Research Article

Impact of developmental stimulation education on maternal knowledge and caregiving practices in stunting: a longitudinal study

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ABSTRACT

Introduction: Stunting is associated not only with impaired physical growth but also with suboptimal child development, partly influenced by inadequate caregiving and insufficient developmental stimulation. This study aimed to evaluate the impact of a developmental stimulation education programme on maternal knowledge and caregiving practices among mothers of children with stunting.

Method: A longitudinal quasi-experimental study with individual-level random allocation was conducted between January and November 2025 involving 87 mothers of children with stunting, of whom 80 completed follow-up and were included in the final analysis. Both groups received routine child health services; however, only the intervention group received a structured developmental stimulation education programme, which included age-appropriate guidance on motor, language, cognitive, and social stimulation integrated into daily caregiving activities and delivered through standardised sessions by trained facilitators. Maternal knowledge and caregiving practices were assessed at baseline, 1 month, 3 months, and 6 months. Data were analysed using generalised linear mixed models.

Results: Maternal knowledge and caregiving practices improved over time in both groups; however, the intervention group demonstrated significantly greater and more sustained improvements. The group-by-time interaction was statistically significant for both outcomes, indicating that the intervention altered the trajectory of maternal knowledge and caregiving practices beyond changes observed with routine care.

Conclusion: The developmental stimulation education programme produced sustained improvements in maternal knowledge and caregiving practices over six months. Integrating caregiver-focused educational interventions into routine maternal and child health services and community-based programmes may strengthen comprehensive stunting management and support early child development.

Keywords: stunting, developmental stimulation, maternal knowledge, caregiving practices, longitudinal study.

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Introduction

Stunting remains a major public health problem with long-term consequences for child health and development.[1,2] In addition to impaired physical growth, stunting is associated with delays in cognitive, motor, and socio-emotional development that may persist into adulthood.[3,4] Although undernutrition is a key determinant, inadequate psychosocial stimulation and suboptimal caregiving practices also contribute substantially to poor developmental outcomes.[5] Therefore, nutrition-focused interventions alone may be insufficient to address the broader developmental risks associated with stunting.

Caregiver-based developmental stimulation is particularly important during early childhood, a period of high neural plasticity.[6] Mothers, as primary caregivers, play a key role in providing stimulation through everyday interactions such as play, communication, and responsive care. However, limited maternal knowledge and suboptimal caregiving practices may reduce the effectiveness of such stimulation, especially among children affected by chronic undernutrition. Educational interventions targeting maternal knowledge and caregiving practices, therefore, represent a promising strategy to improve developmental environments for children with stunting.[7]

Stunting remains highly prevalent in low- and middle-income countries, where socioeconomic constraints and limited access to early childhood interventions persist.[8] Given its scale, even modest improvements in caregiving practices at the household level may produce meaningful population-level benefits. This underscores the need for interventions that are feasible, scalable, and capable of generating sustained developmental gains beyond short-term nutritional recovery. Previous studies on caregiver education for children with stunting have reported promising but inconclusive results, largely due to cross-sectional designs, short follow-up periods, and limited analytical approaches.[9] In addition, many studies emphasized child outcomes without adequately examining maternal knowledge and caregiving practices as proximal determinants of developmental change, thereby limiting causal interpretation.

This study evaluated the impact of a structured developmental stimulation education programme on maternal knowledge and caregiving practices among mothers of children with stunting using a longitudinal design with repeated measurements over six months. By applying a mixed-effects analytical approach, the study examined changes over time while accounting for individual variability, providing robust evidence on the effectiveness of caregiver-focused educational interventions in stunting-related developmental care.

Method

Study Design

This study used a longitudinal quasi-experimental design with individual-level random allocation, conducted between January and November 2025. Participants were recruited from multiple community health centres and randomly assigned to intervention and control groups; however, due to the absence of full trial control procedures (e.g., blinding), the study is described as quasi-experimental. The intervention group received a structured developmental stimulation education programme, while the control group received routine

care. Maternal knowledge and caregiving practices were assessed at baseline, one month, three months, and six months after the intervention (Figure 1).

Population and sample

The study included mothers of children with stunting registered at community health centres, defined as height-for-age below -2 standard deviations according to World Health Organisation growth standards. Eligible participants were primary caregivers who provided informed consent, while those with children with congenital anomalies, chronic illness, severe acute conditions, or multiple births (e.g., twins), as well as mothers with cognitive or severe mental health impairments, were excluded. A total of 87 eligible mother–child dyads were recruited and randomly allocated on an individual basis in a 1:1 ratio to the intervention (n = 44) and control (n = 43) groups, irrespective of community health centre. During follow-up, 7 participants were lost to follow-up, resulting in complete data for 40 participants in each group included in the final analysis.

