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The Effect of Stunting on the Cognitive Development in Children: A Systematic Review and Meta-analysis

Rifzul Maulina[1,2], Mochammad Bagus Qomaruddin[3], Budi Prasetyo[4], Rachmah Indawati[5] and Rosyidah Alfitri[2]

[1]Public Health at Universitas Airlangga
[2]Departement of Midwifery, Institute Technology, Sains and Health R.S. dr Soepraoen
[3]Department of Health Promotion and Behavioral Sciences, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia
[4]Department of Obstetrics and Gynecology, Faculty of Medicine Universitas Airlangga,
[5]Department of Biostatistics and Population Study, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia

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ABSTRACT Stunting among children under five years of age negatively impacts their health and overall development, including their cognitive development in the short and long term. Databases from 2012 to 2022 in PubMed, ProQuest and Google Scholar were systematically reviewed. The selection of eligible studies was conducted according to PRISMA. From 23.625 articles, 12 articles were eligible to be reviewed. From meta-analysis, stunting children have I.Q. scores 2.14 times lower than children who are not stunting, and the results are statistically significant (aOR=2.14; 95% CI=1.14 to 4.01; p=0.02). It was concluded that stunting hurt children's cognitive abilities, which resulted in a lack of I.Q.

INTRODUCTION

Stunting is defined as failure to achieve linear growth potential as indicated by HAZ less than -2 S.D by the current growth reference due to suboptimal health and nutritional status (WHO 2013). Stunting in children is a severe problem because it is associated with a greater risk of morbidity and mortality, obesity and non-communicable diseases in the future, short adulthood, poor cognitive development, and lower productivity and income (Fikawati and Sandra 2017).

Stunting due to chronic malnutrition has short and long-term negative consequences if not treated early. Stunting children do not reach their full developmental potential, leading to poorer cognitive performance and educational achievement than their well-nourished peers (Rakotomanana et al. 2016). Malnutrition is the cause of 3.1 million child deaths every year, or 45 percent of all child deaths (Black et al. 2013).

According to the World Health Organisation (WHO), stunting among children under five is a public health problem if the prevalence is 20 percent or more. Globally, around 162 million children under five are stunting. About 3 out of 4 stunting children worldwide are in Sub-Saharan Africa, while 40 percent and 39 percent are in South Asia (WHO 2018).

According to WHO, health problems in society can be considered chronic if stunting prevalence is more than 20 percent. That is, nationally, the stunting problem in Indonesia. Indonesia is classified as regular, especially in 14 provinces whose prevalence exceeds national figures. Children who experience stunting impact growth, which is impeded and irreversible. The effects of stunting can last a lifetime and influence the next generations (UNICEF 2020).

According to WHO, stunting can lead to increased incidence of illness and death, no optimal cognitive development or intelligence, motor and verbal, and increased health costs in the short term. The long-term impact of the length of stunting is a body posture that is not optimal in adulthood and an increased risk of obesity and other degenerative diseases, a decline in reproductive health, no optimal learning capacity and performance during the school period, and not at its maximum productivity and work capacity (Ministry of Health Republic Indonesia 2016). Due to stunting, children have a low level of intelligence, which can hinder

Address for correspondence:
Rifzul Maulina
Alam Buring Inside 2 F7,
Malang City, Indonesia
Telephone: 081231195071
E-mail: rifzul-maulina.2020@fkm.unair.ac.id

economic growth, poverty increase, and inequality in a country (Basri 2018).

One of the effects of stunting is not optimal for children's cognitive abilities, affecting their life. According to Yusuf, cognitive ability is the ability of children to think more complexly and do reasoning and solve problems, and developing cognitive skills will make it easier for children to master general knowledge. It will allow children to function normally in life and socialise (Yusuf 2010).

Stunting is a complex problem caused by several direct or indirect factors. UNICEF reveals factors that cause stunting. The direct factors are lack of nutritional intake and disease, especially infectious disease. While family food security, parenting style, family eating patterns, environmental health, and health services result in stunting indirectly. The underlying causes of all factors are education, poverty, disparity, socio-cultural, government policies, and politics (Stewart et al. 2013; Trihono 2015; Beal et al. 2019).

Maternal health influences the health of the children to whom they were born. The process of stunting starts from the preconception period (Director General of Public Health, Ministry of Health RI 2018). As a result, the mother suffers from malnutrition and anaemia, as when pregnant, the mother's nutritional intake is insufficient (Sembiring et al. 2018; Castro et al. 2021).

Objectives of the Study

This study aims to examine a systematic review and meta-analysis of the effects of stunting on children's cognitive development.

