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RESEARCH

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Maternal Factors, Low Birth Weight, and Early Stimulation as Determinants of Stunting in Children Aged 24–36 Months: A Systematic Review

Ernawati^{1a*}, Riyadi^{2b}, Johaness Cornelius Mose^{3c}, Hadi Susiarno^{3d}, Meita Dhamayanti^{2e}, Anggraini Alam^{2f}

¹ Magister of Midwifery, Faculty of Medicine, Padjadjaran University, Bandung, Indonesia

² Department of Child Health, Faculty of Medicine, Padjadjaran University, Bandung, Indonesia.

³ Department of Obstetrics and Gynecology, Faculty of Medicine, Padjadjaran University, Bandung, Indonesia.

^a Email address: ernawati24001@mail.unpad.ac.id

^b Email address: riyadispa@gmail.com

^c Email address: johaness@unpad.ac.id

^d Email address: hadi.susiarno@unpad.ac.id

^e Email address: meita.dhamayanti@unpad.ac.id

^f Email address: anggraini.alam@unpad.ac.id

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Abstract

Stunting among children aged 24–36 months is associated with various maternal, perinatal, and environmental factors. This systematic review examined the relationships between maternal factors, birth weight, early stimulation, and stunting in this age group. The review was conducted in accordance with the PRISMA guidelines. Relevant studies were identified through searches of six major databases and selected based on predefined eligibility criteria, including study design, participants' age, and the exposure variables examined. A narrative synthesis was used to summarize the findings. Methodological quality was assessed using the Newcastle–Ottawa Scale and the JBI checklist, while potential risks of bias were also considered. Ten studies were included in the final review. The findings indicated that several maternal factors, including nutritional status, tetanus toxoid immunization, household income, and the quality of antenatal care, were associated with stunting. Low birth weight emerged as a recurring predictor, with reported risk estimates ranging from 1.74 to 3.12. Early stimulation, particularly through responsive parenting and a supportive home environment, was identified as a potentially protective factor. However, differences in measurement methods and study designs limited the comparability of the findings. Variations were also observed in the assessment of exposures and confounding factors, although most studies met the minimum criteria for methodological quality. Overall, the evidence suggests that maternal factors, birth weight, and early stimulation are relevant to stunting among children aged 24–36 months. These findings highlight the need for integrated maternal and child health interventions that address maternal nutrition, access to quality antenatal care, the prevention of low birth weight, and family-based early stimulation to support healthy growth and development.

Keywords: Antenatal care, early stimulation, low birth weight, maternal factors, stunting.

Corresponding Author:

Ernawati

Magister of Midwifery, Faculty of Medicine, Padjadjaran University, Bandung, Indonesia

Email: ernawati24001@mail.unpad.ac.id



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1. INTRODUCTION

Stunting is commonly discussed in relation to physical growth, but its implications may continue well beyond the early years of life. Children who experience persistent growth faltering may also face challenges in cognitive development, health, and later productivity. Evidence from multicountry cohort studies has shown an association between persistent stunting in early childhood and lower cognitive scores at five years of age (Anastasia et al., 2023; Awaludin et al., 2025). The period from conception to a child's second birthday is particularly relevant because substantial changes in growth and development occur during these first 1,000 days. Longitudinal findings further suggest that height at two years of age, together with linear growth during this period, is associated with intellectual functioning and mental health later in childhood (Ekholuenetale et al., 2020; Nguyen et al., 2021).

Evidence of growth faltering can emerge during infancy, rather than only when children approach their second birthday. Declining length-for-age z-scores (LAZ) have been reported in early life, drawing attention to conditions during pregnancy and the period immediately after birth (Kumala Putri et al., 2023). This timing has implications for prevention. Efforts to address stunting need to consider maternal health before conception, conditions throughout pregnancy, and the environment in which children grow after birth. Such efforts also extend beyond the health sector, since the circumstances affecting maternal and child health are not confined to clinical care (Anastasia et al., 2023).

Among the factors examined in relation to stunting are maternal characteristics, low birth weight (LBW), and early stimulation (Ali, 2021; Jana et al., 2023). Maternal circumstances may affect a child's growth from the prenatal stage onward. Nutritional status, maternal age, education, reproductive health, and the quality of antenatal care are among the characteristics associated with pregnancy outcomes and subsequent child growth (Haryani et al., 2022; Marine et al., 2026). Birth weight provides another point of connection between pregnancy and a child's later growth. Infants born with LBW have limited nutritional reserves and are more vulnerable to infection. These conditions may place them at greater risk of impaired growth, including stunting (Burki, 2025; Sihotang et al., 2023).

Experiences after birth are also relevant to children's development. The home environment, particularly the quality of interaction between children and their caregivers, can provide opportunities for learning and developmental progress. Early stimulation through responsive parenting and activities that encourage cognitive development has been associated with better cognitive and motor outcomes. A supportive home environment may also help address some developmental disadvantages experienced by children with poor nutritional status (Attanasio et al., 2022; Upadhyay et al., 2022). These findings place caregiving practices alongside maternal and birth-related conditions when considering the factors associated with early childhood development.

