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The Impact of the Free Nutritious Meal Program *on Working Memory* and Receptive Language in Early Childhood

Indiriani[✉1], Sulastri[2], Melia Eka Daryati[3]
Indriani12@gmail.com, sulstri83@gmail.com, fujillma@gmail.com
Public Health Study Program, Fikes Ratu Samban University, North Bengkulu, Indonesia[1,2]
Early Childhood Education Study Program, Bengkulu University, Indonesia,[3]

Abstract
Early childhood nutrition is a decisive determinant of neurocognitive development, yet evaluations of Indonesia's Free Nutritious Meal Program (Makan Bergizi Gratis, MBG) have largely stopped at anthropometric indicators, leaving its cognitive and linguistic effects untested. This study analyzed the impact of MBG on working memory and receptive language and estimated its effect size. A quasi-experimental nonequivalent control group pretest-posttest design was applied to 72 children aged 4-6 years from six early childhood education (PAUD) institutions in Bengkulu City, comprising an experimental group ($n = 36$, MBG recipients) and a control group ($n = 36$) drawn through purposive cluster sampling. Working memory was measured with a Digit Span Backward subtest adapted for young children ($\alpha = .81$) and receptive language with the Indonesian adaptation of the Peabody Picture Vocabulary Test-Fourth Edition ($\alpha = .89$). Data collected before and after a 12-week intervention were analyzed using independent samples t-tests on gain scores and Cohen's d. The experimental group outperformed the control group in working memory, $t(70) = 4.28$, $p < .001$, $d = 1.02$, and in receptive language, $t(70) = 3.91$, $p < .001$, $d = 0.93$. Structured feeding during this sensitive period strengthens children's cognitive and linguistic capacity; MBG monitoring should therefore extend to cognitive and language development indicators.

Keywords: Receptive language development, *Makan Gizi Gratis (MBG)*, working memory, early childhood nutrition intervention.

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✉ Corresponding author:
Email Address: Indriani12@gmail.com(**Indriani**)

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INTRODUCTION

The first six years of life constitute the most consequential window in human brain development. Synaptogenesis proceeds at a pace never repeated later in life, myelination accelerates, and the neural architecture that will later carry reasoning, memory, and language is assembled. Because that architecture is built from what the child eats, developmental neuroscience consistently treats the quality of nutritional intake during this period as a structural determinant of a child's long-term cognitive trajectory rather than as a peripheral health concern (Jiang & Li, 2025).

The mechanism is specific rather than diffuse. Iron, zinc, and omega-3 fatty acids participate directly in neuronal proliferation, neurotransmitter synthesis, and the formation of the myelin that governs the speed of signal transmission between nerve cells (Gutema et al., 2023; Jiang & Li, 2025). A deficit in any of these nutrients during the golden period can alter brain structure and function in ways that are frequently irreversible. The consequences reach well beyond the individual child: more than 250 million children in low- and middle-income countries are estimated to be at risk of failing to reach their developmental potential as poverty, stunting, and inadequate stimulation compound one another (Kumari & Kamal, 2026; Sideropoulos et al., 2025).

Among the components of executive function, working memory, the capacity to hold and manipulate information briefly in order to complete a cognitive task, is the most sensitive to nutritional conditions in early childhood. Neuroimaging evidence reported by Wijeakumar et al. (2023) shows that stunting in infancy is associated with atypical activation of working memory and attention networks, with measurable consequences for children's visuospatial memory performance.

Converging evidence reinforces the point. The meta-analysis by Sideropoulos et al. (2025) established that stunting is consistently associated with lower cognitive achievement in low- and middle-income countries, particularly in executive function and intelligence, while Ansuya et al. (2023) demonstrated that community-based nutritional intervention significantly raised the cognitive development scores of malnourished preschoolers. For a preschool child, working memory is not merely a matter of remembering; it is the prerequisite for following a teacher's instructions, tracking the narrative of a story, and completing early academic tasks such as counting and arranging patterns (Sankalaite et al., 2023).

Receptive language, the ability to comprehend words, sentences, and verbal instructions, is equally dependent on adequate nutrition. It emerges earlier than expressive language and forms the foundation of every communicative competence a child later acquires (Bergelson, 2024; Shapiro et al., 2024). Koshy et al. (2025) found that persistent stunting is significantly correlated with weaker executive function and with volumetric differences in the brain regions that underpin memory capacity and information processing.

