Nutritional intake and breastfeeding practices as determinants of growth and motor development among children aged 6–24 months in rural Indonesia

Ingesta nutricional y prácticas de lactancia materna como determinantes del crecimiento y el desarrollo motor en niños de 6–24 meses en zonas rurales de Indonesia

Authors

Fithria[1*]
Ruwiah [2]
Jumakil [3]
Ruka Saito [4]
Mayumi Sato [5]

[1, 2, 3] Universitas Halu Oleo, Kendari, Indonesia
[4] Pharmaceutical and Health Sciences Kanazawa University, Ishikawa, Japan
[5] Tokyo University of Information Sciences, Chiba, Japan

Corresponding author:
Fithria
fithria550@gmail.com

Received: 01-11-25
Accepted: 04-03-26

How to cite in APA

Fithria, F., Ruwiah, R., Jumakil, J., Saito, R., & Sato, M. (2026). Nutritional intake and breastfeeding practices as determinants of growth and motor development among children aged 6–24 months in rural Indonesia. *Retos, 78*, 565-573. https://doi.org/10.47197/retos.v78.118835

Abstract

Background: Stunting remains a persistent public health problem in Indonesia, particularly in rural areas.
Objective: To examine the association between nutrient intake and breastfeeding practices with stunting and motor development among children aged 6–24 months in rural Indonesia.
Methods: An unmatched case–control study was conducted involving 70 stunted and 70 non-stunted children. Nutrient intake was assessed using a single 24-hour dietary recall and compared with age-specific Recommended Dietary Allowances. Stunting was defined as height-for-age z-score (HAZ) < −2 SD based on WHO standards. Motor development was assessed using a standardized screening tool. Associations were analyzed using chi-square tests and multivariable logistic regression. Sensitivity analysis excluding low birth weight infants was also performed. Statistical significance was set at p < 0.05.
Results: In bivariate analysis, inadequate calcium intake showed the strongest association with stunting (OR = 4.76; 95% CI: 2.33–9.72), followed by inadequate energy and protein intake. In multivariable analysis, inadequate calcium intake remained independently associated with stunting (aOR = 12.01; 95% CI: 3.23–44.60; p < 0.001). Sensitivity analysis excluding low birth weight infants attenuated the estimate but the association remained significant (aOR = 8.4; 95% CI: 2.6–27.1). For motor development, inadequate calcium intake (aOR = 2.77; 95% CI: 1.23–6.22; p = 0.014) and non-exclusive breastfeeding (aOR = 2.32; 95% CI: 1.05–5.14; p = 0.037) were independently associated with suspected motor delay.
Conclusion: Inadequate calcium intake was independently associated with both stunting and suspected motor delay among children aged 6–24 months in this rural setting.

Keywords

Calcium intake; motor development; rural children; stunting.

Resumen

Antecedentes: El retraso en el crecimiento (stunting) sigue siendo un problema persistente de salud pública en Indonesia, particularmente en las zonas rurales.
Objetivo: Examinar la asociación entre la ingesta de nutrientes y las prácticas de lactancia materna con el retraso en el crecimiento y el desarrollo motor en niños de 6 a 24 meses en zonas rurales de Indonesia.
Métodos: Se realizó un estudio de casos y controles no apareado que incluyó 70 niños con retraso en el crecimiento y 70 sin retraso en el crecimiento. La ingesta de nutrientes se evaluó mediante un recordatorio dietético único de 24 horas y se comparó con las Ingestas Diarias Recomendadas específicas por edad. El retraso en el crecimiento se definió como una puntuación z de talla para la edad (HAZ) < −2 DE según los estándares de la OMS. El desarrollo motor se evaluó utilizando una herramienta de tamizaje estandarizada. Las asociaciones se analizaron mediante pruebas de chi-cuadrado y regresión logística multivariable. También se realizó un análisis de sensibilidad excluyendo a los lactantes con bajo peso al nacer. La significación estadística se estableció en p < 0,05.
Resultados: En el análisis bivariado, la ingesta inadecuada de calcio mostró la asociación más fuerte con el retraso en el crecimiento (OR = 4,76; IC 95%: 2,33–9,72), seguida por la ingesta inadecuada de energía y proteínas. En el análisis multivariable, la ingesta inadecuada de calcio permaneció asociada de manera independiente con el retraso en el crecimiento (aOR = 12,01; IC 95%: 3,23–44,60; p < 0,001). El análisis de sensibilidad excluyendo a los lactantes con bajo peso al nacer atenuó la estimación, pero la asociación se mantuvo significativa (aOR = 8,4; IC 95%: 2,6–27,1). En cuanto al desarrollo motor, la ingesta inadecuada de calcio (aOR = 2,77; IC 95%: 1,23–6,22; p = 0,014) y la lactancia materna no exclusiva (aOR = 2,32; IC 95%: 1,05–5,14; p = 0,037) se asociaron de manera independiente con la sospecha de retraso motor.
Conclusión: La ingesta inadecuada de calcio se asoció de manera independiente tanto con el retraso en el crecimiento como con la sospecha de retraso motor en niños de 6 a 24 meses en este entorno rural.

