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Effect of Lemuru Fish–Based Local Snacks on HAZ and DHA Levels among Stunted Toddlers: A Quasi-Experimental Study

Estuasi Diah Pertiwi[1], Sunarto[1]*, Mohamad Reza Assidhiq[1], Arwin Muhlishoh[1], Arvina Dian Wahyu Permatasari[1]

[1] Department of Nutrition, Poltekkes Kemenkes Semarang, Indonesia

Corresponding Author Email: sunarto.gizi@gmail.com

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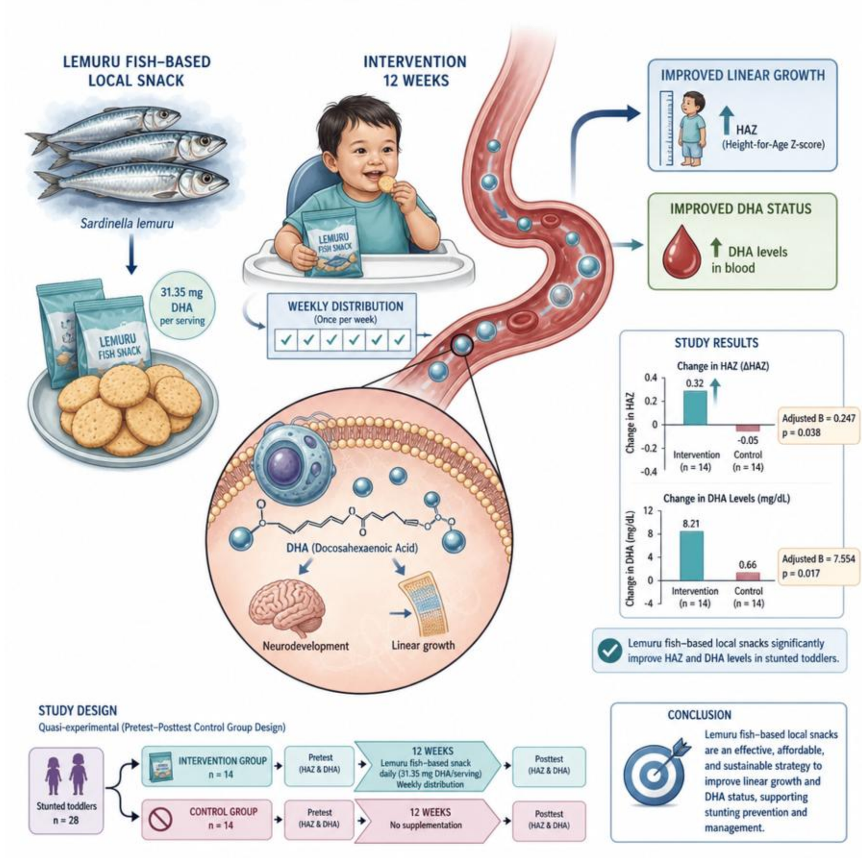
ABSTRACT

Stunting among toddlers remains a persistent public health problem in low- and middle-income countries and is strongly associated with chronic undernutrition, including inadequate intake of omega-3 long-chain polyunsaturated fatty acids such as docosahexaenoic acid (DHA), which are essential for optimal growth and development. Lemuru fish (Sardinella lemuru), a locally abundant and affordable source rich in DHA, has considerable potential as the basis for food based snacks in sustainable nutrition interventions. In this study, stunted toddlers in the intervention group received the lemuru fish–based snack daily for 12 weeks (each serving provided 31.35 mg DHA); DHA distribution was performed once weekly. This study aimed to evaluate the effect of lemuru fish–based local snacks on Height-for-Age Z-score (HAZ) and DHA levels among stunted toddlers. A quasi-experimental study with a pretest–posttest control group design was conducted involving 28 stunted toddlers, equally divided into an intervention group (n = 14) and a control group (n = 14). The intervention group received lemuru fish–based snacks during the intervention period, while the control group received no supplementation. Measurements of HAZ and DHA levels were obtained before and after the intervention. Bivariate analyses indicated greater improvements in HAZ and DHA levels in the intervention group compared with the control group. After adjustment for child and household characteristics using a general linear model (ANCOVA), the intervention was associated with significant improvements in HAZ (B = 0.247; p = 0.038) and DHA levels (B = 7.554 mg/dL; p = 0.017). These findings indicate that lemuru fish–based local snacks effectively improve linear growth and DHA status and represent a promising, locally sourced strategy for stunting prevention and management.

Key Messages:

- Stunting in toddlers is closely associated with chronic undernutrition, including inadequate intake of omega-3 fatty acids such as DHA, which are essential for linear growth and development.
- Lemuru fish *(Sardinella lemuru*), a locally abundant and affordable food source, is rich in DHA and has strong potential to be developed into sustainable local food–based snacks.
- Local food–based interventions utilizing nutrient-dense fish can serve as an effective and context-appropriate strategy for stunting prevention and management in resource-limited settings..

