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RESEARCH ARTICLE

Community-based zinc supplementation for linear growth recovery in stunted under-five children in Indonesia

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ABSTRACT

Stunting remains a significant nutritional challenge in Indonesia and across Southeast Asia, with zinc deficiency identified as a contributing factor to impaired linear growth in early childhood. Zinc is critical for growth hormone synthesis, bone development, and immune regulation. Despite existing intervention programs, stunting prevalence in Indonesia remained at 19.8% in 2024. This study evaluated the effect of zinc supplementation on the linear growth of stunted children aged 0–5 years attending Bangetayu and Genuk Public Health Centres in Semarang. Employing an observational analytic design with a one-group pretest-posttest approach, 42 stunted toddlers received a daily oral dose of 20 mg zinc sulfate syrup for two months. Anthropometric measurements were recorded before and after the intervention, with paired T-tests applied to normally distributed data and Wilcoxon signed-rank tests to non-normal data. After two months of supplementation, 86% of the participants demonstrated improvements in both height and weight. The mean height increased from 79.9 cm to 81.0 cm ($p < 0.001$), while the mean weight increased from 9.28 kg to 9.74 kg ($p < 0.001$). These findings indicate that zinc supplementation significantly enhances linear growth among stunted toddlers. Consequently, integrating zinc supplementation into national nutrition intervention strategies could be pivotal in reducing early childhood stunting.

1. Introduction

Stunting is defined as impaired linear growth in toddlers, primarily caused by chronic malnutrition and repeated infections, especially during the first 1,000 days of life, from conception to 23 months of age. Children are classified as stunted when their height-for-age is below minus two standard deviations (-2 SD) based on WHO growth standards (Coordinating Ministry for Human Development and Cultural Affairs, 2021).

According to the World Health Organisation, the global prevalence of stunting in 2024 was estimated at 23.2% (WHO, 2025). In Southeast Asia, the stunting rate reached 27.4% in 2020, while Indonesia reported a prevalence of 31.8% (Food and Agriculture Organisation of the United Nations, 2025). According to Stunting.go.id (2025), the Indonesian government has targeted a reduction to 14% by 2024, by the National Medium-Term Development Plan (RPJMN) 2020–2024. Achieving this target requires an annual decrease of 3–3.5% in stunting rates, which demands cross-sectoral collaboration and active community involvement

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(Coordinating Ministry for Human Development and Cultural Affairs, 2022). In 2022, the stunting rate in Indonesia declined to 21.6%, with the national target of 14% reaffirmed for 2024 (Public Relations of BKPK, 2023). However, as of 2024, the recorded stunting prevalence remained at 19.8% (Ministry of Health [BKPK], 2025).

Stunting is a chronic nutritional issue influenced by a wide range of intergenerational factors (Aryastami, 2017). These include poor parenting practices, limited maternal knowledge regarding health and nutrition before, during, and after pregnancy, and inadequate breastfeeding practices. Evidence indicates that approximately 60% of infants aged 0–6 months are not exclusively breastfed, and two-thirds of children aged 0–24 months do not receive appropriate complementary feeding. Complementary feeding plays a crucial role in meeting nutritional needs once breast milk alone becomes insufficient and is essential for immune development.

Other contributing factors include limited access to maternal and child healthcare services such as antenatal care (ANC), postnatal care (PNC), immunisations, and early childhood education. According to reports from the Ministry of Health and the World Bank, attendance at integrated health posts declined from 79% in 2007 to 64% in 2013, indicating reduced access to essential health services. Additionally, many children still lack access to immunisation services, and around two-thirds of pregnant women do not consume adequate iron supplements. Access to early childhood education services remains limited. Furthermore, poor access to clean water and sanitation, combined with limited economic access to nutritious food due to its relatively high cost in Indonesia, continues to exacerbate the issue (Sutarto *et al.*, 2018).