The UNICEF conceptual framework for child malnutrition offers a basis for examining these factors in relation to one another. It distinguishes between immediate, underlying, and basic determinants of nutritional outcomes, allowing the circumstances surrounding a child's growth to be considered at different levels. Maternal health and nutrition are relevant to fetal growth and birth outcomes, whereas LBW reflects a biological vulnerability that may begin before delivery. Early stimulation concerns the developmental environment after birth. Although these factors represent different dimensions of child growth, they may be related. Maternal conditions can influence birth weight, and the care children receive subsequently may shape their growth and development. Their relationships with stunting therefore need to be considered without assuming that each operates independently.

Previous epidemiological research has examined associations between stunting and prenatal conditions, maternal nutritional status, LBW, and early stimulation (Kumala Putri et al., 2023; Prendergast & Humphrey, 2014; Sartika et al., 2021). However, the available findings are distributed across studies with differing areas of emphasis. Some have

concentrated on maternal characteristics, while others have focused on birth outcomes or caregiving practices. As a result, the relationships among these factors and their combined relevance to stunting remain insufficiently clear (Saleh et al., 2021; Santosa et al., 2021). Differences in study design, participant characteristics, and measurement methods create further difficulties when findings are compared. Associations reported in one study may not be reproduced in another, reflecting differences in both the populations examined and the methods used (Ardiyanto et al., 2025).

The quality and comparability of the available evidence also require consideration. Small sample sizes, limited adjustment for confounding variables, and the use of non-standardized measures of early stimulation have been reported as methodological concerns. Such limitations make it difficult to establish whether the observed relationships are causal, particularly in research involving children aged 24–36 months (Garina et al., 2024; Upadhyay et al., 2022). There is also limited evidence on whether early stimulation can modify or lessen the adverse effects associated with LBW and maternal risk factors. Without a clearer understanding of this relationship, the contribution of family-based interventions to stunting prevention remains uncertain. This also presents a challenge for developing policies that are supported by research and appropriate to different local contexts (Garina et al., 2024; Upadhyay et al., 2022).

Against this background, this systematic review examines maternal factors, LBW, and early stimulation in relation to stunting among children aged 24–36 months. The review brings together evidence on these three areas to provide a more connected account of the factors examined in previous research. It addresses the maternal factors associated with stunting, the relationship between LBW and stunting, and the potential protective role of early stimulation. The review process is reported in accordance with the PRISMA guidelines, which provide a framework for transparently documenting how evidence is identified, assessed, and synthesized (Putri et al., 2021). The findings are also considered in terms of the remaining research gaps and their implications for policy development and clinical practice (Ma et al., 2020; Moosapour et al., 2021).

2. RESEARCH METHOD

This study used a systematic review approach to examine and synthesize existing evidence on the relationships between maternal factors, low birth weight (LBW), early stimulation, and stunting among children aged 24–36 months. This approach enabled findings from different primary studies to be examined collectively, providing a broader understanding of the factors associated with stunting. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure that the review process was reported transparently. Before the literature search and screening began, a review protocol was developed to establish the procedures for study selection and data synthesis. However, the protocol was not prospectively registered in an international database such as PROSPERO.

Study eligibility was determined using the PICOTS framework. The population (P) consisted of children aged 24–36 months, while the exposures (I) of interest were maternal factors, LBW, and early stimulation. The comparison (C) involved children who were not exposed to the relevant risk factors or who had different levels of exposure, as applicable to each study. The primary outcome (O) was stunting. Regarding the time frame (T), the review focused on studies published between 2020 and 2025, while earlier publications were also considered when they were particularly relevant to the research objectives and frequently cited. Eligible study designs (S) included observational studies, such as cross-sectional, case-control,

and cohort studies, as well as intervention studies and evidence syntheses that reported findings on the relationship between at least one of the specified exposures and stunting.

Relevant literature was identified through systematic searches of six bibliographic databases: PubMed, Scopus, Web of Science, ScienceDirect, Embase, and Google Scholar. The search strategy combined standardized subject headings, including Medical Subject Headings (MeSH) and Emtree terms, with free-text keywords related to stunting, maternal factors, LBW, and early stimulation. Boolean operators (AND and OR) were used to combine search terms and retrieve studies addressing the review's main research questions. The search strategy was adapted to the requirements of each database to accommodate differences in indexing systems and search functionality.

Studies were considered eligible if they met the following criteria: (1) published between 2020 and 2025, although earlier studies were also included when they were particularly relevant to the topic and frequently cited; (2) available in full text; (3) involving children aged 24–36 months; (4) examining the relationship between stunting and at least one of the following factors: maternal characteristics, low birth weight, or early stimulation; and (5) employing an observational or interventional study design.