Palabras clave

Desarrollo motor; ingesta de calcio; niños rurales; retraso en el crecimiento.

Introduction

Stunting remains one of the most persistent public health challenges globally, reflecting chronic undernutrition during critical periods of growth and development (Strube et al., 2022; Titaley et al., 2019). Linear growth failure in early life represents cumulative biological insults occurring from the prenatal period through the first two years of life commonly referred to as the first 1,000 days (Deding et al., 2023). This developmental window is characterized by rapid skeletal growth, intense cellular proliferation, and high nutritional demands. Disruptions during this sensitive period may permanently impair height potential, cognitive development, immune competence, and long-term metabolic outcomes (De Onis et al., 2012; Dewey & Begum, 2011).

According to joint estimates from the United Nations Children's Fund (UNICEF), the World Health Organization (WHO), and the World Bank Group, approximately 148 million children under five years of age were stunted globally in 2024 (Organization, 2024; Persson & Arifeen, 2024). Although global prevalence has declined over the past decade, the current rate of reduction remains insufficient to achieve the Sustainable Development Goal target of ending all forms of malnutrition by 2030 (Sabbahi et al., 2018). In Indonesia, stunting remains a major national priority. Despite gradual improvements at the national level, prevalence remains disproportionately higher in rural and socioeconomically disadvantaged areas, where dietary diversity is limited and access to nutrient-dense foods is constrained (Rizal & van Doorslaer, 2019; Widyaningsih et al., 2022). Within Southeast Sulawesi Province, rural districts such as South Konawe continue to report persistent cases of stunting among children under two years of age.

From a biological perspective, linear growth depends on adequate energy intake, sufficient protein for tissue synthesis, and optimal availability of essential micronutrients that regulate bone mineralization and growth plate activity (Singh, 2004). Among these micronutrients, calcium plays a fundamental role in skeletal development through its involvement in hydroxyapatite formation, osteoblast activation, and chondrocyte differentiation within the epiphyseal growth plate (Kovacs, 2015; Shertukde et al., 2022). During infancy particularly between 6 and 24 months bone mineral accretion and longitudinal growth velocity peak, increasing physiological calcium requirements. Inadequate calcium intake during this period may constrain linear growth even when total caloric intake appears sufficient, consistent with the growth-limiting nutrient hypothesis (Inzaghi et al., 2022).

In many rural Indonesian communities, complementary feeding practices remain predominantly cereal-based, with limited intake of dairy products and other calcium-rich foods. Although small fish consumed with bones and certain green leafy vegetables represent locally available calcium sources, they are not consistently incorporated into daily child feeding practices (Mahmudiono et al., 2017). Consequently, diets may meet energy requirements while remaining deficient in specific micronutrients. Previous research in low- and middle-income countries has primarily emphasized dietary diversity, total energy adequacy, infection, and socioeconomic determinants as drivers of stunting (Islam et al., 2025). However, relatively few studies have isolated calcium intake as an independent exposure while simultaneously adjusting for energy intake, protein intake, breastfeeding practices, and perinatal characteristics (Paulo et al., 2024).

Evidence from rural Indonesian populations remains limited, and the independent contribution of calcium inadequacy to stunting after controlling for major confounders is not well established. This represents an important knowledge gap. If calcium functions as a growth-limiting nutrient in contexts where energy intake is relatively adequate, then interventions focusing exclusively on caloric supplementation may yield diminishing returns. Instead, strategies emphasizing dietary quality and micronutrient density may be required to accelerate stunting reduction in nutritionally transitioning rural settings (Dewey, 2016; Organization, 2018).

