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Effect of Milk–Egg Intervention and Nutrition Education on Knowledge, Diet Quality, and Nutritional Status of Underweight Toddlers: A Quasi-Experimental Study

ALI KHOMSAN[1], DZAKIYYATUL FIKRAH 'ARIFAH[2*], NABILA SUKMA PRIYATNASARI[1], ARRUMAISHA KHANSA KIRANA PUSPAINDRIA[1], JENNIFER HANDAJA[3], YUNITA PURNAMA SARI[3], CHARISMA DILANTIKA[4], IDA SUSILAKSMI[5], JOKO PRASETIJO[6], HENDRIAWAN SULISTIYO[7], MANDUMAH[8], NURMALA HASANAH[9] and EKAWATI AGUSTIANA[10]

[1]Division of Applied Nutrition, Faculty of Medicine and Nutrition, IPB University, Bogor, Indonesia
[2]Nutrition Study Program, Faculty of Medicine, Universitas Negeri Semarang, Indonesia
[3]Nutrition, Health, and Wellness, PT Nestlé Indonesia, Jakarta, Indonesia
[4]Medical Affairs & Scientific Engagement, PT Nestlé Indonesia, Jakarta, Indonesia
[5]Batang District Health Office, Batang, Central Java, Indonesia
[6]Batang District Office of Women's Empowerment, Child Protection, Population Control, and Family Planning, Batang, Central Java, Indonesia
[7]Pasuruan District Regional Development Planning, Research, and Innovation Agency] (BAPPERIDA), Pasuruan, East Java, Indonesia
[8]Pasuruan District Health Office, Pasuruan, East Java, Indonesia
[9]Karawang District Health Office, Karawang, West Java, Indonesia
[10]West Java Representative Office of the Ministry of Population and Family Development, Bandung, West Java, Indonesia

Abstract

Underweight children face high risks of growth disorders. While food intervention and caregiver education are common, multivariable assessments controlling for baseline status and infection remain scarce. To evaluate changes in mother's nutritional knowledge, dietary intake, and toddler weight-for-age z-scores (WAZ) following a six-month combined milk–egg intervention and mother's nutrition education in underweight toddlers. A quasi-experimental, single-group pre–post study was conducted among 276 underweight toddlers aged 12–48 months across three districts (Pasuruan, Karawang, Batang). The intervention provided daily milk and egg provision alongside bimonthly nutrition education. Mother's knowledge, 24-hour dietary intake, and anthropometry were

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CONTACT Dzakiyyatul Fikrah 'Arifah dzakiyyatulfikrah@mail.unnes.ac.id Nutrition Study Program, Faculty of Medicine, Universitas Negeri Semarang, Indonesia

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collected at baseline and endline. Multivariable ANCOVA was performed to identify independent predictors of endline WAZ while controlling for covariates. Following the intervention, mother's nutritional knowledge scores increased significantly by 18.5% ($p < 0.001$). Total animal-source protein intake increased to 22.4 ± 9.0 g ($p < 0.001$), driven by high compliance to milk and egg consumption. Toddler WAZ scores showed positive trajectories, with 29% of participants shifting from underweight to normal status. In the adjusted ANCOVA model ($R^2 = 0.288$), baseline WAZ (B = 0.680, $p < 0.001$), maternal knowledge (B = 0.003, $p = 0.030$), and animal-source protein intake (B = 0.006, $p = 0.051$) were positively associated with endline WAZ. Conversely, acute respiratory infection (ARI) duration exhibited a significant negative association with growth (B = -0.021, $p < 0.001$). Regional district differences were not statistically significant ($p = 0.413$). A six-month package of milk–egg intervention and mother's nutrition education was associated with improved mother's knowledge, increased animal protein intake, and toddler weight gain. However, without a parallel control group, these growth trajectories cannot be definitively isolated from secular trends, seasonal variations, regression to the mean, or concurrent health activities. This represents a promising preliminary community model.

Introduction

A type of malnutrition known as underweight occurs when a child weighs less than is typical for their age. A weight-for-age (WAZ) index is used to assess this nutritional condition, with a z-score threshold between −3 SD and less than −2 SD.[1] The 2024 Indonesian Nutritional Status Survey (SSGI)[2] reported that the prevalence of underweight among children in Indonesia was 16.8%. Children with underweight status are at risk of growth problems.[1] Nearly half of deaths among children under five are attributed to undernutrition, with the majority of cases occurring in developing nations. This condition represents a serious global burden with long-term consequences for development, economic productivity, and social welfare.[3] Underweight is caused by various underlying factors, including inadequate dietary intake in children.[4] Children who consume insufficient food can develop symptoms of malnutrition within about six months and can become underweight. This condition can progress to more severe malnutrition and ultimately lead to loss of appetite and other health impacts.

Other factors contributing to underweight in children include low mother's nutritional knowledge, mother's age during pregnancy, limited access to basic health services, risk of infection, and poverty.[5,6] When children do not receive adequate nutrition during critical growth periods, it can result in physical and cognitive impairments.[4] Malnourished children can experience negative effects on brain and motor development, which can lead to long-term consequences such as poor educational outcomes and economic hardship in adulthood.[7] Underweight can be addressed through several approaches, including consuming nutritious foods, adequate hydration, and supplementation.[4] One common nutritional intervention is supplementary feeding (PMT). This nutritional intervention is designed to supplement rather than replace main meals.

A study conducted in Ecuador[8] discovered that eating one egg a day for six months improved weight-for-age z-scores by 0.61 points in children between the ages of six and nine months who were not suffering from severe acute malnutrition. Another study[9] reported that providing one egg daily for 30 days increased the weight of underweight toddlers aged 6-59 months by 0.3 kg. Furthermore, an intervention providing toddlers' lunch and fortified powdered milk three times a week for three months[10] and mothers' nutrition education improved nutritional status, with 5.7% of underweight children regaining normal weight and a 27.3% increase in the proportion of children with normal nutritional status.

