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The Long-Term Impact of Childhood Stunting on Cognitive Development and Educational Outcomes

Aceng Ali Awaludin[1]*, Annisa Nurrachmawati[2], Arifah Devi Fitriani[3], Casia Reski[4]

[1] Nursing Study Program, STIKes Karsa Husada Garut, Garut, Indonesia.
[2] Public Health Study Program, Faculty of Medicine, Universitas Mulawarman, Samarinda, Indonesia.
[3] Public Health Study Program, Faculty of Medicine, Institut Kesehatan Helvetia, Medan, Indonesia.
[4] Midwifery Study Program, Faculty of Medicine, Universitas Andalas, Padang, Indonesia.

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Corresponding Author:
Aceng Ali Awaludin
acengaligrt@gmail.com

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Abstract: This study aims to analyze the long-term impact of stunting in childhood on cognitive development and educational attainment through a meta-analysis approach. Stunting, which is indicated by stunted linear growth due to chronic malnutrition, has long been associated with various negative consequences on health and social aspects. By systematically examining the results of quantitative studies from various countries and socio-economic contexts, this study identified a consistent pattern of association between stunting in early life and decline in cognitive function and academic achievement in adolescence and adulthood. Data were obtained from 25 studies that met the inclusion criteria published in the 2015 to 2024 range, and were analyzed using fixed-effect and randomized effects models with the help of the JASP application. The results of the meta-analysis showed that children who experienced stunting had an effect on cognitive and education with a pooled effect size value (Hedges' $g = 1.10$ $t = 9.103$; $p < 0.001$) with a high effect size category. These findings confirm that stunting not only has an impact on short-term physical conditions, but also has significant consequences for human resource development in the long term. Therefore, comprehensive nutrition and education interventions in early life are essential to break the chain of loss due to stunting.

Keywords: Child nutrition; Cognitive development; Educational attainment; Meta-analysis; Stunting

Introduction

The first 1,000 days of life, which begins from conception to the age of two, is a crucial period that determines the main foundation for a child's physical, cognitive, social, and emotional growth and development (Koshy et al., 2022; Handryastuti et al., 2022). During this period, the brain undergoes a very rapid development, where more than 80% of the brain structure is formed before the child reaches the age of three (Haywood & Pienaar, 2021). Nutritional deficiencies during this time can lead to permanent damage to brain structure and function that cannot be completely repaired later in life. Therefore, optimal nutritional fulfilment during pregnancy and the first two years is essential to support the development of synapses, myelination, and growth of brain volume that affect the child's learning and behavioral abilities in the future (Robinson & Dinh, 2023). In addition to the neurological aspect, the first 1,000 days are also a golden period for physical growth and the development of the immune system (Dewey & Begum, 2011; Nahar et al., 2020). Chronic nutritional deficiencies during this period, such as protein, iron, iodine, and essential fatty acids, can lead to growth disorders known as stunting (Ajayi et al., 2017).

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Children who experience stunting at an early age are at higher risk of delayed motor and cognitive development, low school readiness, and poor academic achievement. Thus, quality early nutrition and stimulation interventions in the first 1,000 days are essential not only for the survival of children, but also for maximizing their intellectual potential and future productivity (Perignon et al., 2014).

Stunting is a condition of failure to grow in children under five due to chronic malnutrition that occurs from the womb to the age of two (Alam et al., 2020). Clinically, stunting is defined as height or height according to age that is below minus two standard deviations from the WHO median child growth standard. Children who experience stunting not only have shorter postures than children their age, but also have a high risk of cognitive developmental disorders, decreased immunity, and low academic performance and work productivity in adulthood. Stunting is different from acute weight loss (wasting) because it is the result of the accumulation of long-term malnutrition that is not treated immediately (Osei & Lambon-Quayefio, 2022; McGovern et al., 2017).