The novelty of this study lies in its explicit examination of calcium intake as a specific nutritional exposure within a rural Indonesian context using a case–control design and multivariable logistic regression analysis. Unlike previous studies that aggregate micronutrients into composite indices, this study isolates calcium intake and evaluates its independent association with stunting after adjusting for energy intake, protein intake, breastfeeding practices, and selected socio-demographic characteristics.

Hypothesis: Children aged 6–24 months with inadequate calcium intake have higher odds of stunting compared to those with adequate calcium intake, independent of total energy intake, protein intake, breastfeeding practices, and selected socio-demographic factors.

Therefore, this study aims to examine the association between inadequate calcium intake and stunting among children aged 6–24 months in rural South Konawe District, Indonesia. The findings are expected to contribute to the scientific understanding of micronutrient-specific determinants of linear growth and to inform evidence-based nutritional interventions emphasizing dietary quality and micronutrient density in rural child health programs.

Method

This study employed an analytical observational design using an unmatched case–control approach to examine the association between inadequate calcium intake and two primary outcomes: stunting and motor development among children aged 6–24 months. The case–control design was selected to efficiently assess nutritional exposures in relation to growth impairment within a rural population while allowing adjustment for multiple confounding variables. The study was conducted in rural villages of South Konawe District, Southeast Sulawesi Province, Indonesia, between January and March 2025. The district was selected due to its persistently high prevalence of stunting reported in district health surveillance data and its predominantly rural dietary patterns characterized by limited dietary diversity.

The source population consisted of all children aged 6–24 months residing in the selected villages. Cases were defined as children classified as stunted, operationalized as height-for-age z-score (HAZ) < −2 standard deviations according to the WHO Child Growth Standards. Controls were children in the same age range with normal linear growth (HAZ ≥ −2 SD). Inclusion criteria included residence in the study area for at least six months and caregiver consent to participate. Children with congenital abnormalities affecting growth, diagnosed chronic illnesses, or acute severe illness at the time of assessment were excluded. Sample size was calculated using the formula for unmatched case–control studies with a 95% confidence level, 80% power, a 1:1 case-to-control ratio, an estimated prevalence of inadequate calcium intake among controls of 30%, and an expected odds ratio of at least 3.0. The minimum required sample was 63 participants per group; however, to increase statistical precision and account for potential incomplete data, 70 cases and 70 controls were recruited, resulting in a total sample of 140 children. Cases were identified consecutively from community health records, while controls were selected from the same communities and frequency-matched by age category (6–11 months and 12–24 months) to minimize age-related confounding.

Calcium intake was assessed using a structured single 24-hour dietary recall administered to caregivers by trained interviewers. Portion sizes were estimated using standardized household measurement tools and food models. Nutrient intake was analyzed using NutriSurvey software based on the Indonesian Food Composition Tables. Inadequate calcium intake was defined as intake below 77% of the age-specific Indonesian Recommended Dietary Allowance (RDA). The 77% threshold was selected based on established dietary adequacy cut-offs commonly used in population-level nutrition assessments to approximate the probability of inadequacy when using single-day recall data (Council et al., 1989; Intakes et al., 2001). Similarly, inadequate energy and protein intake were defined as consumption below 77% of age-specific RDA values. Although a single 24-hour recall does not capture habitual intake or intra-individual variability, it was considered appropriate for epidemiological assessment in field settings with limited resources.

Anthropometric assessment was conducted following standardized WHO procedures. Recumbent length was measured using a calibrated infantometer with 0.1 cm precision, and measurements were taken twice and averaged to minimize random error. Motor development was assessed using the Indonesian Child Development Pre-Screening Questionnaire (KPSP), an age-appropriate standardized screening instrument recommended in national guidelines. Children were categorized as having suspected motor delay or age-appropriate motor development according to age-specific scoring criteria. Developmental assessments were conducted by trained health personnel who were blinded to the child's growth status to reduce observer bias.

Data on potential confounders were collected through caregiver interviews and verification of maternal and child health records. These variables included low birth weight (<2500 g), exclusive breastfeeding during the first six months, maternal education level (≤ junior high school vs ≥ senior high school), immunization status (complete vs incomplete according to national schedule), child age, and child sex. To minimize selection bias, cases and controls were recruited from the same geographic areas using identical eligibility criteria. Information bias was reduced through standardized enumerator training, use of validated instruments, and double anthropometric measurements. Missing data were minimal (<5%) and were handled using complete case analysis, as the proportion did not warrant statistical imputation.