GRAPHICAL ABSTRACT



INTRODUCTION

Stunting remains one of the most critical chronic nutrition problems affecting toddlers in developing countries, including Indonesia. Defined as a Height-for-Age Z-score (HAZ) below −2 standard deviations according to the World Health Organization (WHO) child growth standards, stunting reflects prolonged nutritional deprivation and repeated health insults beginning in early life [1]. Beyond impaired physical growth, stunting has been consistently linked to adverse long-term outcomes, including delayed cognitive development, lower educational achievement, reduced economic productivity, and an increased risk of non-communicable diseases in adulthood [2,3]. These consequences underscore the urgent need for effective and sustainable interventions targeting early childhood nutrition.

The etiology of stunting is complex and multifactorial, involving inadequate dietary intake, poor diet quality, recurrent infections, and unfavorable socioeconomic conditions [4]. While earlier interventions largely focused on energy sufficiency, growing evidence indicates that diet quality—particularly adequate intake of high-quality animal-source proteins and essential fatty acids—is critical for supporting optimal linear growth during the first years of life. Protein quality, often underexplored in these discussions, plays a pivotal role: high biological value proteins provide essential amino acids (e.g., lysine, often limiting in toddler plant-based diets) that drive growth via elevated insulin-like growth factor 1 (IGF-1) levels, promoting chondrocyte proliferation in growth plates (5). Sardinella lemuru (lemuru), a locally abundant small pelagic fish, provides high-quality protein and is rich in docosahexaenoic acid (DHA). Incorporating lemuru-based snacks into complementary feeding can help correct deficiencies in both high-biological-value protein (high DIAAS/PDCAAS) and essential fatty acids, representing a missed opportunity for synergistic interventions in community nutrition programs. Children whose diets lack high-quality protein and essential fats are substantially more likely to experience growth faltering than those consuming diverse, nutrient-dense foods [6].

While DHA plays an essential role in neurodevelopment and cellular function, the growth-promoting effects of fish-based foods are likely mediated primarily through high-quality protein and

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micronutrients, with DHA serving as an important co-benefit indicator of improved diet quality [7]. Observational studies suggest that low DHA status in early childhood is associated with impaired growth and suboptimal neurodevelopmental outcomes [8]. However, despite strong biological plausibility, evidence from intervention studies assessing the effect of DHA intake on linear growth remains limited and inconsistent, particularly among already stunted toddlers. Most existing research has focused on cognitive outcomes or infant populations, leaving a significant knowledge gap regarding the potential role of DHA in catch-up growth among stunted children.

In Indonesia, DHA intake among toddlers is generally low, largely due to insufficient consumption of marine fish and other DHA-rich foods [9]. This is notable given Indonesia's rich marine biodiversity, including lemuru fish (*Sardinella lemuru*), which is widely available, affordable, and rich in DHA and high-quality protein [10]. Despite this potential, lemuru fish remains underutilized in child feeding programs, and its application in locally developed snack-based interventions has received limited scientific evaluation.

Food-based interventions utilizing locally available resources are increasingly recommended as sustainable strategies for stunting prevention, as they are culturally acceptable, environmentally sustainable, and supportive of local food systems [11]. Several studies have reported positive effects of fish-based or animal-source food interventions on child growth outcomes [10,12]. Nevertheless, many of these studies have not examined biochemical indicators such as DHA status, nor have they adequately controlled for confounding factors, including child age, sex, infection history, breastfeeding practices, and household socioeconomic characteristics—factors known to influence growth responses to nutrition interventions [5,13].

Therefore, a clear gap exists in the evidence regarding the effectiveness of DHA-rich, locally sourced food-based interventions on both linear growth and DHA status among stunted toddlers, particularly when confounding factors are appropriately controlled. The objective of this study was to evaluate the effectiveness of lemuru fish–based local snacks in improving Height-for-Age Z-score (HAZ) and DHA levels among stunted toddlers, using a quasi-experimental design and multivariate analysis to account for potential confounders. This study aims to provide robust evidence to support the development of affordable, context-specific, and sustainable nutrition interventions for stunting reduction in Indonesia.

METHODS

Study Design and Setting

This study employed a quasi-experimental design with intervention and control groups using a pre-test–post-test approach, as full randomization was not feasible due to ethical and logistical constraints: randomly assigning stunted toddlers across villages would disrupt established community health programs, cadre networks, and parental consent tied to local access. The design effectively evaluated the impact of locally produced lemuru fish–based snacks on improving Height-for-Age Z-score (HAZ) and docosahexaenoic acid (DHA) levels among stunted toddlers in selected Indonesian communities with high stunting prevalence, conducted from July to November 2025. Contamination between groups was prevented by selecting geographically isolated villages (>10 km apart), assigning distinct community health cadres for snack distribution/monitoring per arm, and limiting intervention activities/messaging to intervention sites only. Baseline (pre-intervention) and endline (post-intervention) measurements were obtained for all study variables.

