IJCNP : (Indonesian Journal of Clinical Nutrition Physician)

Open Access Full Text Article

KUDUS COHORT STUDY: A TWO-YEAR NUTRITIONAL OBSERVATION OF NEWBORN COHORT UNDER GEMAS INITIATIVE

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Abstract

Maternal and child nutritional issues remain significant public health challenges in Indonesia. Longitudinal cohort data on growth and development from pregnancy through early childhood are scarce. This study describes the nutritional status of a cohort of children assessed at birth and at 6, 12, and 24 months. This operational study included 3,895 newborn infant, 874 children followed from birth to 1 year, and 110 children tracked over the same period till 2 years. Anthropometric measurements of body weight and length were collected. Findings indicate that stunting should not be the sole focus when assessing nutritional status in children up to 2 years of age. Wasting also persists as a significant nutritional issue, with its prevalence increasing when the exclusive breastfeeding period was completed. Low birth weight (LBW) is recognized as an important factor of infant growth and development through 12 months. Implementation of a single-package intervention in the Gemas Maternal and Child Health Program was effective in promoting catch-up growth among cohort children following the exclusive breastfeeding period.

Key words: catch-up growth, Kudus Cohort Study, low birth weight, stunting, wasting.

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

INTRODUCTION

After 80 years of independence, Indonesia is still burdened with major public health problems. MCH problems such as the MMR, IUGR, LBW, undernourished and severely malnourished under-five children, including stunting and micronutrient deficiencies;[1] chronic infectious diseases such as tuberculosis, parasitic infestations like helminthiasis, filariasis and malaria, are still observed to be persistent[2] as if they cannot be overcome even though strengthening primary health care programs has been carried out for decades with increased resources and budgets.[3] Public health problems in Indonesia are becoming increasingly complex with the high incidence and prevalence of NCDs, such as cerebro-cardio-vascular diseases with their risk factors such as overweight and obesity, diabetes, hypertension, dyslipidemia, and cancers,[4] which have drained significant funds from the Social Health Insurance Agency (*Badan Penyelenggara Jaminan Sosial*).[5,6]

Nutrition plays a crucial role in the MCH program. It encompasses the entire spectrum of life, from adolescent girls and brides-to-be, pregnant women and their fetuses, newborns, 2-year old children, and 5-year old children. In this context, Indonesia launched the National Strategy to Accelerate Stunting Prevention (*Stranas Stunting*) in 2017, which was formalized in 2021 through Presidential Regulation No. 72.[7] The program's initial focus was on improving nutrition and health services for pregnant women and children under two, driven by a multi-sectoral, coordinated approach involving various government agencies, civil society organizations, and the private sector.

The elimination of malnutrition and stunting in Indonesia is a complex issue. The WHO defines stunting as the impaired growth and development that children experience due to poor nutrition, repeated infection, and inadequate psychosocial stimulation.[8] Clearly, there are three key elements that are strongly inter-related: chronic malnutrition, repeated infection, and psychosocial stimulation. These three key elements should be used to construct intervention modalities when needed. Although Indonesia ranks among the top four countries in the incidence of lung tuberculosis world-wide,[9] until now, there is no data on the prevalence of malnutrition and stunting in households with lung tuberculosis, given the fact that the core family in Indonesia may be extended to second level family tree, grandparents. Therefore, there is still piecemeal interdisciplinary action against malnutrition and stunting.

With the complexity of the abovementioned public health problems, accompanied by the existence of regional autonomy,[10-12] there is a need for the evidence of regional existence by developing a community-based MCH program model as a complementary and supporting programs to the government's MCH program, especially the regional governments of Central Java and Kudus Regency, so that evidence-based policy recommendations and solutions can be formulated. *Gemas* (Movement to Preserve the Golden Age) MCH Program, initiated by the Universitas Diponegoro, Indonesian Medical Association Kudus Regency, and Kudus Health Regency is a model of health and nutrition program that potentially leverages a key strategy for institutional- and community-based health nutritional interventions.

This study aimed to describe the nutritional status of a cohort of two years old children, starting at birth, and then at 6, 12, and 24 months of age. This paper also explains the extent to which nutritional status at birth may influence the ability to catch-up growth in later months/years.

METHODS

STUDY DESIGN

The design of this project was an operational study. The recruitment of the participants followed the scheduled times of the working team. Overall, the recruitment procedures were real-life. Therefore, our cohort was a partially *retrospective* rather than a *prospective cohort* with a complete set of predetermined criteria, as in well-designed studies. Group participants were informed that apart from their nutritional and clinical assessments, consultation and appropriate medical treatment were also delivered, and their data would be used for scientific deliberations. Prior group informed consent was obtained, and the data were kept confidential and anonymous. The proposal and protocol of this operational study were approved by the Komisi Etik Penelitian Kesehatan, Faculty of Medicine, Universitas Diponegoro, Semarang, Indonesia *(Ethical Clearance No. 007/EC/KEPK/FK-UNDIP/I/2026).*

TARGET GROUP

The target group of this study was a cohort of newborn infants until two-year old children. These children were obtained from a cohort of pregnant mothers who work as cigarette rollers located in Kudus Regency, Central Java Province.

Conduct of the study

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

The Gemas MCH Program is a wide-ranging operational study that involves many project elements, so that observations can be carried out comprehensively. The human resource elements include field implementing cadres, supervisors, and project management, DCGs (monitor clinical parameters and deliver medical treatment), health regency, heads of Primary Health Care centers (to synchronize Primary Health Care Center data), academics to monitor the academic value of the project, anthropometric assessors, data administrator, and biostatistician.

Roles of cadres

The preparation of Gemas MCH Program started in 2017 with the recruitment of a number of dedicated cadres. They were trained (for two months) to undertake the following responsibilities: 1). Developing MCH training materials, which covered materials for pregnant women (1st - 3rd trimester of pregnancy), nutrition, child's growth and development, children's health, and pregnancy exercises; 2). Socializing and training on nutrition and lifestyle (pregnancy and growth and development); and 3). Measuring BW and BL/Ht for monitoring and evaluation of under-five children's growth and development.

Roles of DCGs

The Gemas MCH Program involved 30 primary care physicians practicing at Primary Health Care facilities *(Faskes Pratama)*. The primary care physician group is part of the DCG. The DCGs implemented primary care programs in their respective areas for the target population of women-of-reproductive-age, pregnant women, and under-five children.

The DCGs' main responsibilities were: 1). providing primary care to newborn infants with LBW and or stunting, and appropriately referring them to the pediatricians; and 2). providing primary care to infants and toddlers with developmental disorders, including the treatment of diagnosed infectious diseases.