METHODOLOGY

This study is a systematic review and meta-analysis to relate stunting to children's cognitive development. This research is guided by PRISMA (Preferred Reporting Item for Systematic Review and Meta-Analysis). PRISMA helps to ensure clarity and transparency in reporting systematic reviews. This study's analytical methods and inclusion criteria were specified and documented in the protocol.

Search Strategy

A literature search uses the keywords "stunting AND cognitive development OR growth" through search engines in various databases, such as PubMed, ProQuest and Google Scholar. The literature search was carried out from April 2022 to June 2022.

Sample

The sample in this study comprises articles that are relevant to the study objectives, with the following inclusion criteria are:

1. Stunting measurement using measurement anthropometry according to WHO criteria
2. Cognitive development measuring tools use standard measuring tools in each country to assess children's growth and development
3. The full text of the examination must be available in English and Indonesian
4. The articles considered for the study were from the year 2012 to 2022
5. Articles should be in full text and open access
6. Performed analysis test until (OR)

Extract Data

Data extraction is done by reading the article's title with items viewed with the PICOS format used as the basis to conduct the systematic review (Table 1).

Selection Process

Data selection and analysis were carried out through a literature search with article filters during the year 2010-2021 and full text obtained from

Table 1: PICOS format

Criteria (PICOS)	*Inclusion*	*Exclusion*
Population	Pre and school age children with stunting children	Children < 1 years
Intervention	-	-
Comparison	Normal children or without comparison	-
Outcome	Cognitive development	-
Study design	Cross-sectional, case-control, cohort	The systematic review, meta-analysis, qualitative

23,625 PubMed (3.072), Proquest (3.653), and Google Scholar (16.900) articles. A total of 20,089 irrelevant, potentially relevant articles were screened based on inclusion and exclusion criteria, of which 3.358 do not match the criteria. Twelve papers were tested for feasibility by reading them systematically. The aims, methods and results of all 12 articles were summarised to identify the association between stunting on cognitive development. For an overview of the data, the selection process is described in Figure 1.

Data Analysis

This research analysed a meta-analysis test and data using RevMan 5.3. The strength of the association between cognitive development and stunting was determined by the odds ratio (OR) with a 95 percent confidence interval (CI). A *random-effects* model was used to analyse if $I^2 > 50$ percent and a *fixed effect* if $I^2 < 50$ percent. The Z test with P< determined the significance of the overall effect (OR) 0.05. The degree of heterogeneity was estimated using the Chi^2 estimator, the test for heterogeneity, and the I^2 statistic. Q tests with $P<0.05$ and I^2 statistic > 50 percent were considered heterogeneous.

RESULTS

The study selection begins by entering keywords and filtering existing titles and abstracts according to predetermined criteria. Publications are included if they are written in English or Indonesian and published in a peer-reviewed journal. Furthermore, publications are from 2012 to 2022 with related search terms in the title, abstract and keywords. All publications deemed potentially relevant are retained, and the full text was reviewed for eligibility. Disagreements are resolved through discussions to reach a final decision by the reviewer. Finally, articles that do not meet the criteria are dropped. From article search to data extraction, 12 articles were most compatible with the search criteria. The articles included in the systematic review are by Poh et al. (2013), Miller et al. (2015), Pantaleon et al. (2016), Haile et al. (2016), Probosiwi and Nugroho (2017), Kang et al. (2018), Nahar et al. (2019), Ekholuenetale (2020), Ernawati et al. (2020),

