)
6 months	3 (10.0)
12 months	6 (20.0)
24 months	9 (30.0)

Source: 2026 Research Data

Table 4 demonstrates a progressive increase in the prevalence of stunting during the follow-up period. At 6 months of age, 3 children, or 10.0%, were classified as stunted. This number increased to 6 children, or 20.0%, at 12 months and reached 9 children, or 30.0%, at 24 months. These findings indicate that the prevalence of stunting increased as the children grew older. The pattern suggests that, in addition to prenatal factors, postnatal conditions occurring during the first two years of life may contribute to impaired linear growth.

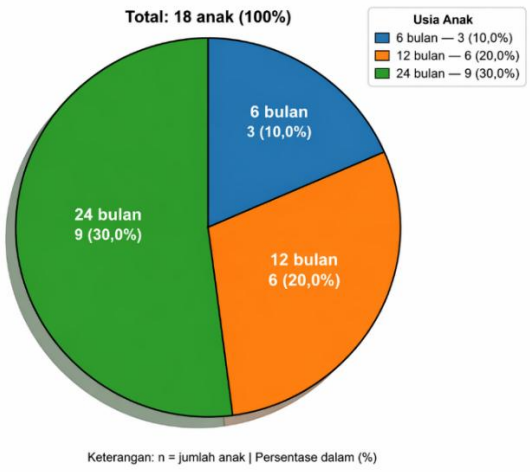

Figure 1. Longitudinal Prevalence of Stunting

The results of this study indicate a trend toward an association between maternal stress during pregnancy and an increased risk of stunting in children at 24 months of age, although this association has not yet reached statistical significance ($p > 0.05$). This finding remains important because the relatively large odds ratio indicates a clinically meaningful association. Thus, these findings can be viewed as relevant *preliminary evidence* in explaining the role of maternal psychological factors in child growth (Adar, 2022).

Biologically, this relationship can be explained by chronic activation of the hypothalamic–pituitary–adrenal (HPA) axis due to maternal stress, which increases cortisol secretion (Azzahra et al., 2025). Excess cortisol can cross the placenta and affect the intrauterine environment, including fetal growth processes. This condition has the potential to disrupt hormonal and metabolic regulation which are critical for linear growth thereby increasing the risk of stunting later in life (Batra et al., 2026; Dable-Tupas et al., 2026).

Furthermore, the results of this study also indicate a trend toward increased DNA methylation in the growth gene (IGF2) among mothers in the high-stress group. Although this association is not yet statistically significant, these findings support the hypothesis that epigenetic mechanisms serve as a biological pathway linking maternal stress to child growth outcomes. Epigenetic changes, such as DNA methylation, can influence gene expression without altering the genetic structure, thereby having long-term effects on children's growth and development (Azmi et al., 2025; Wang & Zhang, 2025; Eskandar, 2025).

The lack of statistical significance in this study was most likely influenced by the relatively small sample size (n = 30), which resulted in low statistical power. This is evident from the fairly wide confidence intervals in the multivariate analysis. Nevertheless, the consistent direction of the relationship between maternal stress, epigenetic changes, and the incidence of stunting suggests a biologically plausible pattern that aligns with previous literature.

In addition to prenatal factors, the increase in the prevalence of stunting from 6 to 24 months of age in this study indicates a contribution from postnatal factors, such as nutritional intake, feeding practices, and exposure to infections (Furuse et al., 2021). This reinforces the notion that stunting is a multifactorial condition influenced by the interaction between biological and environmental factors.

The implications of this study highlight the importance of integrating mental health aspects into antenatal care (Rohmawati et al., 2026). Early detection and intervention for maternal stress have the potential to serve as preventive strategies to reduce the risk of stunting. Furthermore, the epigenetic approach opens opportunities for the development of biomarker-based interventions in the future, although further research with larger and more comprehensive designs is still needed.

This study has several limitations, including a small sample size and limitations in evaluating a broader range of epigenetic gene variations. Therefore, follow-up studies with larger sample sizes, multi-center designs, and the exploration of a wider variety of biomarkers are highly recommended to strengthen these findings.

Conclusion

Research This study indicates a potential association between maternal stress during pregnancy and an increased risk of stunting in children aged 0–24 months, suggesting a role for epigenetic mechanisms via DNA methylation of the growth gene (IGF2). Although not yet statistically significant, the consistent direction of the association and the high odds ratio suggest a clinically meaningful association. These findings underscore the importance of maternal psychological factors in stunting prevention and indicate that postnatal factors also contribute, suggesting that interventions should be implemented from pregnancy through early childhood.

A limitation of this study is its small sample size, which limits it to an exploratory nature. Therefore, further studies with larger samples and more comprehensive biomolecular approaches are needed. Practically, this study recommends integrating maternal stress screening and management into antenatal care as a more holistic strategy for preventing stunting.

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