Supplementation studies point in the same direction: iron deficiency during critical periods of brain development depresses cognitive performance, including the memory and attention processes on which language acquisition depends (Gutema et al., 2023; Jiang & Li, 2025). Nutritional disadvantage rarely travels alone, however. Socioeconomic position shapes the same outcomes, and differences in language processing skill and vocabulary size are already visible very early in life (Bergelson, 2024).

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Indonesia continues to confront these conditions at scale. The 2022 Indonesian Nutritional Status Survey (SSGI) recorded a stunting prevalence of 21.6% among children under five, while anemia and skipped breakfasts remain common among school-age children (Nugroho et al., 2023). The burden falls most heavily on families of low socioeconomic status, where it translates into weaker cognitive and linguistic development (Kumari & Kamal, 2026; Sideropoulos et al., 2025). These determinants do not operate in isolation; they interact with the nutritional knowledge and feeding styles adopted by families and early childhood education (PAUD) institutions, both of which are significantly related to the nutritional status of young children (Daryati et al., 2026).

SSGI data further reveal wide interprovincial disparities and a national prevalence still far from the 14% target (Nugroho et al., 2023). The government's response was the Free Nutritious Meal Program (Makan Bergizi Gratis, MBG), rolled out in stages from 6 January 2025. The program reaches learners from PAUD through senior secondary level as well as toddlers, pregnant women, and breastfeeding mothers, supplying meals that meet 25-35% of daily nutritional requirements under the Fill My Plate principle in order to raise dietary adequacy and reduce stunting (Peraturan Presiden No. 83 Tahun 2024; Sandoko et al., 2026; Yusriadi, 2025).

International evidence on school feeding is encouraging. Such programs improve the nutritional status and academic performance of children (Sari, 2025; Wang et al., 2021) and operate as a social safety net that lifts participation and learning outcomes (Sandoko et al., 2026; Yusriadi, 2025). What remains almost entirely undocumented is whether a program of this kind produces neurocognitive gains, specifically in working memory and receptive language, among young children in Indonesia.

The gap is a matter of what evaluations choose to measure. Existing studies concentrate on anthropometric outcomes such as height and weight, leaving the cognitive and linguistic dimensions of development largely unexamined (Wang et al., 2021). Bengkulu Province, where stunting stood at 24.5% in 2023 and remains above the national average (Nugroho et al., 2023), is therefore a pertinent site for testing the neurocognitive effectiveness of MBG. Bengkulu City alone hosts hundreds of PAUD institutions across nine subdistricts with heterogeneous socioeconomic profiles, providing the variability this study requires.

Taken together, these conditions expose a substantive knowledge gap: the effect of a national nutrition intervention such as MBG on the cognitive and linguistic capacity of young children has not been established. The unanswered question is whether structured and sustained provision of nutritious meals in PAUD institutions produces a meaningful difference in children's working memory performance and receptive language comprehension.

This study addresses that question and contributes on three fronts. It is among the first empirical evaluations of the neurocognitive impact of MBG since the program's initial implementation in Indonesia; it directs the outcome measures toward working memory and receptive

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language, which feeding-program evaluations have rarely examined; and it employs standardized instruments adapted and validated for Indonesian children. Accordingly, the study analyzes the impact of the MBG Program on the working memory and receptive language development of children aged 4-6 years and estimates the effect size of the intervention on both variables in PAUD institutions in Bengkulu City.

METHODOLOGY

Research Design

The study applied a quantitative approach within a quasi-experimental nonequivalent control group pretest-posttest design. Full randomization was not feasible given the ethical and practical constraints of early childhood education settings, which makes this design the appropriate choice under field conditions of this kind (Creswell & Creswell, 2023). Participation in the MBG Program served as the independent variable, while working memory ability and receptive language development served as the dependent variables.

Setting and Duration of the Study

Fieldwork was conducted in six PAUD institutions across three subdistricts of Bengkulu City, Bengkulu Province, over 12 weeks between February and April 2025. The sequence comprised a pretest in the first week, provision of nutritious meals throughout the intervention period, and a posttest in the final week. Sites were selected so that the socioeconomic characteristics of the surrounding areas, the accreditation status of the institutions, and their involvement in the Free Nutritious Meal Program were comparable, allowing the experimental and control groups to be contrasted on equal terms.