Delivering mother's nutrition education alongside food interventions for toddlers can increase children's WAZ by 0.49 points.[11] Additionally, children's eating habits are influenced by their home environment.[12] Mothers and children's behavior and eating habits are positively impacted by nutrition education.[13] The provision of 16 weeks of nutrition education significantly increased the HEI score approximately 11.4%.[14]

Supplemental feeding is one method to improve toddlers' nutritional status by boosting nutrient intake, in addition to nutrition education. In order to sustain future growth and avoid long-term negative effects, underweight children need to consume enough energy and protein. Combining milk and eggs provides a highly complementary nutritional profile: milk supplies energy, carbohydrates, and essential micronutrients[15] such as calcium and phosphorus for bone development[16], while eggs contribute high-quality protein and fat.[17] A previous 90-day intervention showed that combined milk and egg consumption significantly improved overall nutrient intake in toddlers but did not lead to significant improvements in nutritional status.[18] Therefore, there remains a need to evaluate the longer-term impact of a sustained, combined food intervention and nutrition education. This study addresses this gap by examining changes in nutritional status, nutritional knowledge, nutrient adequacy, and diet quality following six months of combined milk–egg intervention and nutrition education among underweight toddlers. A hypothesis proposed was a six-month milk–egg intervention package combined with mother's education would be associated with significant positive shifts in mother's knowledge, animal-source protein intake, and toddler weight-for-age z-scores (WAZ).

Materials and Methods

A quasi-experimental single-group pre–post design was utilized to observe changes in dietary consumption and growth indicators over a six-month period. Between July and December 2025, the intervention was implemented in three districts: Pasuruan, Batang, and Karawang. The Health Research Ethics Committee of Muhammadiyah University of Semarang's Faculty of Nursing and Health has granted ethical approval for this study (No. 382/KE/05/2025). All participating children's parents or legal guardians are required to provide informed consent prior to study participation.

Children in the three districts of Karawang, Batang, and Pasuruan who were underweight and between the ages of 12 and 48 months made up the study population. Non-probability sampling was the method employed, and the District Health Office provided the data. The required sample size for the mean difference between two dependent means (matched pairs) was determined using G*Power 3.1.[19] Based on previous study of similar characteristics that involved a 90-day milk-egg intervention among toddlers[18], the sample size estimate was calculated using an effect size of 0.6, an alpha level of 0.05, and a power of 85%.

These presumptions meant that 42 children were the minimal sample size needed. However, a total of 276 children were enrolled and given the intervention for six months in order to improve population representativeness and preserve the external validity of the study findings. A larger group was initially enrolled to improve population representativeness across the three districts and to buffer against expected participant attrition over the six-month follow-up. Due to the demanding nature of a daily feeding intervention, some toddlers discontinued the study because of family relocation, non-compliance with daily milk and egg consumption (e.g. taste fatigue), or failure to attend the final anthropometric measurement sessions. Ultimately, 276 toddlers successfully completed the entire six-month protocol with complete anthropometric, dietary, and maternal knowledge records at both baseline and endline. A complete-case analysis was applied to this final cohort of completers, with no statistical imputation or intention-to-treat (ITT) analysis performed for any incomplete records. Children that are suitable the following requirements are eligible to participate:

1. Children between 12 and 48 months of age.
2. Children without comorbid conditions who have a WAZ (weight-for-age z-score) of -3 SD $\leq$ WAZ < -2 SD are classified as underweight.
3. Children who are not allergic to eggs or milk.
4. Children are not receiving nutritional intervention support from other programs.

Intervention

The intervention consisted of nutrition education and the provision of supplementary foods (milk and eggs). Nutrition education sessions were aimed at mothers of toddlers and community health volunteers (Posyandu cadres). Nutrition education sessions were conducted three times during the intervention period (once every two months), with each session lasting approximately 60 – 120 minutes. Educational sessions were delivered three times during the intervention period to the mothers of toddlers invited within their respective regions. The first session focused on 'Nutritional Problems and Child Dietary Patterns,' the second covered 'Healthy Snacks for Children and Ensuring Food Safety,' and the third addressed 'Clean and Healthy Lifestyle Practices' (commonly referred to in Indonesia as PHBS). In addition to the child-focused intervention, mothers of underweight toddlers also received a nutrition education intervention to support feeding practices.

Providing one serving of milk and one egg daily to an underweight toddler was implemented with the following considerations:

1. The intervention consisted of one serving of powdered milk (approximately 170 mL after adding water) and one egg per day.
2. In order to evaluate the effectiveness of the intervention and reduce the possibility of continued over-nutrition or undernutrition, indicators of improvement in children's nutritional status were regularly examined.
3. Implementation of the intervention was monitored regularly every month.
4. Close coordination was maintained with local health workers and facilities to ensure appropriate implementation of the intervention.
5. The nutritional composition of milk and eggs is presented in Table 1

Table 1: Nutrient composition of milk and eggs

Nutrients	Milk	Eggs		
	Nutrient content	RDA (%)	Nutrient content	RDA (%)
Energy (kcal)	170	12.4	85	6.2
Fat (g)	6	12.6	5.7	12.0
Protein (g)	5	22.2	6.8	30.2
Carbohydrate (g)	23	10.6	0.4	0.2
Iron (mg)	3.30	17.8	1.65	19.4
Phosphorus (mg)	140.0	29.2	141.9	29.6
Calcium (mg)	220.0	26.7	47.3	5.7

Data Collection

Data collection was conducted by trained enumerators consisting of students or graduates of Diploma (D3), Applied Bachelor (D4), or Bachelor (S1) programs in nutritional science. Prior to data collection, all enumerators received training to ensure a clear understanding of the questionnaire and research procedures and to address the research objectives accurately.

The data analysis used in this study is derived from a larger main study. The observed variables were nutrient intake, child and family characteristics, the frequency of milk and egg consumption, and dietary quality as measured by the Healthy Eating Index (HEI). Additionally, the children's nutritional health and underweight status were evaluated using the weight-for-age index (WAZ).

Child and Family Characteristics

The study gathered demographic and socioeconomic data to characterize the traits of the households and children. In-person interviews using a structured questionnaire were used to gather this data. Child age, birth weight, length, sex, history of infectious diseases (such as diarrhea and acute respiratory infections), residential area, parental age (father and mother), mother's age at marriage, parental occupation (father and mother), household income, and family size were among the variables gathered. Household income was divided into two categories: (1) non-poor (above the poverty level) and (2) poor (below the poverty line). This categorization was based on per capita income compared to the poverty line set by the World Bank[20], which is USD 2.15 per capita per day, equivalent to approximately IDR 1,044,062 per capita per month.