Roles of Lokadata

The Gemas MCH Program involves Lokadata (founded in 2016), a data research and analytics firm that focuses on assisting organizations and companies in strategic decision-making *(http://lokadata.id/)*. In this study, Lokadata's primary functions included cleaning raw data from the field, converting raw data into database format, and interpreting them in the dashboard development for the regular monitoring and evaluation of the project.

Anthropometric measurement

Anthropometric indicators were measured by trained personnels. With appropriate clothes, BW was measured in kilograms to the nearest 0.1 kg using a digital scale (Onemed type EB-7010, Indonesia). Ht was measured in centimeters to the nearest 0.1 cm standing position with bare feet, using a microtois (GEA stature meter, China). The BW and BL of the newborn infants were measured in kilograms and centimeters to the nearest 0.1 kg and 0.1 cm using an infant scale and infantometer (Onemed type 721, Indonesia), respectively. WHO Child Growth Standards was used to define nutritional status of newborn infants, infants and under-five years old children.[13,14]

Operational definitions

Table 1 describes the following definitions of cut-off for newborn infants, infants, and two years old children.

Table 1. Operational definitions and cut-off values.

Parameter	Cut-off values/Measurement	Interpretation
Nutritional status		
Newborn baby		
Birth weight[17,18]	< 2.5 kg	Low birth weight
	≥ 2.5 kg	Normal birth weight
Body length[17,18]	< 48 cm	Stunted newborn baby
	≥ 48 cm	Normal body length
Under-five children		
Weight-for-age z-score (WAZ)[13,14]	-2 ≤ WAZ ≤ +1	Normal
	-3 ≤ WAZ < -2	Moderate underweight
	WAZ < -3	Severe underweight
Height-for-age z-score (HAZ)[13,14]	HAZ > +2	Tall for age
	-2 ≤ HAZ ≤ +2	Normal
	-3 ≤ HAZ < -2	Moderately stunted
	HAZ < -3	Severely stunted
Weight-for-height z-score (WHZ)[13,14]	-2 ≤ WHZ < +1	Normal
	-3 ≤ WHZ < -2	Moderate wasting

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

WHZ < -3	Severe wasting

[13]WHO and UNICEF. United Nations Children's Fund. WHO child growth standards and the identification of severe acute malnutrition in infants and children: A Joint Statement. Geneva: World Health Organization; 2009.
[14]World Health Organization. WHO child growth standards: length/height-for-age. weight-for-age. weight-for-length. weight-for-height and body mass index-for-age: methods and development. Geneva: World Health Organization; 2006.

Nutritional intervention strategies for infants after 6-month old till two years old children

All newborn infants till two years old children were required to undergo a nutritional assessment once a month for 24 months. Their nutritional status was evaluated monthly. If BW and or BL/Ht were stagnant in two subsequent measurements, they were referred to the DCGs for medical evaluation and treatment of any underlying illnesses, and whenever necessary, they were referred to the pediatricians.

In the Gemas MCH Program, both specific and sensitive nutritional interventions were delivered. Nutrition-sensitive intervention was undertaken in other projects with relevant partners. Figure 1 illustrates the framework of the Gemas MCH Program. The nutrition-specific intervention strategies for infants after 6-month old till two years of age followed the following principles: 1). For wasting (W/H z-score): from mild to severe, nutritional intervention was in the form of complementary foods (fresh milk, energy-dense biscuits, incrementally with additional daily energy intake of approximately 200 – 400 kcal and protein 6 – 11 g) and multi-vitamins; 2). For stunting (H/A z-score): a) if wasting was present, nutritional intervention followed the wasting pattern. b) if wasting was absent, nutritional intervention followed the stunting pattern (fresh milk, energy-dense biscuits, incrementally with additional daily energy intake of approximately 150 – 300 kcal and protein 5 – 10 g) and multi-vitamins; 3). if there were accompanying illnesses in the form of infections such as diarrhea, helminthiasis and other parasitosis, pulmonary tuberculosis (children and parents or other family members in the same house), it was absolutely necessary to treat them regularly. 4). nutritional education and parenting skills. Appropriate refrigerators were provided for the storing of milked breast-milk during working hours.

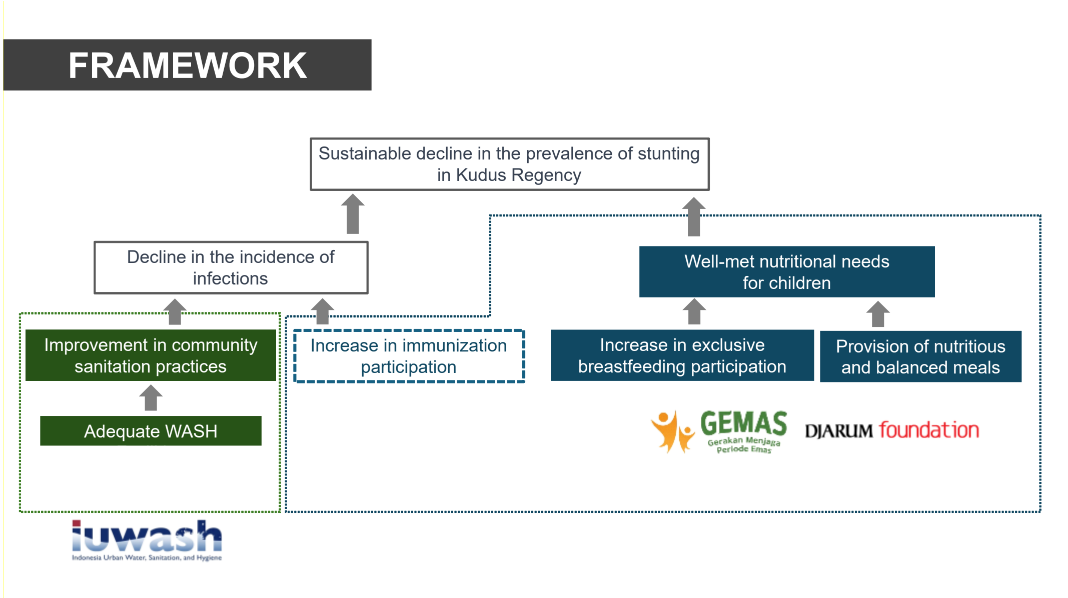

Figure 1. Framework of the Gemas MCH Program.

Data Management and Data Cleaning Procedures

A template database structure was developed, and statistical exclusion was performed to filter outlier values and improve the study's internal validity. Data were treated as categorical and numerical data. Categorical data included data on gender (1= male, 2= female), newborn infants' BW (1= < 2.5 kg, categorized as LBW; 2= ≥ 2.5 kg categorized as NBW) and stunting condition (1= < 48 cm, categorized as stunted newborn infants; 2= ≥ 48 cm, categorized as non-stunted newborn infants). Numerical data on the newborn infants and under-five years old children consisted of age at the first encounter (months) and age at subsequent visits, BW at birth (kg) and BW (kg) at the subsequent visits (in months), BL at birth (cm) and BL or Ht (cm) at the subsequent visits. The compiled data were carried forward in the analyses during regular observation of newborn infants, and the growth and development of children till the age of 24 mos.