Instruments

Maternal knowledge and caregiving practices were measured using structured questionnaires developed for this study based on established child development and stunting-related care guidelines. Content validity was confirmed through expert review (I-CVI 0.83–1.00; S-CVI/Ave 0.92), and both instruments demonstrated good internal consistency (Cronbach's alpha ≥0.80). The questionnaires assessed maternal knowledge of stunting and developmental stimulation, as well as caregiving practices across motor, language, cognitive, and social domains, and were administered at baseline and at one, three, and six months after the intervention.

Data collection

Data were collected sequentially, beginning with baseline assessment following recruitment and eligibility screening. Mothers completed the questionnaires under the supervision of trained research assistants, after which the intervention group received structured developmental stimulation education delivered by trained facilitators using standardized materials. Follow-up assessments were conducted at one, three, and six months using identical procedures in both groups to ensure measurement consistency. Both groups continued to receive the same routine child health services, including growth monitoring and standard community-based care. The only difference between groups was the provision of the structured developmental stimulation education programme to the intervention group.

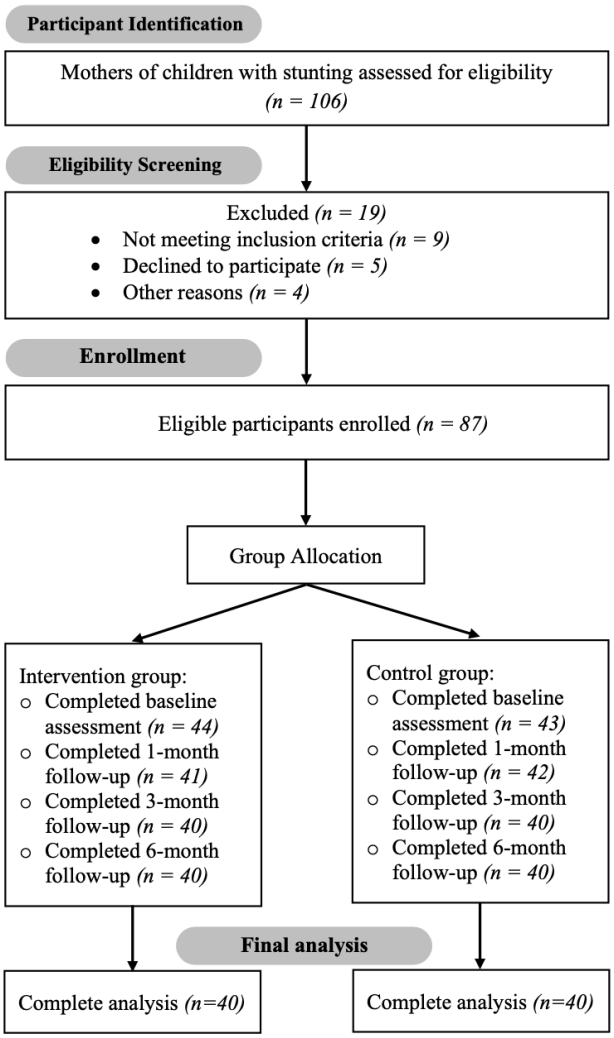

Figure 1. Adapted CONSORT-style flow diagram of participant recruitment, allocation, follow-up and analysis

The educational intervention was delivered over four sessions within a one-month period, with each session lasting approximately 30–45 minutes. Sessions were conducted weekly by trained facilitators using interactive methods, including demonstrations, guided practice, and simple visual aids (e.g., flipcharts). The content focused on age-appropriate stimulation activities across motor, language, cognitive, and social domains, which could be integrated into daily caregiving routines. The sessions were delivered in the local language to ensure comprehension, and mothers were encouraged to practice the activities at home. No formal standardized external programme was adopted; however, the intervention was developed based

on established child development and early stimulation guidelines.

Data analysis

Data were analysed using SPSS version 31, with descriptive statistics summarizing participant characteristics and outcome measures. Longitudinal changes in maternal knowledge and caregiving practices were examined using generalized linear mixed models with fixed effects for group, time (treated as a continuous variable coded as 0, 1, 3, and 6 months), and their interaction. The inclusion of both main effects and the interaction term followed the hierarchical modelling principle. A random intercept was specified to account for between-subject variability. Statistical significance was set at $p < 0.05$, with 95% confidence intervals reported where appropriate.