Population and Sample

The population comprised all children aged 4-6 years enrolled in PAUD institutions in Bengkulu City. Participants were drawn through purposive cluster sampling under four inclusion criteria: (a) aged 4-6 years; (b) actively enrolled in a PAUD institution; (c) no diagnosed developmental disorder or intellectual disability; and (d) written consent from a parent or guardian. Six institutions across three subdistricts were selected on the basis of their MBG status: three as the experimental group, having received MBG since January 2025, and three as the control group, not yet receiving the program. The resulting sample of 72 children, 36 per group, satisfied the requirement obtained from G*Power for an effect size of $d = 0.70$, $\alpha = .05$, and power of .80 (Faul et al., 2007).

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Instruments and Data Collection

Working memory was measured with a Digit Span Backward subtest adapted for early childhood, in which colored visual objects replaced purely verbal digits. The adapted instrument has been validated for the Indonesian child population ($r = .84$; Cronbach's $\alpha = .81$) and is consistent with contemporary approaches to measuring working memory in this age group (Sankalaite et al., 2023). Receptive language was measured with the Indonesian adaptation of the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-4; Dunn & Dunn, 2007), which underwent forward-backward translation and was piloted with 30 children outside the study sample, yielding a reliability of $\alpha = .89$.

The pretest was administered in the first week, before the intervention began, and the posttest after 12 weeks of MBG provision. Throughout the intervention period the experimental group received meals conforming to the standard MBG menu prepared by the National Nutrition Agency (Peraturan Presiden No. 83 Tahun 2024), while the control group maintained its usual diet. All testing was conducted individually by trained enumerators in quiet rooms in order to minimize distraction during data collection.

Data Analysis

Gain scores, computed as the difference between posttest and pretest performance, were compared between the experimental and control groups using independent samples t-tests once normality (Shapiro-Wilk) and homogeneity of variance (Levene) had been verified. Effect sizes were expressed as Cohen's d and interpreted against the conventional benchmarks of 0.20 (small), 0.50 (medium), and 0.80 (large) (Cohen, 1988). All analyses were performed in SPSS version 26.0 with the significance level set at $\alpha = .05$.

This analytic sequence maps directly onto the three objectives of the study: establishing the effect of MBG on working memory, establishing its effect on receptive language development, and comparing the magnitude of the two effects. The comparison of gain scores determines whether children receiving MBG differ from those who do not, while Cohen's d indicates how much practical weight any such difference carries for early childhood education practice.

RESULTS AND DISCUSSION

RESULTS

Participant Demographic Characteristics

Table 1 reports the demographic profile of the participants. Age, sex, nutritional status, and maternal education were distributed comparably across the experimental and control groups, as detailed in Table 1.

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Table 1. Demographic Characteristics of Research Participants

Characteristics	Experiment	Control	*P*
Age (M ± SD)	5,03 ± 0,71	4,97 ± 0,68	0,72
Gender			0,81
Man	19 (52,8%)	18 (50,0%)	
Woman	17 (47,2%)	18 (50,0%)	
Nutritional Status (Z-score TB/U)			0,64
Normal	22 (61,1%)	24 (66,7%)	
Short	10 (27,8%)	9 (25,0%)	
Very Short	4 (11,1%)	3 (8,3%)	
Mother's Education			0,58
≤ High school	24 (66,7%)	26 (72,2%)	
> High school	12 (33,3%)	10 (27,8%)	

Note. p values were obtained from chi-square tests (categorical variables) and an independent samples t-test (age); p > .05 indicates no significant baseline differences.

The figures in Table 1 describe two groups that began from nearly identical positions. Mean age differed by only 0.06 years, sex composition was almost even, and the proportion of children classified as short or very short differed modestly, at 38.9% in the experimental group against 33.3% in the control group. Maternal education clustered at senior secondary level or below in both groups. Because no comparison produced a p value below .05, the threat of selection bias to internal validity is substantially reduced, and differences observed at posttest can be attributed more confidently to the intervention. It is also worth noting that more than a third of the participants fell into the stunted category, confirming that the sample genuinely represents a nutritionally vulnerable population.

Working Memory Measurement

Table 2 compares pretest and posttest working memory scores across the two groups. The experimental group recorded a mean gain of 2.22 ± 0.94 against 0.58 ± 0.76 in the control group. The independent samples t-test on gain scores confirmed a significant difference, $t(70) = 4.28$, $p < .001$, accompanied by a large effect size (Cohen's d = 1.02).