Mother's Nutritional Knowledge

Nutritional knowledge was assessed at baseline and endline. This refers to the nutritional knowledge of mothers whose toddlers are underweight. Scores were obtained through a 13-item questionnaire administered during interviews, with all items having undergone validity and reliability testing. Prior to the study, the questionnaire was pilot-tested among a comparable cohort of mothers in a non-study area to ensure clarity and appropriateness. The instrument demonstrated excellent construct validity, and its internal consistency was highly robust, yielding a Cronbach's alpha coefficient of >0.8, indicating a highly reliable scale for assessing nutritional knowledge. To create a standardized scale, the knowledge score was determined simply dividing the total number of items by the number of correct responses, then multiplying the result by 100. Subsequently, nutritional knowledge levels were categorized into three groups based on Khomsan (2021): (1) Poor (<60), (2) Moderate (60–80), and (3) Good (>80).[21]

Frequency of Milk and Egg Consumption

A standardized questionnaire was used in interviews to gather information on the frequency of milk and egg consumption. Four categories of ordinal data were collected to record the frequency of milk and egg consumption. The categories for milk consumption were (1) not consuming milk, (2) less than 2 times per week, (3) 2–3 times per week, and (4) 4–7 times per week or more. The categories for egg consumption were (1) no egg consumption, (2) less than 2 times per week, (3) 2–3 times per week, and (4) 4–7 times per week. Additionally, a one-day food recall approach was used to measure actual milk and egg intake. This technique calculated the daily intake of eggs (measured in grams), liquid milk (measured in milliliters), and powdered milk (measured in grams).

Nutritional Intake

A one-day food recall method was used to gather data on children's food consumption. The data was then processed using Microsoft Excel with the aid of the Indonesian Food Composition Table (TKPI) database[22]. The nutritional intake variables analyzed in this study included energy and macronutrient (protein, fat, and carbohydrate) intake. Furthermore, the one-day food recall results are used to categorize specific protein sources (such as milk, egg, fish, meat, poultry, and plant-based protein), yielding data on the amount of food consumed in that food category, expressed as weight in grams. Furthermore, the recall results are further subdivided into animal and plant proteins, which are displayed as protein intake in grams.

Diet Quality (HEI – Healthy Eating Index)

Further analysis to assess diet quality was conducted by analyzing children's nutritional intake data obtained from one-day dietary food recall using the Healthy Eating Index (HEI) instrument[23]. The Healthy Eating Index is used to evaluate overall diet quality, with components consisting of adequacy and moderation. The maximum score for the HEI is 100. Each component receives the maximum score if the food consumed meets the balanced nutrition guidelines (*Pedoman gizi seimbang* or PGS[24]). The standards for the maximum score and the standard for the minimum score of zero are used, taking into account the balanced nutrition guidelines (PGS) and the RDA (AKG[25]) for children. The detailed score classifications and cut-offs are presented in the supplementary files.

Dietary Diversity (IDDS)

Further analysis to assess dietary diversity was conducted by analyzing children's nutritional intake data obtained from a one-day food recall using the Individual Dietary Diversity (IDDS) instrument[26]. Cereals and tubers, dark green leafy vegetables, vitamin A-rich fruits and vegetables, other fruits and vegetables, organ meats, flesh meats and seafood, eggs, legumes and nuts, and milk and dairy products are the nine categories into which the dietary evaluation divided food intake. Consumption for each group was recorded using a binary scale (1 for 'Yes' and 0 for 'No') based on the participants' intake during the 24-hour period preceding the interview. The maximum IDDS score is 9 points.

The supplemental files provide the specific score classes and cut-offs.

Nutritional Status

Nutritional status was assessed by recording the children's weight, height, and birth dates, with data subsequently processed using the World Health Organizations (WHO) Anthro software. Body weight was measured using a digital scale. Depending on the child's age and ability to stand, stature was measured standing (using a microtoise) or lying down (using a length board). For measurements taken contrary to age guidelines (under two years standing, or over two years lying down), a 0.7 cm correction factor was applied prior to recording. Measurements were taken twice to increase validation by trained enumerators. This study focuses specifically on the weight-for-age z-score (WAZ)[1] indicator to evaluate potential improvements among underweight children following the intervention.

Table 2: Toddler and Family Characteristics

Characteristics	Total (n=276)
Toddler Profile	
Pasuruan / Karawang / Batang (Number of Toddlers in District), n (%)	111 (40.2) / 58 (21.0) / 107 (38.8)
Age (months), median (IQR)	35.3 (28.9 – 41.6)
Birth Weight (kg), median (IQR)	2.9 (2.7 – 3.2)
Birth Length (cm), median (IQR)	48.0 (47.0 – 50.0)
Gender (Female / Male), n (%)	150 (54.3) / 126 (45.7)
ARI (Acute Respiratory Infection) History (Yes), n (%)	62 (22.5)
Diarrhea History (Yes), n (%)	19 (6.9)
Parental Profile	
Father's Age / Mother's Age (years), median (IQR)	35.0 (30.0 – 40.0) / 30.0 (26.0 – 35.0)
Mother’s Age at Marriage (years), median (IQR)	20.0 (18.0 – 22.0)
Parental Education Level (Father/Mother), n (%)	
No formal education	2 (0.7) / 3 (1.1)
Primary school or equivalent	129 (46.8) / 127 (46.0)
Junior high school or equivalent	69 (25.0) / 77 (27.9)
Senior high school or equivalent	66 (23.9) / 55 (19.9)
Diploma (D-III)	2 (0.8) / 2 (0.7)
Bachelor’s degree (D-IV/S1)	8 (2.9) / 12 (4.3)
Parental Occupation (Father/Mother), n (%)	
Unemployed	1 (0.4) / 213 (77.2)
Entrepreneur	42 (15.2) / 23 (8.3)
Private sector employee	68 (24.6) / 11 (4.0)
Government employee	3 (1.1) / 2 (0.7)
Laborer	93 (33.8) / 1 (0.4)
Others	69 (24.9) / 26 (9.4)
Socio-Economic Status	
Household Income (IDR), median (IQR)	2,800,000 (2,000,000 – 4,079,167)
Poor / Non-Poora, n (%)	225 (81.5) / 51 (18.5)
Family Size, median (IQR)	5.0 (4.0 – 6.0)

a Poverty line based on the World Bank (USD 2.15/cap/day).[20]