Various stunting control efforts have been implemented in Indonesia, ranging from the provision of complementary feeding to the administration of micronutrient supplementation, including zinc. Purwandini & Atmaka (2023) reported a significant association between zinc consumption and stunting incidence. This relationship is attributed to zinc's essential functions in the body related to growth, such as growth hormone synthesis, bone elongation, immune function enhancement, and stimulation of taste receptors, which can help increase appetite (Purwandini & Atmaka, 2023).

Kasanah & Muawanah (2020) showed a significant difference in height gain between children who received zinc supplementation and those in the control group, with a p-value of 0.001. The average height gain in the intervention group was 3.35 cm, compared to only 1 cm in the control group. In terms of weight, the intervention group gained an average of 0.885 kg, while the control group gained only 0.17 kg. The study recommended providing zinc supplementation to stunted toddlers, especially those under two years of age, at a dose of 20 mg (10 mL) twice weekly, accompanied by regular monitoring and a balanced diet rich in essential nutrients.

In contrast, Gera *et al*. (2019) concluded that zinc supplementation did not lead to significant improvements in anthropometric indicators or reductions in malnutrition among children under five. The authors suggested that zinc supplementation, when applied as a public health strategy, may not be effective in all resource-limited settings.

Given the inconsistent results in previous studies, further research is needed to evaluate the effect of zinc supplementation on stunted toddlers, particularly in real-world, community health settings. This study aims to assess the impact of zinc supplementation on the linear growth of stunted children aged 0–5 years at Bangetayu and Genuk Public Health Centres in Semarang City.

2. Materials and Methods

2.1. Study Design and Ethical Approval

This study was an analytical observational study utilising a one-group pretest–posttest design to assess the effect of zinc supplementation on the linear growth of stunted toddlers. The research was conducted over two months at the Bangetayu and Genuk Community Health Centres, located in Semarang City, Central Java, Indonesia. The study protocol was reviewed and approved by the Bioethics Commission of the Faculty of Medicine, Universitas Islam Sultan Agung, Semarang (Decree No. 175/IV/2025/Bioethics Commission).

2.2. Population and Sampling

The target population included children aged 0–5 years classified as stunted, defined by a height-for-age z-score (HAZ) below -2 standard deviations (SD) based on WHO Child Growth Standards. The accessible population consisted of stunted children within the same age range who resided in the catchment areas of the two selected community health centres. A total of 42 stunted toddlers who met the inclusion criteria were enrolled in the study using a purposive sampling technique.

2.3. Intervention and Anthropometric Measure ments

Participants received oral zinc in the form of zinc sulfate syrup at a dosage of 20 mg (5 mL) once

daily for 60 consecutive days. The supplementation was administered under parental supervision and monitored weekly by health workers to ensure compliance. Anthropometric data were collected before and after the intervention. Measurements included: (1) Body height, measured using a stadiometer or infantometer (depending on the child's age), recorded to the nearest 0.1 cm, and (2) Body weight, measured using a calibrated digital scale, recorded to the nearest 0.1 kg. All measurements were conducted by trained personnel following WHO standardised measurement procedures.

2.4. Data Analysis

Univariate analysis was used to describe participant characteristics, such as age and sex distribution. Bivariate analysis was performed to assess changes in height and weight before and after zinc supplementation. The Paired T-test was applied for normally distributed data, while the Wilcoxon signed-rank test was used for non-normally distributed data. All analyses were conducted using a standard statistical software package, with a p-value < 0.05 considered statistically significant.

Table 1. Characteristics of Study Participants (n = 42)

Characteristics	n (%)
Gender	
• Male	23 (54.8)
• Female	19 (45.2)
Age	
• 0-24 Months	18 (42.9)
• 25-60 Months	24 (57.1)

3. Results

A total of 42 stunted toddlers from the Bangetayu and Genuk Community Health Centres completed the two-month zinc supplementation intervention. The baseline characteristics of the study participants are presented in Table 1. Most participants were male (54.8%) and aged between 25 and 60 years (57.1%).

