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Improved sanitation and co-occurrence of anemia and stunting in Indonesian children: A retrospective cohort study

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Abstract

Anemia and stunting are major public health concerns in low- and middle-income countries, including Indonesia, with significant impacts on child development, morbidity, and mortality. The aim of this study was to assess the effect of improved sanitation on the co-occurrence of anemia and stunting (CAS) in Indonesian children using pooled data from the Indonesian Family Life Survey (IFLS) across three waves, from IFLS 3 in 2000, IFLS 4 in 2007, and IFLS 5 in 2014. The sample included 839 children aged 1–5 years with complete anthropometric and hemoglobin data, measured in 2000 as the baseline cohort and followed across subsequent waves. The main independent variable was improved sanitation, and other covariates included maternal and child characteristics, parental factors, and socio-economic status. Multinomial logistic regression was used to assess the impact of sanitation over time. The prevalence of CAS was 30.75% in 2000, 6.08% in 2007, and 4.29% in 2014. Stunting-only prevalence increased from 16.21% in 2000 to 27.41% in 2007 but decreased to 19.31% in 2014. Anemia-only prevalence decreased from 31.23% in 2000 to 10.25% in 2007 and slightly rose to 16.92% in 2014. The analysis found that children with unimproved sanitation were at significantly higher risk of CAS (crude relative risk ratio (RRR): 2.49; 95% confidence interval (CI): 1.92–3.23), which decreased after adjusting for confounding factors (adjusted RRR: 1.55; 95%CI: 1.12–2.14). Similarly, the risk for anemia was higher in children with unimproved sanitation (adjusted RRR: 1.43; 95%CI: 1.07–1.90). However, the risk for stunting was not statistically significant after adjustment. This study underscores the importance of improved sanitation in reducing anemia and stunting but also highlights the need to address other factors, such as nutrition, maternal health, and socioeconomic inequalities, through comprehensive public health policies.

Keywords: Anemia, co-occurrence of stunting and anemia, improved sanitation, malnutrition, stunting

Introduction

Anemia is a serious global public health issue, particularly affecting children and pregnant women. The World Health Organization (WHO) estimated that in 2019, based on data from 192 countries, 39.8% of children under five years old and 36.5% of pregnant women suffered from anemia [1]. Anemia is a condition when the number of red blood cells or hemoglobin (Hb) in the blood is insufficient to meet the body's physiological needs. This condition can lead to symptoms such as fatigue, weakness, dizziness, and shortness of breath [2]. In Indonesia, the prevalence of

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anemia among children under five has shown an increasing trend over the years. In 2007, the prevalence of anemia in children aged 0–59 months was 27.7%, rising to 28.1% in 2013 and further increasing to 38.5% in 2018. Similarly, the prevalence of anemia among adolescents rose from 22.7% in the 2013 Indonesian–Basic Health Research to 32% in the 2018 Basic Health Research survey. Furthermore, the prevalence of anemia among women of reproductive age (WRA) rose from 19.7% in 2007 to 23.9% in 2013 and 27.2% in 2018 [3]. Anemia in children can lead to poor health and even increase the risk of death. Low iron levels in early childhood affect long-term health, weakening the immune system and making children more vulnerable to serious illnesses and higher mortality rates. A meta-analysis found that non-anemic children had a 1.3 times lower risk of mortality compared to anemic children [4]. Beyond health and mortality concerns, anemia also affects child development. Research indicates that anemia disrupts oxygen transportation in the body, potentially causing irreversible impairments in growth and development. Consequently, efforts to combat anemia should commence well before a child's birth, specifically during the critical 1000-day window, and even target teenage mothers to disrupt the cycle of anemia throughout life [5].

Since anemia in early childhood can impair growth and development, it is often intertwined with other forms of malnutrition, such as stunting. Stunting remains a public health issue in Indonesia. The Basic Health Research data recorded a stunting prevalence of 30.8% in 2018 [6]. The 2022 National Nutrition Status Survey (*Survei Status Gizi Indonesia*/SSGI) data showed a stunting prevalence of 21.6% in Indonesia and 21.5% in 2023 from the Indonesian Health Survey [7]. The stunting prevalence condition in Indonesia is also lagging behind several neighbouring countries, such as Malaysia (17%), Thailand (16%), and Singapore (4%). Low- and middle-income countries (LMICs) bear a disproportionately high burden of undernutrition, including anemia and stunting, compared to high-income nations [8]. The prevalence of co-occurrence of anemia and stunting (CAS) among children in Egypt was reported in 2020 at 8.8% for those aged 6–8 years and 9.9% for those aged 6–11 years [9]. An analysis of data from 46 low- and middle-income countries revealed a considerable variation in CAS prevalence among children under five, but overall, it remains notably high in these nations [10].