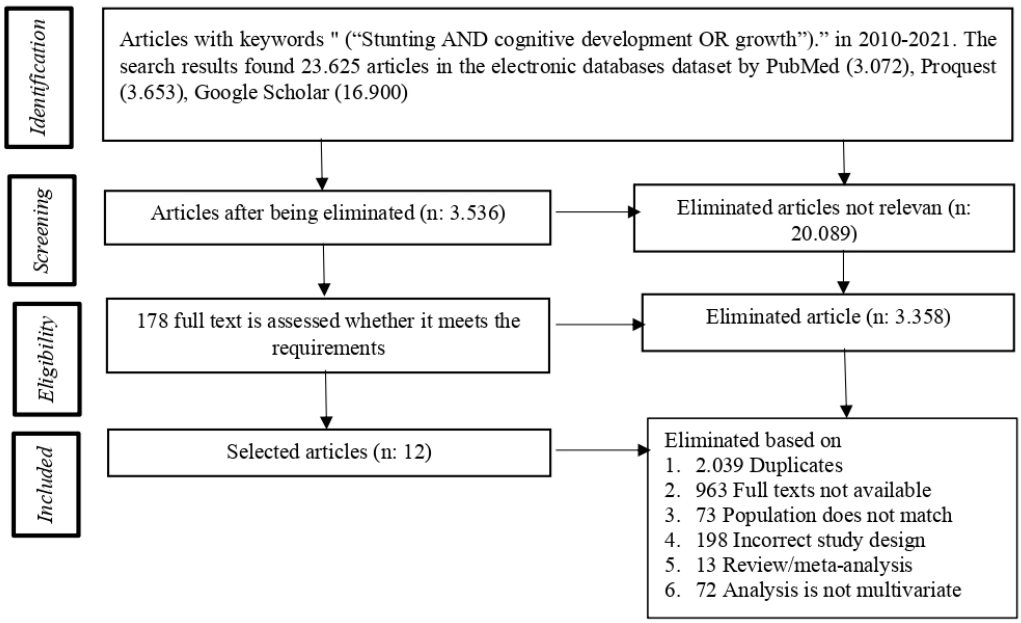

Fig. 1. Selection process
Source: Authors

Indah et al. (2020), Mireku et al. (2020) and Oumer et al. (2022). All of them use cross-sectional and case-control approaches and explain the relationship between stunting and children's cognitive development.

Meta-analysis of 12 articles showed a heterogeneity value of I^2 = 99 percent. The analysis model used was a random effect. The Forest plot shows that stunting children get I.Q. scores 2.14 lower than children who are not stunting, and the results are statistically significant (aOR= 2.14; 95% CI= 1.14 to 4.01; p= 0.02). The funnel plot shows that there is a potential for publication bias, which is indicated by the overestimate effect, which is characterised by an asymmetric distribution between plots (7 plots on the right, 4 plots on the left, and 1 plot touches the vertical line).

DISCUSSION

Children who experience stunting can affect their cognitive development. It can be seen in the size of the heads of children who have stunted smaller head sizes, so it is associated with brain volume and thinking power. Stunting children have a high number of brain cells reduced, and there is immaturity and biochemical imperfections in the brain. This situation can affect the development of children's intelligence. Children who experience stunting are predicted to experience high performance and poor cognitive and psychological abilities later in life. It is due to insufficient brain development (neurodevelopment), affecting the child's thinking and emotional abilities (Beckmann et al. 2021).

Stunting is caused by chronic nutrient intake malnutrition, which can cause disturbances in growth and development. The impact of malnutrition in children causes decreased brain development, which can also impact children's intelligence (Ekholuenetale 2020). In the brain's nervous system, there are synaptic disorders and synaptic neurotransmitter disorders, slowing myelination, and overall there is a decrease in the production of dendritic brain development. Malnutrition in infancy can affect the central nervous system (CNS) and is related to the structural development of the central nervous system and the development of the neurotransmitter system (Mireku et al. 2020).

Results of a literature review from 12 journals show that stunting children get I.Q. scores 2.14 times lower than children who are not stunting. In