Study selection began with an examination of titles and abstracts by two independent reviewers. Each record was assessed against the eligibility criteria, and any disagreements were discussed until a consensus was reached. When the reviewers could not reach an agreement, a third reviewer was consulted to make the final decision. Data from the selected articles were then extracted, covering the first author's name, publication year, country or study setting, research design, participant characteristics, sample size, maternal factors, birth weight, early stimulation, stunting outcomes, and potential confounding variables reported in each study. The study identification and selection process is presented in the PRISMA flow diagram.

A meta-analysis was not conducted because the included studies varied considerably in their research designs, methods of measuring exposures, definitions of stunting, and reported measures of association. These differences made it difficult to combine the findings statistically in a meaningful way. Instead, the results were examined narratively, with the main characteristics and findings of each study summarized in comparative tables.

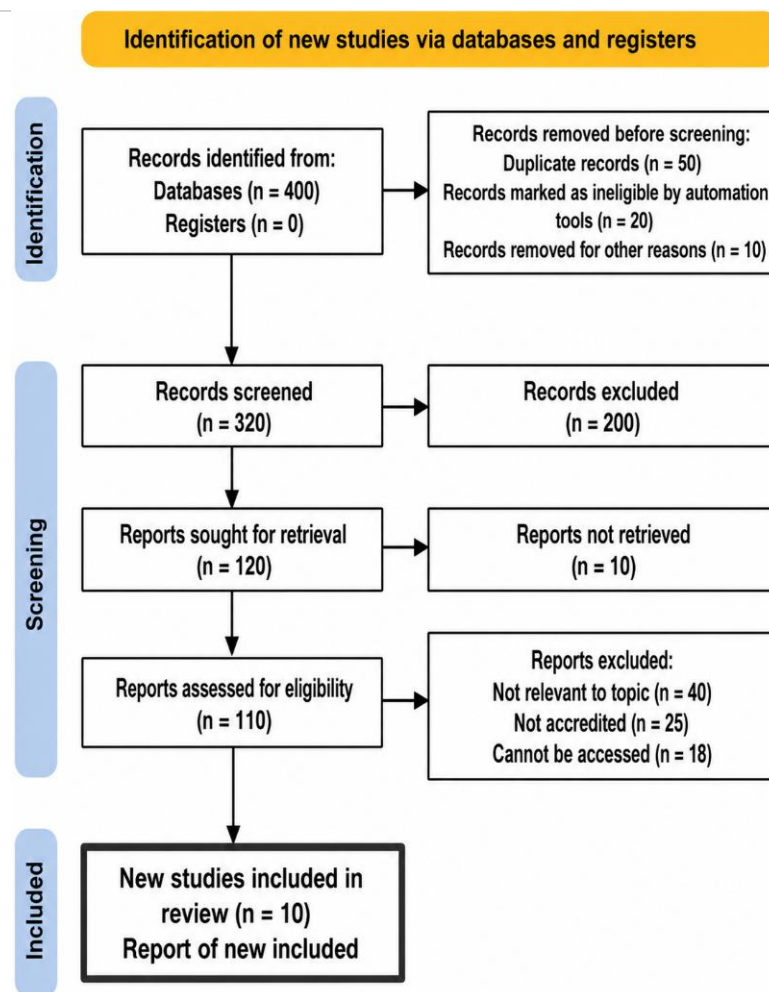


Figure 1 PRISMA flow diagram

Figure 1 presents the study selection process based on the PRISMA framework. Following the application of the eligibility criteria, ten studies were retained for the final review. Articles were excluded for several reasons, primarily because they did not address the focus of the review, employed ineligible study designs, or lacked sufficient information for assessment. The findings of the included studies were then examined through a narrative thematic synthesis, focusing on maternal factors, low birth weight, and early stimulation in relation to stunting. Two reviewers independently assessed the methodological quality and potential risk of bias of each study. Any differences in their assessments were discussed and resolved by consensus. Given the substantial differences in study methods and reported outcomes, the findings were not pooled in a quantitative meta-analysis. The review was reported in accordance with the PRISMA 2020 Statement. Although a review protocol was prepared before the screening process began, it was not prospectively registered in PROSPERO or any other international registry.

3. RESULTS AND DISCUSSION

Ten studies were included in the final synthesis. Across these studies, stunting was examined in relation to maternal factors, low birth weight (LBW), and early stimulation. The reported odds ratios for LBW ranged from 1.74 to 3.12, although the magnitude of the association differed between studies and across the other determinants examined.

The literature search initially produced 400 records. After duplicate records had been removed and records flagged by the automated screening tool had been excluded, 320 records remained for title and abstract screening. From this stage, 110 articles were considered potentially relevant and were retrieved for full-text assessment. The full-text review subsequently reduced the number of eligible studies to 10, as these were the studies that satisfied all of the predefined inclusion criteria. These ten studies formed the basis of the final synthesis.

Characteristics of Included Studies

The evidence base consisted of ten studies published between 2022 and 2025. Two earlier studies, published in 2017 and 2019, were also retained because of their relevance to the relationship between LBW and stunting. Most of the studies were conducted in Indonesia. The evidence also included one global scoping review and several analyses using national survey data.

