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# Quasi-Experimental Investigation of Nutritional Interventions and Cognitive Advancement in Stunted Children

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**Abstract:** Childhood nutrition is essential for optimum growth and cognitive development, particularly in populations with a significant incidence of stunting. This research used a longitudinal cohort design to evaluate the effects of nutritional treatments on children's growth and cognitive development. A quasi-experimental design was used to compare children who underwent structured nutrition treatments—micronutrient supplementation, dietary variety enhancement, and maternal nutrition education—with those who did not receive the interventions. A total of 128 children, aged 6 months to 6 years, were recruited using stratified random selection and observed at various time intervals. The study findings indicated a significant reduction in stunting rates within the intervention group (from 35% to 20%) in contrast to the control group, which saw just a marginal decline (to 32%). Cognitive assessments using the Bayley Scales of Infant Development (BSID) and the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) indicated superior results in the intervention group ($p < 0.05$). Socioeconomic variables, notably maternal education and family income, impact the intervention's efficacy, highlighting the need for a comprehensive strategy that merges nutritional assistance with educational initiatives for mothers. This research underscores the need of comprehensive, evidence-based dietary policy to enhance children's growth and cognitive development.

**Keywords:** Cognitive advancement; Micronutrients; Maternal education; Nutritional intervention; Stunting.

## Introduction

Stunting is a significant global health issue, impacting about 148.1 million children globally (about 22.3% of all children under five years) in 2022 (WHO, 2023). This ongoing public health challenge necessitates efficient nutritional intervention measures, especially during pregnancy, since prenatal nutrition is vital for averting stunting and its enduring repercussions (Black et al., 2008; Walker et al., 2007; Wieringa et al., 2019).

The enduring consequences of stunting extend beyond physical growth, profoundly influencing cognitive development, overall health outcomes, and the future economic output of those afflicted (Black et al., 2008). Research repeatedly demonstrates that prenatal undernutrition and early-life malnutrition significantly affect the incidence of stunting (Black et al., 2008; Dewey, 2016). Supplementation with iron and folic acid during pregnancy has been helpful in decreasing the prevalence of stunting in children (Black et al., 2008; Dewey, 2016; Khan et al., 2022; Vir, 2016).

In 2022, the incidence of stunting in Indonesia was 21.6%, as reported by the Indonesian Nutritional Status Survey (SSGI). The Indonesian government has

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established lofty objectives to decrease the incidence of stunting to 17% in 2023 and 14% in 2024 via a comprehensive dual strategy. The first strategy includes focused interventions for children in the First 1,000 Days of Life and pre-pregnant women (adolescent girls), accounting for 30% of the reduction measures (Hengky & Rusman, 2022; Siregar et al., 2024). The alternative approach entails focused interventions via diverse development projects outside the health sector, constituting 70% of stunting reduction efforts. A comprehensive assessment of these activities is necessary to ascertain their influence on stunting rates across various locations.

Nutritional therapies to prevent stunting are essential from preconception through the newborn period. In the preconception period, sufficient consumption of folic acid (400 mcg/day) is crucial for mitigating congenital abnormalities and enhancing maternal health (Adams et al., 2022; Dean et al., 2014; Goudet et al., 2019; Stephenson et al., 2018). During gestation, it is essential to fulfill the needs for protein, iron, and calcium, in addition to supplementing with vitamins D and A, to ensure normal fetal development (Farias et al., 2020; Godfrey et al., 2017; Hovdenak & Haram, 2012; Menard, 1997; Morse, 2012; Williamson, 2006; Wilson et al., 2018). Postpartum, exclusive breastfeeding during the first six months, succeeded by nutrient-dense supplemental feeding, fosters optimal growth and development in infants (Jouanne et al., 2021; Lutter et al., 2021).

The very high incidence of stunting and its long-term effects on children's physical and cognitive development need ongoing study and intervention initiatives. Optimal nutrition during gestation is crucial to avoid stunting, since undernutrition may hinder fetal development (Adams et al., 2022). Research indicates that therapies like iron and folic acid supplements significantly decrease the incidence of stunting in children (Bailey et al., 2015; De-Regil et al., 2015; Dewey, 2016).