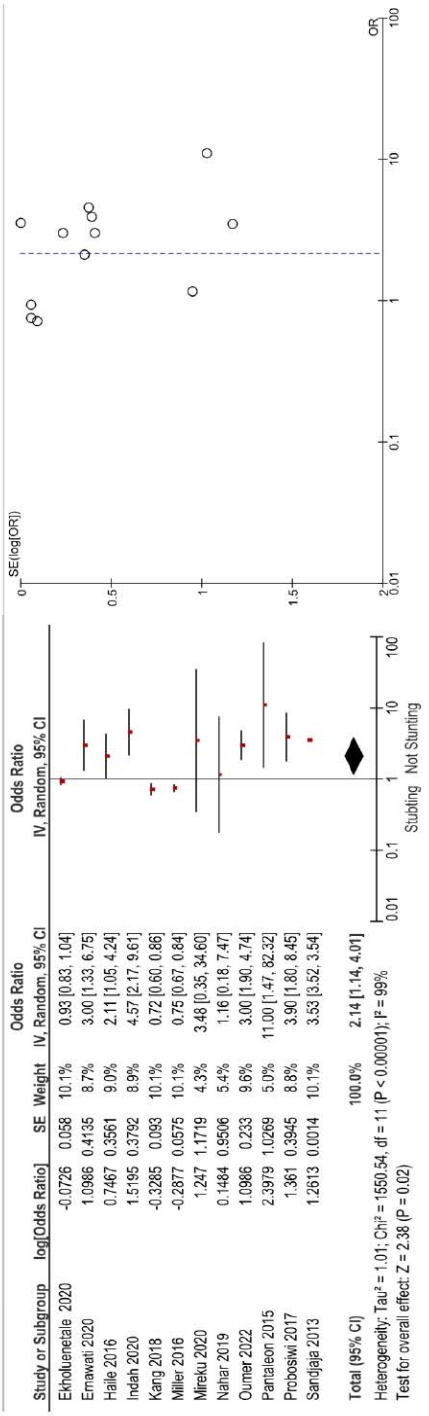

Fig. 2. Meta-analysis result
Source: Authors

Table 2: Characteristic study

S.No.	*Title and author, and year*	*Research place*	*Methods*	*Sample*	*Instrument*	*Result (Aor)*
1	Poh et al. 2013	Southeast Asian Nutrition Survey (SEANUTS) - Indonesian, Malaysia, Thailand, and Vietnam	Cross-Sectional	6746 school-age childrenbase	Nutritional status: measurement anthropometry according to criteria WHO. IQ assessment: Raven's Progressive Matrices (RPM) (for children aged 6–12 years) and Test of Non-Verbal Intelligence, third edition (TONI-3)	Children with Z score low in BMI/Uand low TB/U have the opportunity to have an IQ non-verbal <89 compared with a child who doesn't experience stunting (aOR 3.53 and 95 % CI 3.52, 3.54)
2	Pantaleon et al. 2015	Sedayu District, Bantul, Yogyakarta	Case-control	50 children stunting and 50 normal children	Height anthropometry assesses one hundred children stunting according to age (WHO 2005). Measurement of child development with Bayley Scales of method Infant Development II	More stunting children have a lot of cognitive development: (12%) if compared with children who are not stunting (8%) (p: 0.002 and aOR: 11 and 95 % CI 1.47-82.03
3	Haile et al. 2016	Southeast Ethiopia	Cross-sectional	539 elementary school children Evaluation cognitive:	Socio-demographic character: structured questionnaire. Food intake: method qualitative re-call food for 24 hours. CI=0.002- 4.21). Kaufman Assessmen Battery for Children (KABC-II) and Raven's Colored Progressive Matrices (RCPM).	There is a positive relationship between High Body based on Z score math for kids with stunting math scores 2.11 lower than non-stunting children. (aOR = 2.11; 95%
4	Miller et al. 2016	Countries with (MICS-4)	Cross-sectional	58,513 children aged 36–59 month	Stunting, maternal education, family wealth, , parenting and gender of the child: fifteen Multiple Indicator Cluster Survey (MICS). Physical, learning, literate letters/counting and	Children who experience severe stunting with a Z score <-3SD index body length or height according to child's age hurt child development (OR=0.75; 95% CI=0.67- 0.83).

Table 2: Contd....

S.No.	Title and author, and year	Research place	Methods	Sample	Instrument	Result (Aor)
`					domain socio-emotional development: ten-item Early Childhood Development Index (ECDI)	
5	Probosiwi and Nugroho 2017	Purwomartani Village Kalasan Sleman	Cross-sectional	106 children	Measurement of child development with Bayley Scales of method Infant Development II	There is a relationship that is statistically significant between stunting and child development p <0.05 and OR=3.9 (95%CI=1.8-8.9). The analysis results in multivariable stunting by controlling the birth length and energy intake effect by 8% with children aged 12-60 months.
6	Kang et al. 2018	Bangladesh, Bhutan, \ Nepal, and Pakistan	Cross-sectional	31.037 children aged 36 to 59 months	Child development indicators were introduced in MICS Round 4	learning/cognition development was negatively associated with stunting (OR= 0.72, 95% CI (0.60, -0.86)
7	Indah et al. 2020	Palembang City	Case-Control	75 children stunting and 75 normal children	Nutritional status: measurement anthropometry according to criteria WHO 2007. Assessment cognitive: CPM test (Colored Progressive matrix)	This research shows that stunting childrenget IQ scores lower than 4.57 times compared to children who are not stunting. The stunting child with an IQ score below an average of 48 children (64%). (aOR: 4.57 (95% CI:2.1733-9.6873)
8	Ekholuenetale 2020	Demographic Survey Data and Benin Health (BDHS) which is representative national in 12 regions	Cross-Sectional	6.573 children	Nutritional status: measurement anthropometry according to criteria WHO 2007. Assessment cognitive: measured from 8 composite statement	Children with stunting experienced a 7% decrease in cognitive development compared with children who were not stunting (RR=0.93; 95% CI=0.83 - 0.98). Cognitive development is affected by geographic area, customs/ religion, education mother, and the mother's job.
9	Mireku et al. 2020	Allada and Benin	Cross-sectional	632 children	stunting was length-for-age. Cognitive and motor functions were assessed using the Mullen Scales of Early Learning	Stunting is associated with cognitive (aOR: 3.48, 95% confidence interval 0.35-6.62)

Table 2: Contd....