Figure 1 illustrates the proportion of stunted toddlers who experienced changes in height after receiving zinc supplementation over two months. The chart shows that 86% of the children experienced an increase in body height and weight, while 14% showed no significant body height and weight improvement. These findings suggest that zinc supplementation was effective in promoting both linear growth and weight

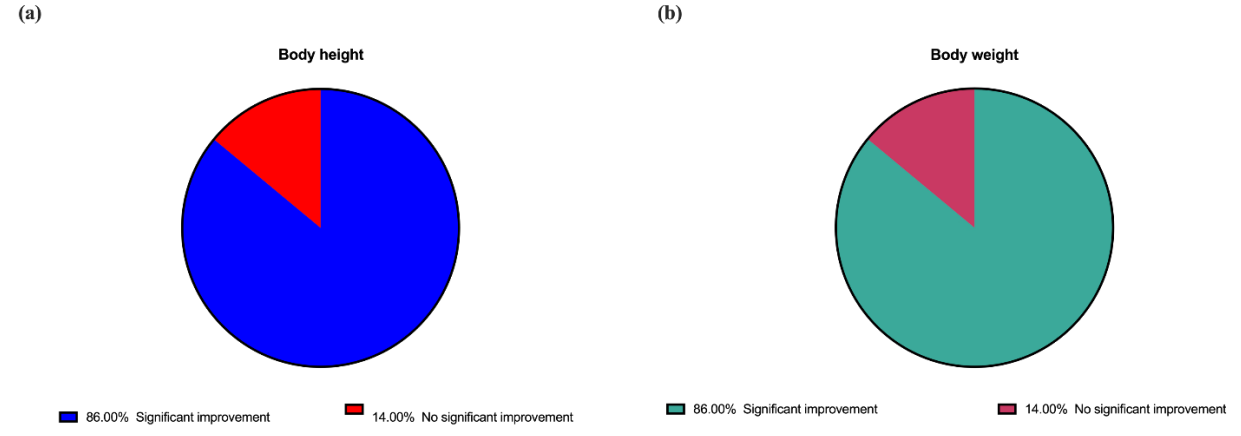

Figure 1. Changes in height and weight after zinc supplementation among 42 stunted toddlers

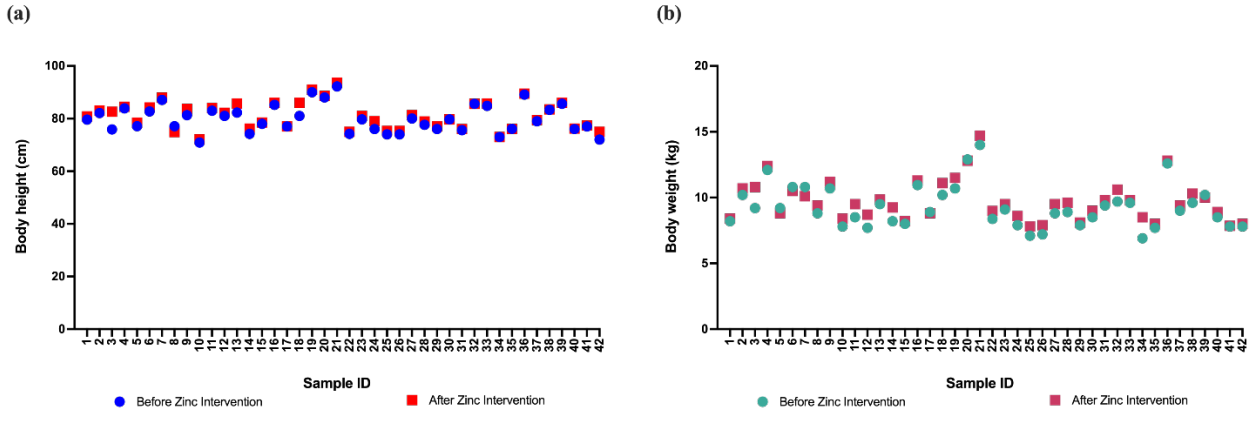

Figure 2. Effect of zinc supplementation on height (a) and weight (b) in stunted children aged 1–5 years