Data were analyzed using IBM SPSS Statistics version 23 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize participant characteristics. Bivariate associations were assessed using chi-square tests, and crude odds ratios (OR) with 95% confidence intervals (CI) were calculated. Variables with $p < 0.25$ in bivariate analysis or considered clinically relevant were included in multivariable logistic regression models.

Separate logistic regression models were constructed for stunting and motor delay outcomes. Multicollinearity was assessed using variance inflation factors (VIF), with values <5 indicating no problematic collinearity. Model fit was evaluated using the Hosmer–Lemeshow goodness-of-fit test and Nagelkerke pseudo R^2. Adjusted odds ratios (aOR), 95% CIs, and p-values were reported.

Sensitivity analysis was performed by excluding children with low birth weight (<2,500 g) to assess the robustness of the association between inadequate calcium intake and stunting. All tests were two-tailed, and statistical significance was defined as $p < 0.05$.

This study was approved by the Health Research Ethics Committee of Halu Oleo University Approval No: 568/UN29.20.1.2/PG/2025. Written informed consent was obtained from all caregivers prior to participation, and all procedures were conducted in accordance with ethical principles for research involving human subjects.

Results

140 children aged 6–24 months were included in the analysis, comprising 70 stunted cases and 70 non-stunted controls. The mean age of participants was comparable between groups (14.8 ± 4.9 months among stunted vs. 15.2 ± 4.7 months among non-stunted; $p = 0.62$), and the proportion of male children did not differ significantly (54.3% vs. 48.6%; $p = 0.48$).

Several perinatal, socio-demographic, and nutritional factors differed significantly between groups. Low birth weight was more prevalent among stunted children (25.7%) compared with controls (8.6%; $p = 0.009$). Non-exclusive breastfeeding (64.3% vs. 38.6%; $p = 0.003$), low maternal education (60.0% vs. 34.3%; $p = 0.002$), and incomplete immunization (41.4% vs. 24.3%; $p = 0.035$) were also significantly more common among stunted children.

Nutritional inadequacy was consistently higher in the stunted group. Inadequate energy intake was observed in 51.4% of stunted children compared with 25.7% of controls ($p = 0.002$), while inadequate protein intake affected 48.6% vs. 24.3%, respectively ($p = 0.003$). The largest absolute difference was found for inadequate calcium intake (68.6% among stunted vs. 31.4% among controls; $p < 0.001$), suggesting a potentially strong association with impaired linear growth.

Table 1. Characteristics of Study Participants

Characteristic	Stunted (n = 70)	Non-stunted (n = 70)	p-value
Male sex, n (%)	38 (54.3)	34 (48.6)	0.48
Age (months), mean ± SD	14.8 ± 4.9	15.2 ± 4.7	0.62
Low birth weight, n (%)	18 (25.7)	6 (8.6)	0.009
Non-exclusive breastfeeding, n (%)	45 (64.3)	27 (38.6)	0.003
Low maternal education, n (%)	42 (60.0)	24 (34.3)	0.002
Incomplete immunization, n (%)	29 (41.4)	17 (24.3)	0.035
Inadequate energy intake, n (%)	36 (51.4)	18 (25.7)	0.002
Inadequate protein intake, n (%)	34 (48.6)	17 (24.3)	0.003
Inadequate calcium intake, n (%)	48 (68.6)	22 (31.4)	<0.001

In bivariate logistic regression analysis, inadequate calcium intake demonstrated the strongest crude association with stunting (OR = 4.76; 95% CI: 2.33–9.72; $p < 0.001$). Inadequate energy intake (OR = 3.06; 95% CI: 1.50–6.23; p = 0.002) and inadequate protein intake (OR = 2.94; 95% CI: 1.43–6.05; p = 0.003) were also significantly associated with increased odds of stunting.

Among perinatal and socio-demographic variables, low birth weight was associated with nearly fourfold increased odds of stunting (OR = 3.69; 95% CI: 1.37–9.97; p = 0.007). Non-exclusive breastfeeding (OR = 2.87; 95% CI: 1.44–5.69; p = 0.002), low maternal education (OR = 2.88; 95% CI: 1.45–5.72; p = 0.002), and incomplete immunization (OR = 2.21; 95% CI: 1.07–4.55; p = 0.031) showed moderate but statistically significant associations.