Globally, stunting is still a significant public health problem (Stein et al., 2023). According to a report by UNICEF, WHO, and the World Bank Group (2023), around 148.1 million children under the age of five worldwide are stunted, or about 22.3% of the total population of children under five. In Indonesia itself, based on the 2022 Indonesian Nutrition Status Survey (SSGI), the prevalence of stunting reached 21.6%, down from 24.4% in the previous year but still above the threshold set by WHO, which is 20% (Suryawan et al., 2022). This high number shows that stunting is a major challenge in human resource development efforts in Indonesia, which not only impacts health aspects but also education and the long-term economy. Therefore, holistic and sustainable intervention efforts are needed to significantly reduce stunting rates (Amusa et al., 2022). Stunting has a significant direct impact on the physical condition of children. Stunting children exhibit stunted linear growth, lower muscle mass, and delays in fine and gross motor development (Sideropoulos et al., 2024). This condition makes them more susceptible to infectious diseases due to a weakened immune system due to a lack of essential nutrients such as protein, iron, and vitamin A (Dewey & Begum, 2011). In the long term, stunted children have a higher risk of developing abdominal obesity, hypertension, and other non-communicable diseases in adulthood. In addition, their physical capacity to work and participate in productive activities also tends to be lower than that of optimally grown children.

The indirect impacts of stunting include impaired cognitive development and low educational achievement (Woldehanna et al., 2017; Soliman et al., 2021). Chronic malnutrition in early life has an impact on brain development, including the process of myelination and the formation of synapses that play an important role in learning and memory functions. As a result, stunted children tend to experience speech delays, difficulty in solving problems, and low IQ scores. Longitudinal studies show that children who are stunted are less likely to attend school on time, complete basic education, and achieve high academic achievement. These effects are long-term and contribute to the cycle of intergenerational poverty, as low levels of education will limit economic and social opportunities in adulthood (Dessie et al., 2025; Setianingsih et al., 2020).

Research by Martorell et al. (2010) conducted in Guatemala showed that individuals who experienced stunting at an early age had significantly lower cognitive test scores and smaller incomes as adults compared to those who grew normally. These results are in line with the findings of Walker et al. (2015) in several developing countries that show that stunting is correlated with delayed cognitive development, impaired brain executive function, and decreased performance in academic tasks that demand concentration and working memory. Another study conducted by Sudfeld et al. (2015) in African and Southeast Asian countries also revealed that stunted children are more likely to fall behind in education, including late school attendance, class repetition, and lower educational attainment. In a meta-analysis study by Prado et al. (2019), it was found that stunting has a significant negative effect on executive function and academic outcomes (Elfira & Santosa, 2023; Pravana et al., 2017; Duc, 2009).

Although studies have shown a link between stunting in childhood and decreased cognitive development and educational achievement later in life, there are still some important gaps in the literature that need further study. Most of the studies conducted were observational or longitudinal in a geographically limited context, resulting in findings with a high degree of heterogeneity (Ekholuenetale et al., 2020; Moelyo et al., 2025). This makes it difficult to generalize results globally, especially given variations in contextual factors such as socioeconomic, cultural, and access to education and health services. Thus, a more comprehensive quantitative synthesis approach, such as meta-analysis, is needed to consolidate the results of various studies and measure the strength of the relationship between stunting and long-term developmental outcomes in a more objective and systematic manner. Based on this, this study aims to analyze the long-term impact of stunting in childhood on cognitive development and educational attainment through a meta-analysis approach.

Method

Research Design

This study uses a quantitative meta-analysis approach to examine the long-term impact of stunting on cognitive development and educational attainment. Meta-analysis is a systematic method that aims to integrate the results of various empirical studies in order to obtain a more accurate and generalizable estimate of effects. The study was designed with stages that included literature identification, study selection based on inclusion and exclusion criteria, data extraction, and statistical analysis using fixed-effect and random-effects models.

Literature Collection

Literature collection is carried out systematically through several international databases, such as PubMed, Scopus, Web of Science, Google Scholar, and ScienceDirect, with a publication range from 2015 to 2024. The keywords used in the search process include: "childhood stunting," "cognitive development," "educational outcomes," "long-term impact," and "meta-analysis." The search process also follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standard to ensure transparency and replication.

Inclusion Criteria

In meta-analysis research must meet the inclusion criteria, namely Quantitative empirical studies (cross-sectional, longitudinal, cohort) that examine the relationship between stunting and cognitive development or educational attainment, Studies published in accredited and peer-reviewed journals., Studies provide quantitative data that allow calculation of effect size, Respondents are children who experience stunting at the age of 0–5 years and Available in English or Indonesian.