Considerable variation was found in the characteristics of the studies. They differed in research design, sample size, and the variables used to represent maternal factors, birth weight, and early stimulation. Rather than examining exactly the same set of factors, the studies addressed different aspects of the relationship between these determinants and stunting. This variation provides evidence from several perspectives but also needs to be considered when the findings are compared across studies. The characteristics of the individual studies are presented in Table 1.

Table 1. Characteristics, quality assessments, and key findings of the included studies

Author (Year)	Design	Sample size	Key Exposures	Key Findings	Quality/Risk of Bias
Garina et al. (2024)	Cross-sectional study	119	Maternal factors, LBW	Maternal TT immunization and LBW are significantly associated with stunting	High/Medium
Haryani et al. (2022)	Cross-sectional study	20	Income, birth weight	Low parental income was significantly associated with stunting ($p = 0.032$)	Medium/High
Sari et al. (2025)	Case-control study	100	Early stimulation	Poor stimulation increases the risk of stunting	High/Low
Aryastami et al. (2017)	Secondary analysis	24,020	LBW	LBW increases the risk of stunting (OR = 1.74)	High/Low
Hadi et al. (2019)	Secondary analysis	290	LBW	LBW increases the risk of stunting (OR = 3.12)	High/Low
Anastasia et al. (2023)	Cross-sectional study	National survey	Maternal determinants	Maternal health and socioeconomic factors are associated with stunting	High/Medium

Haryani et al. (2022)	Cluster-randomize controlled trial	490	Maternal assistance	Increased fetal growth and improved child nutritional outcomes	High/Low
D. P. Sari et al. (2024)	Secondary analysis	National datasets	ANC, LBW	Adequate ANC reduces the risk of LBW	Medium/Medium
Ardiyanto et al. (2025)	Scoping review	27 studies	LBW	Consistent relationship between LBW and stunting was observed (ORs 2.19–2.42)	High/Low
Lestari et al. (2024)	Cross-sectional study	26	SDIDTK	Early stimulation supports child development	Medium/Medium

Detailed Study Synthesis

The studies included in this review are summarized in Table 2. The table provides information on the study populations, participants' age groups, exposure factors, and the main findings concerning stunting.

Table 2. Detailed synthesis of the included studies

Author (Year)	Population / Settings	Age Range	Exposure Variables	Key Findings
Garina et al. (2024)	Children in Padalarang, Indonesia	24–59 months	Maternal factors, LBW, TT immunization	Incomplete TT immunization and LBW are associated with stunting.
Haryani et al. (2022)	Children in Rejang Lebong	12–59 months	Income, birth weight	Low parental income is associated with stunting.
Sari et al. (2025)	Children in Surabaya	24–59 months	Stimulation and nurturing	Poor stimulation increases the risk of stunting.
Aryastami et al. (2017)	Indonesian Children	12–23 months	LBW	Low birth weight was found to be the primary predictor of stunting.
Hadi et al. (2019)	Children in Banten	<5 years old	LBW	The risk of stunting increased by a factor of 3.12 in children with low birth weight.
Anastasia et al. (2023)	Children under five	<5 years old	Maternal factors	Maternal health and socioeconomic

				status affect stunting.
Haryani et al. (2022)	Indonesian women	Pregnancy to early childhood	Maternal assistance	Increased fetal growth and improved nutritional outcomes
Sari et al. (2024)	High-risk births	<5 years old	ANC, LBW	Better ANC reduces the risk of LBW.
Ardiyanto et al. (2025)	Global studies	<5 years old	LBW	LBW consistently increases the risk of stunting.
Lestari et al. (2024)	Children in Padang Panjang	24–36 months	SDIDTK	SDIDTK supports age-appropriate development.

Table 2 provides an overview of the studies included in the review. It summarizes the characteristics of the study populations, the exposures examined, and the main findings related to maternal conditions, birth weight, and early stimulation in relation to stunting.

Key Findings and Narrative Synthesis

Across the studies, several maternal conditions were linked to stunting. The factors reported included inadequate use of antenatal care, poor maternal nutritional status, low household income, and incomplete maternal immunization. [Garina et al. \(2024\)](#), [Anastasia et al. \(2023\)](#), and [Haryani et al., \(2022\)](#) each reported findings indicating that maternal health during pregnancy was related to the nutritional condition of children. Although the specific maternal factors examined were not identical across the studies, the findings generally draw attention to the period of pregnancy as an important stage in determining subsequent child growth.

Birth weight showed a relatively clear pattern across the available evidence. Children born with low birth weight (LBW) were more frequently reported to experience stunting than children with higher birth weights. The reported odds ratios ranged from 1.74 to 3.12. [Aryastami et al. \(2017\)](#) found that children with LBW had 1.74 times the odds of experiencing stunting, whereas [Hadi et al. \(2019\)](#) reported an estimate of 3.12. Similar evidence was also noted in the scoping review by [Ardiyanto et al. \(2025\)](#), which described a positive relationship between LBW and stunting across different settings. Taken together, these studies indicate that birth weight is an important factor to consider when examining early childhood growth.