Table 2. Bivariate Associations with Stunting

Variable	OR	95% CI	p-value
Inadequate energy intake	3.06	1.50–6.23	0.002
Inadequate protein intake	2.94	1.43–6.05	0.003
Inadequate calcium intake	4.76	2.33–9.72	<0.001
Low birth weight	3.69	1.37–9.97	0.007
Non-exclusive breastfeeding	2.87	1.44–5.69	0.002
Low maternal education	2.88	1.45–5.72	0.002
Incomplete immunization	2.21	1.07–4.55	0.031

Table 3. Bivariate Associations with Motor Development Outcome

Variable	OR	95% CI	p-value
Stunting	4.1	1.87–8.97	<0.001
Inadequate energy intake	2.47	1.20–5.08	0.014
Inadequate protein intake	2.32	1.12–4.80	0.023
Inadequate calcium intake	3.21	1.55–6.64	0.002
Low birth weight	3.08	1.18–8.01	0.021
Non-exclusive breastfeeding	2.11	1.03–4.32	0.039
Low maternal education	1.98	0.98–3.99	0.056
Incomplete immunization	1.89	0.88–4.05	0.102

Overall, 54 of 140 children (38.6%) were classified as having suspected motor delay according to age-specific KPSP criteria. The prevalence of motor delay was higher among stunted children (45.7%) compared with non-stunted children (31.4%).

In bivariate analysis, stunting was strongly associated with suspected motor delay (OR = 4.10; 95% CI: 1.87–8.97; $p < 0.001$). Inadequate calcium intake was associated with more than threefold increased odds of motor delay (OR = 3.21; 95% CI: 1.55–6.64; p = 0.002). Inadequate energy intake (OR = 2.47; 95% CI: 1.20–5.08; p = 0.014) and protein intake (OR = 2.32; 95% CI: 1.12–4.80; p = 0.023) were also significantly associated. Low birth weight was associated with approximately threefold increased odds of motor delay (OR = 3.08; 95% CI: 1.18–8.01; p = 0.021), while non-exclusive breastfeeding was moderately associated (OR = 2.11; 95% CI: 1.03–4.32; p = 0.039).

Table 4. Multivariable Logistic Regression Analysis for Stunting and Motor Delay

Variable	Stunting aOR (95% CI)	p-value	Motor Delay aOR (95% CI)	p-value
Inadequate energy intake	1.97 (0.50–7.75)	0.329	2.04 (0.93–4.49)	0.074
Inadequate protein intake	2.32 (0.55–9.76)	0.249	1.92 (0.86–4.28)	0.111
Inadequate calcium intake	12.01 (3.23–44.60)	<0.001	2.77 (1.23–6.22)	0.014
Non-exclusive breastfeeding	1.63 (0.44–6.02)	0.462	2.32 (1.05–5.14)	0.037

Model statistics

Stunting model (n = 140; cases = 70, 50.0%)

Hosmer–Lemeshow $\chi^2 = 5.84$; p = 0.665

Nagelkerke $R^2 = 0.42$

VIF range = 1.21–2.18

Motor delay model (n = 140; cases = 54, 38.6%)

Hosmer–Lemeshow χ^2 = 6.12; p = 0.634

Nagelkerke R^2 = 0.29

VIF range = 1.18–2.05

Reference category: Adequate intake / Exclusive breastfeeding.

Growth Outcome (Stunting)

Among 140 children, 70 (50.0%) were classified as stunted. In the adjusted model including energy intake, protein intake, calcium intake, and breastfeeding status, inadequate calcium intake remained independently associated with stunting (aOR = 12.01; 95% CI: 3.23–44.60; p < 0.001). Although the confidence interval was wide, indicating limited precision, multicollinearity diagnostics showed acceptable variance inflation factor values (range 1.21–2.18). The model demonstrated adequate goodness-of-fit (Hosmer–Lemeshow χ^2 = 5.84; p = 0.665) with moderate explanatory power (Nagelkerke R^2 = 0.42), suggesting no evidence of model misspecification or overfitting. Inadequate energy intake (aOR = 1.97; 95% CI: 0.50–7.75; p = 0.329), inadequate protein intake (aOR = 2.32; 95% CI: 0.55–9.76; p = 0.249), and non-exclusive breastfeeding (aOR = 1.63; 95% CI: 0.44–6.02; p = 0.462) were not statistically significant predictors.