Data Analysis

To achieve proper processing and check data quality, Microsoft Excel was used for data cleaning. IBM SPSS Statistics 26 was used for the statistical analysis. A complete-case analysis was applied. Follow-up measures, including repeat invitations for measurement, were undertaken to minimize missing data. Subjects who ultimately failed to attend were excluded, and no imputation or intention-to-treat analysis was conducted for incomplete records. This study used both descriptive and inferential statistics. For every measured variable, frequency distributions are displayed as descriptive data. Inferential analysis was utilized to evaluate changes before and after the six-month milk-egg intervention using the paired t-test for normally distributed data and the Wilcoxon signed-rank test for non-normally distributed data. Additional statistical analysis was selected based on the data's normalcy. For normally distributed data, the Pearson product-moment correlation test was employed; for non-normally distributed data, the Spearman rank test was employed. The independent t-test or the Mann-Whitney U-test were employed for two-group comparisons. For non-normally distributed data, the Kruskal-Wallis test was employed; for data with more than two normally distributed groups, the one-way ANOVA test was utilized. Furthermore, to address the multifactorial etiology of pediatric underweight, a multivariable Analysis of Covariance (ANCOVA) was performed to determine the independent predictors of endline Weight-for-Age Z-scores (WAZ). Statistical significance for all analyses was established at $p \leq 0.05$.

Results

Data on toddler and family characteristics included demographic and socioeconomic variables. A total of 276 toddlers participated in this study. Complete baseline characteristics of the toddlers and their families, based on demographic and socioeconomic variables, are presented in Table 2.

Furthermore, the relationship between baseline Weight-for-Age (WAZ) Z-scores and toddler-family characteristics was investigated. This analysis aimed to explore the association between WAZ and toddler features, household characteristics, and nutritional consumption data in order to identify factors associated with variations in underweight levels among toddlers prior to the intervention.

Table 3: Factors Associated with WAZ Before the Intervention

Variables	Statistics	p-value
Toddler and Family Characteristics		
Toddler Age (months)	$\rho = -0.012$	0.847[a]
Birth Weight (kg)	$\rho = 0.177$	0.003*[a]
Birth Length (cm)	$\rho = 0.075$	0.212[a]
Father's Age (years)	$\rho = 0.018$	0.762[a]
Mother's Age (years)	$\rho = 0.021$	0.732[a]
Mother's Age at Marriage (years)	$\rho = 0.023$	0.707[a]
Father's Education	H = 5.000	0.544[b]
Mother's Education	H = 1.790	0.877[b]
Father's Occupation	H = 8.040	0.430[b]
Mother's Occupation	H = 2.344	0.886[b]
Household Income (IDR)	$\rho = 0.032$	0.594[a]
Family Size	$\rho = -0.064$	0.289[a]
Infectious Diseases		
Acute Respiratory Infection (ARI)	Z = -0.885	0.376[c]
Diarrhea	Z = -1.780	0.075[c]
Dietary Intake		
Energy Intake (kcal)	$\rho = -0.078$	0.195[a]
Protein Intake (g)	$\rho = -0.045$	0.456[a]
Fat Intake (g)	$\rho = -0.144$	0.017*[a]
Carbohydrate Intake (g)	$\rho = -0.030$	0.624[v]

[a]Spearman's rank correlation; b Kruskal-Wallis Test; c Mann-Whitney Test; *Significant if p-value ≤ 0.05.

Variables related to nutritional status and milk–egg consumption at baseline and end line of the intervention are presented in Table 4. This table provides a descriptive frequency distribution of toddler nutritional status based on weight-for-age (WAZ), milk consumption, and egg consumption.

Table 4: Distribution of Mother's Nutritional Knowledge, Milk–Egg Consumption, Toddler Nutritional Status, and Infectious Diseases from Baseline to End line

Variables	Baseline		End line		% of Reduced or Increased
Mother's Nutrition Knowledge	**n**	**%**	**n**	**%**	
Poor (<60)	44	15.9	27	9.8	↓ 6.2
Moderate (60 – 80)	104	37.7	70	25.4	↓ 12.3
Good (>80)	128	46.4	179	64.9	↑ 18.5
Milk Consumption					
Not consuming milk	43	15.6	1	0.4	↓ 15.2
<2 times per week	52	18.8	2	0.7	↓ 18.1
2-3 times per week	41	14.9	4	1.4	↓ 13.4
4-7 times per week	140	50.7	269	97.5	↑ 46.7
Egg Consumption					
Not consuming eggs	1	0.4	1	0.4	–
<2 times per week	18	6.5	2	0.7	↓ 5.8
2-3 times per week	72	26.1	19	6.9	↓ 19.2
4-7 times per week	185	67.0	254	92.0	↑ 25.0
ARI in the past 2 weeks					
Yes	62	22.5	124	44.9	↑ 22.5
No	214	77.5	152	55.1	↓ 22.5
Diarrhea in the past 2 weeks					
Yes	19	6.9	26	9.4	↑ 2.5
No	257	93.1	250	90.6	↓ 2.5
Weight-for-Age Z-score (WAZ)					
−3SD ≤ Z-score < −2SD (Underweight)	276	100.0	196	71.0	↓ 29.0
−2SD ≤ Z-score ≤ +1SD (Normal)	0	0.0	80	29.0	↑ 29.0

A comparison of nutritional, dietary, and infectious disease variables among toddlers at the baseline and endline of the study is presented in Table 5. This table illustrates changes in toddlers' nutritional status scores, frequency of milk–egg consumption, nutrient intake, dietary quality, dietary diversity, and duration of infectious diseases. Statistical tests were conducted to determine significant differences between variables before and after the intervention.