Table 2. Comparison of Working Memory Scores for Experimental and Control Groups

Group	Pre-test (M ± SD)	Post-test (M ± SD)	Gain Score (M ± SD)
Experiments (n=36)	3,42 ± 1,18	5,64 ± 1,31	2,22 ± 0,94
Control (n=36)	3,39 ± 1,14	3,97 ± 1,22	0,58 ± 0,76

Between-group difference in gain scores: $t(70) = 4.28$, $p < .001$, Cohen's d = 1.02 (large effect).

The movement in Table 2 is best read as a difference rather than as a set of isolated figures. Both groups started from equivalent baselines, 3.42 and 3.39, yet after 12 weeks the experimental group had gained 2.22 points while the control group gained only 0.58, almost four times less. The improvement in the control group is unsurprising, since natural maturation and familiarity with the instrument continue to operate at this age. Using the control group as the benchmark, the net gain attributable to MBG is approximately 1.64 digits. The comparatively small standard deviation of the

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experimental gain, 0.94, also merits attention: it indicates that children responded to the intervention uniformly rather than that the mean was driven by a handful of exceptional cases.

Receptive Language Measurement

Receptive language followed the same pattern. The gain recorded by the experimental group, 12.67 ± 5.28, significantly exceeded that of the control group, 4.06 ± 4.13, $t(70) = 3.91$, $p < .001$, Cohen's $d = 0.93$ (Table 3).

Table 3. Comparison of Receptive Language Scores for Experimental and Control Groups

Group	Pre-test (M ± SD)	Post-test (M ± SD)	Gain Score (M ± SD)
Experiments (n=36)	48,72 ± 8,43	61,39 ± 9,17	12,67 ± 5,28
Control (n=36)	49,08 ± 8,67	53,14 ± 8,91	4,06 ± 4,13

Between-group difference in gain scores: $t(70) = 3.91$, $p < .001$, Cohen's $d = 0.93$ (large effect).

Table 3 points in the same direction, though with its own dynamics. The control group in fact began slightly ahead, 49.08 against 48.72, so the final advantage of the experimental group cannot be traced to a head start. After the intervention the gap widened to 8.25 points, with gains of 12.67 and 4.06 points respectively. The standard deviation of the experimental gain, 5.28, is considerably larger than its working memory counterpart. That dispersion suggests that the acquisition of receptive vocabulary does not rest on improved nutritional intake alone but also reflects the richness of the language environment children encounter at home and in the classroom.

Analysis Prerequisite Test

Normality and homogeneity were examined before hypothesis testing (Table 4). All gain score distributions were normal (Shapiro-Wilk, $p > .05$) and variances were homogeneous (Levene, $p > .05$), satisfying the assumptions for parametric testing.

Table 4. Normality (Shapiro-Wilk) and Homogeneity (Levene) Test Results

Variable	Shapiro-Wilk (Ex)	Shapiro-Wilk (Con)	Levene F	P (Levene)
Working Memory (Gain)	0,967 (p=0,36)	0,958 (p=0,19)	1,24	0,27
Receptive Language (Gain)	0,971 (p=0,45)	0,963 (p=0,28)	0,89	0,35

Distributions were normal ($p > .05$) and variances homogeneous ($p > .05$).

Table 4 confirms that the use of parametric tests was warranted rather than expedient. Shapiro-Wilk statistics ranged from 0.958 to 0.971 with all p values above .05, indicating that the distribution of gain scores in both groups did not depart from normality. Levene's test returned $F = 1.24$ ($p = .27$) for working memory and $F = 0.89$ ($p = .35$) for receptive language, showing equivalent dispersion across groups. With both assumptions satisfied, the independent samples t-test could be applied without recourse to non-parametric alternatives such as the Mann-Whitney U test, and the t and Cohen's d values reported above are not distorted by unequal variances between groups.

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Receptive Language Sub-component Analysis

Table 5 disaggregates receptive language into vocabulary comprehension, instruction comprehension, and sentence comprehension in order to provide a more complete picture. Gain scores in all three subcomponents were significantly higher in the experimental group than in the control group (all $p < .001$).