Study Population, Sample Size, and Sampling Technique

The study population consisted of toddlers aged 24–59 months who were classified as stunted (HAZ < −2 SD) based on the WHO Child Growth Standards. Participants were selected using purposive sampling according to predefined inclusion criteria, including residence in the study area, absence of congenital abnormalities or chronic illnesses, and willingness of parents or caregivers to participate.

A total of 28 toddlers were included in the study, with 14 allocated to the intervention group and 14 to the control group. Sample size was calculated to detect differences in mean outcomes between two independent groups with a 95% confidence level and 80% statistical power, following established

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procedures for quasi-experimental nutrition studies [1]. Group allocation was conducted to minimize contamination between participants.

Intervention

The intervention consisted of the provision of locally developed lemuru fish–based snacks formulated to be appropriate for toddler consumption and rich in DHA and high-quality protein. The intervention group received the snacks regularly throughout the intervention period, while the control group did not receive any supplementation and continued their usual dietary practices. Adherence to the intervention was monitored through caregiver interviews and routine field supervision.

Study Variables

The dependent variables were post-intervention HAZ and post-intervention DHA levels. The primary independent variable was intervention status (lemuru fish–based snack vs. control). To reduce potential bias and obtain more accurate effect estimates, covariates were included based on previous empirical evidence.

For the post-intervention HAZ model, covariates included pre-intervention HAZ, child sex, birth length, birth weight, maternal age during pregnancy, child energy intake, protein intake adequacy, breastfeeding status, maternal education, paternal education, maternal occupation, paternal occupation, and recent infection status [2,3].

For the post-intervention DHA model, covariates included pre-intervention DHA levels, child sex, child age, maternal age during pregnancy, energy intake, protein intake adequacy, DHA intake adequacy, breastfeeding status, maternal education, paternal education, maternal occupation, paternal occupation, and recent infection status [4,5].

Data Collection

Anthropometric measurements were conducted by trained enumerators using standardized procedures. Body length or height was measured to the nearest 0.1 cm using calibrated length boards or stadiometers. HAZ values were calculated using the WHO Anthro software.

DHA levels were assessed through venous blood sampling conducted by certified health personnel and analyzed using validated laboratory methods. Dietary intake data, including energy, protein, and DHA intake, were collected through structured interviews with parents or caregivers using a pre-tested Food Frequency Questionnaire (FFQ). Data on demographic characteristics, socioeconomic status, breastfeeding practices, and child morbidity were collected using standardized questionnaires [6].

Data Analysis

Data analysis was performed using statistical software. Descriptive statistics were used to summarize participant characteristics. Normality of continuous variables was assessed using the Shapiro–Wilk test. Based on distributional assumptions, Independent-samples t-tests were used for bivariate comparisons between groups when the outcome was normally distributed.

Multivariate analysis was conducted using the General Linear Model (ANCOVA) to assess the effect of the intervention on post-intervention HAZ and DHA levels while controlling for relevant covariates. Results were reported as regression coefficients (B), 95% confidence intervals (CI), p-values, and partial eta squared as an indicator of effect size. Statistical significance was set at $p < 0.05$ [7,8].

CODE OF HEALTH ETHICS

Ethical approval for this study was obtained from the Health Research Ethics Committee, Poltekkes Kemenkes Semarang, Ministry of Health, Semarang Health Polytechnic (Ethical Approval No. 1026/EA/F.XXIII.38/2025). The study was carried out in accordance with the ethical standards set forth in the Declaration of Helsinki and relevant national regulations governing health research involving human subjects.

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RESULTS

Sample Characteristics

The following table 1 presents the characteristics of the study sample, including demographic variables, nutritional status, nutrient intake, and health-related factors of mothers and children. Respondent characteristics are presented as mean ± standard deviation for continuous data and as frequency and percentage distributions for categorical data, to provide an overall description of the subjects' conditions before further analysis.