Overall, the six-month intervention yielded positive distributional shifts in mothers' nutritional knowledge, dietary consumption, and nutritional adequacy categories at endline compared to baseline. Significant increases in average energy, protein, fat, and carbohydrate intakes were accompanied by a significant improvement in overall diet quality, as assessed by the Healthy Eating Index (HEI), reflecting a marked enhancement in toddlers' dietary patterns. Although dietary diversity (IDDS) exhibited a positive upward trend, this change did not reach statistical significance. This positive nutritional trajectory was highly consistent with the significant improvements in toddler Weight-for-Age Z-scores

(WAZ) and weight gain, indicating clinical recovery from underweight status after the intervention period. However, a concurrent increase in the duration and reporting of acute respiratory infections (ARI) was observed among toddlers during the six-month intervention period, highlighting the need for targeted sanitation and infection control strategies alongside dietary interventions.

Table 5: Baseline-Endline Changes in Mother's Nutritional Knowledge, Milk–Egg Consumption, Nutrient Intake, and Toddler Nutritional Status from Baseline to Endline

Variables	Baseline[a]	Endline[a]	Δ[a]	p-value[b]
Mother's Nutritional Knowledge Score	74.6 ± 17.7	82.2 ± 17.1	7.6 ± 13.9	<0.001*
Powdered Milk Consumption (g)	10.5 ± 28.1	40.2 ± 29.2	29.7 ± 38.5	<0.001*
Liquid Milk Consumption (ml)	69.8 ± 121.5	41.0 ± 82.2	-28.8 ± 131.7	<0.001*
Egg Consumption (g)	51.2 ± 48.0	66.1 ± 45.9	14.9 ± 61.5	<0.001*
Energy Intake (kcal)	1043.0 ± 377.8	1202.0 ± 318.4	159.0 ± 417.3	<0.001*
Protein Intake (g)	34.6 ± 14.0	39.3 ± 12.7	4.7 ± 17.2	<0.001*
Plant-based protein intake (g)	3.3 ± 5.9	1.9 ± 3.2	-1.4 ± 6.5	0.002*
Animal-source protein intake (g)	19.5 ± 11.5	22.4 ± 9.0	2.9 ± 13.4	<0.001*
Fat Intake (g)	41.2 ± 19.4	45.1 ± 15.4	3.9 ± 22.3	0.004*
Carbohydrate Intake (g)	130.8 ± 51.9	163.2 ± 63.5	32.4 ± 70.9	<0.001*
Healthy Eating Index (HEI)	54.3 ± 10.9	58.9 ± 11.6	4.5 ± 14.7	<0.001*
Dietary Diversity (IDDS)	5.9 ± 1.5	6.1 ± 1.5	0.2 ± 2.1	0.172
Weight-for-Age Z-score (WAZ)	-2.4 ± 0.2	-2.2 ± 0.4	0.2 ± 0.3	<0.001*
Weight (kg)	10.3 ± 1.2	11.4 ± 1.3	1.1 ± 0.5	<0.001*
ARI duration in the past 2 weeks (days)	0.8 ± 1.8	2.3 ± 3.4	1.4 ± 3.8	<0.001*
Diarrhea duration in the past 2 weeks (days)	0.2 ± 0.9	0.2 ± 0.8	0.0 ± 1.2	0.547

[a]Data presented as mean ± standard deviation; bWilcoxon Signed Rank-Test; *Significant if p-value ≤ 0.05.

Table 6: Multivariable ANCOVA Model for Factors Determining Endline Weight-for-Age Z-Score

Predictor / Covariate	Unstandardized B	Std. Error	F-value	p-value	95% Confidence Interval (B)
Baseline WAZ	0.680	0.082	68.682	<0.001*	[0.519, 0.842]
ARI duration in the past 2 weeks (days)	-0.021	0.006	12.717	<0.001*	[-0.032, -0.009]
Endline Mother's Nutritional Knowledge Score	0.003	0.001	4.785	0.030*	[0.000, 0.005]
Animal-source protein intake (g)	0.006	0.003	3.846	0.051	[-0.000, 0.012]
Gender (Female vs Male)	-0.118	0.063	11.276	0.001*	[-0.242, 0.006]
Districts	—	—	0.888	0.413	—
Pasuruan	-0.050	0.067	—	0.452	[-0.182, 0.081]
Karawang	0.103	0.084	—	0.222	[-0.063, 0.268]
Batang (Reference)	0[a]	—	—	—	—

Based on a backward elimination approach, statistically non-significant covariates that did not improve the explanatory power of the model (such as partial macronutrient intakes: energy, total protein, fat, and carbohydrates) were excluded from the final model. This simplification increased degrees of freedom and statistical power. Specific grammages of powdered milk, liquid milk, and eggs were included as control variables in the model estimation but are presented cumulatively under the Animal-Source Protein Intake variable to avoid multicollinearity among intervention food items.

Discussion

The distribution of study areas across the three districts was relatively balanced. This cross-regional distribution reflects the heterogeneity of social, economic, and cultural contexts, which can influence children's diets and feeding practices. A total of 276 toddlers were included in this study, with a median age of 35.3 months (IQR = 28.9–41.6). Respondents were in the toddler age group, mostly aged two to three years. This age range represents the golden period, considered a critical phase for children's growth and development, particularly for physical and brain development.[27] A critical phase of development characterized by rapid development of sensory abilities, cognitive functions, language skills, speech, social behavior, and other important developmental domains[28] occurring during the first 1,000 days of life.

The median birth weight of toddlers was 2.9 kg (IQR = 2.7–3.2), indicating that, on average, they were not classified as low birth weight (LBW).[29] However, some infants had a birth length <48 cm, with a median birth length of 48.0 cm (IQR = 47.0–50.0). Gender distribution was relatively balanced, suggesting minimal potential gender-related bias in intervention outcomes. A history of infectious diseases was also assessed, specifically acute respiratory infections (ARI) and diarrhea. At baseline, 22.5% of children had an ARI, while 6.9% had diarrhea.