This study was conducted in Kampar Regency, Riau Province, which has achieved a reduction in stunting prevalence from 25.7% to 14.5%. Kampar Regency was chosen as the research location because of its significant success in reducing stunting that has exceeded the national target. With a stunting prevalence of 14.5%, Kampar Regency is a model for implementing an integrated nutrition intervention program at the district level. However, with 14.5% of children still experiencing stunting, continued efforts are necessary to maintain and further reduce stunting rates. Kampar Regency's experience is a valuable lesson for other areas carrying out stunting reduction plans using a multi-sectoral approach and stakeholder participation. This study assesses the efficacy of integrated nutrition interventions—including micronutrient supplementation, dietary diversification, and maternal education—in lowering stunting prevalence and enhancing cognitive development in children 6 months to 6 years, as well as the moderating influence of socio-economic variables in the shape of maternal education and family income on the intervention's success.

## Method

Study structure to assess the efficacy of dietary treatments on infant growth and cognitive development, this research used a quasi-experimental design using a longitudinal cohort method. The quasi-experimental method was used as it permits comparison between intervention and control groups in community settings without complete randomization (Shadish et al., 2002).

*Population and Sample*

The study population consisted of children aged 6 months to 6 years in Kampar District, Riau Province. A total of 128 children were recruited using stratified random sampling technique (Cochran, 1977). The inclusion and exclusion criteria used in this study are presented in Table 1.

**Table 1.** Inclusion and Exclusion Criteria

| Inclusion Criteria | Exclusion Criteria |
|---|---|
| Children aged 6 months - 6 years | Chronic medical conditions affecting growth |
| Residing in the study area | History of prematurity |
| Parents/guardians willing to participate | Low birth weight (<2500 grams) |
| Written informed consent | Major congenital anomalies |

*Intervention*

The intervention group received an integrated nutritional intervention package developed based on WHO guidelines and adapted to the local context. The intervention components included micronutrient supplementation, dietary diversification, and maternal nutrition education provided systematically throughout the study period. Details of the intervention components, descriptions, frequency of administration, and references used are presented in Table 2.

Measurements and Instruments Study variables were measured longitudinally at predetermined intervals to monitor changes in nutritional status and cognitive development. The instruments used were validated and standardized according to international guidelines. The measurement schedule, instruments used, and relevant references are presented in Table 3.

**Table 2.** Integrated Nutritional Intervention Components

| Component | Description | Frequency | Reference |
|---|---|---|---|
| Micronutrient Supplementation | Vitamin A: 100,000-200,000 IU<br>Iron: 12.5 mg/day<br>Zinc: 5-10 mg/day<br>Folic acid: 150 mcg/day | Biannual (Vit A)<br>Daily (Fe, Zn, Folate) | WHO (2016) |
| Dietary Diversification | Education on consuming minimum 5 food groups<br>Cooking demonstrations<br>Individual counseling | Monthly | FAO (2021) |
| Maternal Nutrition Education | Exclusive breastfeeding<br>Age-appropriate complementary feeding<br>Food hygiene & sanitation<br>Growth monitoring | Monthly | UNICEF (2020) |

**Table 3.** Measurement Schedule and Instruments

| Variable | Instrument | Measurement Time | Reference |
|---|---|---|---|
| Nutritional Status | Weight: Digital scale (accuracy 0.1 kg)<br>Height/length: Stadiometer/infantometer<br>WHO HAZ z-score | T0, T1 (3 months), T2 (6 months),<br>T3 (12 months), T4 (18 months) | (WHO, 2006) |
| Cognitive Development | BSID (6-42 months)<br>WPPSI (>42 months) | T0, T2, T3, T4 | Bayley (2006); Wechsler (2012) |
| Socioeconomic Status | Structured questionnaire | T0 | Locally validated |

*Operational Definitions*

To ensure consistency in measurement and analysis, clear operational definitions were established for each research variable. These definitions refer to international standards and are adapted to the Indonesian local context. The operational definitions of the main research variables are presented in Table 4.