The WHOAnthro application was used to convert the anthropometric data of the under-five children to z-scores, namely weight-for-age, height-for-age, and weight-for-height z-scores (WAZ, HAZ, and WHZ, respectively). WHOAnthro undertook basic self-cleaning anthropometric data of the newborn infants' BW and BL, which were assumed to be premature or twin babies. Only newborn infants from singleton and matured pregnancy were included in the analyses.

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

We had an initial data of 4,020 newborn infants. We then performed data cleaning in stages. The following newborn infants were excluded: 1). 69 newborn infants with BW < 2 kg.; 2). 22 newborn infants with BL > 55 cm; 3). two newborn infants with missing BL values; 4). five newborn infants with BW of 5.2, 5.6, 7, 7.4, and 7.8 kgs, as the WHOAnthro produced a value of 999.99 indicating 'the child's data is biologically implausible'; 5). 18 newborn infants with BL ranging 12 - 37 cm, as the WHOAnthro produced a value of 999.99, which means 'the child's data is biologically implausible'.[18] Furthermore, we excluded 9 under-two years old children, who had BL/Ht differences at aged 12 months minus aged 6 months less than or equal zero. At this data cleaning stage, we had a total number of 3895 children.

We then defined a cohort of the children with several age points: 1) newborn infants, whose nutritional status is the outcome of intrauterine growth and development; 2) infants aged 6 months, considering that this age marks the end of exclusive breastfeeding; 3) children aged 12 mos, considering that this age point is important for observing the capacity of early catch-up growth; 4) children aged 24 mos, considering that this age has been known as the end of 'the golden age period'.

From the above data cleaning steps, we obtained the first cohort with the same children from newborn, aged 6 months, and aged 12 months of 874 cohort children. For the second cohort with the same children from newborn, aged 6 mos, aged 12 mos, and aged 24 mos, we obtained a total of 110 cohort children. Figure 2 shows the flowchart of the data cleaning of the children.

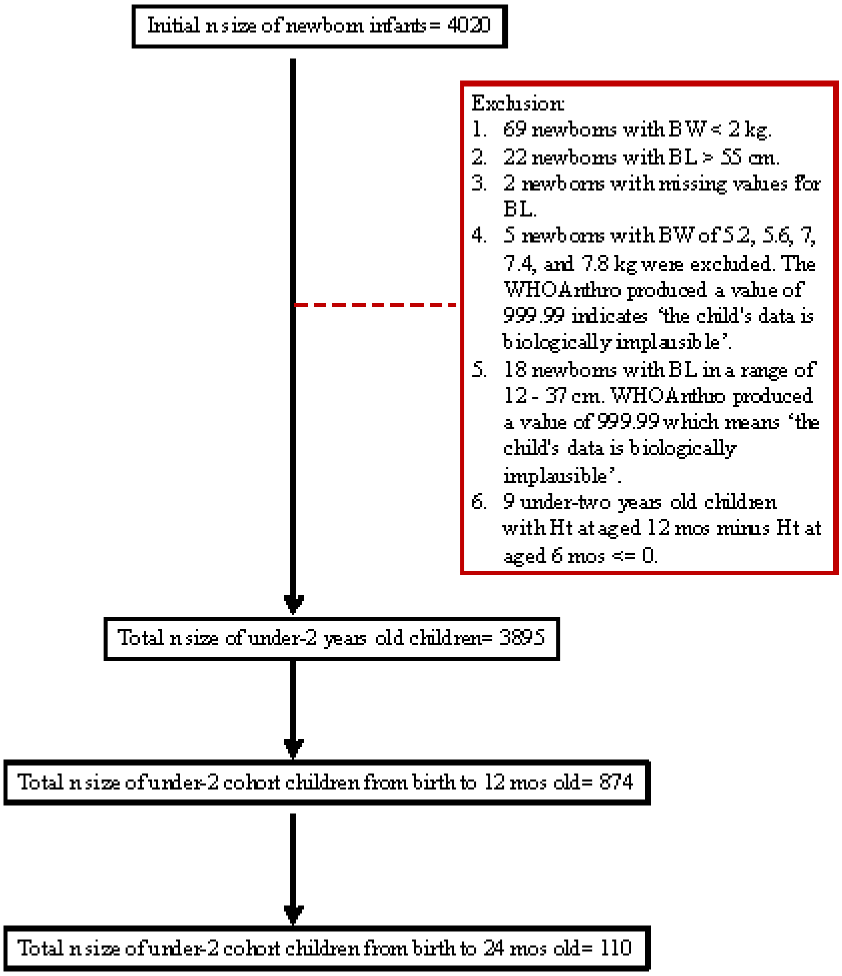

Figure 2. Flow chart of the data cleaning of under-two years old children.

Statistical Analyses

Data analyses were performed using IBM SPSS version 25. The distributions of continuous variables were assessed for normality using the Kolmogorov-Smirnov. For continuous variables with normal distribution, such as BW, BL/Ht, descriptive statistics were presented as means ± SD, otherwise, they were presented as median (minimum – maximum).

We used the WHO Anthro Survey Analyser[15] to detect extreme outliers in the data. It said 'The syntax file flags any extreme (i.e. biologically implausible) z-scores for each indicator. The extreme z-scores were defined as follows: weight-for-age z-score (WAZ) WAZ < -6 or WAZ > 5; length/height-for-age z-score (HAZ), HAZ < -6 or HAZ > 6; weight-for-length/height z-score (WHZ), WHZ < -5 or WHZ > 5'.[15]

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

Basic descriptive analyses were done at 4 age group data points, namely at birth, aged 6, 12, and 24 mos old. In the subsequent analyses, we performed descriptive analyses on the cohorts at birth, 6, and 12 mos of age; and the same analyses on the cohorts at birth, 6, 12, and 24 mos of age.

The newborn infants' nutritional status, LBW *vs* NBW and stunted *vs* non-stunted newborn infants, was then explored whether it determined their catch-up growth at the age of 6, 12, and 24 mos, respectively. Significant differences of catch-up growth values at each age point were statistically tested using t-test if the catch-up growth values were normally distributed, or Mann-Whitney test if the values were not normally distributed.

RESULTS

In the dataset, the number of children aged 6, 12, and 24 mos was not equal. This was due to the fact that in time of the data analyses, some children had not yet reached the age of 6, 12, or 24 mos for the monitoring of their nutritional status. Furthermore, some children were absent when the monitoring of nutritional status was due.