In a separate urban-based study conducted in Nigeria, nearly half of the participants aged 12–18 years were found to experience both anemia and stunting simultaneously. This cross-sectional study involved 400 male and female participants within this age range and also assessed vitamin A levels and thinness [11]. Conversely, Ethiopia reported a lower prevalence of CAS compared to Nigeria, but the study focused on 2,902 children aged 6–23 months [12]. The high prevalence of CAS is particularly alarming, as both stunting and anemia individually pose substantial challenges to children's health and survival. When combined, their coexistence exacerbates the risks, making it even more detrimental to children's well-being and placing an additional burden on health systems [9,10,13]. Despite the presence of populations with high rates of both anemia and stunting, evidence suggests these conditions rarely co-occur beyond random chance, indicating that they are distinct issues requiring separate attention. Consequently, interventions targeting only one condition may not effectively address the other, underscoring the importance of tailored strategies to reduce both stunting and anemia.

The United Nations Children's Fund (UNICEF) conceptual framework for malnutrition underscores the interplay between underlying factors—such as resource availability, accessibility, and utilization—and the immediate causes of malnutrition [14]. This framework provides a holistic view of the shared drivers of malnutrition at population, household, and individual levels. Building on this, organizations like the World Bank Group have developed frameworks tailored to anemia and malnutrition, specifically [8]. If anemia and growth faltering share common determinants, addressing these shared factors could offer a cost-effective and streamlined approach to combating multiple forms of malnutrition simultaneously, allowing for unified strategies that target several conditions through a single indicator [13].

Nutrition is intricately linked to various determinants [15,16]. While malnutrition is primarily driven by inadequate dietary intake, underlying factors such as limited access to clean water and sanitation contribute to recurrent infectious diseases, including diarrhea and intestinal worm infections. These infections disrupt the digestive process by competing for nutrients and impairing nutrient absorption, ultimately compromising immune function [10, 11]. It is estimated that up to 45% of child deaths related to malnutrition worldwide could be prevented through improvements in water, sanitation, and hygiene (WASH) conditions and practices [17-19]. Emerging evidence suggests that poor sanitation affects the nutritional status of children, especially linear growth in early childhood [20-22] and adolescence [23,24]. In Indonesia, 17 million people practice open defecation and less than 10% have access to safely managed sanitation services, endangering public health and the environment [25]. Exposure to fecal pathogens resulting from inadequate hygiene, poor sanitation, and contaminated water is a known cause of intestinal infections [24]. The risk of stunting is over three times higher in households that rely on untreated water and use unimproved latrines [22].

The current knowledge indicates a lack of prior studies addressing the CAS in Indonesia. Existing research predominantly focuses on either anemia or stunting independently without examining their combined prevalence [26]. This gap highlights the need for more studies on the CAS among children and adolescents [9,27]. In Indonesia, both anemia and stunting remain significant public health concerns. A study in Indonesia reported that 8.8% of children aged 6–9 years suffer from co-occurring anemia and stunting [28], a condition further exacerbated by poor sanitation practices [11,14]. Given the shared risk factors of these conditions, a high prevalence of CAS was anticipated in Indonesia. Previous studies discussing anemia and stunting mostly used cross-sectional study designs and focused on children under five [29,30]. This research used data from the Indonesian Family Life Survey (IFLS), which is the largest longitudinal study in Indonesia, covering 80% of the country's regions at the time of the first survey [31]. Therefore, the research is not limited to the under-five children but can also examine its effects on children in different phases, including adolescence. The aim of this study was to quantify the prevalence of CAS among Indonesian children and to assess the role of improved sanitation in influencing this phenomenon using longitudinal data.

Methods

Study design

This study was quantitative research employing a retrospective cohort design. It utilized data from the IFLS, a longitudinal household survey and the most comprehensive survey ever conducted in Indonesia. IFLS is a panel study that integrates data collection from households, individuals, and public facilities across five waves. The IFLS has been conducted since 1993 across 24 provinces in Indonesia, including North Sumatra, West Sumatra, Riau, Jambi, Riau Islands, Bangka Belitung, South Sumatra, Lampung, all provinces in Java, Bali, Nusa Tenggara Barat (NTB), and all provinces in Kalimantan, South Sulawesi, and West Sulawesi. The fifth wave (IFLS wave 5) was carried out at the end of 2014, encompassing 15,900 households, 709 communities, and a total of 50,000 individuals. This was a collaborative effort between Research and Development (RAND) Social and Economic Well-Being and SurveyMeter [32].