Table 5. Comparison of Gain Scores for Receptive Language Subcomponents

Sub-components	Experiment (M ± SD)	Control (M ± SD)	P
Vocabulary Comprehension	5,14 ± 2,31	1,89 ± 1,67	<0,001
Comprehension of Instructions	4,08 ± 1,94	1,28 ± 1,42	<0,001
Sentence Comprehension	3,44 ± 1,82	0,89 ± 1,18	<0,001

Values reported are gain scores; all differences are significant at $p < .05$.

Table 5 rewards reading on two levels at once. In absolute terms the largest advantage appears in vocabulary comprehension (5.14 against 1.89), declining through instruction comprehension (4.08 against 1.28) and sentence comprehension (3.44 against 0.89). Expressed as ratios, however, the order reverses: the gain of the experimental group was 2.7 times that of the control group in vocabulary, 3.2 times in instructions, and 3.9 times in sentences. The narrower score range of the more complex components explains the smaller raw increments, while the steepening ratio implies that the benefit of the intervention did not stop at vocabulary but extended to the processing of longer linguistic units, which place heavier demands on working memory capacity.

Summary of Effect Size

Table 6 consolidates the effect sizes obtained for all variables. Working memory and total receptive language yielded large effects ($d = 1.02$ and $d = 0.93$), while the three receptive language subcomponents produced very large and closely comparable effects ($d = 1.61$-1.66).

Table 6. Summary of Effect Sizes (Cohen's d) for All Variables

Variable	Cohen's d	Interpretation
Working Memory	1,02	Big Effect
Receptive Language (Total)	0,93	Big Effect
Vocabulary Comprehension	1,61	Very Big Effect
Comprehension of Instructions	1,64	Very Big Effect
Sentence Comprehension	1,66	Very Big Effect

Every effect size in Table 6 exceeds the threshold of 0.8 conventionally read as large. One feature warrants caution: the subcomponent d values (1.61-1.66) exceed the value obtained for the total receptive language score (0.93). The discrepancy is metric rather than substantive, because the much smaller standard deviations of the subcomponent scores convert an equivalent mean difference into a larger standardized figure. The subcomponent d values are therefore better read as evidence that the findings point consistently in one direction than as a claim that the intervention works more

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powerfully on any particular aspect. Cohen's d is also prone to upward bias at moderate sample sizes, so these figures should be treated as promising initial indications pending replication.

DISCUSSION

Children who received the Free Nutritious Meal Program for 12 weeks improved in working memory and receptive language to a degree that was both statistically significant and practically meaningful relative to children who did not receive the intervention. The result aligns with a rapidly consolidating body of evidence connecting nutritional adequacy to the development of cognitive function in early childhood.

Ansuya et al. (2023), in a randomized controlled trial, found that community-based nutritional intervention significantly raised the cognitive development scores of malnourished preschool children. Koshy et al. (2025) reported that growth status, persistent stunting versus catch-up growth, was an important predictor of executive function, including working memory, and the meta-analysis by Sideropoulos et al. (2025) confirmed the association between stunting and cognitive development outcomes.

The working memory gain in the experimental group, d = 1.02, constitutes a large effect under the classification of Cohen (1988). A neurobiological account explains it: micronutrient intake, particularly iron, zinc, and B vitamins, sustains the functioning of the hippocampus and the prefrontal cortex, the two neural substrates of working memory (Gutema et al., 2023; Jiang & Li, 2025).

Designed around the Fill My Plate principle, the MBG menu delivers 25-35% of daily nutritional requirements through a balanced composition of carbohydrates, animal protein, vegetables, and fruit, securing the nutrients that active synaptogenesis and myelination demand in children aged 4-6 years. This corresponds with the review by Jiang and Li (2025) and the systematic review by Roberts et al. (2022), both of which concluded that overall diet quality, rather than single micronutrient supplements, yields the more consistent neurocognitive benefit.

The receptive language gain, d = 0.93, provides equally strong evidence that nutritional intervention reaches children's linguistic capacity. Subcomponent analysis showed very large and closely comparable effects across vocabulary comprehension (raw mean gain = 5.07, d = 1.61), instruction comprehension (raw mean gain = 4.80, d = 1.64), and sentence comprehension (raw mean gain = 4.53, d = 1.66), indicating that the intervention benefited all three receptive language subcomponents to a similar degree. The pattern indicates that the intervention strengthened not only the lexical foundation but also the capacity to process more complex linguistic structures.