The prevalence of LBW newborn infants was 8.9%, and the prevalence of stunted newborn infants was 28.1%. These values are presented in Table 2.

Table 2. Prevalence of low-birth weight and stunted newborn infants.

Birth weight category	n	Percent	Body length category	n	Percent
BW < 2.5 kg	346	8.9	BL < 48 cm	1094	28.1
BW ≥ 2.5 kg	3549	91.1	BL ≥ 48 cm	2801	71.9

Notes: BW= body weight at birth/body weight; BL= body length at birth; Ht= height.

Tables 3 explains the growth and development of the cohort children observed continuously from birth, aged 6, and 12 mos. The mean and median of nutritional status values in the context of WHZ, WAZ, and HAZ did not indicate wasting, underweight, or stunting according to WHO criteria. Severe wasting, severe underweight, and severe stunting values were seen at the minimum values across different age cohorts.

Table 3. Changes in nutritional status of 874 cohort children during observation at birth, 6, and 12 months old.

	WHZ			WAZ			HAZ		
	At birth	6 mos	12 mos	At birth	6 mos	12 mos	At birth	6 mos	12 mos
N	847	869	872	874	872	874	874	874	873
Missing	27	5	2	0	2	0	0	0	1
Mean	-0.42	-1.14	-0.81	-0.65	-0.01	-0.54	-0.77	-0.95	-0.87
Median	-0.41	-1.10	-0.80	-0.62	-0.12	-0.60	-0.73	-0.92	-0.84

SD		1.15	1.31	1.21	1.01	1.44	1.33	0.92	1.00	1.06
Minimum		-4.28	-5.00	-4.71	-5.98	-5.92	-5.06	-3.21	-4.28	-4.12
Maximum		4.69	4.68	4.58	2.07	4.24	3.78	2.67	2.42	3.61
Percentiles	10	-1.92	-2.85	-2.37	-2.05	-1.80	-2.20	-1.91	-2.18	-2.21
	25	-1.17	-1.98	-1.61	-1.15	-0.95	-1.46	-1.42	-1.59	-1.55
	50	-0.41	-1.10	-0.80	-0.62	-0.12	-0.60	-0.73	-0.92	-0.84
	75	0.24	-0.32	-0.04	0.06	0.96	0.34	-0.10	-0.28	-0.23
	90	0.98	0.50	0.71	0.46	1.97	1.24	0.31	0.34	0.48

Notes: WHZ= weight-for-height z-score; WAZ= weight-for-age z-score; HAZ= height-for-age z-score; mos= months.

However, when we look at the prevalence of wasting, underweight and stunting (Figure 3), the results were different. The prevalence of wasting (WHZ < 2) in 6-mo-old infants was almost three fold higher than that of newborn infants. The prevalence declined by ~7% in 12-mo old children compared to the 6-mo-old children.

On the other hand, the prevalence of severe stunting (HAZ < 2) at birth was 10.6%, but it was lower at 6.9% in 6-mo-old infants, and then went up at 12.1% in 12-mo old children.

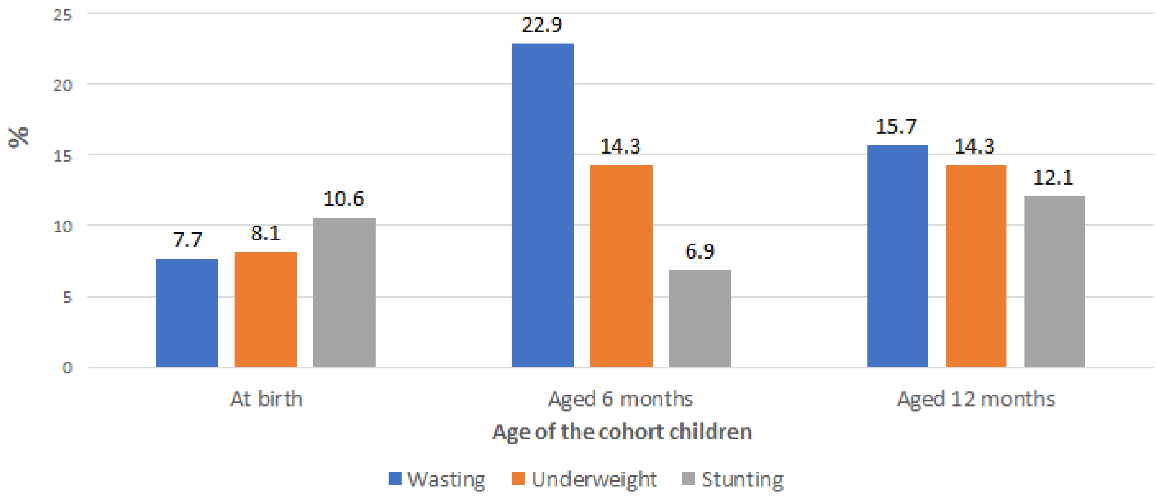

Figure 3. Changes in the prevalence of wasting, underweight, and stunting of 874 cohort children during observation at birth, 6, and 12 months old.

Tables 4 explains the growth and development of the cohort children observed continuously from birth, aged 6, 12, and 24 mos. The mean and median of nutritional status values in the context of WHZ, WAZ, and HAZ did not indicate wasting, underweight, or stunting according to WHO

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

criteria. Severe wasting, severe underweight, and severe stunting values are seen at the minimum values across different age cohorts.

Table 4. Changes in nutritional status of 110 cohort children during observation at birth, 6, 12, and 24 months old.

		WHZ				WAZ				HAZ			
		At birth	6 mos	12 mos	24 mos	At birth	6 mos	12 mos	24 mos	At birth	6 mos	12 mos	24 mos
n		106	110	109	110	110	110	110	110	110	110	110	110
Missing		4	0	1	0	0	0	0	0	0	0	0	0
Mean		-0.46	-1.21	-1.07	-0.55	-0.59	0.23	-0.30	-0.67	-0.75	-0.86	-0.97	-0.72
Median		-0.43	-1.27	-1.07	-0.83	-0.47	0.08	-0.39	-0.63	-0.73	-0.82	-0.90	-0.83
SD		1.10	1.30	1.10	1.42	1.00	1.53	1.39	1.17	0.90	1.03	1.06	1.24
Minimum		-3.36	-4.68	-3.43	-3.88	-4.69	-3.19	-5.06	-4.06	-3.21	-4.28	-3.80	-3.47
Maximum		4.69	1.84	1.75	4.90	1.12	3.82	3.35	2.20	2.63	1.89	1.67	3.66
Percentiles	10	-1.91	-2.93	-2.47	-1.98	-2.05	-1.63	-2.09	-2.38	-1.88	-2.13	-2.45	-2.13
	25	-1.01	-2.05	-1.84	-1.44	-1.00	-0.83	-1.12	-1.31	-1.42	-1.59	-1.72	-1.51
	50	-0.43	-1.27	-1.07	-0.83	-0.47	0.08	-0.39	-0.63	-0.73	-0.82	-0.90	-0.83
	75	0.19	-0.42	-0.27	0.08	0.06	1.40	0.69	-0.05	-0.16	-0.19	-0.22	-0.06
	90	0.69	0.44	0.37	1.21	0.59	2.14	1.50	1.02	0.36	0.35	0.24	0.77

Notes: WHZ= weight-for-height z-score; WAZ= weight-for-age z-score; HAZ= height-for-age z-score; mos= months.