The studies that focused on early stimulation approached the issue from a somewhat different perspective. Their findings centered mainly on the quality of parenting, caregiver responsiveness, and opportunities provided for children's development. [Sari et al. \(2025\)](#) reported that inadequate stimulation and less optimal parenting were associated with a higher risk of stunting. In contrast, [Lestari et al. \(2024\)](#) reported improvements in developmental outcomes following the implementation of the SDIDTK program. These findings suggest that children's experiences after birth may also be relevant, particularly when stimulation and caregiving are considered alongside nutritional conditions.

Taken together, the evidence covers factors operating at different stages of a child's early life. Maternal nutritional and socioeconomic conditions may influence fetal growth and, subsequently, birth weight. After birth, the child's daily caregiving environment becomes another part of the picture, including the stimulation and interaction provided by family members. The studies reviewed here therefore suggest that stunting cannot be understood solely

in terms of one maternal or child-level factor. Attention to maternal health, efforts to prevent LBW, and support for appropriate stimulation within the family may need to be considered alongside one another when designing approaches to stunting prevention.

General Discussion of Research Findings

Across the studies included in this review, maternal conditions, birth weight, and early stimulation were repeatedly examined in relation to stunting among children aged 24–36 months. Maternal circumstances were evident in several of the studies. Garina et al. (2024) found that incomplete maternal tetanus toxoid immunization and family risk conditions were significantly associated with a higher risk of stunting. A similar concern was reported by Haryani et al. (2022), who identified socioeconomic conditions, particularly parental income, as factors related to children's nutritional status. These findings place the period surrounding pregnancy and the first 1,000 days of life within an important context for understanding subsequent child growth.

Birth weight showed a more consistent pattern across the evidence reviewed. LBW was identified as an important predictor of stunting in most of the studies that examined this factor. Aryastami et al. (2017) reported that children born with LBW were 1.74 times more likely to experience stunting. Hadi et al. (2019) reported an even higher estimate, with a 3.12-fold increased risk. Evidence from Ardiyanto et al. (2025), points in the same direction. Their scoping review reported a 2.19–2.42-fold increase in the risk of stunting among children with LBW.

Findings from seven studies also draw attention to conditions during pregnancy, particularly the intrauterine environment and maternal nutritional status. These conditions are relevant because fetal growth is closely connected to the nutritional and physiological circumstances experienced before birth. The fetal programming hypothesis provides one possible explanation for the observed association. According to this perspective, unfavorable conditions in utero may produce lasting changes in metabolic and physiological functions, which can leave children more susceptible to impaired growth after birth. LBW, therefore, may be viewed not simply as an outcome measured at delivery, but also as an indicator of nutritional and environmental conditions experienced during the prenatal period.

The evidence concerning early stimulation was less uniform than that concerning LBW. Sari et al. (2025) reported that parenting, caregiving, and nurturing practices were related to stunting, particularly through inadequate parenting and insufficient developmental stimulation. Lestari et al. (2024), meanwhile, found that implementation of the SDIDTK program supported child development, although approximately 10% of the children remained malnourished. The results point to the relevance of the child's postnatal environment, particularly the quality of interactions and developmental opportunities provided by caregivers. This may be especially important for children who already face biological risks, including those associated with LBW.

Differences between studies may partly reflect how early stimulation was assessed. Some researchers focused on parenting practices and patterns of interaction between caregivers and children, whereas others evaluated stimulation through developmental monitoring programs such as SDIDTK. Consequently, the measures used to represent early stimulation were not identical, making direct comparison of effect sizes difficult. The variation should therefore be considered when interpreting the evidence rather than assuming that differences in reported effects necessarily represent contradictory findings.

The findings are also in line with the WHO Foster Care Framework, which places responsive caregiving, opportunities for early learning, adequate nutrition, and a supportive environment within the same developmental context. From this perspective, stimulation is not an isolated intervention but part of the broader environment in which children grow and

develop. Appropriate stimulation may help children reach their developmental potential and may lessen some of the developmental consequences associated with biological vulnerabilities such as LBW. However, the differences in measurement and study approaches indicate that the extent of this contribution should be interpreted with caution.

The Influence of Maternal Factors on Stunting

Several of the studies reviewed point to conditions surrounding the mother as relevant to stunting among children aged 24–36 months. [Garina et al. \(2024\)](#) reported a relationship between maternal nutritional status, access to health services during pregnancy, Tetanus Toxoid (TT) immunization, and the risk of stunting. The findings reported by [Haryani et al. \(2022\)](#) draw attention to another dimension of the maternal and family context, particularly household income and its relationship with children's nutritional status. These results indicate that circumstances experienced before and during pregnancy can be relevant to the child's subsequent growth, although the specific factors identified were not identical across studies.