Ethical approval

Ethical approval was obtained from an institutional health research ethics committee (No. 248.6/II.3.AU/F/KEPK/VIII/2024), and the study was conducted in accordance with the Declaration of Helsinki; written informed consent was obtained from all participants, with confidentiality and the right to withdraw assured.

Results

Baseline characteristics of participants were comparable between the intervention and control groups (Table 1). Maternal age, child age, and educational levels were similar across groups, indicating no substantial baseline differences. As shown in Figure 1 (CONSORT flow diagram), 87 eligible mother–child dyads were recruited and randomly allocated to the intervention (n = 44) and control (n = 43) groups. Seven participants were lost to follow-up, resulting in complete data from 40 participants in each group at six months. These participants were included in the final longitudinal analysis.

Maternal knowledge scores increased over time in both groups, with greater and more sustained improvements observed in the intervention group compared to the control group (Table 2). Similarly, caregiving practices improved progressively in the intervention group, whereas changes in the control group were modest, indicating that the educational intervention was associated with concurrent improvements in maternal knowledge and caregiving practices Table 3).

The mixed-effects analysis (Table 4) showed a statistically significant group-by-time interaction for both maternal

Table 1. Baseline characteristics of participants

Variable	Intervention (n = 40)	Control (n = 40)
Maternal age (years), mean ± SD	29.4 ± 5.8	28.9 ± 6.1
Child age (months), mean ± SD	24.7 ± 8.3	25.1 ± 7.9
Maternal education, n (%)		
– No formal education	8 (20.0)	9 (22.5)
– Primary education	18 (45.0)	17 (42.5)
– Secondary or higher	14 (35.0)	14 (35.0)

Table 2. Maternal knowledge scores by group and time

Time point	Intervention group (Mean ± SD)	Control group (Mean ± SD)
Baseline	7.00 ± 0.00	6.50 ± 0.51
1 month	7.60 ± 0.78	7.18 ± 0.38
3 months	8.60 ± 0.84	7.83 ± 0.71
6 months	10.00 ± 0.00	7.83 ± 1.24

Table 3. Maternal caregiving practices scores by group and time

Time point	Intervention group (Mean ± SD)	Control group (Mean ± SD)
Baseline	6.00 ± 0.00	5.90 ± 0.45
1 month	7.80 ± 0.79	6.20 ± 0.41
3 months	9.00 ± 0.85	6.80 ± 0.60
6 months	10.00 ± 0.00	7.10 ± 0.74

Table 4. Generalised linear mixed model analysis of maternal outcomes

Fixed effect	Estimate (β)	SE	95% CI	p-value
Maternal Knowledge				
Intercept	6.82	0.09	6.64 to 7.00	<0.001
Group (Intervention vs Control)	0.24	0.13	-0.01 to 0.49	0.060
Time	0.20	0.02	0.16 to 0.25	<0.001
Group × Time	0.29	0.03	0.23 to 0.35	<0.001
Caregiving Practices				
Intercept	5.91	0.11	5.69 to 6.13	<0.001
Group (Intervention vs Control)	0.27	0.14	-0.01 to 0.55	0.058
Time	0.31	0.03	0.25 to 0.37	<0.001
Group × Time	0.42	0.04	0.34 to 0.50	<0.001

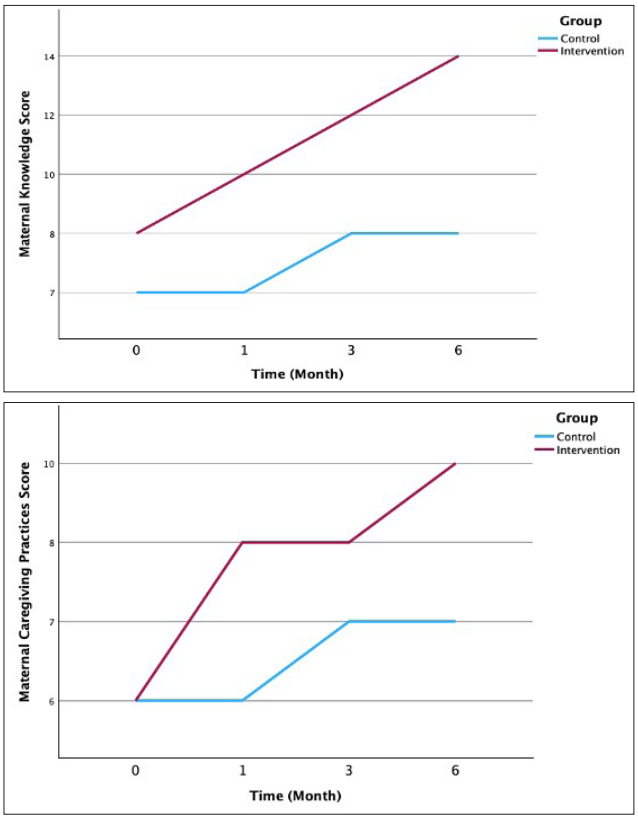

Figure 2a and b. Estimated marginal means from the generalized linear mixed models showing trajectories of maternal knowledge and caregiving practices over time. Note the non-linear scale of the X-axes