However, when we look at the prevalence of wasting, underweight and stunting (Figure 3), the results were different. The prevalence of wasting (WHZ < 2) of 6-mo old infants was more than 2.5 times higher than that in the newborn infants. The prevalence then declined to 15.1% and 12.8% at aged 12-mo and 24-mo old children, respectively.

The prevalence of stunting (HAZ < 2) at birth was 9.7%, then declined to 6.7% in 6-mo old infants, but then went up to 15% in 24-mo old children.

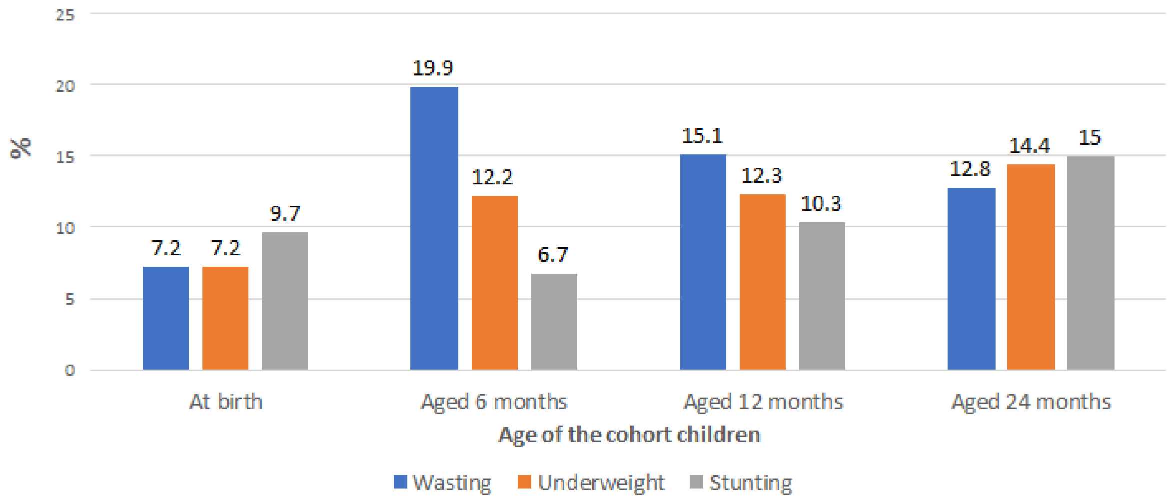

Figure 4. Changes in the prevalence of wasting, underweight, and stunting of 110 cohort children during observation at birth, 6, 12, and 24 months old.

Tables 5 and 6a, and b describe the extent to which LBW *vs* NBW, and stunted *vs* non-stunted newborn infants were determinants of growth and development of children aged 6, 12, and 24 mos. Existing data demonstrated that catch-up growth in children aged 6 to 12 mos with BW at birth < 2.5 kg and BL at birth < 48 cm was significantly lower than their counterparts with BW at birth ≥ 2.5 kg and BL at birth ≥ 48 cm.

Table 5. Catch-up growth at 6 mos and at 12 mos between LBW *vs* NBW, and between stunted *vs* non-stunted newborn infants.

BW/BL category of newborn infants	n	BW at 6 mos (kg)	p	BW at 12 mos (kg)	p	Ht at 6 mos (kg)	p	Ht at 12 mos (kg)	p
LBW < 2.5 kg	88	6.40 (4.90 – 9.30)	0.000	8.00 (6.10 – 11.10)	0.000	65.05 (59.50 – 75.50)	0.000	72.00 (64.50 – 84.00)	0.000
NBW ≥ 2.5 kg	786	7.00 (4.70 – 10.40)		8.54 (5.50 – 18.00)		67.50 (49.00 – 78.00)		74.00 (64.50 – 85.00)	
Stunted (birth BL < 48 cm)	257	6.80 (4.70 – 9.50)	0.000	8.40 (6.10 – 18.00)	0.000	66.30 (49.00 – 75.00)	0.000	73.10 (64.50 – 84.00)	0.000
Non-stunted (birth BL ≥ 48 cm)	617	7.10 (4.90 – 10.40)		8.60 (5.50 – 14.40)		67.90 (51.00 – 78.00)		74.50 (64.50 – 85.00)	

Notes: Notes: BW= body weight at birth/body weight; BL= body length at birth; Ht= height; mos= months. Values are presented in median (minimum – maximum). Differences between groups of BW and BL at birth are calculated using Mann-Whitney test.

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

Table 6a. Catch-up growth at 6 mos, 12 mos, and 24 mos between LBW *vs* NBW, and between stunted *vs* non-stunted newborn infants.

BW/BL category of newborn infants	n	BW at 6 mos (kg)	P	BW at 12 mos (kg)	P	BW at 24 mos (kg)	P
LBW < 2.5 kg (n= 7)	7	6.94	0.006	8.08	0.016	9.50 (8.20 – 17.10)#	0.089
NBW ≥ = 2.5 kg (n= 103)	103	7.22		8.63		11.00 (8.30 – 18.50)#	
Stunted (birth BL < 48 cm)	24	6.97	0.548	8.48	0.650	11.20 (8.20 – 13.20)#	0.648
Non-stunted (birthBL ≥ 48 cm)	86	7.27		8.63		10.92 (8.30 – 18.50)#	

Notes: Notes: BW= body weight at birth/body weight; BL= body length at birth; Ht= height; mos= months. Values are presented in mean ± SD. T-test was used to assess significance between the groups. #Values are presented in median (min – max). Differences between groups of BW and BL at birth are calculated using Mann-Whitney test.

If we extend the observation to 24 months of age, LBW was only able to predict the growth of BW in children up to 12 mos of age, but not in children aged 24 mos. Furthermore, LBW predicted the growth of BL/Ht in children up to 12 mos of age, but not in children aged 24 mos.

Table 6b. Catch-up growth at 6 mos, 12 mos, and 24 mos between LBW *vs* NBW, and between stunted vs non-stunted newborn infants.