Data Analysis

Table 1. Effect size interpretation criteria (Hedges' g)

Score of Effect Size (Hedges' g)	Interpretation
0.00–0.19	Very Small Effect
0.20–0.49	Small Effect
0.50–0.79	Moderate Effect
≥ 0.80	Large Effect

Source: Nurtamam et al. (2023), Rahman et al. (2023), Tamur et al. (2020), Asnur et al. (2024), and Suyatmo et al. (2023)

Data were analyzed using JASP software with a random-effects model approach to accommodate heterogeneity between studies. The effect size value was calculated using Hedges' g, which is the standard measure in meta-analysis when comparing two groups. In addition, heterogeneity analysis was performed using Q and I^2 statistics, and the potential for publication bias was analyzed through the plot funnel as well as the Egger test. The interpretation of the effect size value is carried out based on the classification of Cohen (1988) as shown in Table 1.

Result and Discussion

Based on the results of data search through the database, 25 studies/articles met the inclusion criteria. The effect size and error standard can be seen in Table 2.

Table 2. Effect size and standard error

Code Journal	Years	Effect Size	Standard Error
GR1	2024	0.67	0.33
GR2	2020	0.91	0.29
GR3	2023	1.04	0.16
GR4	2022	0.90	0.32
GR5	2024	1.45	0.22
GR6	2023	1.90	0.25
GR7	2022	2.05	0.40
GR8	2023	1.23	0.37
GR9	2024	0.77	0.37
GR10	2022	1.43	0.39
GR11	2022	0.66	0.20
GR12	2023	0.52	0.10
GR13	2023	0.31	0.29
GR14	2023	0.29	0.25
GR15	2022	1.09	0.40
GR16	2024	1.44	0.44
GR17	2022	1.10	0.20
GR18	2020	2.70	0.51
GR19	2022	1.12	0.24
GR20	2018	0.97	0.35
GR21	2019	0.50	0.30
GR22	2018	0.36	0.19
GR23	2020	1.29	0.30
GR24	2024	1.58	0.30
GR 25	2022	0.41	0.15

Based on Table 2, the effect size value of the 25 studies ranged from 0.31 to 2.70. According to Borenstein et al. (2007) of the 25 effect sizes, 8 studies (32 %) had medium criteria effect sizes and 17 studies (68%) had high criteria effect size values. Furthermore, 25 studies were analyzed to determine an estimation model to calculate the mean effect size. The analysis of the fixed and random effect model estimation models can be seen in Table 3.

Table 3. Residual heterogeneity test

Qe	df	P
102.361	24	< 0.001

Based on Table 3, a Q value of 143,961 was obtained higher than the value of 102. 361 with a coefficient interval of 95% and a p value of 0.001 <. The findings can be concluded that the value of 25 effect sizes analyzed is heterogeneously distributed. Therefore, the model used to calculate the mean effect size is a random effect model. Furthermore, checking publication bias through funnel plot analysis and Rosenthal fail safe N (FSN) test (Tamur et al., 2020; Hukom, 2023; Ichsan et al., 2023; Borenstein et al., 2007; Santosa et al., 2024; Swandana et al., 2023; Winiasri et al., 2023; Zulyusri et al., 2023). The results of checking publication bias with funnel plot can be seen in Figure 1.

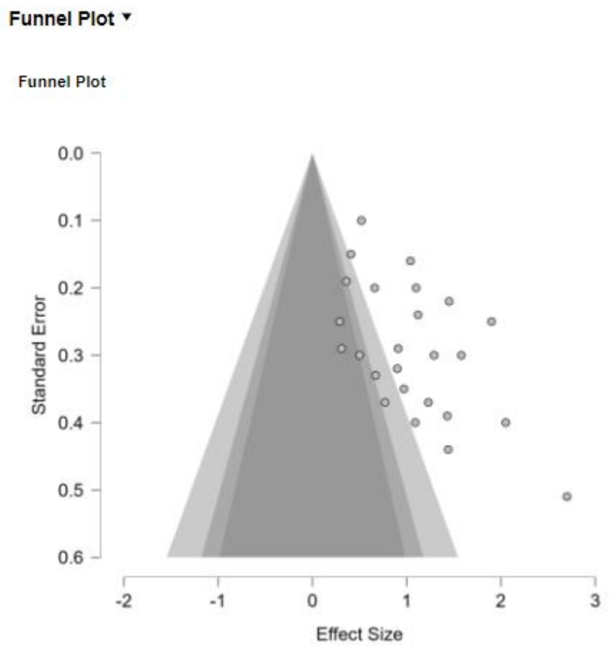

Figure 1. Funnel plot standard error

Based on Figure 1, the analysis of the funnel plot is not yet known whether it is symmetrical or asymmetrical, so it is necessary to conduct a Rosenthal Fail Safe N (FSN) test. The results of the Rosenthal Fail Safe N calculation can be seen in Table 4.