Family characteristics included father's and mother's age, education, and occupation, as well as other socioeconomic indicators such as household income and family size. The median age of fathers was 35.0 years (IQR = 30.0–40.0), while the median age of mothers was 30.0 years (IQR = 26.0–35.0), indicating that most parents were in the productive age group.[30] The median age of mothers at marriage was 20.0 years (IQR = 18.0–22.0). This median is above the legal minimum age for marriage for women in Indonesia, which is 19[31], although some cases were recorded below this threshold. Mothers aged 15–19 have reportedly double the risk of pregnancy-related death compared to women aged 20 and over. This increased risk is associated with biological factors as well as limited access to antenatal, delivery, and postnatal care. As a result, premature birth, complicated deliveries, and low birth weight are more common in children born to younger mothers.[32] Older mothers' age at marriage is associated with later age at childbirth, which may contribute to improved child nutritional status.[33] However, age alone does not determine optimal parenting and feeding practices.

Adequate education and socioeconomic status are also important, as they influence household food choices.[34] Child care and feeding practices can also be shaped by cultural and ethnic factors, parental experience, age at marriage, and educational attainment, which collectively influence family practices.[35] Furthermore, increasing mothers' caregiving capacity can improve the provision of energy and protein intake for children.[36] The majority of parents' education levels were elementary school. Most fathers (46.7%) and mothers (46.0%) had completed elementary school or its equivalent, followed by junior high and senior high school. The proportion of parents with higher education (diploma and bachelor's degree) was very low (<5%). This relatively low level of education can impact nutritional literacy, understanding of proper feeding practices, and the ability to access health information, as education is closely related to the absorption of information and individual skills.[37]

In terms of employment, the majority of fathers worked in the informal and semi-formal sectors, such as laborers (33.8%), others (such as service workers) (24.9%), private employees (24.6%), and entrepreneurs (15.2%). This pattern reflects the predominance of jobs with unstable incomes and vulnerability to economic fluctuations. Meanwhile, the majority of mothers were unemployed or housewives (77.2%), which may provide advantages in terms of time devoted to caregiving but remains highly dependent on the overall economic stability of the household. The median household income was IDR 2,800,000 (IQR: IDR 2,000,000–4,079,167), and the majority of families (81.5%) were classified as poor and living below the poverty line according to World Bank[20] criteria. This condition indicates a high level of economic vulnerability in the study population. Low socioeconomic status is an important determinant of malnutrition, as it is associated with limited access to nutritious food, reduced dietary diversity, and limited access to health services.[38] The median family size was 5 members (IQR: 4–6), with almost half categorized as small families (50.0%), although a substantial proportion of medium and large families were also present. Larger family size can increase the household's economic burden and influence food distribution within the household[39]. These structural determinants underscore the high baseline vulnerability of the cohort, moderation by which must be considered when evaluating program effectiveness.

Bivariate analysis of baseline determinants showed that birth weight showed that birth weight has a significant positive correlation with weight-for-age z-score (WAZ) ($\rho = 0.177$; $p = 0.003$). Toddlers with higher birth weights tended to have better nutritional status. Birth weight is known to be a predictor of lean body mass, although its association with later overweight is relatively weak.[40] Toddlers with low birth weight have a higher risk of mortality, and each 1 kg increase in birth weight is associated with increased bone mineral concentration and a reduced risk of cardiovascular death.[41] Birth weight was also associated with triglyceride levels, although not with LDL, with triglycerides potentially mediated by BMI in adulthood.[42] Overall, higher birth weight was associated with more favorable metabolic outcomes. In contrast, birth length did not show a statistically significant association with nutritional status ($p = 0.212$). This suggests that birth weight may have a stronger influence on weight-based anthropometric indices, such as the WAZ, than birth length.

Other socioeconomic variables (including toddler age, father's and mother's age, mother's age at marriage, parental education, parental occupation, household income, and family size) did not show a significant association with underweight. Infectious diseases also did not show a significant association with underweight status in this study. Despite the well-established infection-malnutrition cycle, where infectious diseases can impair nutrient absorption, increase metabolic demands, and reduce appetite, ultimately contributing to weight loss.[43] The findings of this study did not demonstrate such an association. This may be because the incidence of infectious diseases in children is influenced not only by nutritional status but also by environmental sanitation, hygiene practices[44], access to health services, and exposure to infectious agents. In terms of dietary factors, fat intake showed a significant negative association with underweight ($\rho = -0.144$; $p = 0.017$). This may reflect an imbalanced diet, where increased fat intake is not accompanied by improvements in overall diet quality. One possible explanation is the high consumption of snack foods among toddlers, which are typically low in essential nutrients but high in fat and carbohydrates.[45] Thus, even if fat intake increases, it does not necessarily contribute to better nutritional status due to poor dietary quality. Meanwhile, no significant bivariate associations were found between total energy, protein, carbohydrate intake, and nutritional status. Children in low- and middle-income countries (LMICs) face a higher burden of risk factors for developmental delays compared to children in high-income countries.[46] A comprehensive and holistic approach is increasingly recognized as essential for identifying determinants of nutritional status in children under five years of age.[47] Early-life interventions are crucial; nutrition interventions, including micronutrient supplementation and complementary feeding, have demonstrated greater impact in improving outcomes compared to other strategies.[48] However, further research should also target broader determinants such as mother's education and WASH (water, sanitation, and hygiene), which are expected to play a critical role in addressing global child development challenges.[48] Achieving optimal nutritional status requires ensuring adequate nutritional intake from the early stages of life.[33]

The ANCOVA model revealed that baseline WAZ ($B = 0.680$, $p < 0.001$) was the primary predictor of endline WAZ, indicating strong physical growth tracking. Endline mother's nutritional knowledge ($B = 0.003$, $p = 0.030$) and cumulative animal-source protein intake ($B = 0.006$, $p = 0.051$) maintained positive associations with endline WAZ after adjustment. Female toddlers exhibited lower endline WAZ scores that males ($B = -0.118$, $p =$

0.001). Notably, district-level differences (Pasuruan, Karawang, Batang) were not statistically significant ($p = 0.413$), demonstrating that intervention operated consistently across geographically distinct locations despite regional socioeconomic variations.