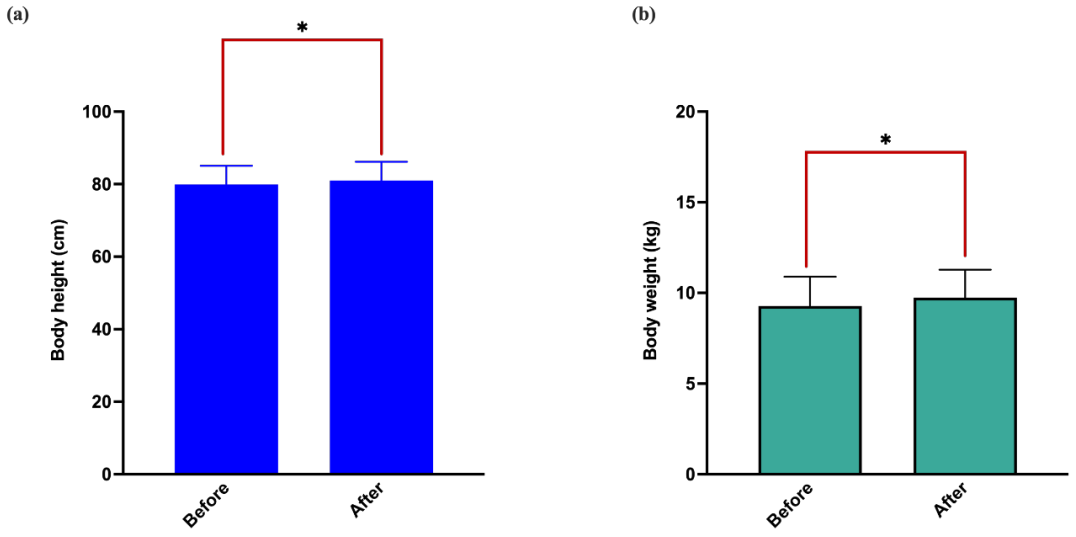

Figure 3. Improvements in height (a) and weight (b) after zinc supplementation among stunted children aged 1–5 years. *Indicated a significant difference between before and after zinc intervention

gain in most of the participating stunted children.

Figure 2 presents the results of a zinc supplementation intervention in stunted children under five years of age, showing the proportion of participants who experienced improvements in height (Figure 2a) and weight (Figure 2b) over a two-month period.

Zinc supplementation resulted in significant improvements in both height and weight among stunted toddlers. A paired t-test showed a statistically significant increase in mean height from 79.9 cm before intervention to 81.0 cm after intervention ($p < 0.001$), indicating a positive effect on linear growth (Figure 3a) The Wilcoxon signed-rank test revealed a significant rise in mean body weight from 9.28 kg to 9.74 kg ($p < 0.001$), confirming a meaningful enhancement in nutritional status (Figure 3b). These findings demonstrate that zinc supplementation effectively promotes growth in stunted children.

4. Disscussion

This study demonstrates that zinc supplementation had a significant positive impact on both height and weight among stunted toddlers. Zinc is vital for child growth, functioning through the activation and synthesis of growth hormone (GH) and stabilisation of cell membranes. It is involved in the activity of over 300 enzymes and more than 1,000 transcription factors (Prasad, 2013). Being present in all body tissues and organs, zinc deficiency in toddlers can lead to impaired growth and developmental delays.