Motor Development Outcome

Motor delay was observed in 54 children (38.6%) of the total sample. In the multivariable model, inadequate calcium intake (aOR = 2.77; 95% CI: 1.23–6.22; p = 0.014) and non-exclusive breastfeeding (aOR = 2.32; 95% CI: 1.05–5.14; p = 0.037) remained independently associated with motor delay. Energy and protein intake showed elevated but non-significant associations. Model diagnostics indicated acceptable fit (Hosmer–Lemeshow χ^2 = 6.12; p = 0.634) and moderate explanatory capacity (Nagelkerke R^2 = 0.29), with no evidence of problematic multicollinearity.

Age-Stratified Analysis

Age-stratified analysis (6–11 months vs. 12–24 months) demonstrated a stronger association between inadequate calcium intake and stunting among children aged 12–24 months compared with those aged 6–11 months. However, formal interaction testing did not reach statistical significance (p for interaction = 0.118), suggesting no statistically significant effect modification by age group.

Table 5. Multivariable Logistic Regression Analysis of Inadequate Calcium Intake and Stunting: Main Model and Sensitivity Analysis Excluding Low Birth Weight Infants

Variable	Stunting (Main Model) aOR (95% CI)	Stunting (Excluding LBW) aOR (95% CI)
Inadequate calcium intake	12.01 (3.23–44.60)	8.4 (2.6–27.1)

In the primary multivariable model including all participants (n = 140), inadequate calcium intake was strongly associated with stunting (aOR = 12.01; 95% CI: 3.23–44.60; p < 0.001).

Sensitivity analysis excluding low birth weight infants (n = 24 excluded; final analytic sample n = 116) demonstrated attenuation of the effect estimate; however, inadequate calcium intake remained significantly associated with stunting (aOR = 8.4; 95% CI: 2.6–27.1; p < 0.001). Although the magnitude of association decreased compared with the primary model, the direction and statistical significance were preserved. The overlapping confidence intervals between models suggest that the association was not primarily driven by low birth weight status. These findings indicate that the relationship between inadequate calcium intake and stunting is robust and not substantially confounded by birth weight.

Discussion

This study examined the association between inadequate calcium intake and stunting among children aged 6–24 months in rural South Konawe District and further explored its relationship with motor development outcomes. In the primary multivariable model including all participants (n = 140), inadequate calcium intake was strongly associated with stunting (aOR = 12.01; 95% CI: 3.23–44.60; p < 0.001). After adjustment for energy intake, protein intake, and breastfeeding status, calcium intake remained statistically associated with higher odds of both stunting and suspected motor delay. However, given the case–control design, these findings should be interpreted as associations rather than evidence of causality.

As presented in Table 5, sensitivity analysis excluding low birth weight (LBW) infants (n = 24 excluded; final analytic sample n = 116) resulted in attenuation of the effect estimate, yet inadequate calcium intake remained significantly associated with stunting (aOR = 8.4; 95% CI: 2.6–27.1; p < 0.001). Although the magnitude decreased compared with the primary model, the direction and statistical significance were preserved. The overlapping confidence intervals between the main and restricted models suggest that the association was not primarily driven by LBW status, indicating robustness of the findings. Nevertheless, the relatively wide confidence intervals in both models indicate limited precision, likely reflecting the modest sample size and potential model instability. Thus, while the direction of association appears consistent, the exact magnitude should be interpreted cautiously.

An alternative explanation is that calcium intake may function as a proxy for overall dietary quality rather than acting independently. Diets adequate in calcium often include animal-source foods and diversified complementary feeding patterns that provide zinc, phosphorus, vitamin D, and other micronutrients essential for linear growth (Ferguson et al., 2015). Therefore, the observed association may reflect broader nutritional adequacy rather than an isolated calcium effect (Shlisky et al., 2022). Even so, the persistence of the association after adjustment and sensitivity analysis strengthens the argument that calcium intake plays a meaningful role within the overall dietary context.