Following the six-month intervention, mother's nutritional knowledge showed a significant improvement after the intervention, with an overall increase of 18.5%. The proportion classified as having good nutritional knowledge increased significantly from 46.4% at baseline to 64.9% after the intervention. Conversely, the proportion of mothers with poor nutritional knowledge decreased from 15.9% to 9.8% (−6.2%). Improved maternal knowledge correlates with better child weight management, enhanced dietary selection, and heightened caregiving awareness. Mothers' nutritional knowledge also improved significantly, with an average increase of 7.6 points. Furthermore, mothers' nutritional knowledge was positively and significantly associated with children's body weight.[49] Previous studies have shown that nutrition education can improve mothers' knowledge, which in turn may contribute to the prevention of nutritional problems in children.[50] Improving mothers' understanding of their child's nutritional status is likely to increase awareness in providing an appropriate diet and adequate healthcare.[51] Furthermore, nutrition education has been linked to improved mothers' ability to choose safe and appropriate foods for their children.[50] These improvements were subsequently reflected in children's dietary intake patterns, indicating positive changes in food consumption.

This educational advancement accompanied high intervention adherence. Toddlers consuming milk 4-7 times per week increased from 50.7% to 97.5%. Analysis of the aggregate dietary data across the study population revealed significant shifts in total consumption between baseline and endline. Representing the cumulative intake of all participants, the findings highlight a substantial increase in the consumption of powdered milk (mean baseline = 10.5 g; mean endline = 40.0 g) and eggs (mean baseline = 51.2 g; mean endline = 65.8 g), which nearly doubled and showed a considerable elevation, respectively, alongside a positive trend in fish (mean baseline = 13.3 g; mean endline = 14.9 g) intake. Conversely, aggregate consumption of meat (mean baseline = 23.1 g; mean endline = 15.9 g) and liquid milk (mean baseline = 69.8 ml; mean endline = 41.0 ml) declined, plant-based protein sources (mean baseline = 20.6 g; mean endline = 21.7 g) and poultry (mean baseline = 16.5 g; mean endline = 18.1 g) intake remained relatively stable. The previous data reflects the types of foods consumed by participants, while the nutritional analysis shows changes in protein intake over the study period. Total protein intake increased significantly from 34.6 ± 14.0 g to 39.3 ± 12.7 g, with a mean difference of 4.7 ± 17.2 g ($p < 0.001$), representing an increase of approximately 13.6%. The increase in total protein intake was primarily driven by higher reported consumption of animal-source protein from milk and eggs, which increased from 19.5 ± 11.5 g to 22.4 ± 9.0 g ($p < 0.001$), equivalent to an increase of approximately 14.9%. Conversely, plant protein intake decreased significantly from 3.3 ± 5.9 g to 1.9 ± 3.2 g ($p = 0.002$), representing a decrease of approximately 42.4%.

These findings indicate a substantial shift in dietary pattern toward higher-quality protein sources, such as eggs, milk, fish, meat, and poultry. Animal-based protein is considered high-quality protein because it provides a complete range of essential amino acids with high bioavailability[52], which is important for supporting child growth, tissue development[53], bone growth, neurocognitive development[54], and overall nutritional status. Therefore, increased animal-based protein intake may have positively contributed to the increase in total protein intake observed in this study. Meanwhile, the decrease in plant-based protein intake may indicate that participants relied less on plant-based protein sources such as tofu, tempeh, and nuts during the intervention period. This pattern may reflect increased dietary diversity and increased access to nutrient-dense foods, particularly animal-based foods. This marked increase in milk and egg consumption aligns with the intervention's six-month daily supplementation protocol and the accompanying nutritional education sessions. Overall, increased total protein intake, particularly from animal sources, may support better growth outcomes and help reduce the risk of malnutrition in children.

All aspects of dietary intake improved after the study. Average energy (+15.2%), protein (+13.6%), fat (+9.4%), and carbohydrate (+24.8%), while overall diet quality improved by 8.4% and dietary diversity by 2.9%. Despite improvements in dietary intake, levels remained below the Recommended Dietary Allowance (RDA), indicating that children's nutritional needs were not fully met. This indicates that diet quality gains stemmed from higher consumption of specific provided nutrient-rich foods rather than broad diversification across new food groups. Furthermore, despite post-intervention increases, total nutritional intake remained below Recommended Dietary Allowances (RDA). Because 81.5% of households live below the poverty line, low purchasing power and staple price volatility continue to constrain full dietary adequacy beyond intervention-provided foods.

The toddler's nutritional status improved after the intervention. At the beginning of the study, all toddlers were classified as underweight, but after the intervention, there was a positive shift toward normal nutritional status. Nutritional status improved by 29% from the beginning of the study, with 80 toddlers moving to normal status. Despite improvements in nutrition and child weight (mean gain of 1.1 kg; 29% moving to normal WAZ status), infectious disease patterns presented a contrasting dynamic. Acute respiratory infection (ARI) duration in the preceding two weeks increased significantly from baseline to endline ($p < 0.001$; multivariable B = -0.021, $p < 0.001$), whereas diarrhea duration remained unchanged ($p = 0.547$). The worsening ARI morbidity may indicate that participants remained exposed to risk factors for respiratory infections throughout the study period. These factors likely include poor ventilation and inadequate indoor air quality[55], as well as seasonal variations[56], and ongoing community transmission.[57] In contrast, the duration of diarrhea remained relatively unchanged, suggesting a more stable pattern of gastrointestinal morbidity.

The frequency of both diarrhea and ARI in the past 2 weeks increased at endline compared with baseline. This finding may indicate that participants remained exposed to infectious risk factors during the intervention period. The increase in morbidity could be related to seasonal variation[58], environmental conditions[59], inadequate sanitation[60], or household transmission[57], which were not directly targeted by the intervention. In addition, nutritional interventions may require a longer duration to produce measurable effects on infectious morbidity outcomes. The multivariable ANCOVA model confirms that intercurrent ARI episodes significantly attenuate weight recovery. Consequently, nutritional supplementation alone is insufficient to fully eliminate growth faltering unless complemented by interventions targeting indoor air quality, hygiene practices, and infection control.

The weight gains and WAZ improvements observed in this trial align with existing global literature on animal-source food supplementation. A study showed egg consumption can increase fat and protein intake[17], and that a 90-day combined milk–egg intervention can significantly improve overall nutritional intake in toddlers.[18] This finding is particularly important given that the intervention included nutrition education and the daily provision of milk and eggs. However, the majority of participating households (82%) were below the poverty line, which may have limited their ability to access a wide range of foods beyond those provided through the intervention. Low income growth and inadequate control of staple food prices can lead to an inability to access, purchase, make, or prepare food.[61] Lack of access to nutritious and affordable food is associated with poor diet quality and an increased risk of nutrition-related diseases.[62] Consequently, while the intervention may have improved specific aspects of diet quality, broader dietary adequacy and diversity remain constrained by underlying socioeconomic conditions.