Data collection

The IFLS survey collected extensive information on demographic characteristics, socio-economic conditions of individuals and households, individual health, social capital, infrastructure conditions of residential areas, and other variables. The IFLS dataset also included comprehensive physical health assessments, which represented a key strength of the survey. In the initial IFLS wave, anthropometric measurements (height and weight) were collected from all respondents. Starting with IFLS wave 2 in 1997, the range of health assessments was significantly expanded. Each household interview team included a trained nurse who measured respondents' height, weight, blood pressure, pulse, lung capacity, and hemoglobin levels. Additionally, respondents performed a timed sit-to-stand test to evaluate physical functioning [31-33]. Specific health measures collected included height and hemoglobin levels. Height measurements were recorded for all household members, with children under two years measured while lying down. Hemoglobin levels, a marker for iron deficiency, were measured in household members aged one year and older using a capillary blood sample obtained through a fingertip prick. The sample was analyzed with a photometer, and the results appeared within 14–45 seconds. These detailed assessments, implemented in the IFLS waves 2 and above, provide robust data for evaluating health and nutritional outcomes across different age groups [31].

Population and sample

The study focused on children aged 1–5 years old in 2000 (IFLS wave 3) who were followed longitudinally until they were 8–12 years old in 2007 (IFLS wave 4) and 15–19 years old in 2014 (IFLS wave 5). Data were collected from 15,900 households involving 50,580 individuals, including household and child respondents aged 0–59 months. The inclusion criteria encompassed biological children living with their parents, born as singletons, alive during the study period, and possessing complete anthropometric and hemoglobin level data. Participants with extreme anthropometric values, premature birth, or classified as small-for-gestational-age (SGA) were excluded from the analysis. The sample size was determined by the size of the original IFLS survey. However, to ensure sufficient power, sample size calculations were conducted based on hypothesis testing for the difference between the two proportions. Using this calculation, the minimum required sample size was calculated as 2,038 for improved water source and 3,194 for improved sanitation, based on expected proportions of 17.9% vs 22.9% and 17.2% vs 21.1%, respectively [34], with 80% power and 95% confidence interval (CI). A full description of the sample size calculation is provided in the **S1 Appendix**. The sampling frame for this study consisted of combined data for children aged 1–5 years from IFLS wave 3 who had complete records of height, weight, hemoglobin measurement, and age (n=839). These same children were followed up and reassessed in subsequent waves, allowing for an examination of the outcome of interest in 2007 and 2014 (waves 4–5). The pooled data identified a sub-sample of 2.517 children below five years old to be estimated. The selection of the respondents in this study is presented in **Figure 1**.

Outcome variables

The prevalence and risk factors of CAS among children were measured at three different times. CAS among children was defined as when a child was both anemic and stunted. Anemia was recorded according to the WHO guidelines for children: (1) for children aged 6–59 months, anemia is defined as Hb levels <11.0 mg/dL, while non-anemia is Hb ≥11.0 mg/dL; (2) Hb <11.5 g/dl for those aged 5–11 years and <12 g/dl for those aged 12–14 years; (3) for boys aged 15 years and older, anemia is defined as Hb <13.0 mg/dL, and non-anemia is Hb ≥13.0 mg/dL; and (4) for girls aged 15 years and above, anemia is defined as Hb <12.0 mg/dL, and non-anemia is Hb ≥12.0 mg/dL. Additionally, adjustments for Hb levels were necessary for individuals who smoke, with a reduction of -3 g/L applied when the smoking frequency is unknown or for those who smoke 0.5–1 packet per day, -5 g/L for those smoking 1–2 packets per day, and -7 g/L for those smoking more than 2 packets per day [2]. Stunting among children was defined as height-for-age Z scores <-2 SD [35,36].

Independent variables

The main independent variable was the type of sanitation, which the Joint Monitoring Programme (JMP) classified sanitation facilities into "improved" and "unimproved" categories based on their ability to hygienically separate human waste from human contact. Improved sanitation includes non-shared facilities such as those that flush or pour-flush to a piped sewer system, septic tank, or pit latrine, as well as ventilated improved pit latrines, pit latrines with slabs, and composting toilets. On the other hand, unimproved sanitation includes shared facilities and open defecation (no facility, bush, or field) [36].