S.No.	*Title and author, and year*	*Research place*	*Methods*	*Sample*	*Instrument*	*Result (Aor)*
10	Nahar et al. 2019	Bangladesh	Cohort	265 children	The Bayley Scales Development III; child length and weight using standard procedures.	Stunting children had significantly lower developmental scores: cognitive (95% CI =”0.16 (“0.31, 0.0],P= .049),
11	Ernawati et al. 2020	Bogor Regency	Cohort prospective	150 children	Data were obtained from longitudinal research on the nutritional status of pregnant women and their born children by the Applied Technology Center for Clinical Health and Epide-miology (PT2TKEK	Toddlers born stunting and continue to be stunting until the age of three years have lower cognitive development than stunting infants who can reach a normal height at the age of three. (p: 0.009 and aOR: 3.000 and 95 % CI 1.334- 6.747)
12	Oumer et al. 2022	Southwest Ethiopia	Cohort prospective	507 children aged 12 – 59 months	Anthropometrics were calculated in Anthros software.	Stunting in children aged significantly early is negatively related to cognitive performance child (p: 0.0001 and aOR: 3.000 and 95 % CI 1.9 – 4.7)

the research by Miller, it was found that severely stunting children with Z-score < -3SD of long index body or height according to the child's age hurt the child's development based on the Early Childhood Development Index (ECDI) (OR=0.75; 95% CI=0.67-0.83) (Miller et al. 2015). In line with Haile's research, which found significantly positive relationship statistics between the correlation of all test scores and cognitive and academic achievement as seen from maths scores (P<0.05) (Haile et al. 2016). Research by Ekholuenetale showed that children with stunting decreased by 7 percent cognitive development compared to children who are not stunting (Ekholuenetale 2020). In a study by Pantaleon, 12 percent of children who are stunting are more likely to have a lack of cognitive development than 8 percent of children who did not (Pantaleon et al. 2016).

The researcher, Sandjaja, shows that children with a Z value low score according to BB/U are likely to have a non-verbal I.Q. < 89. Likewise, children with BMI/U and Low TB/U have the opportunity to have a non-IQ verbal < 89 compared with children who are not experiencing stunting. Children who experience stunting in the first two years of life likely have an I.Q. < 89 compared to children who are not stunting (Poh et al. 2013). Meanwhile, according to Aurora, stunting children have I.Q. scores that are 4.57 times lower than those of children who are not stunting, where the child is stunting with I.Q. scores below average for as many as 48 children (64%). While for children who are not stunting, the average I.Q. score is above 72 percent, and the average I.Q. score at the bottom is 28 percent (Indah et al. 2020).

Research conducted by Woldehanna stated that children with stunting score 16.1 percent lower on the Picture Peabody Vocabulary Test (PPVT) and 48.8 percent lower in quantitative assessment tests at the age of eight (Woldehanna et al. 2018). Furthermore, other research conducted by Picauly and Toy on schoolchildren in Kupang and East Sumba shows that students with stunting have poorer learning achievement. In contrast, more non-stunting students have good learning achievements. Therefore, it could be concluded that children who experience stunting will experience bottlenecks in the process of thinking and memory, impacting the lack of learning achievement (Picauly and Toy 2013).

Stunting has biological implications for the brain's neurological development to decline in cognitive values that impact the lack of learning achievement. Stunting is a long process starting from the preconception period, where maternal health dramatically affects the unborn child's health. Stunting is not only a problem of malnutrition but a multi-factor and multi-sector problem (Stewart et al. 2013).

CONCLUSION

Of all the literature that has been reviewed, it can be concluded that stunting negatively influences children's cognitive abilities, such as lower I.Q. and academic achievement. Results of a literature review from 12 journals show that stunting children get I.Q. scores lower than 2.14 times compared to children's I.Q. who are not stunting. It is necessary to cooperate from various sectors so that healthy children will be formed to become the next generation of quality.

RECOMMENDATIONS

To prevent stunting, parents must fulfil their child's nutritional needs, provide exclusive breastfeeding for six months, and conduct early detection by regularly consulting and measuring their child's weight and height. For further researchers, it is recommended to develop an instrument to detect stunting from an early age so that prevention can be given early and cognitive decline does not occur in children.

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