Table 1. Characteristics of the Study Sample

Variable	n	Mean ± SD
Child HAZ (pre)	28	−2.94 ± 0.82
Child DHA (pre)	28	67.78 ± 21.28
Child age (months)	28	37.46 ± 8.28
Maternal age during pregnancy (years)	28	28.18 ± 7.28
Maternal nutrition knowledge	28	86.67 ± 12.03
Adequacy of child protein intake (%)	28	182.57 ± 84.24
Adequacy of child DHA intake (%)	28	28.14 ± 50.56
Child body length (cm)	28	85.15 ± 5.95
Child sex		
Male	13	46.4%
Female	15	53.6%
Maternal education		
Primary education	16	57.1%
Upper secondary and higher	12	42.9%
Paternal education		
Primary education	17	60.7%
Upper secondary and higher	11	39.3%
Maternal employment		
Unemployed	17	60.7%
Employed	11	39.3%
Exclusive breastfeeding history		
Exclusive breastfeeding	24	85.7%
Not exclusive breastfeeding	4	14.3%
History of infection		
Infection	9	32.1%
No infection	19	67.9%

Based on the table, the mean pre-intervention HAZ of children was −2.94 ± 0.82, indicating that all children were classified as stunted. The mean pre-intervention DHA level was 67.78 ± 21.28, with considerable variability. The mean child age was 37.46 ± 8.28 months, while the mean maternal age during pregnancy was 28.18 ± 7.28 years, both within the productive age range. The mean maternal nutrition knowledge score was 86.67 ± 12.03. The mean adequacy of child protein intake reached 182.57 ± 84.24%, while the adequacy of child DHA intake was 28.14 ± 50.56%, indicating wide variation in nutrient intake. The mean child body length was 85.15 ± 5.95 cm. Regarding categorical characteristics, the proportion of female children (53.6%) was slightly higher than that of male children (46.4%). Most mothers (57.1%) and fathers (60.7%) had primary education. The majority of mothers were unemployed (60.7%). In addition, most children received exclusive breastfeeding (85.7%), and 67.9% had no history of infection.

Data Distribution

The following table 2 presents the results of normality tests for the distribution of each study variable based on the intervention and control groups. Normality was assessed using the Shapiro–Wilk test, given that the sample size in each group was fewer than 50 subjects. The results of this test were used as the basis for selecting appropriate statistical tests in subsequent analyses.

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Table 2. Normality Test of Data by Group (Shapiro–Wilk)

Variable	Group	Statistic (W)	df	p
Child's body length	Intervention	0.839	14	0.016
	Control	0.950	14	0.562
Child age	Intervention	0.892	14	0.085
	Control	0.926	14	0.264
Maternal age during pregnancy	Intervention	0.922	14	0.237
	Control	0.943	14	0.462
Maternal nutrition knowledge	Intervention	0.853	14	0.024
	Control	0.908	14	0.150
Adequacy of child protein intake	Intervention	0.847	14	0.020
	Control	0.958	14	0.685
HAZ pre	Intervention	0.804	14	0.006
	Control	0.888	14	0.076
HAZ post	Intervention	0.716	14	0.001
	Control	0.905	14	0.132
DHA pre	Intervention	0.967	14	0.831
	Control	0.952	14	0.589
DHA post	Intervention	0.960	14	0.726
	Control	0.939	14	0.409
Adequacy of child DHA intake	Intervention	0.572	14	<0.001
	Control	0.621	14	<0.001

Based on the Shapiro–Wilk test results, in the intervention group, child body length ($p = 0.016$), maternal nutrition knowledge ($p = 0.024$), adequacy of child protein intake ($p = 0.020$), HAZ pre ($p = 0.006$), HAZ post ($p = 0.001$), and adequacy of child DHA intake ($p < 0.001$) showed non-normal distributions ($p < 0.05$). Meanwhile, child age, maternal age during pregnancy, DHA pre, and DHA post in the intervention group were normally distributed. In the control group, all variables showed p values ≥ 0.05, indicating normal distributions, except for adequacy of child DHA intake, which was not normally distributed ($p < 0.001$). Based on these normality test results, variables with non-normal distributions in each group were analyzed using the nonparametric Mann–Whitney test, whereas variables with normal distributions were analyzed using the parametric Independent t-test.

Data Homogeneity

The following table 3 presents the results of homogeneity tests for respondent characteristics between the intervention and control groups before comparative analysis. Homogeneity testing was conducted using Independent t-tests, Mann–Whitney U tests, Chi-square tests, and Fisher's Exact tests, selected according to data type and normality test results. These tests aimed to ensure the equivalence of baseline characteristics between the study groups.

Table 3. Homogeneity Test of Baseline Characteristics Between Intervention and Control Groups

Variable	Intervention	Control	p
Maternal age during pregnancy (years)	29.07 ± 8.31	27.29 ± 6.28	0.527*
Adequacy of child protein intake (%)	188.25 ± 90.74	176.89 ± 80.23	0.728*
DHA pre	65.51 ± 22.91	70.06 ± 20.11	0.581*
Child body length (cm)	84.78 ± 6.94	85.52 ± 5.00	0.854**
HAZ pre	−2.95 ± 0.97	−2.94 ± 0.66	0.679**
Child age (months)	37.00 ± 9.22	37.93 ± 7.54	0.908**
Maternal nutrition knowledge	87.62 ± 12.22	85.71 ± 12.22	0.605**
Adequacy of child DHA intake (%)	17.43 ± 35.52	38.86 ± 61.65	0.566**
Child sex			
Male	6 (46.2%)	7 (53.8%)	0.705***
Female	8 (53.3%)	7 (46.7%)	
Exclusive breastfeeding history			
Exclusive breastfeeding	11 (45.8%)	13 (54.2%)	0.596****
Not exclusive breastfeeding	3 (75.0%)	1 (25.0%)	
Maternal education			
Primary education	8 (50.0%)	8 (50.0%)	1.000***
Secondary–higher education	6 (50.0%)	6 (50.0%)	
Paternal education			