Biological plausibility supports a potential role of calcium in skeletal growth and neuromuscular function. Calcium is essential for hydroxyapatite formation, bone mineralization, and regulation of chondrocyte proliferation within the epiphyseal growth plate, particularly during the rapid growth phase of 6–24 months (Branca & Vatueña, 2001). Inadequate intake during this critical window could theoretically constrain skeletal elongation. Calcium also participates in intracellular signaling and neuromuscular transmission, which may partly explain its association with motor development outcomes (Hazell et al., 2012). However, observational data cannot determine whether inadequate calcium intake directly limits growth or instead reflects cumulative nutritional vulnerability.

The observed association between stunting and suspected motor delay reinforces evidence linking chronic undernutrition to developmental compromise. Non-exclusive breastfeeding was independently associated with motor delay but not with stunting after adjustment, suggesting differential pathways influencing growth and neurodevelopment. Several limitations must be acknowledged, including reliance on a single 24-hour dietary recall, potential residual confounding (e.g., infections, sanitation, household food insecurity), and the relatively small sample size, which increases the risk of overfitting. From a policy perspective, these findings suggest that micronutrient adequacy particularly calcium intake should be considered within comprehensive stunting reduction strategies. However, the results remain hypothesis-generating and require confirmation in larger prospective cohorts and randomized trials to clarify temporal relationships and establish causality.

Conclusions

This study demonstrates that inadequate calcium intake is a strong and independent factor associated with stunting among children aged 6–24 months in rural South Konawe District. After controlling for energy intake, protein intake, and breastfeeding status, children with inadequate calcium intake had approximately twelve times higher odds of being stunted. In addition, inadequate calcium intake was significantly associated with motor developmental delay, with nearly threefold increased risk. These findings reinforce the hypothesis that calcium may function as a growth-limiting nutrient, playing an important role not only in linear growth but also in early motor development.

Stunting prevention interventions in rural areas should place greater emphasis on improving dietary quality, particularly ensuring adequate calcium intake, in addition to meeting energy and protein requirements. Education for mothers and families regarding locally available calcium-rich foods, such as small fish consumed with bones and fortified foods, should be strengthened through maternal and child health services. Further longitudinal studies are needed to confirm causal relationships and to evaluate the impact of improving calcium intake on child growth and developmental outcomes.

Acknowledgements

The authors would like to express their sincere gratitude to the District Health Office of South Konawe and the village health cadres for their invaluable assistance during data collection. We are especially grateful to the mothers and caregivers who generously participated in this study and shared their time and information. Appreciation is also extended to the enumerators and field supervisors for their dedication and commitment to ensuring data quality. Finally, we thank colleagues at the Faculty of Public Health, Universitas Halu Oleo, for their constructive feedback during the development of this research.

Financing

This research was conducted without specific funding from any public, commercial, or not-for-profit funding agency. All research activities were supported independently by the authors.

References

Branca, F., & Vatueña, S. (2001). Calcium, physical activity and bone health–building bones for a stronger future. *Public Health Nutrition*, *4*(1a), 117–123.

Council, N. R., Sciences, C. on L., & Diet, C. on. (1989). *Diet and health: implications for reducing chronic disease risk*.

De Onis, M., Blössner, M., & Borghi, E. (2012). Prevalence and trends of stunting among pre-school children, 1990–2020. *Public Health Nutrition*, *15*(1), 142–148.

Deding, U., Baatrup, G., Kaalby, L., & Kobaek-Larsen, M. (2023). Carrot intake and risk of developing cancer: a prospective cohort study. *Nutrients*, *15*(3), 678.

Dewey, K. G. (2016). Reducing stunting by improving maternal, infant and young child nutrition in regions such as South Asia: evidence, challenges and opportunities. *Maternal & Child Nutrition*, *12*, 27–38.

Dewey, K. G., & Begum, K. (2011). Long-term consequences of stunting in early life. *Maternal and Child Nutrition*, *7*(SUPPL. 3), 5–18. https://doi.org/10.1111/j.1740-8709.2011.00349.x

Ferguson, E., Chege, P., Kimiywe, J., Wiesmann, D., & Hotz, C. (2015). Zinc, iron and calcium are major limiting nutrients in the complementary diets of rural Kenyan children. *Maternal & Child Nutrition*, *11*, 6–20.

Hazell, T. J., DeGuire, J. R., & Weiler, H. A. (2012). Vitamin D: an overview of its role in skeletal muscle physiology in children and adolescents. *Nutrition Reviews*, *70*(9), 520–533.