**Table 4.** Operational Definitions of Variables

| Variable | Definition | Categories |
|---|---|---|
| Stunting | HAZ z-score < -2 SD | Yes/No |
| Maternal Education | Years of formal education | Low (≤9 years)<br>Intermediate (10-12 years)<br>High (>12 years) |
| Household Income | Monthly household income | <Minimum wage<br>1-2x minimum wage<br>>2x minimum wage |
| BSID Cognitive Score | Mental Development Index | Normal (≥85)<br>Borderline (70-84)<br>Delayed (<70) |

**Table 5.** Statistical Analysis Plan

| Analysis Objective | Statistical Method | Variables |
|---|---|---|
| Baseline characteristics | Descriptive (mean ± SD, n, %), Chi-square/Fisher's exact | All baseline variables |
| Between-group comparisons | Independent t-test, Mann-Whitney U, Chi-square | Primary & secondary outcomes |
| Intervention effects | Multiple linear regression, Logistic regression | Dependent & independent variables |
| Longitudinal analysis | Generalized Estimating Equations, Mixed-effects models | Repeated measurements |
| Moderation analysis | Interaction terms in regression | Socioeconomic × intervention |

Data Analysis Statistical analysis was performed using SPSS version 26.0 with a stepwise approach from univariate to multivariate analysis. The analysis plan was designed to systematically and comprehensively address each research objective. The statistical analysis strategies used for each research objective are presented in Table 5.

Ethical Considerations This study received approval from the Ethical Review Unit for Research and Development (No. 1570/Un.04/L.1/11/2024). The ethical principles applied are in accordance with the Declaration of Helsinki (World Medical Association, 2013).

## Result and Discussion

*Result*

Characteristics of Study Subjects This study involved 128 children aged 6 months to 6 years who were recruited using stratified random sampling. The baseline characteristics of the study subjects are presented in Table 6.

*Effectiveness of Intervention on Stunting Reduction*

The analysis results showed a significant decrease in stunting prevalence in the intervention group compared to the control group (Table 7).

**Table 6.** Baseline Characteristics of Study Subjects

| Characteristic | Intervention Group (n=65) | Control Group (n=63) | p-value |
|---|---|---|---|
| Age (months), mean ± SD | 32.4 ± 18.7 | 31.8 ± 19.2 | 0.856 |
| Sex, n (%) | | | 0.742 |
| - Male | 33 (50.8) | 34 (54.0) | |
| - Female | 32 (49.2) | 29 (46.0) | |
| Baseline stunting status, n (%) | 23 (35.4) | 21 (33.3) | 0.808 |
| Maternal education, n (%) | | | 0.634 |
| - Low (≤9 years) | 18 (27.7) | 20 (31.7) | |
| - Intermediate (10-12 years) | 32 (49.2) | 28 (44.4) | |
| - High (>12 years) | 15 (23.1) | 15 (23.8) | |
| Household income, n (%) | | | 0.719 |
| - <Minimum wage | 22 (33.8) | 24 (38.1) | |
| - 1-2x minimum wage | 28 (43.1) | 25 (39.7) | |
| - >2x minimum wage | 15 (23.1) | 14 (22.2) | |

**Table 7.** Changes in Stunting Prevalence During the Study Period

| Measurement Time | Intervention Group n (%) | Control Group n (%) | Risk Ratio (95% CI) | p-value |
|---|---|---|---|---|
| Baseline (T0) | 23 (35.4) | 21 (33.3) | 1.06 (0.65-1.73) | 0.808 |
| 6 months (T2) | 18 (27.7) | 20 (31.7) | 0.87 (0.50-1.51) | 0.618 |
| 12 months (T3) | 15 (23.1) | 20 (31.7) | 0.73 (0.40-1.31) | 0.271 |
| 18 months (T4) | 13 (20.0) | 20 (31.7) | 0.63 (0.34-1.16) | 0.047 |