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Variable	Intervention	Control	p
Primary education	8 (47.1%)	9 (52.9%)	0.699***
Secondary–higher education	6 (54.5%)	5 (45.5%)	
Maternal employment			
Unemployed	9 (52.9%)	8 (47.1%)	0.699***
Employed	5 (45.5%)	6 (54.5%)	
History of infection			
Infection	5 (55.6%)	4 (44.4%)	1.000****
No infection	9 (47.4%)	10 (52.6%)	

* Independent t-test; ** Mann–Whitney U test ; *** Chi-square test; **** Fisher's Exact test

Based on the homogeneity test results, no statistically significant differences were found in baseline characteristics between the intervention and control groups (p > 0.05). For continuous variables, there were no significant differences in maternal age during pregnancy, child age, child body length, maternal nutrition knowledge, HAZ pre, DHA pre, adequacy of protein intake, or adequacy of DHA intake between the two groups.

For categorical variables, the proportions of child sex, maternal education, paternal education, and maternal employment were analyzed using the Chi-square test and showed no significant differences between groups. Meanwhile, exclusive breastfeeding history and history of infection were analyzed using Fisher's Exact test due to more than 20% of cells having expected counts below 5, and the results also indicated no statistically significant differences.

Effect of the Intervention on HAZ and DHA

Bivariate Analysis

The following figure compares changes in Height-for-Age Z-score (HAZ) and docosahexaenoic acid (DHA) levels between intervention and control groups from pre-intervention (baseline) to post-intervention (after 12 weeks of 1 mg lemuru fish–based snack daily). This visualization illustrates group differences in short-term changes, noting that observed HAZ shifts may partly reflect measurement variability rather than true catch-up growth, while providing an initial overview of intervention. associations.

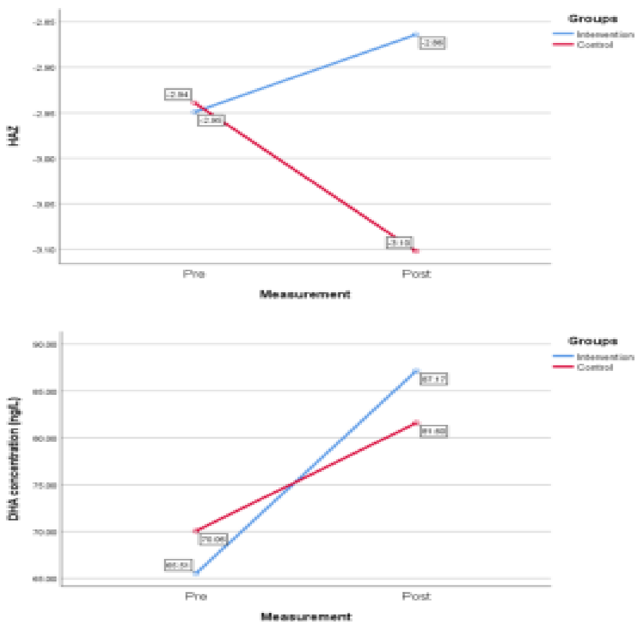

Figure 1. Changes in HAZ and DHA Levels in the Intervention and Control Groups Based on Pre- and Post-Measurements

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Based on the figure, the intervention group demonstrated a more favorable pattern of change compared with the control group. For the HAZ indicator, the intervention group showed an increase from −2.95 at pre-measurement to −2.86 at post-measurement, indicating an improvement in linear growth status. In contrast, the control group experienced a decline in HAZ values from −2.94 to −3.10, suggesting a tendency toward worsening growth status during the observation period. For DHA levels, both groups showed increases from pre- to post-measurement. However, the increase in the intervention group was greater, rising from 65.51 mg/dL to 87.17 mg/dL, compared with the control group, which increased from 70.06 mg/dL to 81.60 mg/dL. This difference in the magnitude of increase suggests that the intervention was more effective in improving DHA levels. Overall, the figure illustrates a consistent direction of change, in which the greater increase in DHA levels in the intervention group was accompanied by an improvement in HAZ, whereas in the control group, a smaller increase in DHA was not followed by an improvement in HAZ. These findings support the assumption that the intervention contributed to increased DHA levels and was associated with improvements in children's linear growth status.