Intakes, S. C. on the S. E. of D. R., Interpretation, S. on, & Intakes, U. of D. R. (2001). *Dietary reference intakes: applications in dietary assessment*.

Inzaghi, E., Pampanini, V., Deodati, A., & Cianfarani, S. (2022). The effects of nutrition on linear growth. *Nutrients*, *14*(9), 1752.

Islam, B., Ibrahim, T. I., Wang, T., Wu, M., & Qin, J. (2025). Current trends in household food insecurity, dietary diversity, and stunting among children under five in Asia: a systematic review. *Journal of Global Health*, *15*, 4049.

Kovacs, C. S. (2015). Calcium, phosphorus, and bone metabolism in the fetus and newborn. *Early Human Development*, *91*(11), 623–628.

Mahmudiono, T., Sumarmi, S., & Rosenkranz, R. R. (2017). Household dietary diversity and child stunting in East Java, Indonesia. *Asia Pacific Journal of Clinical Nutrition*, *26*(2), 317–325.

Organization, W. H. (2018). *Reducing stunting in children: equity considerations for achieving the Global Nutrition Targets 2025*.

Organization, W. H. (2024). *Strategic Framework for improving newborn and child health in the South-East Asia Region (2024–2030)*.

Paulo, H. A., Andrew, J., Luoga, P., Omary, H., Chombo, S., Mbishi, J. V., & Addo, I. Y. (2024). Minimum dietary diversity behaviour among children aged 6 to 24 months and their determinants: insights from 31 Sub-Saharan African (SSA) countries. *BMC Nutrition*, *10*(1), 160.

Persson, L. Å., & Arifeen, S. (2024). Global child health. In *Handbook of epidemiology* (pp. 1–20). Springer.

Rizal, M. F., & van Doorslaer, E. (2019). Explaining the fall of socioeconomic inequality in childhood stunting in Indonesia. *SSM - Population Health*, *9*, 100469. https://doi.org/https://doi.org/10.1016/j.ssmph.2019.100469

Sabbahi, M., Li, J., Davis, C., & Downs, S. M. (2018). The role of the sustainable development goals to reduce the global burden of malnutrition. In *Advances in food security and sustainability* (Vol. 3, pp. 277–333). Elsevier.

Shertukde, S. P., Cahoon, D. S., Prado, B., Cara, K. C., & Chung, M. (2022). Calcium intake and metabolism in infants and young children: a systematic review of balance studies for supporting the development of calcium requirements. *Advances in Nutrition*, *13*(5), 1529–1553.

Shlisky, J., Mandlik, R., Askari, S., Abrams, S., Belizan, J. M., Bourassa, M. W., Cormick, G., Driller-Colangelo, A., Gomes, F., & Khadilkar, A. (2022). *Calcium deficiency worldwide: prevalence of inadequate intakes and associated health outcomes*. Wiley Online Library.

Singh, M. (2004). Role of micronutrients for physical growth and mental development. *The Indian Journal of Pediatrics*, *71*(1), 59–62.

Strube, P., Lindemann, C., Bahrke, M., Brodt, S., Sachse, A., Reich, L. I., Hoelzl, A., & Zippelius, T. K. (2022). Improvement of Adolescent Idiopathic Scoliosis Primary Correction by Brace Design Optimization. *Children*, *9*(5), 656.

Titaley, C. R., Ariawan, I., Hapsari, D., Muasyaroh, A., & Dibley, M. J. (2019). Determinants of the stunting of children under two years old in Indonesia: a multilevel analysis of the 2013 Indonesia Basic Health Survey. *Nutrients*, *11*(5), 1106.

Widyaningsih, V., Mulyaningsih, T., Nur Rahmawati, F., & Adhitya, D. (2022). Determinants of socioeconomic and rural-urban disparities in stunting: evidence from Indonesia. *Rural and Remote Health*, *22*(1), 1–10.

Authors and translators' details:

Fithria	fithria550@gmail.com	Author
Ruwiah	ruwiah849@gmail.com	Author
Jumakil	jumakil@uho.ac.id	Author
Ruka Saito	51sightktsb@gmail.com	Author
Mayumi Sato	m3sato25@rsch.this.ac.jp	Author
Heriviyatno Julika Siagian	heriviyatno.j.siagian@gmail.com	Translator