Covariates at the child level included child age (categorized into 12–24 months, and 25–59 months), sex, preterm birth (defined as births at less than 37 weeks), low birth weight (defined as less than 2500 grams at birth), exclusive breastfeeding (defined as the practice of giving an infant only breastmilk for the first six months of life, with no other food, other liquids, or even water), early initiation of breastfeeding, history of acute respiratory infection (ARI), diarrhea, infection history, outpatient visits in the past two weeks, children's smoking habits, food consumption, and physical activity. Maternal and paternal characteristics included maternal height (≤150 cm vs >150 cm), maternal education (no formal education, primary, secondary, or higher education), maternal employment, paternal education, paternal employment, and paternal smoking behavior.

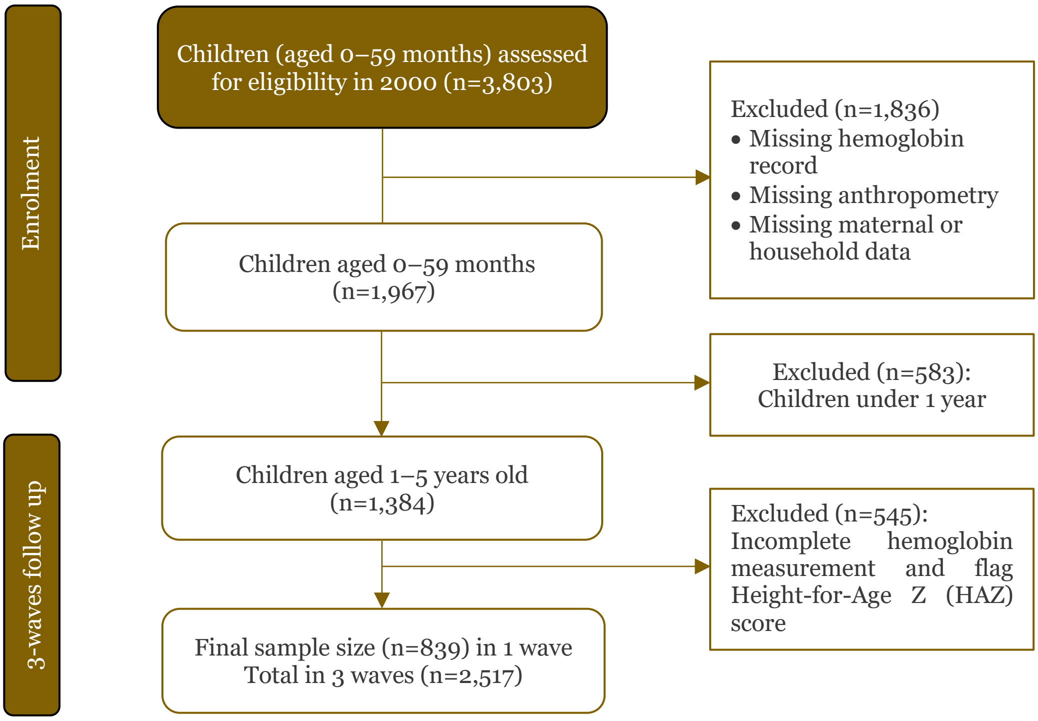

Figure 1. Flow chart of study respondent selection.

Household-level factors included the percentage of household food expenditure (categorized as good if <60% and poor if ≥60%) [37,38], household asset ownership (measured in quintiles) [40], and place of residence (urban or rural). Household asset ownership reflects a family's economic capacity based on the possession of valuable goods, which are converted into rupiah. These assets included houses, land, vehicles, savings, jewelry, and electronic items. To measure economic status, the total value of these assets is calculated and categorized into five quintiles, providing a comparative framework for assessing household wealth distribution [39]. Data for these variables were collected across multiple time points (2000, 2007, and 2014) to assess their association with stunting and anemia in children, except for data on children's characteristics, which were only measured in 2000.

For the variables related to children's smoking habits, food consumption, and physical activity, data from 2007 and 2014 were used. Smoking habits were measured for respondents aged 15 years and older, so this variable applied to children who reached this age during the study period. The operational definition of food consumption is based on the food consumption score (FCS), commonly used by the World Food Programme (WFP) and its partners. The FCS is a composite score derived from dietary diversity, food consumption frequency, and the nutritional value of food groups, calculated by asking households how often they consume food items from eight different food groups (including condiments) over a 7-day period. This also includes data on the sources of food, providing insight into the household's self-reliance or dependency on outside sources [40]. For physical activity, a modified short form of the International Physical Activity Questionnaire (IPAQ) was used to assess types and durations of physical activities across work, home, and exercise. The total duration was converted into Metabolic Equivalent of Tasks (METs)-minutes to estimate weekly physical activity, which was then categorized as poor or good [41].