BW/BL category of newborn infants	n	Ht at 6 mos (kg)	p	Ht at 12 mos (kg)	p	Ht at 24 mos (kg)	p
LBW < 2.5 kg	7	67.29	0.011	74.52	0.004	83.64	0.060
NBW ≥ = 2.5 kg	103	68.35		75.06		84.92	
Stunted (birth BL < 48 cm)	24	68.44	0.761	75.42	0.250	84.29	0.763
Non-stunted (birthBL ≥ 48 cm)	86	68.23		74.91		84.90	

Notes: BW= body weight at birth/body weight; BL= body length at birth; Ht= height; mos= months. Values are presented in mean ± SD. T-test was used to assess significance between the groups. Values are presented in median (min – max) in differences between birth weight category for birth weight at 24 mos. Differences between groups of BW and BL at birth were measured using Mann-Whitney test.

DISCUSSION

This study attempts to explain the nutritional status of cohort children from birth, through to aged 6, 12, and 24 mos. Data on changes in the nutritional status of cohort children is hardly available in Indonesia. One landmark study in Indonesia that examined the nutritional status of children through adolescence was the Tanjungsari Cohort Study, which initially conceptualized for perinatal and neonatal research with the goal of reducing mortality rates.[16] The Kudus Cohort Study is more comprehensive than the Tanjungsari Cohort Study. In the Kudus

Cohort Study, researchers also observed fetal growth and development in the womb, and more comprehensive nutritional parameters are assessed, and complemented with specific and sensitive nutritional interventions.

In this study, both specific and sensitive nutritional interventions were delivered. As far as the nutrition-specific intervention is concerned, it consisted of complementary foods such as fresh milk, energy-dense biscuits, and multivitamins, but the compliance was not assessed. Therefore, to determine whether improvements in nutritional status were due to nutrition-specific interventions in this study could not be ascertained. Clearly, this paper discusses interventions in the form of the overall Gemas MCH Program, which covers both specific and sensitive nutritional interventions, aiming at improving the health and nutritional status of pregnant women and under-five children.

The prevalence of LBW in newborn infants in this study was approximately 2% higher than that of the 2023 SKI national data, and the prevalence of stunted newborn infants was approximately 8% higher compared to the 2023 SKI national data, and 4% higher than that of the SKI Central Java data.[17] The only explanation for the discrepancy in these figures is the difference in the calculation, where the calculation of prevalence in SKI was using a proportion, ie. the proportion of low birth weight/low birth length= number of children aged 0-59 months with birth weight < 2500 g or birth length < 48 cm divided by total number of children aged 0-59 mos with LBW/LBL times 100%, whereas in the Gemas MCH program, due to its smaller scope area, the calculation of prevalence is the number of LBW or LBL values divided by the total population of newborn babies.

One finding of this study, which may have been previously reported, is the consistency of data regarding growth faltering at the end of the exclusive breastfeeding period, with different trajectory values.[18,19] These findings are consistent across both cross-sectional and cohort observation, although the mean and median values of nutritional status in our data have not exceeded the cut-off value to indicate wasting or stunting.

An important note from our data is the increasing prevalence of wasting in infants aged 6 mos, following the end of exclusive breastfeeding. Meanwhile, the prevalence of stunting declined during the same period. In fact, the nutrition specific intervention in this study was carried out on infants after 6 mos

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

of age, which is the age after the end of exclusive breast-feeding. Early growth faltering could be consequential for persistent growth faltering and mortality during the first 24 months of life.[20]

Of many references, wasting during the exclusive breastfeeding period is less thoroughly explored. During exclusive breastfeeding, a newborn's sole source of nutrition is breast milk. Therefore, we must ensure a balance between the quantity, frequency, and quality of breast milk and the newborn's calorie and nutritional needs, aiming to achieve desirable growth and development of the newborns.

The energy requirements of a newborn weighing 2.5 kg range from 250 - 337 Kcal per day, which should be met with a volume of breast milk of 400 - 450 mL per day.[21] Human lactation study showed that there is an incremental volume of breast milk production from the first day of breastfeeding at 56 mL/day to 848 mL/day on the 180th day. However, breast milk intake in infants is slightly lower than the available breast milk volume.[22] While the breastfeeding rate is high among Asians[23] including Indonesians, there is no adequate data on the daily volume of breast milk given to infants. Damanik et al.[24] conducted a phenomenal study by providing 150 g of Torbangun (*Coleus amboinicus* Lour) lactagocum per day in the form of soup to mothers after giving birth, they were able to demonstrate the increment of the volume of breast milk by 361 mL on the 8th day, then increasing to 479 mL on the 28th day, further 440 mL on the 40th day, and again increasing to 478 mL on the 50th day. They concluded that the Torbangun lactagocum was able to extend its effect until the 2nd month after giving birth. Indonesia has quite variety of breast milk enhancers like katuk leaves *(Sauropus androgynous)*[25] and papaya leaves (*Carica papaya*)[26] that can be studied and explored for their application in breast-feeding mothers. It seems reasonable to promote lactagocum to early breastfeeding mothers, especially those in rural areas and marginalized mothers, so that breast milk volume can meet the daily energy needs of newborns.

It was reported that newborn infants with a history of IUGR experiencing growth retardation in BL/Ht during 12-month observation.[27] We conducted a similar analysis by comparing newborn infants with LBW vs NBW and stunted vs non-stunted growth and development of BW and BL/Ht at the ages of 6, 12, and 24 months. It has been well documented that LBW infants, to many extent, is due to the existence of IUGR during pregnancy.[28-30] Our data again confirm the previous findings that LBW seems to be a strong predictor for the growth and development of children aged 6 to 12 months. Therefore, IUGR and LBW are priorities that cannot be ignored to overcome LBW, and wasting, as well as stunting in

Indonesian children's later life. The inability of LBW newborn infants to predict child growth and development up to 24 mos could be due to the small sample size in the cohort observation of growth and development up to 24 mos.

Overall, the data demonstrate that although catch-up growth occurs during infancy, infants born with LBW or low BL remain significantly smaller than their normal counterparts at both 6 and 12 mos of age. These findings suggest that IUGR exerts a sustained influence on early postnatal growth trajectories, underscoring the importance of early-life nutritional and growth monitoring, and appropriate interventions for infants born with suboptimal anthropometric parameters. Delivery of interventions under Gemas MCH Program has demonstrated positive catch-up growth outcomes of the children at 12 and 24 mos of age.