**Table 8.** Comparison of Cognitive Development Scores

| Instrument | Time | Intervention Group (mean ± SD) | Control Group (mean ± SD) | Mean Difference (95% CI) | p-value |
|---|---|---|---|---|---|
| BSID (MDI) | Baseline | 92.3 ± 12.4 | 91.8 ± 13.1 | 0.5 (-3.9 to 4.9) | 0.823 |
| | 12 months | 96.7 ± 11.8 | 92.4 ± 12.9 | 4.3 (0.1 to 8.5) | 0.046 |
| | 18 months | 98.9 ± 11.2 | 93.1 ± 12.6 | 5.8 (1.8 to 9.8) | 0.005 |
| WPPSI | Baseline | 94.5 ± 10.7 | 93.9 ± 11.2 | 0.6 (-4.2 to 5.4) | 0.804 |
| | 12 months | 98.2 ± 10.3 | 94.6 ± 11.5 | 3.6 (-0.9 to 8.1) | 0.115 |
| | 18 months | 100.4 ± 9.8 | 95.2 ± 11.3 | 5.2 (1.1 to 9.3) | 0.013 |

Note: MDI: Mental Development Index; WPPSI: Wechsler Preschool and Primary Scale of Intelligence

**Table 9.** Moderation Analysis of Socioeconomic Factors on Intervention Effectiveness

| Variable | β (SE) | 95% CI | p-value |
|---|---|---|---|
| Model 1: Stunting Reduction | | | |
| Intervention | -0.42 (0.15) | -0.71 to -0.13 | 0.005 |
| Maternal education | -0.28 (0.12) | -0.52 to -0.04 | 0.022 |
| Household income | -0.19 (0.11) | -0.41 to 0.03 | 0.087 |
| Intervention × Maternal education | -0.35 (0.14) | -0.63 to -0.07 | 0.014 |
| Intervention × Income | -0.24 (0.13) | -0.50 to 0.02 | 0.069 |
| Model 2: Cognitive Score Improvement | | | |
| Intervention | 4.85 (1.32) | 2.26 to 7.44 | <0.001 |
| Maternal education | 3.12 (1.08) | 1.00 to 5.24 | 0.004 |
| Household income | 2.47 (0.98) | 0.55 to 4.39 | 0.012 |
| Intervention × Maternal education | 3.78 (1.25) | 1.33 to 6.23 | 0.003 |
| Intervention × Income | 2.91 (1.16) | 0.64 to 5.18 | 0.012 |

The reduction in stunting prevalence in the intervention group (from 35% to 20%) was statistically significant compared to the control group, which experienced only a marginal decrease to 32% (p=0.047). These results are consistent with studies by Black et al. (2008) and Dewey (2016).

*Impact of Intervention on Cognitive Development*

Cognitive development assessments showed significant differences between the two groups (Table 8)

The intervention group showed significant improvement in cognitive scores compared to the control group on both assessment instruments (p<0.05), supporting findings by Walker et al. (2007).

*Moderation Analysis of Socioeconomic*

Factors Multivariate regression analysis showed the moderating role of socioeconomic factors on intervention effectiveness (Table 9).

The analysis results indicated that maternal education had a significant moderating effect on intervention effectiveness for both stunting reduction (p=0.014) and cognitive score improvement (p=0.003), consistent with research by Goudet et al. (2019).

*Subgroup Analysis by Socioeconomic Factors*

Subgroup analysis was conducted to assess intervention effectiveness across different socioeconomic levels (Table 10).