Data quality

To ensure data quality, field surveyors conducted checks for completeness and consistency. Complete data were coded and entered by the central team, followed by cleaning to minimize bias. Anthropometric data were analyzed using WHO Anthro for children aged 0–60 months and WHO AnthroPlus for children aged 5–19 years. Extreme Z-scores (HAZ <-6 SD or >+6 SD) were excluded to prevent measurement bias. Missing data were handled using appropriate imputation methods where feasible, and inverse probability weighting (IPW) was applied to mitigate attrition bias, ensuring that complete case analyses remained representative of the overall population. Additionally, adjustments were made to hemoglobin levels in smokers to reduce misclassification bias. These steps were implemented to enhance the validity and reliability of the study findings.

Statistical methods

Data were analyzed using STATA 15 software (StataCorp LLC, Texas, USA). The primary focus of this paper was to assess the role of improved sanitation and CAS among children using different times (children under five until they were adolescents). Descriptive statistics, frequency, percentage, mean, range, and standard deviation (SD) were calculated to describe relevant variables. The proportions were determined for categorical variables in relation to CAS.

The multivariable analysis utilized multinomial logistic regression to evaluate the impact of improved sanitation on CAS, accounting for repeated measures and covariates at different follow-up times from the same child. A multinomial logistic regression model was used to generate odds ratios and corresponding 95%CI, using data from children aged 1–5 years old, 8–12 years old, and 15–19 years old. Before conducting multinomial logistic analysis, the dependent variable was assumed nominal and mutually exclusive and consisted of four categories: 'no anemia or stunting,' 'stunting only,' 'anemia only,' and 'stunting and anemia together' (CAS). The 'no anemia or stunting' category was set as the reference.

Results

Characteristics of the respondents

The sociodemographic and economic characteristics of the study participants in IFLS 2000 (wave 3) as baseline data included in this study are presented in **Table 1**. Among the child characteristics, there was a slightly higher proportion of male (51.49%) than female children, with most children being in the 12–23 months age group (51.85%). A majority of children had a healthy birth weight (93.80%), and preterm birth was less common (8.46%). Almost all children were breastfed early (98.09%), with very few not receiving this essential care (1.91%). However, when it comes to health outcomes, acute respiratory infections (74.14%) were more prevalent than diarrhea (18.36%), and most children had a history of infectious diseases (81.64%). The occurrence of fever was nearly balanced between those with and without it, while fewer children had outpatient visits.

Regarding parental characteristics, almost all fathers were employed (98.57%), but maternal employment was less common (42.31%). Educational levels among parents showed a higher proportion of mothers with lower education levels, as most had only completed junior high school or lower (67.94%). Smoking was more prevalent among fathers (67.82%) and maternal height below 150 cm was noted in a significant proportion of the sample (44.93%), though the majority of mothers were taller. From a socioeconomic and household environmental perspective, more children lived in urban than rural areas. A significant number of households had poor food expenditure (≥60%), with a relatively even distribution of assets across different quartiles (**Table 1**).

Table 1. Sociodemographic characteristics and economic conditions of study participants in Indonesian Family Life Survey (IFLS) 2000 (n=839)

Variables	n	%
Child characteristics		
Sex		
Female	407	48.51
Male	432	51.49
Age groups		
12–23 months	435	51.85
24–59 months	404	48.15

Variables	n	%
Low birth weight		
No	787	93.80
Yes	52	6.20
Preterm birth		
No	768	91.54
Yes	71	8.46
Early initiation breastfeeding		
Yes	823	98.09
No	16	1.91
Diarrhea		
No	685	81.64
Yes	154	18.36
Acute respiratory infection		
No	217	25.86
Yes	622	74.14
History of infectious diseases		
No	154	18.36
Yes	685	81.64
Fever		
No	408	48.63
Yes	431	51.37
Out-patient visit		
No	583	69.49
Yes	256	30.51
Parental characteristics		
Paternal employment		
No	12	1.43
Yes	827	98.57
Father's educational level		
Senior high school-higher education and above?	322	38.38
Junior high school and under	517	61.62
Paternal smoking status		
No	270	32.18
Yes	569	67.82
Maternal employment		
No	484	57.69
Yes	355	42.31
Mother's educational level		
Senior high school-higher education and above?	269	32.06
Junior high school and under	570	67.94
Maternal height		
≥150 cm	462	55.07
<150 cm	377	44.93
Socioeconomic characteristics and household environmental conditions		
Place of residence		
Urban	451	53.75
Rural	388	46.25
Percentage of household food expenditure		
Good, <60%	312	37.19
Poor, ≥60%	527	62.81
Total assets		
Quartile 1	184	21.93
Quartile 2	162	19.31
Quartile 3	174	20.74
Quartile 4	162	19.31
Quartile 5	157	18.71