The following table presents the results of the analysis of the effect of the intervention on post-intervention HAZ and DHA levels. The analysis compares the intervention group with the control group as the reference. The information presented includes mean and standard deviation values, regression coefficients (B), 95% confidence intervals, p-values, and partial eta squared as a measure of the magnitude of the intervention effect on each dependent variable.

Table 4. Effect of the Intervention on HAZ and DHA Levels (Post)

Variable	Group	Mean ± SD	B	95% CI B	p	Partial Eta Squared
HAZ Post (mg/dL)	Intervention	−2.86 ± 0.88	0.238	−0.371 to 0.847	0.429*	0.024
	Control	−3.10 ± 0.68	0	–	–	–
DHA Post (mg/dL)	Intervention	87.17 ± 21.02	5.570	−9.592 to 20.732	0.457*	0.021
	Control	81.60 ± 17.89	0	–	–	–

*Independent t test

Based on the table, for post-intervention HAZ, the intervention group had a mean value 0.238 units higher than the control group (B = 0.238; 95% CI: −0.371 to 0.847; p = 0.429). However, this difference was not statistically significant, and the magnitude of the intervention effect accounted for only 2.4% of the variance. For post-intervention DHA levels, the intervention group had a mean value 5.57 mg/dL higher than the control group (B = 5.570; 95% CI −9.592 to 20.732; p = 0.457). This difference was also not statistically significant, and the magnitude of the intervention effect accounted for only 2.1% of the variance.

Multivariate Analysis

The following figure shows the output of the analysis illustrating changes in HAZ and DHA values from pre- to post-measurement between the intervention and control groups. The analysis was conducted using a General Linear Model (GLM/ANCOVA) to compare changes between groups while controlling for potential confounding covariates.

For the HAZ effect analysis, the model was adjusted for pre-intervention HAZ, child sex, birth length, birth weight, maternal age during pregnancy, energy intake, adequacy of protein intake, breastfeeding status, maternal education, paternal education, maternal occupation, paternal occupation, and history of infection; whereas for the DHA effect analysis, adjustments included pre-intervention DHA, child sex, child age, maternal age during pregnancy, energy intake, adequacy of protein intake, breastfeeding status, maternal education, paternal education, maternal occupation, paternal occupation, and history of infection. These covariate adjustments minimized confounding and enabled robust comparison of intervention effects on both outcomes.

This figure presents the pattern of changes in HAZ and DHA from pre- to post-measurement after adjustment for covariates, thereby reflecting the controlled effect of the intervention.

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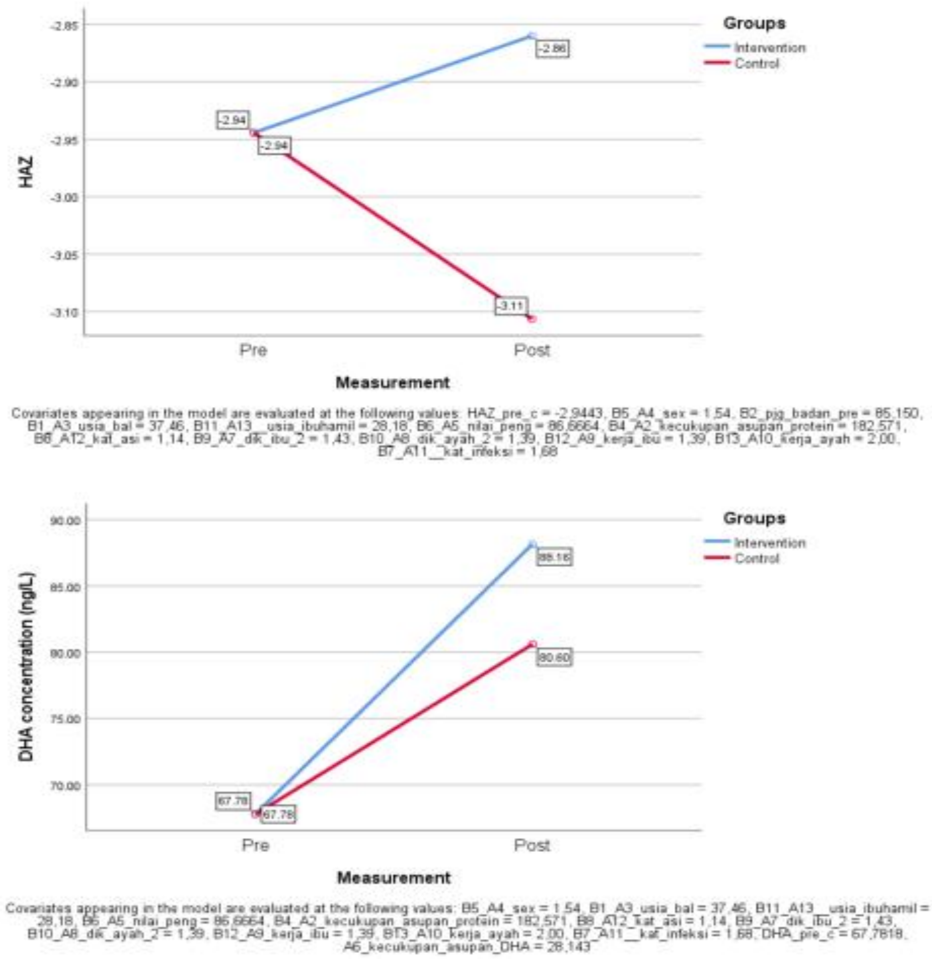