CONCLUSION

Results of this study strongly indicate that stunting should not be the only primary issue in defining the nutritional status of infants up to 2 years of age. Wasting is also an unresolved nutritional problem, and its prevalence indeed increases at the end of exclusive breastfeeding period. This condition should be of concern for policymakers, and promotion of increased breast milk volume and feeding frequency should be intensified, and the use of lactagocum should be considered to fulfill the energy requirements of exclusively breast-fed infants. Nutritional intervention, both specific and sensitive should be delivered, aiming to achieve positive catch-up growth outcomes of under-2 year children at 12 and 24 mos of age. Delivery of one package intervention in Gemas MCH Programs seemed to be effective for positive catch-up growth of the cohort children after the end of the exclusive breast-feeding period.

It is apparent from the current findings that LBW is an important factor of infant growth and development up to 12 mos of age. LBW is a well-known outcome of IUGR during pregnancy, and this notion justifies reporting fetal growth and development data in the near future. Nutritional interventions for at-risk pregnant women should be prioritized.

Acknowledgment

We would like to thank the management team of the Yayasan Djarum for its continuous support on the Gemas MCH Program: Mr. Achmad Budiharto, the Program Director, Mr. David Setiadi, the Deputy Program Director, and Dr. Roscoe

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

Pongoh, the Deputy Manager for Community Development, who, with their enthusiasm, have jointly monitored and evaluated the program with their subordinate program implementers.

We are grateful to the cadres and field supervisors for their diligence and perseverance in delivering the health and nutrition promotion to the mothers, measuring nutritional parameters, and providing complementary feeding to infants after they have completed the exclusive breastfeeding period. We thank all mothers of the infants and 2-year old children who have actively participated in this study.

We are thankful to Lokadata team coordinated by Mr. Maulana Ihsan Wardhaha, who has monitored and evaluated the making of data cohort, and audit the data entry, especially for presumed extreme outlier values.

We are indebted to Mr. Deddy Andy who has carried out comprehensive data cleaning, and made the data meet the logic for statistical analyses. We are appreciative with the help of Dr. Sutantik E. W. Kasunjatan, a qualified clinical epidemiologist and biostatistician, who has undertaken basic and advanced statistical analysis.

This project is fully supported by Yayasan Djarum, an independent nonprofit organization established in 1986 that operates in accordance to the laws of the Republic of Indonesia.

Competing Interest

The authors declare no competing interest since the commencement of the study until the development of this manuscript. Dr. Widjaja Lukito is a member of the Editorial Board of the Indonesian Journal of Clinical Nutrition Physician.

List of Abbreviations

BL: body length; BW: body weight; CHD: coronary heart disease; CVD: cardio-vascular disease; DCGs: Doctors Closed Group; Faskes: fasilitas kesehatan; Gemas: Gerakan Menjaga Periode Emas; HAZ: height-for-age z score; Ht: height; IUGR: Intra-Uterine Growth Restriction; LBW: low birth weight; MCH: maternal and child health; MMR: Maternal Mortality Rate; MoH: Ministry of Health; mos: months; NBW: normal birth weight; NCDs: Non-Communicable Diseases; PHCC: Primary Health Care Center; SD: standard deviation; SKI: Survei Kesehatan Indonesia; Stranas: Strategi Nasional; UNICEF: United Nations Children's Fund; WAZ: weight-for-age z score; WHO: World Health Organization; WHZ: weight-for-height z score.

Authors' Contribution

FAR and ABH: deliberated leadership in the Gemas MCH Program, supervised the overall conduct of the project, reviewed the draft manuscript and provided significant inputs to the final manuscript.

AS[3] and AF: coordinated the DCGs in the regular deliberation of providing medical and nutritional promotion and treatment, ensured the quality of ultrasound reports for the data validity, provided significant inputs on the conduct of the study for the completeness of describing Methods in the manuscript, reviewed the draft manuscript, and provided significant inputs to the final manuscript.

AA: deliberated leadership in the coordination amongst Primary Health Care Centers, supervised the data quality provided by Primary Health Care Centers, reviewed the draft manuscript, and provided significant inputs to the final manuscript.

DW, INK, DAK, NHA, and S: synchronized the data of pregnant mothers (risks for the development of non-communicable diseases) and newborns data (birth weight) with the Gemas MCH Program; undertook health and nutrition promotion; involved in the monitoring and evaluation of the project.

DCGs: undertook medical and nutritional care for under-five children with severe malnutrition, provided medical care for pregnant mothers with risks for non-communicable diseases, appropriately referred pregnant mothers with serious diseases that may impair pregnancy outcomes, undertook ultrasonography assessment, assessed fetal development.

AS[12-14] and WL: monitored, evaluated, and provided academic advices during the conduct of the study; ensured the project had valid dataset and statistical interpretations that aligned with academic standards; undertook statistical analyses, conceptualized, drafted, wrote, and finalized the manuscript.

Availability of Data and Materials

The supplementary materials are available as an attachment of this manuscript.

Declaration on the Use of Artificial Intelligence

The authors declare that artificial intelligence (AI) tools were utilized solely for language editing and grammatical refinement to improve the clarity and readability of the manuscript. The specific AI tool used was Grammarly Pro. AI was not involved in content generation, data analysis, interpretation, or any decision-making processes. All scientific content, interpretations, conclusions, and responsibilities related to the manuscript rest solely with the authors.