Maternal characteristics were not associated with stunting in exactly the same way across the available evidence. [Aryastami et al. \(2017\)](#) reported a significant relationship between socioeconomic status and stunting, whereas [Hadi et al. \(2019\)](#) identified maternal employment and parental income as factors associated with stunting risk. [Haryani et al. \(2022\)](#) however, found that maternal education and parenting practices were not always statistically significant. Such differences may reflect variation in the populations studied, the characteristics of households, and the way maternal or socioeconomic variables were measured. Nevertheless, household conditions remain relevant when considering the nutritional and developmental circumstances of young children.

Antenatal care provides another link between maternal conditions and child growth. [Ardiyanto et al. \(2025\)](#) highlighted the importance of the quality of antenatal care, particularly supplementation and nutrition education provided during pregnancy. These components may be particularly relevant for pregnancies in which the infant is subsequently born with low birth weight (LBW). Maternal health during pregnancy can also be affected by conditions such as anemia, hypertension, and infection, all of which have potential implications for fetal and child growth. However, these comorbidities were not specifically examined in some of the studies included in the review and therefore should not be interpreted as established determinants on the basis of this evidence alone.

The role of maternal factors also appears to depend on the context in which they are examined. [Lestari et al. \(2024\)](#) reported findings in which maternal factors were not statistically significant, illustrating that associations observed in one population may not necessarily be reproduced in another. Differences in socioeconomic circumstances, access to health services, maternal characteristics, and study methods may contribute to this variation. Maternal factors should therefore be considered as part of a broader set of conditions surrounding pregnancy and early childhood rather than as uniform predictors of stunting across all populations.

The Relationship Between Birth Weight (BW) and Stunting

Low birth weight (LBW) appears repeatedly in the literature reviewed as a factor associated with stunting among children aged 24–36 months. The association was reported in studies involving community-based populations, although its strength was not identical across settings. [Garina et al. \(2024\)](#) found that children with a history of LBW had a significantly higher risk of stunting. A similar pattern was reported by [Aryastami et al. \(2017\)](#), whose secondary analysis showed that children born with LBW were 1.74 times more likely to experience stunting than children with normal birth weight. [Hadi et al. \(2019\)](#) reported a higher estimate, with LBW associated with a 3.12-fold increase in the risk of stunting. These results

place birth weight among the factors that need to be considered when examining differences in linear growth during early childhood.

Several biological pathways may help explain this relationship. Infants born with LBW generally have lower nutritional reserves and may experience greater physiological vulnerability during the early stages of life. Organ immaturity and increased susceptibility to infection can further affect the ability of the child to maintain adequate growth. In this context, inadequate nutrient availability and impaired metabolic function may contribute to slower linear growth, particularly during the first two years of life. [Ardiyanto et al., \(2025\)](#), in their scoping review, reported a 2.19–2.42-fold increase in the risk of stunting associated with LBW. [Aryastami et al. \(2017\)](#) also highlighted the contribution of neonatal disease, providing additional support for the possibility that illness during the neonatal period may further affect the growth of children born with LBW.

The association was not uniform across all study settings. [Haryani et al. \(2022\)](#) in a study conducted in an urban setting in Surabaya, found no significant relationship between LBW and stunting. Differences in access to health services and the availability of nutritional interventions may be relevant when interpreting this result, although these factors cannot be established as the direct explanation from the available findings alone. In other settings, the association was more apparent. [Hadi et al. \(2019\)](#) whose study was conducted in Teluknaga, and [Garina et al. \(2024\)](#), in Padalarang, reported significant associations between LBW and stunting.

The variation across locations indicates that the relationship between birth weight and subsequent growth may be shaped by conditions after birth as well as by the circumstances surrounding birth itself. Differences in healthcare access, nutritional support, and the broader living environment may influence how children born with LBW grow during early childhood. LBW should therefore be understood within the context of the child's subsequent care and environment rather than treated as an isolated explanation for stunting.

The Role of Early Stimulation in Stunting Risk

Early stimulation is closely related to the experiences children receive from their caregivers during the first years of life. These experiences include the way parents respond to children, daily caregiving practices, and the opportunities provided for children to interact and learn. [Sari et al. \(2025\)](#) reported a significant association between the pattern of Sharpening, Compassion, and Nurturing and the incidence of stunting. The result points to the possible relevance of inadequate stimulation in children who experience growth and developmental problems. [Lestari et al. \(2024\)](#) reported a related finding after examining the implementation of the SDIDTK program. According to their study, age-appropriate development was observed in 90% of children aged 24–36 months following the implementation of the program.

Not all studies in the review assessed stimulation as a specific exposure. [Aryastami et al. \(2017\)](#) and [Garina et al. \(2024\)](#) for example, did not directly measure early stimulation. Their findings on nutritious food intake and feeding practices nevertheless provide information about the caregiving conditions surrounding children's nutritional status. This distinction is important because stimulation and nutrition are not interchangeable concepts, even though both are influenced by the child's home environment and caregiving practices. The available evidence therefore provides a basis for considering early stimulation as one component of child care rather than as an independent explanation for stunting.