Prevalence of stunting, anemia, and co-occurrence stunting and anemia (CAS)

The prevalence of stunting, anemia, and their co-occurrence (CAS) among children across three survey years (2000, 2007, and 2014) is presented in **Table 2**. Children classified as normal exhibited a significant increase in prevalence, rising from 21.81% in 2000 to 56.26% in 2007 and further to 59.48% in 2014. Conversely, the prevalence of CAS sharply declined, from 30.75% in 2000 to 6.08% in 2007 and 4.29% in 2014, highlighting a marked reduction in the co-occurrence of stunting and anemia. The stunting-only and anemia-only categories reveal fluctuating trends. Stunting-only prevalence increased from 16.21% in 2000 to 27.41% in 2007 before declining to 19.31% in 2014. In contrast, anemia-only prevalence decreased significantly between 2000

(31.23%) and 2007 (10.25%) but rose slightly to 16.92% in 2014. The substantial reductions in CAS prevalence, alongside shifts in stunting-only and anemia-only categories, may reflect changes in nutritional and health interventions over time.

Table 2. Prevalence of stunting, anemia, and CAS in Indonesian Family Life Survey (IFLS) 2000, IFLS 2007, and IFLS 2014 (n=2,517)

Stunted and anemia status	Year	n	Percentage	Standard error (%)	95%CI
Normal	2000	183	21.81	1.43	19.15–24.74
	2007	472	56.26	1.71	52.88–59.58
	2014	499	59.48	1.69	56.11–62.75
Co-occurrence of stunting and anemia (CAS)	2000	258	30.75	1.59	27.72–33.96
	2007	51	6.08	0.82	4.65–7.91
	2014	36	4.29	0.70	3.11–5.89
Stunting-only	2000	136	16.21	1.27	13.87–18.86
	2007	230	27.41	1.54	24.50–30.53
	2014	162	19.31	1.36	16.78–22.12
Anemia-only	2000	262	31.23	1.60	28.18–34.45
	2007	86	10.25	1.05	8.37–12.49
	2014	142	16.92	1.29	14.54–19.62

Relationship between improved sanitation and co-occurrence of stunting and anemia (CAS)

The relationship between improved sanitation and co-occurrence of stunting and anemia (CAS) across different survey years (2000, 2007, and 2014) is revealed in **Table 3**. In 2000, a significant relationship was observed between sanitation and nutritional status (p=0.002). Children with unimproved sanitation were more likely to experience CAS (44.19%) and stunting-only (41.18%) compared to those with improved sanitation (55.81% for CAS and 58.82% for stunting-only). Conversely, anemia-only cases were more prevalent among children with improved sanitation (67.56%) than among those with unimproved sanitation (32.44%). These results suggest that unimproved sanitation in 2000 contributed to poorer nutritional outcomes, particularly CAS and stunting.

By 2007, the association between sanitation and nutritional status was no longer statistically significant (p=0.440). Although children with improved sanitation still had a higher proportion of normal nutritional status (76.91%) and stunting-only cases (74.78%), the differences between groups narrowed. For example, children with unimproved sanitation accounted for 23.09% of normal cases and 25.22% of stunting-only cases.

In 2014, the association between sanitation and nutritional status remained statistically insignificant (p=0.460). The proportion of children with normal nutritional status was highest among those with improved sanitation (84.37%) compared to those with unimproved sanitation (15.63%). Similarly, stunting-only cases were more frequent among children with improved sanitation (82.10%) than among those with unimproved sanitation (17.90%). These results indicate a declining disparity in nutritional outcomes based on sanitation status over time, possibly due to broader public health interventions and improvements in sanitation infrastructure.