Tabel 4. Fail safe N

File Drawer Analysis	Fail Safe N	Target Significance	Observed Significance
Rosenthal	2708	0.050	< 0.001

Based on Table 4, the Fail Safe N value of 27085is greater than the value of 5k + 10 = 5(24) + 10 = 135, so it can be concluded that the analysis of 25 effect sizes in this data is not biased by publication and can be scientifically accounted for. Next, calculate the p-value to test the hypothesis through the random effect model. The results of the summary effect model analysis with the random effect model can be seen in Table 5.

Tabel 5. Pooled effect size

Estimates	Standard error	t	df	p
1.010	0.120	9.103	24	< 0.001

Table 5 explain the model that children who experience stunting have an effect on cognition and education with a pooled effect size value (d = 1.010; SD = 0.120). These findings show that children who experience stunting have a significant effect on cognition and education with a value of t = 9.103; p < 0.001 large effect size category. Stunting children tend to have lower IQ scores, impaired short- and long-term memory function, and limitations in attention and concentration abilities. Longitudinal studies conducted in various developing countries indicate that this impact is not temporary, but sustainable until adolescence and even adulthood. This is thought to be caused by disruptions in brain development, particularly in the area of the prefrontal cortex responsible for executive function (Barham et al., 2025).

Stunting has a negative effect on long-term educational outcomes. Children who are stunted are more likely to be late to school, experience class repetition, and eventually drop out of school early. Research by Grantham-McGregor et al. (2007) showed that stunted children had a 19% lower chance of completing basic education than children with normal growth. This effect shows that stunting is not only a nutritional problem, but also an obstacle to human capital accumulation which has an impact on the quality of human resources in the future. The impact of stunting on cognitive development and education is exacerbated by socioeconomic factors (Gelli et al., 2018; Yan et al., 2025). Children from poor families who experience stunting tend to face double barriers, both in terms of limited nutritional intake and access to adequate cognitive stimulation. The poor stimulative home environment and the low level of parental education also strengthen the negative impact of stunting on children's academic achievement. This study emphasizes that a holistic approach is needed to break the chain of stunting and education inequality (Walker et al., 2015).

The findings also indicate that early intervention can reduce the long-term impact of stunting on cognition and education. An integrated nutrition program that starts from pregnancy to the age of two, or known as the window of opportunity 1000 HPK (first day of life), has been proven effective in increasing the physical growth and cognitive abilities of children (Gabain et al., 2023). In addition, education-based interventions such as home-based early stimulation programs or early childhood education institutions (PAUD) also have a significant positive impact on the development of brain function and learning readiness. From a policy perspective, these findings emphasize the importance of integration between the education and health sectors in addressing stunting (Balza et al., 2025). The government needs to develop cross-sector policies that synergize supplementary feeding programs, nutrition education, improved sanitation, and access to maternal and child health services (Barham et al., 2025). On the other hand, schools can also act as early detection agents for growth disorders and provide curriculum-based interventions that are able to stimulate the cognitive development of stunted children (Astuti et al., 2025).

Conclusion

From the results of this meta-analysis, it can be concluded that children who experience stunting have an effect on cognition and education with a pooled effect size value (Hedges' $g = 1.10$; $t = 9.103$; $p < 0.001$) with a high effect size category. These findings confirm that stunting not only has an impact on short-term physical conditions, but also has significant consequences for human resource development in the long term. Therefore, comprehensive nutrition and education interventions in early life are essential to break the chain of loss due to stunting.

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Author Contributions
This study consists of three authors consisting of: Aceng Ali Awaludin, Annisa Nurrachmawati, contributed to collecting data, selecting data, and analyzing and interpreting data in this study. Casia Reski contributes to providing input, correcting and giving advice.

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Conflicts of Interest
The authors declare no conflict of interest.

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