These outcomes accord with Sideropoulos et al. (2025), who documented an association between growth retardation and weaker achievement across cognitive domains including language, and with Shapiro et al. (2024), who found that diversity of complementary food exposure correlated with children's comprehension of food-related words during the early stages of receptive language

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development. Bergelson (2024) similarly argues that exposure to a language-rich environment and systemic support for families interact with nutritional adequacy in sustaining cognitive and linguistic growth.

Nutrition education in Indonesia delivered through early childhood learning media, picture media and folklore-based big books alike, has been shown to improve children's knowledge of balanced nutrition and their consumption of vegetables and fruit (Daryati & Suryadi, 2025; Suryadi et al., 2026). Meal provision accompanied by teachers' conversation and explanation therefore carries clear potential to reinforce vocabulary acquisition and the comprehension of instructions.

Two pathways plausibly link nutrition to receptive language. The direct neurobiological pathway runs through essential nutrients that build and maintain the neural circuits processing linguistic information, including the regions responsible for comprehension (Gutema et al., 2023; Jiang & Li, 2025). The indirect pathway runs through behavior: well-nourished children are more active, sustain attention more effectively, and respond more readily to language stimulation in the classroom (Sari, 2025; Wang et al., 2021).

Communal mealtimes within MBG implementation in PAUD add a further layer, generating social interaction and meaningful teacher-child conversation that enrich receptive language input (Bergelson, 2024; Daryati et al., 2026; Shapiro et al., 2024). This convergence of improved nutrition and psychosocial stimulation is consistent with evidence that combined nutrition-and-stimulation interventions outperform single-component approaches (Ansuya et al., 2023; Roberts et al., 2022).

The effect sizes observed here are larger than those reported in comparable international studies, and several contextual factors plausibly account for the difference. First, the high prevalence of stunting and anemia in Bengkulu (24.5%) means that many children in the sample entered the study from a suboptimal nutritional baseline, where intervention produces more visible returns (Gutema et al., 2023).

Second, although 12 weeks is a relatively short intervention, it fell within a highly plastic phase of brain development in which nutritional improvement translates readily into cognitive gain (Jiang & Li, 2025; Wijeakumar et al., 2023). Third, the MBG menu follows national standards for balanced nutritional composition and therefore constitutes a holistic intervention, unlike the many earlier studies that tested only a single micronutrient supplement.

Several limitations qualify these conclusions. The quasi-experimental design, lacking full randomization, leaves room for uncontrolled confounding despite the baseline equivalence demonstrated between groups. The 12-week window is too short to establish long-term impact, so longitudinal work is required to determine whether the effects persist. Nutritional intake at home, which may vary considerably between individuals, was not measured.

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Moderator variables such as the quality of stimulation at home and at school were likewise not measured separately, and the possible role of social interaction during mealtimes in enriching language exposure remains a plausible but untested hypothesis rather than an observed component of the intervention. Subsequent research should adopt a randomized controlled design with long-term follow-up, incorporate measurement of nutritional biomarkers, explicitly assess psychosocial stimulation during mealtimes, and model the mediating pathways among nutrition, brain development, and cognitive outcomes more comprehensively.

CONCLUSION

The Free Nutritious Meal Program exerted a positive, significant, and practically meaningful effect on the working memory and receptive language of children aged 4-6 years in PAUD institutions in Bengkulu City. After 12 weeks of intervention, recipients outperformed the control group in working memory, $t(70) = 4.28$, $p < .001$, with a large effect size ($d = 1.02$). Receptive language followed the same pattern, $t(70) = 3.91$, $p < .001$, $d = 0.93$, and the advantage held across all three subcomponents, namely vocabulary, instruction, and sentence comprehension, with very large effect sizes ($d = 1.61$-1.66). All three research objectives were thus met: MBG improved working memory, improved receptive language, and generated large to very large effects.

These findings reposition MBG as a neurocognitive investment in children's learning readiness rather than an anthropometric intervention alone, and they argue for widening program evaluation from indicators of nutritional status to indicators of cognitive and language development. PAUD educators should pair communal mealtimes with deliberate language stimulation and with nutrition education that involves parents, particularly in areas of high stunting prevalence. The quasi-experimental design, the brevity of the intervention, and the absence of data on dietary intake at home mark the boundaries of these conclusions and define the agenda for randomized, larger-scale, and longitudinal research capable of testing whether the impact of the program endures.

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