Table 3. Improved sanitation and co-occurrence of anemia and stunting (CAS) status (n=2517)

Year	Sanitation	CAS status								p-value*
		Normal		CAS		Stunting		Anemia		
		n	%	n	%	n	%	n	%	
IFLS 2000 (n=839)	Improved	131	71.58	144	55.81	80	58.82	177	67.56	0.002
	Unimproved	52	28.42	114	44.19	56	41.18	85	32.44	
IFLS 2007 (n=839)	Improved	363	76.91	36	70.59	172	74.78	60	69.77	0.440
	Unimproved	109	23.09	15	29.41	58	25.22	26	30.23	
IFLS 2014 (n=839)	Improved	421	84.37	29	80.56	133	82.10	112	78.87	0.460
	Unimproved	78	15.63	7	19.44	29	17.90	30	21.13	

IFLS: Indonesian Family Life Survey
*Analyzed using Chi-squared test

Risk of CAS by sanitation status compared to non-stunted and non-anemic (normal) children

The risk of CAS, stunting-only, and anemia-only by sanitation status, with unimproved sanitation compared to improved sanitation as the reference category is presented in **Table 4**. The analysis reveals that children with unimproved sanitation are at a significantly higher risk of CAS, with a crude relative risk ratio (RRR) of 2.49 (95%CI: 1.92–3.23), which decreases after adjustment for confounding factors to 1.55 (95%CI: 1.12–2.14). This result is statistically significant (p=0.008), indicating that unimproved sanitation is associated with an elevated risk of CAS, even after controlling for factors such as time of observation, child characteristics, residential area, parental education and employment, smoking status, food consumption, physical activity, and sociodemographic factors.

For stunting-only, the crude relative risk for unimproved sanitation is 1.42 (95%CI: 1.12–1.81), and after adjustment, it slightly decreases to 1.23 (95%CI: 0.94–1.60), but the adjusted result is not statistically significant (p=0.130). In contrast, for anemia-only, children with unimproved sanitation are at a significantly higher risk, with a crude relative risk of 1.55 (95%CI: 1.21–1.97), and an adjusted relative risk of 1.43 (95%CI: 1.07–1.90), which remains statistically significant (p=0.014). These findings suggest that unimproved sanitation contributes to a higher risk of anemia and CAS, but the impact on stunting alone is less pronounced. A detailed analysis based on household asset quantiles and its association with CAS across different years is presented in the **Supplementary Table**.

Table 4. Risk of CAS by sanitation status, compared to non-stunted and non-anemic (normal) (n=2,517)[a]

Sanitation	CAS vs normal (*ref*)		Stunting only vs normal (*ref*)		Anemia only vs normal (*ref*)	
	Crude	Adjusted[b]	Crude	Adjusted[b]	Crude	Adjusted[b]
Improved	1.00 (*ref*)	1.00 (*ref*)	1.00 (*ref*)	1.00 (*ref*)	1.00 (*ref*)	1.00 (*ref*)
Unimproved	2.49 (1.92–3.23)	1.55 (1.12–2.14)	1.42 (1.12–1.81)	1.23 (0.94–1.60)	1.55 (1.21–1.97)	1.43 (1.07–1.90)
p-value[a]	<0.001	0.008	0.004	0.130	<0.001	0.014

CAS: co-occurrence of anemia and stunting; Ref: reference group
Values are presented as relative risk ratios (95%CI)
[a]Data were analyzed using multinomial logistic regression analysis, α=5%
[b]Adjusted for the time of observation, child characteristics, residential, parental education, parental working status, smoking status, food consumption score, physical activity, and sociodemographic factors. Improved sanitation as a reference

Discussion

The prevalence of CAS among children under five in this study (30.75%) is slightly higher than reported in other studies. For instance, a study conducted in Peru observed a CAS prevalence of 30.4% among children under five [13]. However, several studies have reported lower prevalence rates [10,13]. A global analysis involving data from 81 countries estimated a pooled CAS prevalence of 21.5% (95%CI: 21.2–21.9), with Albania having the lowest proportion and Yemen the highest [10]. Similarly, research in Sudan reported a CAS prevalence of 23.9% [26], and a study in India found a prevalence of 21.5% [13]. These variations underscore the significant geographical and contextual differences in the burden of CAS.

For school-aged children in IFLS 2007 (aged 8–12 years old) and IFLS 2014 (aged 15–19 years old), as presented in **Table 2**, the CAS prevalence in this study was lower, reaching 6.08% in 2007 (8–12 years old) and 4.29% in 2014 (15–19 years old). These findings are lower compared to other studies examining similar or broader age groups. For instance, a study in Indonesia reported a CAS prevalence of 20.2% among children aged 5–18 years [42]. In Egypt, 9.9% of children aged 6–11 years were found to experience CAS [9]. A study in Nigeria reported that among adolescents aged 10–19 years, 3.2% of boys and 3.8% of girls experienced CAS [43].