REFERENCES

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

1. Central Bureau of Statistics, Republic of Indonesia. *Angka kematian bayi menurut Provinsi 1971, 1980, 1990, 1994, 1997, 2000, 2002, 2007, 2010, 2012* (Infant mortality rate by provinces 1971, 1980, 1990, 1994, 1997, 2000, 2002, 2007, 2010, 2012) [cited 2018/11/1] Available from: https://www.bps.go.id/statictable/2009/02/20/1270/angka-kematian-bayi-menurut-provinsi-1971-1980-1990-1994-1997-2000-2002-2007-2010-2012-dan-kematian-dibawah-usia-lima-tahun-menurut-provinsi-1971-1980-1990-1994-1997-1999-2007-dan-2012-.html
2. Fauziyah S, Putri SMD, Salma Z, Wardhani HR, Hakim FKN, Sucipto TH, et al. How should Indonesia consider its neglected tropical diseases in the COVID-19 era? Hopes and challenges (Review). Biomed Rep 2021;14:53. doi:10.3892/br.2021.1429
3. Gillespie S, Mason J, Martorell R, eds. How nutrition improves – nutrition policy discussion paper no. 15. A report based on an ACC/SCN workshop held on 25-27 September 1993 at the 15th IUNS International Congress on Nutrition. Adelaide. Australia.
4. Gani A, Budiharsana MP. The consolidated report on Indonesia health sector review 2018: National health system strengthening. Jakarta: Ministry of National Development Planning/Bappenas; 2019.
5. Marthias T, Anindya K, Nawi Ng, McPake B, Atun R, Arfyanto H, et al. Impact of non-communicable disease multimorbidity on health service use, catastrophic health expenditure and productivity loss in Indonesia: a population-based panel data analysis study. BMJ Open 2021;11:e041870. doi:10.1136/bmjopen-2020-041870
6. Nurwahyuni A, Soewondo P, Nadjib M, Farianti Y, Mukhlisa MN, Wahyuningsih H, et al. Health care spending for cardiovascular disease under National Health Insurance Scheme in Indonesia before and during COVID-19: Descriptive analysis and policy recommendations. J Indones Health Policy Adm. 2023;8:79-88. doi:10.7454/ihpa.v8i2.6851
7. *Peraturan Presiden Republik Indonesia Nomor 72 Tahun 2021 Tentang Percepatan Penurunan Stunting* [Presidential Regulation of the Republic of Indonesia on the Acceleration Stunting Reduction]. Jakarta: Government of the Republic of Indonesia; 2021 (in Indonesian).
8. World Health Organization. Reducing stunting in children: equity considerations for achieving the Global Nutrition Targets 2025. Geneva: World Health Organization; 2018.
9. World Health Organization. Global tuberculosis report 2023. Geneva: World Health Organization; 2023. Licence: CC BY-NC-SA 3.0 IGO.
10. Undang-Undang Republik Indonesia Nomor 25 Tahun 1999 Tentang Perimbangan Keuangan antara Pemerintah Pusat dan Daerah [Law of the Republic of Indonesia on Financial Balance between Central and Regional Government]. Jakarta: Government of the Republic of Indonesia; 1999 (in Indonesian).
11. Undang-Undang Republik Indonesia Nomor 22 Tahun 1999 Tentang Pemerintahan Daerah [Law of the Republic of Indonesia on Regional Government]. Jakarta: Government of the Republic of Indonesia; 1999 (in Indonesian).
12. Undang-Undang Republik Indonesia Nomor 23 Tahun 2014 Tentang Pemerintahan Daerah [Law of the Republic of Indonesia on Regional Government]. Jakarta: Government of the Republic of Indonesia; 2014 (in Indonesian).
13. World Health Organization. United Nations Children's Fund. WHO child growth standards and the identification of severe acute malnutrition in infants and children: A Joint Statement. Geneva: World Health Organization; 2009.

14. World Health Organization. WHO child growth standards: length/height-for-age. weight-for-age. weight-for-length. weight-for-height and body mass index-for-age: methods and development. Geneva: World Health Organization; 2006.
15. World Health Organization. WHO Anthro Survey Analyser. Geneva: World Health Organization, 2019.
16. Lukito W, Wibowo L, Wahlqvist ML. Maternal contributors to intergenerational nutrition, health, and well-being: revisiting the Tanjungsari Cohort Study for effective policy and action in Indonesia. Asia Pac J Clin Nutr 2019;28(Suppl 1):S1–S16. doi:10.6133/apjcn.201901_28(S1).0001.
17. *Kementerian Kesehatan Republik Indonesia Badan Kebijakan Pembangunan Kesehatan* (Ministry of Health of the Republic of Indonesia, Health Development Policy Agency). *Survei Kesehatan Indonesia (SKI) 2023 Dalam Angka* (Indonesia Health Survey (IHS) 2023 in Figures), 2023 (in Indonesian).
18. Victora CG, de Onis M, Hallal PC, Blössner M, Shrimpton R. Worldwide timing of growth faltering: revisiting implications for interventions. Pediatrics 2010;125:e473–e480. doi:10.1542/peds.2009-1519
19. Shrimpton R, Victora CG, de Onis M, Lima RC, Blössner M, Clugston G. Worldwide timing of growth faltering: implications for nutritional interventions. Pediatrics 2001;107:1-7. URL: http://www.pediatrics.org/cgi/content/full/107/5/e75
20. Mertens A, Benjamin-Chung J, Colford Jr JM, Coyle J, van der Laan MJ, Hubbard AE, et al. Causes and consequences of child growth faltering in low-resource settings. Nature 2023;621:568-75. https://doi.org/10.1038/s41586-023-06501-x
21. Food and Agriculture Organization of the United Nations. Human energy requirements. Report of a Joint FAO/WHO/UNU Expert Consultation. Rome, 17–24 October 2001.
22. Neville MC, Keller R, Seacat J, Lutes V, Neifert M, Casey C, et al. Studies in human lactation: milk volumes in lactating women during the onset of lactation and full lactation. Am J Clin Nutr. 1988;48:1375-86.
23. Marks KJ, Nakayama JY, Chiang KV, Grap ME, Anstey EH, Boundy EO, et al. Disaggregation of breastfeeding initiation rates by race and ethnicity — United States, 2020–2021. Prev Chronic Dis 2023;20:230199. doi: http://dx.doi.org/10.5888/pcd20.230199
24. Damanik R, Wahlqvist ML, Wattanapenpaiboon N. Lactagogue effects of *Torbangun*, a Bataknese traditional cuisine. Asia Pac J Clin Nutr. 2006;15:267-74.
25. Kumalasari R. Katuk leaf juice improves breast milk production in postpartum mothers: evidence from an Indonesian Community Study. J Curr Health Sci. 2025, 5: 137-144. doi:10.47679/jchs.2025125
26. Herawati1 N, Nursitiyaroh. The effectiveness of local plants katuk leaves and papaya leaves as galactagogues in increasing breast milk production at TPMB Badriah Susilawati in 2022. IJHP 2022:744-9.
27. Alisjahbana B, Rivami DS, Octavia L, Susilawati N, Pangaribuan M, Alisjahbana A, Diana A. Intrauterine growth retardation (IUGR) as determinant and environment as modulator of infant mortality and morbidity: the Tanjungsari Cohort Study in Indonesia. Asia Pac J Clin Nutr

Received : 14 June 2026
Accepted : 20 July 2026
Publish : 2 August 2026

2019;28(Suppl 1):S17-S31. doi: 10.6133/apjcn.201901_28(S1).0002
28. Svefors P, Sysoev O, Ekstrom E-C, Persson LA, Arifeen SE, Naved RT, et al. Relative importance of prenatal and postnatal determinants of stunting: data mining approaches to the MINIMat cohort, Bangladesh. BMJ Open. 2019;9:e025154. doi:10.1136/bmjopen-2018-025154.
29. Peleg D, Kennedy CM, Hunter SK. Intrauterine growth restriction: identification and management. Am Fam Physician 1998;58:453–460.
30. Da Silva Lopes K, Ota E, Shakya P, Dagvadorj A, Balogun OO, Peña-Rosas JP, et al. Effects of nutrition interventions during pregnancy on low birth weight: an overview of systematic reviews. BMJ Glob Health. 2017;2:e000389. doi:10.1136/bmjgh-2017-000389.