The possible contribution of stimulation becomes particularly relevant when children have other conditions that may place them at risk of poor growth. LBW is one such condition. [Haryani et al. \(2022\)](#) and [Hadi et al. \(2019\)](#) focused more strongly on maternal and economic characteristics, while [Lestari et al. \(2024\)](#) demonstrated that a structured stimulation program was associated with age-appropriate development even when factors such as LBW and other

maternal variables were not dominant. [Ardiyanto et al. \(2025\)](#) likewise identified LBW as a biological risk factor for stunting. Viewed alongside these findings, the caregiving environment may have a role in supporting children's development when biological risks are already present. However, the available evidence does not establish that stimulation directly offsets the effects of LBW on stunting.

Differences in the way stimulation was assessed also need to be considered when comparing the studies. [Sari et al. \(2025\)](#) used indicators related to parenting patterns, whereas [Lestari et al. \(2024\)](#) examined stimulation through the SDIDTK program. These approaches capture different aspects of children's developmental experiences. In contrast, [Aryastami et al. \(2017\)](#) did not include early stimulation among the variables analyzed. Consequently, the absence of an association in a study that did not measure stimulation cannot be interpreted in the same way as a study that specifically assessed parenting or developmental stimulation.

For this reason, differences in measurement instruments, children's age ranges, and intervention settings are relevant when interpreting the evidence on early stimulation. Parenting-based measures may capture everyday caregiver behavior in ways that differ from assessments based on a structured developmental program such as SDIDTK. The variation between these approaches may partly account for the differences observed across studies and should be taken into account when considering the relationship between early stimulation and stunting.

Integrative Analysis: Interaction of Maternal Factors, Birth Weight, and Early Stimulation

The three factors examined in this review do not occur independently during a child's early life. Maternal conditions may influence what happens during pregnancy and at birth, while the circumstances surrounding birth can affect the child's vulnerability during the following years. [Garina et al. \(2024\)](#) for example, reported findings involving incomplete tetanus toxoid immunization and less favorable household conditions in relation to the growth of children with a history of LBW. [Haryani et al. \(2022\)](#) also drew attention to the economic circumstances of the family, particularly family income, as part of the conditions associated with children's nutritional status. Similar socioeconomic dimensions were reported by [Hadi et al. \(2019\)](#) and [Aryastami et al. \(2017\)](#), who identified maternal income and employment status as significant factors in the relationship examined between LBW and stunting.

The role of birth weight is more apparent when the results from different study designs are considered together. Cross-sectional studies, case-control research, and analyses of secondary data have all reported an association between LBW and stunting. [Aryastami et al. \(2017\)](#) estimated a 1.74-fold increase in the risk of stunting among children born with LBW, while [Hadi et al. \(2019\)](#) reported a 3.12-fold increase. [Ardiyanto et al. \(2025\)](#) reported a similar pattern in their review, with the risk of stunting among children with LBW increasing by 2.19–2.42-fold. These findings help explain why birth weight is relevant when maternal factors are considered. Poor maternal nutrition, for instance, may affect conditions during pregnancy and thereby contribute to an unfavorable birth outcome, including LBW. This pathway provides one possible explanation for an association between maternal conditions and stunting that is not necessarily direct.

The period after birth introduces another part of this relationship. Early stimulation concerns the child's everyday interactions and the care provided by caregivers, and it may be particularly relevant for children who begin life with biological vulnerabilities. [Sari et al. \(2025\)](#) reported a significant relationship between the Pattern of Nurturing, Compassion, and Nurturing (PAA) program and stunting risk, with the findings relating this pattern to the quality of interaction and care. [Azrimaidaliza et al. \(2024\)](#), in their examination of SDIDTK implementation, likewise provided evidence that comprehensive early stimulation may support

children's development and help prevent developmental delays, although a small proportion of children remained malnourished.

The evidence for an interaction among these factors is, however, still incomplete. [Garina et al. \(2024\)](#) and [Hadi et al. \(2019\)](#), did not include early stimulation as a specific study variable, so their results cannot directly show whether stimulation changes the relationship between LBW and stunting. The same limitation applies to the review by [Ardiyanto et al. \(2025\)](#), which primarily addresses LBW as a biological risk factor. Consequently, the available studies allow the three domains to be considered within the same developmental pathway, but they do not provide sufficient evidence to establish a statistical interaction or moderating effect between them.

Viewed in this way, maternal conditions, birth weight, and early stimulation represent different points along the child's early-life trajectory. Maternal circumstances are relevant before and during pregnancy, LBW reflects vulnerability at birth, and stimulation concerns the environment in which the child develops afterward. The evidence supports examining these factors together, while recognizing that the current studies differ in what they measured and in the extent to which they were able to capture relationships between the factors.