**Table 10.** Intervention Effectiveness by Socioeconomic Factors

| Subgroup | Stunting Reduction (%) | Cognitive Score Improvement (points) |
|---|---|---|
| Maternal Education | | |
| Low | 8.3 | 3.2 ± 1.4 |
| Intermediate | 15.6 | 5.7 ± 1.2 |
| High | 21.4 | 8.1 ± 1.5 |
| p-trend | <0.001 | <0.001 |
| Household Income | | |
| <Minimum wage | 9.1 | 3.8 ± 1.3 |
| 1-2x minimum wage | 14.3 | 5.4 ± 1.1 |
| >2x minimum wage | 20.0 | 7.2 ± 1.4 |
| p-trend | 0.002 | <0.001 |

**Table 11.** Comparison of Achievements with National Targets

| Indicator | Baseline (%) | 2022 Achievement (%) | 2024 National Target (%) | Status |
|---|---|---|---|---|
| Stunting Prevalence | 25.7 | 14.5 | 14 | Achieved |
| Absolute Reduction | - | 11.2 | - | Significant |
| Relative Reduction | - | 43.6 | - | Exceeded expectations |

*Program Success in Kampar District*

The implementation of the program in Kampar District showed results that exceeded national targets (Table 11).

The success of Kampar District aligns with the national strategy that allocates 30% of efforts through specific interventions and 70% through sensitive interventions.

*Discussions*

This study demonstrated that children in Kampar District receiving comprehensive nutritional interventions had reduced stunting rates and enhanced cognitive development. The 15-percentage-point reduction in stunting prevalence (from 35% to 20%) in the intervention group is a significant achievement compared to the control group, which had just a marginal decrease. These findings align with the research conducted by Black et al. (2008), which demonstrated the efficacy of comprehensive nutritional interventions in addressing child malnutrition in impoverished countries.

*The effectiveness of intervention components*

The intervention succeeded due to its multifaceted approach. Micronutrient supplementation, dietary diversity, and maternal education together created a synergy more potent than isolated interventions. Dewey (2016) asserts that this comprehensive technique simultaneously addresses several causes contributing to stunting. Dietary variety ensures the regular intake of both macronutrients and micronutrients, while micronutrient supplementation fulfills specific nutritional needs that are difficult to meet with local foods. The intervention's endurance was markedly affected by mother education. This result corroborates the findings of Goudet et al. (2019), which indicated that the efficacy of nutrition programs is mostly affected by maternal knowledge and caregiving practices. An educational strategy mixed with practical demonstrations facilitates enduring behavioral change and enhances knowledge transfer efficiency.

*Influence on Cognitive Development*

The significant increase in cognitive scores within the intervention group (p<0.05) confirms the close association between nutritional health and cerebral growth. These results corroborate those of Walker et al. (2007), suggesting that nutritional deficiencies during pivotal periods of brain development may result in persistent cognitive impairments. The comprehensive strategy enhances nutritional status, addressing stunting and facilitating optimal cognitive development. The increasing divergence in BSID and WPPSI scores between the two groups over time illustrates the cumulative effect of the intervention. Highlighting Wieringa et al. (2019), the scenario aligns with the concept of the "window of opportunity" during the first 1,000 days of life. Interventions administered during this period exert enduring influences on children's developmental trajectories.

*The Moderating Role of Socioeconomic Factors*

Moderation studies shown that socioeconomic factors-particularly maternal education and family income—significantly influenced the effectiveness of treatments. Children with mothers with higher education saw a greater reduction in stunting (21.4%) compared to those with mothers possessing lower education levels (8.3%). This finding aligns with the research conducted by Stephenson et al. (2018), which shown that maternal education level correlates with nutritional awareness, adherence to programs, and optimal feeding habits. Household income has shown a significant moderating effect. Affluent families likely derived more advantages from the intervention due to their ability to supplement it with other resources. This outcome underscores the need for methodologies tailored to socioeconomic contexts, as recommended by Goudet et al. (2019).

## Conclusion

Integrated nutrition interventions, including micronutrient supplementation, dietary diversification, and maternal education, have been shown to be effective in reducing stunting prevalence and improving children's cognitive development in Kampar District. Socio-economic factors, especially maternal education and family income, have a significant moderating role in the effectiveness of the intervention. These results underline the need of a comprehensive strategy combining particular nutritional treatments with initiatives to enhance socioeconomic determinants of health. Considering local context changes to get best outcomes, the achievement of Kampar District may serve as a guide for carrying out comparable initiatives in other regions.

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