Figure 2. Adjusted Changes in HAZ and DHA Levels in the Intervention and Control Groups Before and After the Intervention

In the HAZ graph, the mean HAZ values at baseline (pre) were relatively similar between the intervention and control groups, at −2.94 and −2.98, respectively. After the intervention, the intervention group showed an increase in HAZ to −2.69, whereas the control group experienced a decrease to −3.10. This difference in the direction of change indicates that the intervention contributed to improvements in children's linear growth status compared with the control group after controlling for covariates.

In the DHA graph, mean DHA levels at baseline were also comparable between the intervention and control groups, at 87.70 mg/dL and 87.78 mg/dL, respectively. At post-measurement, DHA levels increased in both groups; however, the increase was greater in the intervention group, reaching 88.52 mg/dL, compared with the control group, which increased to 80.58 mg/dL. This finding indicates that the intervention had a stronger effect on increasing DHA levels after adjustment for dietary intake and child and family characteristics. Overall, the figure demonstrates that the intervention group experienced greater improvements in HAZ and DHA levels at post-measurement compared with the control group, after accounting for relevant covariates in the analysis model.

The following analytical model shows the effect of the intervention on post-intervention HAZ and DHA levels between the intervention and control groups. The analysis was conducted using a multivariate t-test (general linear model/ANCOVA) to compare group means while controlling for potential confounding covariates.

For the post-intervention HAZ analysis, the model was adjusted for pre-intervention HAZ, child sex, birth length, birth weight, maternal age during pregnancy, energy intake, adequacy of protein intake, breastfeeding status, maternal education, paternal education, maternal occupation, paternal occupation,

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and history of infection. For the post-intervention DHA analysis, the model was adjusted for pre-intervention DHA, child sex, child age, maternal age during pregnancy, energy intake, adequacy of protein intake, breastfeeding status, maternal education, paternal education, maternal occupation, paternal occupation, and history of infection. Through the use of this multivariate t-test (ANCOVA), the estimated differences in mean post-intervention HAZ and DHA levels between groups reflect the pure effect of the intervention after controlling for covariates.

Table 5. Effect of the Intervention on HAZ and DHA Levels (Post)

Variable	Group	Mean ± SD	B	95% CI B	p	Partial Eta Squared
HAZ Post (mg/dL)	Intervention	−2.86 ± 0.88	0.247	0.016 to 0.477	0.038	0.273
	Control*	−3.10 ± 0.68	0	–	–	–
DHA Post (mg/dL)	Intervention	87.17 ± 21.02	7.554	1.545 to 13.563	0.017	0.342
	Control*	81.60 ± 17.89	0	–	–	–

Based on the table, the mean HAZ in the intervention group was −2.86 ± 0.88, which was higher than that in the control group (−3.10 ± 0.68). The analysis showed that the intervention had a statistically significant effect on HAZ, as indicated by a p-value of 0.038 and a 95% confidence interval that did not cross zero. The regression coefficient B of 0.247 indicates that the intervention increased HAZ by 0.247 units compared with the control group after adjusting for covariates (B = 0.247; 95% CI: 0.016–0.477; p = 0.038). The partial eta squared value of 0.273 indicates that the intervention explained 27.3% of the variance in HAZ.

For DHA, the intervention group had a mean level of 87.17 ± 21.02 mg/dL, which was higher than that of the control group (81.60 ± 17.89 mg/dL). The analysis showed that the intervention also had a statistically significant effect on DHA levels, as indicated by a p-value of 0.017 and a 95% confidence interval entirely above zero. The regression coefficient B of 7.554 indicates that the intervention increased DHA levels by 7.554 mg/dL compared with the control group after adjusting for covariates (B = 7.554; 95% CI: 1.545–13.563; p = 0.017). The partial eta squared value of 0.342 indicates that the intervention explained 34.2% of the variance in DHA levels. Overall, these results confirm that the intervention had statistically significant effects on both HAZ and DHA levels after controlling for confounding factors in the analytical model.