All dietary intake variables showed significant improvements following the intervention, with the exception of dietary diversity. Dietary diversity did not change significantly during the intervention period; however, a positive trend was observed. In contrast, overall diet quality improved significantly, indicating that although the variety of foods consumed did not increase substantially, the nutritional value and quality of the diets improved. Given the limited changes in dietary diversity, the observed increase is most likely explained by increased consumption of nutrient-rich foods rather than food group diversification.

In turn, these dietary changes were accompanied by improvements in nutritional status, as evidenced by changes in WAZ and body weight. Interventions in the form of providing eggs and milk as well as nutritional education linked to 29% of toddlers to achieve normal nutritional status. The toddler's weight increased significantly, with an average increase of 1.1 kg at the end of the intervention. These results are consistent with previous research. A study among schoolchildren in China[7] showed that consuming one egg per day improved underweight status. Similarly, a study in Ecuador[8] of toddlers aged 6–9 months found that daily egg consumption for six months increased WAZ by 0.61 and decreased underweight prevalence by 74%. Furthermore, children in the intervention group showed higher egg consumption and reduced intake of sweets compared to the control group. Overall, egg consumption is an effective, accessible, and nutrient-rich intervention, particularly for children experiencing chronic malnutrition.[7]

Other studies have reported similar findings. Research among toddlers in Karawang showed that providing food and milk three times a week for three months improved nutritional adequacy and nutritional status in underweight children[10]. Milk supplementation for 45 days in stunted toddlers aged 1-3 years[63] was also shown to significantly increase weight gain by 185 g, while a 16-week milk intervention in toddlers without nutritional problems (normal nutritional status) aged 3.5 – 4 years[64] improved nutrient intake and growth compared to a non-intervention group with increased weight gain by 1.3 points and an increase in WAZ by 0.64 points. Animal-source foods, particularly milk, play a crucial role in addressing malnutrition in children.[63] Milk and dairy products provide energy, protein, and essential micronutrients that support growth and development.[15] Furthermore, milk consumption has been shown to significantly improve bone health, particularly in the forearm, highlighting its potential as a strategic dietary intervention to support skeletal development in children.[16]

Milk and eggs represent accessible, high-density source foods containing essential protein, micronutrients, and energy vital for skeletal and tissue development. However, because this study utilized a single-group pre-post design without a randomized parallel control group, the observed physical growth trajectories cannot be attributed exclusively to the intervention. Uncontrolled factors, such as normal child developmental growth velocity, regression to the mean, and secular seasonal trends, may also have contributed to the observed anthropometric improvements. Overall, these findings indicate that integrating daily milk and egg provision with maternal education is associated with improved nutrient adequacy, dietary quality, and weight recovery in underweight toddlers within socioeconomically vulnerable environments.

Several methodological limitations must be acknowledged when interpreting these findings. Most prominently, as a quasi-experimental single-group pre–post-trial lacking a randomized parallel control group, this study cannot definitively establish direct causality. Consequently, the observed anthropometric and dietary trajectories (including improvements in toddler weight, WAZ scores, and maternal knowledge) cannot be completely isolated from external confounding influences. These include underlying secular trends in childhood growth and regression toward the mean among severely underweight children occurring during the six-month period. Additionally, dietary intake was assessed using 24-hour dietary recalls, which may be subject to recall bias and social desirability bias from participating mothers.

Conclusion

In conclusion, a six-month combined intervention package consisting of daily milk and egg supplementation alongside maternal nutrition education was associated with positive shifts in maternal nutritional knowledge, animal-source protein consumption, overall diet quality, and toddler weight recovery. An adjusted multivariable ANCOVA model confirmed that endline nutritional status was independently predicted by baseline WAZ, maternal knowledge, and animal protein intake, while intercurrent acute respiratory infections exerted a significant negative counter-effect on growth.

These findings suggest that community-based egg and milk provision combined with maternal education represents a promising strategy for targeted malnutrition programs in vulnerable rural communities. However, given the non-controlled design of this pre–post-trial, these results should be considered preliminary before being applied in other locations. Future research should prioritize rigorously designed randomized controlled trials (RCT), and integrated water, sanitation, and hygiene (WASH) components to effectively decouple nutritional intervention effects from seasonal trends, health-system activities, and environmental morbidity burdens.

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Conflict of Interest
The author(s) do not have any conflicts of interest.

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Ethics Statement
This study was approved by the Health Research Ethics Committee of the Faculty of Nursing and Health, Universitas Muhammadiyah Semarang (No. 382/KE/05/2025).

Informed Consent Statement
Informed consent was obtained from the parents or legal guardians of all children involved in this study.

Clinical Trial Registration
This research does not involve any clinical trials.

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Not Applicable.

Author Contributions

- **Ali Khomsan:** Conceptualization, Supervision, Methodology, Writing – Original Draft.
- **Dzakiyyatul Fikrah 'Arifah:** Visualization, Data Collection, Writing – Original Draft.
- **Nabila Sukma Priyatnasari:** Visualization, Project Administration, Data Collection.
- **Arrumaisha Khansa Kirana Puspaindria:** Visualization, Data Collection.
- **Jennifer Handaja:** Conceptualization, Funding Acquisition, Resources, Supervision.
- **Yunita Purnama Sari:** Funding Acquisition, Resources, Supervision.
- **Charisma Dilantika:** Funding Acquisition, Resources, Supervision.
- **Ida Susilaksmi:** Project Administration, Data Collection, Resources of Sampling.
- **Joko Prasetijo:** Project Administration, Data Collection, and Resources of Sampling.
- **Hendriawan Sulistiyo:** Project Administration, Data Collection, and Resources of Sampling.
- **Mandumah:** Project Administration, Data Collection, and Resources of Sampling.
- **Nurmala Hasanah:** Project Administration, Data Collection, and Resources of Sampling.
- **Ekawati Agustiana:** Project Administration, Data Collection, and Resources of Sampling.

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