knowledge and caregiving practices, indicating different trajectories between the intervention and control groups. Mothers in the intervention group demonstrated greater and more sustained improvements over time compared with the control group, even after accounting for individual variability.

Figure 2 presents the model-predicted trajectories derived from the generalized linear mixed models rather than raw observed means. The mixed-effects models indicated meaningful between-subject variability in maternal outcomes, supporting the inclusion of random intercepts to account for individual differences (Table 4). This confirmed the appropriateness of the generalized linear mixed modelling approach for analysing longitudinal changes over time. Although the theoretical maximum score for both outcome measures was 10, model-predicted values from the generalized linear mixed models are not mathematically constrained to the instrument's scale limits. Values exceeding ten in the graphical representation reflect extrapolated model estimates rather than observed raw scores.

Discussion

This study demonstrated that a developmental stimulation education program produced sustained improvements in maternal knowledge and caregiving practices among mothers of children with stunting, consistent with previous evidence on the importance of caregiver-focused educational interventions.[3,10]

While earlier studies often relied on short-term or cross-sectional designs, the longitudinal findings of this study indicate that improvements in maternal knowledge were maintained over six months. These results suggest that structured caregiver education may support enduring cognitive and behavioural change rather than transient learning effects.[2,11]

The observed improvements in caregiving practices support previous evidence that caregiver knowledge can translate into behavioural change when educational interventions are practical, contextually relevant, and reinforced over time.[6,12] The significant group-by-time interaction demonstrated that the intervention altered the trajectory of maternal knowledge and caregiving practices rather than producing short-term effects, extending earlier findings by capturing longitudinal change and individual variability.[5,6,13] Overall, these findings corroborate existing literature by showing that structured developmental stimulation education can produce sustained improvements in maternal capacity, highlighting the importance of caregiver-focused strategies in stunting-related developmental care.[14,15]

Clinical and health system implications

The findings highlight the clinical value of caregiver-focused educational interventions in improving maternal capacity to provide developmentally supportive care for children with stunting. Integrating developmental stimulation education into routine maternal and child health services, particularly through nurses and community health workers, may extend care beyond nutrition toward comprehensive developmental support. At the health system level, caregiver education represents a feasible and scalable strategy that can complement existing stunting programs and support early intervention efforts.

Beyond clinical implementation, these findings have broader implications for public health programmes and policy. Integrating caregiver education into community-based child health initiatives, including early childhood development programmes, may enhance coverage beyond health facilities. Strategies involving community health workers, home-based education, and integration

with existing child development services may improve accessibility and sustainability. Further operational research is needed to adapt and scale such interventions in resource-limited settings.

Study limitations

This study has several limitations, including the quasi-experimental design without randomization and the use of self-reported measures, which may introduce residual confounding and social desirability bias. In addition, the study was conducted in a single community setting, potentially limiting the generalizability of the findings. Nevertheless, the longitudinal design, complete follow-up, and use of mixed-effects modelling strengthen confidence in the observed intervention effects.

Conclusion

This study demonstrated that a developmental stimulation education program produced sustained improvements in maternal knowledge and caregiving practices among mothers of children with stunting over a six-month period. Integrating caregiver-focused developmental stimulation education into routine maternal and child health services may strengthen stunting management by enhancing the developmental environment of affected children. Further, it is important that early stimulation education of the mothers and caregivers be incorporated into nutritional rehabilitation programmes and become part of standard nutritional care protocols.

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Declaration of Generative AI and AI-assisted Technologies in the writing process

During the development of this manuscript, AI-assisted tools were utilized solely to support language refinement and clarity. All generated content was carefully reviewed, revised, and validated by the authors, who assume full responsibility for the accuracy and integrity of the final manuscript.

Conflicts of Interest: The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics Approval: The study was approved by the Ethics Committee of the Faculty of Health and Sciences, Universitas Muhammadiyah Gombong, Indonesia (Approval No. 248.6/II.3.AU/F/KEPK/VIII/2024). Written informed consent was obtained from all participants prior to study enrolment.

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