At the molecular level, zinc is essential for the formation of insulin-like growth factor 1 (IGF-1), phosphorylation of IGF-1 receptors, and activation of deoxythymidine kinase (TK), all of which are critical processes in cellular growth and division. Several studies have confirmed zinc's role in promoting child growth due to its involvement in numerous physiological and biochemical pathways (Prasad, 2013). During periods of rapid growth, such as infancy and early childhood, children are especially vulnerable to zinc deficiency (Roohani *et al.*, 2013). Zinc supplementation has been shown to elevate serum zinc levels and enhance the nutritional status of toddlers (Wahyuningsih *et al.*, 2022).

Zinc is also highly concentrated in bone tissue and plays a central role in bone metabolism. It stimulates osteoblastic activity by enhancing collagen synthesis and inhibits osteoclastic activity, thereby reducing bone resorption. Additionally, zinc amplifies the anabolic effects of IGF-1 in osteoblasts through intricate signalling networks (Prodam & Aimaretti, 2013). Guo *et al.* (2020) reported that zinc supplementation significantly increased IGF-1 levels in humans, with greater effects observed after more than eight weeks of supplementation and among younger participants. Similarly, Rocha *et al.* (2015) found an increase in IGF-1 levels following zinc supplementation. These findings align with zinc's fundamental roles in DNA replication, RNA transcription, and endocrine regulation, especially during periods of accelerated growth (Gibson, 2006). 3, GH, and IGF-1, making it indispensable for normal growth and skeletal development (Adriani & Wirjatmadi, 2014; Alves *et al.*, 2012). A recent study by Priyantini *et al.* (2023) further supports a significant association between daily zinc intake and reduced risk of stunting. Likewise, Ahmad *et al.* (2022) demonstrated the effectiveness of zinc supplementation in improving linear growth, especially in children aged 2–5 years.

Evidence from a meta-analysis of 54 randomised

controlled trials supports these findings, with nearly 70% of the studies showing a positive and often statistically significant effect of zinc supplementation on child growth (Imdad & Bhutta, 2011). These results reinforce the recommendation of oral zinc supplementation as a targeted intervention to combat stunting in early childhood. The effectiveness is particularly notable when zinc is administered as a standalone supplement. Accordingly, zinc supplementation should be prioritised in national public health strategies to reduce stunting in children under five, particularly in low- and middle-income countries.

Sex-specific differences in zinc requirements have also been noted. Males typically have a higher demand due to their greater linear growth potential and larger muscle mass, as muscle tissue contains more zinc than adipose tissue (Hotz & Brown, 2004). In the present study, a greater proportion of stunted toddlers were male (54.8%), consistent with the notion that boys may be more susceptible to growth impairments due to zinc deficiency.

Moreover, zinc is not only a structural component of bone tissue but also regulates bone remodelling processes. It enhances collagen matrix synthesis, mineralisation, and bone regeneration. Zinc has been shown to stimulate runt-related transcription factor 2 (Runx2), which promotes osteoblast differentiation, while simultaneously inhibiting osteoclastogenesis and inducing osteoclast apoptosis—thereby maintaining bone homeostasis (Molenda & Kolmas, 2023).

In this study, 36 out of 42 stunted toddlers demonstrated an increase in height following two months of zinc supplementation. Similarly, 36 toddlers experienced weight gain, suggesting a substantial effect of zinc on both linear and ponderal growth. However, it is important to interpret these findings within the context of the study's limitations. First, the relatively short duration of the intervention (two months) may not capture the full potential of zinc's long-term effects on growth. Second, several possible confounding factors were not controlled for, including dietary intake, concurrent illness, environmental sanitation, maternal education, immunisation status, parental income, and breastfeeding practices. Lastly, the absence of a control group of stunted toddlers who did not receive zinc supplementation limits causal inferences, as it is difficult to attribute the observed improvements solely to the intervention.

5. Conclusions

This study concludes that two months of zinc supplementation significantly improved both height and weight among stunted children aged 1–5 years at the Bangetayu and Genuk Health Centres in Semarang. These findings highlight the potential of zinc as a targeted nutritional intervention to support linear growth and weight gain in early childhood.

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Conflict of interest

All authors have no conflict of interest in this article.

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