DISCUSSION

This study demonstrated that the provision of local lemuru fish–based snacks resulted in a more favorable pattern of improvement in Height-for-Age Z-score (HAZ) and DHA levels among stunted toddlers compared with the control group. Although the bivariate analyses did not show statistically significant differences between groups, the multivariate analysis controlling for key covariates revealed that the intervention had a significant positive effect on both post-intervention HAZ and DHA levels. These findings directly address the research objective and suggest that locally sourced, DHA-rich food-based interventions can contribute to improvements in linear growth and nutritional status among stunted children.

The discrepancy between bivariate and multivariate results highlights the importance of controlling for baseline nutritional status, dietary intake, and socioeconomic factors when evaluating nutrition interventions. Similar patterns have been reported in previous studies, where crude comparisons underestimated intervention effects that became evident after adjustment for confounders [1]. This finding aligns with evidence from systematic reviews and meta-analyses indicating that food-based interventions can improve linear growth, although effect sizes vary widely depending on intervention composition, duration, and contextual factors [1].

The significant improvement in DHA levels observed in the intervention group supports the biological plausibility of lemuru fish–based snacks as an effective nutritional strategy. Fish is a well-established source of high-quality protein and long-chain omega-3 fatty acids, particularly DHA, which

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plays a critical role in cellular growth and tissue development [2]. Although interventional evidence linking DHA intake directly to linear growth remains limited, observational studies consistently show positive associations between consumption of animal-source foods rich in DHA and improved growth and nutritional outcomes in children [3]. The present findings contribute to this limited body of interventional evidence, particularly among stunted toddler populations.

Consistent with this study, evaluations of fish-based supplementation programs in community and government settings have reported improvements in HAZ scores, especially when interventions leverage locally available resources and are supported by community engagement and policy frameworks [4]. This suggests that locally adapted interventions, such as lemuru fish–based snacks, may offer greater sustainability and acceptability compared with imported or highly processed supplements.

Previous studies examining local food-based supplementary feeding interventions have also demonstrated improvements in anthropometric indicators, largely mediated through increased energy and protein intake [5]. These findings support the notion that diversification and optimization of local diets represent a contextually appropriate strategy for addressing stunting in resource-limited settings.

Beyond food provision alone, the broader literature indicates that integrated nutrition interventions—combining dietary improvement with caregiver education and family involvement—tend to achieve more substantial and sustained impacts [6]. Although the current study focused primarily on a food-based intervention, these findings suggest that incorporating nutrition education to promote sustained fish consumption at the household level could enhance long-term benefits.

Nevertheless, the duration of intervention and follow-up must be considered when interpreting the results. Linear growth responds slowly to nutritional improvements, and studies with intervention periods longer than six months generally report stronger effects on HAZ compared with shorter interventions [7]. The relatively short duration of the present study may therefore have limited the magnitude of observed growth changes, despite statistically significant effects after adjustment.

Several limitations should be acknowledged. First, the quasi-experimental design and small sample size may limit generalizability and statistical power. Second, purposive sampling and non-random allocation may introduce selection bias, although the use of ANCOVA helped mitigate baseline differences. Third, dietary intake data were collected using FFQ, which is subject to recall bias. Finally, unmeasured factors such as environmental sanitation or caregiving practices may have influenced outcomes.

Despite these limitations, this study provides important evidence that locally available, protein- and DHA-rich foods can play a meaningful role in stunting reduction strategies. In the broader context, the findings support national and global recommendations advocating food-based, locally sourced nutrition interventions integrated with health, education, and social support systems [8].

Overall, lemuru fish–based local snacks show promise as an affordable, culturally appropriate, and sustainable intervention to improve linear growth and DHA status among stunted toddlers. Scaling up such interventions, alongside comprehensive strategies addressing dietary practices and socioeconomic determinants, may enhance their impact on stunting reduction in Indonesia and similar settings.

CONCLUSION

Lemuru fish–based snacks were associated with modest improvements in docosahexaenoic acid (DHA) status and small changes in Height-for-Age Z-score (HAZ) after adjustment for confounders such as baseline nutritional status, dietary intake, breastfeeding, and sociodemographic factors. Although crude analyses showed limited statistical significance, multivariate models (ANCOVA) revealed clearer intervention effects. Given the small sample size and quasi-experimental design, these findings should be interpreted as preliminary evidence of promise. The intervention shows strong potential as a locally appropriate, sustainable complementary strategy—rather than a stand-alone solution—for enhancing nutrient quality and supporting stunting reduction, particularly when integrated with nutrition education, growth monitoring, and broader health programs.

DECLARATION OF THE USE OF AI

The authors declare that no artificial intelligence (AI), AI-assisted technologies, or large language

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models (LLMs) were used in the conception of the study, data analysis, or the drafting, writing, and editing of this manuscript. The only exception is the graphical abstract, which was created using the design platform Illustrae (https://illustrae.co/). The authors take full responsibility for the content and accuracy of the graphical abstract and the entire manuscript.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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