Methodological Quality of the Studies Reviewed and Risk of Bias

The evidence reviewed came from studies with different methodological approaches. [Haryani et al. \(2022\)](#), [Lestari et al. \(2024\)](#), and [Garina et al. \(2024\)](#) used cross-sectional designs, whereas [Sari et al. \(2025\)](#) employed a case-control design. This difference in design affects how the reported associations between maternal factors, low birth weight (LBW), early stimulation, and stunting should be interpreted. Cross-sectional studies can identify relationships between variables, but the exposure and outcome are assessed within the same period, making the temporal sequence difficult to establish. A case-control approach allows researchers to compare children with and without the outcome of interest, although information collected retrospectively may be affected by recall. The studies based on secondary data, including [Aryastami et al. \(2017\)](#) and [Hadi et al. \(2019\)](#), benefit from access to large population datasets. At the same time, the quality of their findings depends partly on the completeness and accuracy of the information available in the original surveys or records.

Several limitations were also apparent in the individual studies [Haryani et al. \(2022\)](#) and [Lestari et al. \(2024\)](#) used relatively small samples, which may restrict the extent to which their findings can be applied to other populations. The variables examined and the instruments used to measure them were not consistent across the studies. Early stimulation, for instance, was not directly assessed by [Garina et al. \(2024\)](#). [Sari et al. \(2025\)](#), by comparison, assessed stimulation through components related to Parenting Patterns, Enrichment Patterns, and Affection Patterns. Differences of this kind make it difficult to compare results across studies as though the same exposure had been measured in the same way.

The setting in which participants were recruited also needs consideration. [Sari et al. \(2025\)](#), collected data through health centers, which may have produced a study population that differed from children and families who did not use these facilities. This creates a potential for selection bias and may limit the representativeness of the findings. Another concern is the limited availability of longitudinal evidence. Because most of the studies did not follow participants over time, the sequence linking maternal or birth-related factors with later stunting cannot always be established with certainty.

Several sources of potential bias should therefore be considered when interpreting the results. Recall bias may affect case-control research when parents are required to report information about previous parenting practices or birth weight, as in [Sari et al. \(2025\)](#). Measurement bias is another possible concern where anthropometric data are collected by

different personnel, particularly in studies such as [Lestari et al. \(2024\)](#) and [Garina et al. \(2024\)](#). Differences in measurement procedures or implementation may influence the recorded values and consequently the observed associations.

The evidence base may also be affected by publication bias. [Ardiyanto et al. \(2025\)](#) noted a tendency among published studies to report significant associations between LBW and stunting. If studies with non-significant findings are less likely to be published or identified, the available literature may give a stronger impression of the association than would be observed across all completed studies. In addition, some maternal characteristics rely on information reported by participants, including income, education, and TT immunization history. The accuracy of such information may vary and should be taken into account when interpreting the findings of [Aryastami et al. \(2017\)](#), [Hadi et al. \(2019\)](#), and [Garina et al. \(2024\)](#).

Overall, the methodological differences do not invalidate the evidence, but they do affect the degree of certainty that can be attached to individual associations. Study design, sample size, participant selection, measurement procedures, and the quality of reported maternal information all need to be considered when interpreting the relationship between maternal factors, LBW, early stimulation, and stunting.

4. CONCLUSION

The evidence reviewed in this study places maternal conditions, birth weight, and early stimulation at different points in the development of stunting among children aged 24–36 months. Maternal nutritional status, socioeconomic circumstances, immunization, and the quality of antenatal care were among the factors associated with child growth. These conditions are particularly relevant during pregnancy because they may affect fetal development and the circumstances surrounding birth.

LBW showed the clearest and most repeated association with stunting in the studies examined. The results therefore draw attention to the period before birth as an important part of the stunting pathway. However, birth weight alone does not account for the subsequent growth of the child. Conditions after birth, including caregiving and opportunities for early stimulation, also form part of the environment in which growth and development take place. The available evidence indicates that responsive parenting and appropriate stimulation may support development, including among children who have biological vulnerabilities such as LBW, although the evidence is not sufficient to establish a direct protective effect on stunting.

The findings also indicate that stunting needs to be viewed across the continuum from pregnancy to early childhood rather than being attributed to a single factor. For this reason, prevention efforts during the first 1,000 days should address maternal nutrition, antenatal care, and the prevention of LBW while continuing to support appropriate caregiving and developmental monitoring after birth. Public health programs can incorporate these components into existing maternal and child health services. Attention to responsive parenting and early stimulation may also provide families with practical support during the child's early developmental period.

Further studies are needed to clarify how these factors relate to one another over time. Longitudinal research would be particularly useful for establishing the temporal relationship between maternal conditions, birth weight, early stimulation, and subsequent growth. Future studies would also benefit from using more consistent measures of early stimulation and maternal factors. Such approaches could produce stronger evidence concerning the pathways through which prenatal and postnatal conditions are associated with stunting and could help inform more context-specific prevention strategies.

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