The prevalence of anemia in this study was 31.23% among children under five years old (IFLS 2000), followed by 10.25% among children aged 8–12 years (IFLS 2007), and 16.92% among adolescents aged 15–19 years (IFLS 2014), respectively (**Table 2**). The prevalence of anemia significantly differs by age, with preschool children exhibiting higher rates than school-aged children. This discrepancy is attributed to the rapid growth and increased nutritional demands in

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children under five years old, which make them particularly vulnerable to malnutrition and deficiencies in essential vitamins and minerals [44]. Regardless of socioeconomic status (SES), preschool children face a heightened risk of iron deficiency anemia, likely due to their accelerated growth occurring in environments unable to adequately meet their dietary needs. Factors such as poor sanitation, helminth infections, malaria, and extended breastfeeding without proper dietary supplementation exacerbate anemia in this age group [44-46]. As children transition to school age, anemia prevalence tends to decline. This is partly due to slower growth rates and reduced nutritional requirements. The reduction is especially evident among school-aged children in middle-SES settings, where improved living conditions mitigate anemia risk. Access to healthcare, deworming programs, better hygiene, and enhanced food security in these regions play a crucial role in reducing anemia prevalence compared to children living in poverty. These factors collectively explain the differences in anemia rates observed across socioeconomic strata [44].

Conversely, the increase in anemia prevalence highlights gaps in addressing micronutrient deficiencies during adolescence. Adolescents, particularly girls, are vulnerable to anemia due to increased iron requirements during growth spurts and menstruation [47]. Despite some progress in promoting iron supplementation and dietary diversity, challenges such as poor adherence to supplementation programs and low consumption of iron-rich foods have hindered significant improvements [5]. These contrasting trends emphasize the need for comprehensive strategies that integrate early childhood and adolescent nutrition interventions to simultaneously address stunting and anemia.

A study in Indonesia using IFLS wave 5 (2014) data in 2023 found that the age of child was found to be associated with anemia and CAS at the individual level [28], which indicates that children in the younger age group (6–7 years) face a 1.9 times higher risk of anemia and a 2.0 times higher risk of CAS compared to those in the older age group (8–9 years) [28]. These findings are consistent with a previous study conducted in Turkey [48], which reported significantly higher rates of anemia among children aged 6 and 7 years compared to those aged 8 and 9 years. The increased requirement for absorbed iron and recommended dietary allowance (RDA) among children aged 5.5–8.5 years rises with age but then declines from 9 to 13 years. This decline is due to factors such as increased basal iron losses, greater hemoglobin mass, and the expansion of tissue (non-storage iron), with the assumption that girls do not reach menarche before age 14. The differing RDA requirements, combined with insufficient iron intake, likely explain the higher prevalence of anemia observed in younger children in this study [48].

The relatively low prevalence of stunting among children under five (16.21%) in this study appears to be influenced by the coexistence of stunting and anemia in this age group. This suggests that anemia may play a role in masking the full extent of stunting during early childhood, as the overlapping burden of both conditions might dilute the proportion attributed solely to stunting. As children age, the prevalence of anemia tends to decline, potentially due to improved dietary intake, enhanced health interventions, or physiological adaptations. However, this decline in anemia appears to expose or exacerbate the issue of stunting, leading to a higher prevalence of 27% among children aged 8–12 years. This finding underscores the complex interplay between nutritional deficiencies and growth outcomes across different developmental stages.

The results also raise important questions regarding the timing and focus of nutritional interventions. While efforts to address anemia in younger children are essential, the concurrent rise in stunting prevalence among older children suggests the need for sustained and comprehensive strategies targeting both conditions throughout childhood. Such strategies could include improving access to balanced nutrition, addressing underlying socioeconomic determinants, and implementing regular growth monitoring to identify and mitigate risks early [34].

The findings of this study indicate a significant association between unimproved sanitation among children with CAS and anemia status after adjusting for other covariates. However, no similar studies were found supporting these findings related to CAS, but some studies showed similar results for anemia and stunting [22,49,50]. A study reported a large global dataset to examine links between access to improved water or sanitation and anemia prevalence in children aged <5 years, which found that improved sanitation was associated with a reduced risk of anemia (adjusted for child sex and age, family socioeconomic status, maternal education, urban or rural residence, and presence of systemic inflammation) in seven of the countries examined [49]. A possible explanation for this is due to the fact that unimproved sanitation increases exposure to fecal contamination, leading to higher rates of diarrheal diseases and environmental enteropathy, both of which impair nutrient absorption and contribute to growth faltering [22]. A cross-sectional study for children aged 6 to 19 years old in Malaysia revealed strong evidence of the relationship between environmental and nutritional factors and the risk of stunting [50]. The observed associations were specific, remained consistent after adjusting for various covariates, and were independent of the height reference used to define stunting. For household sanitation, three distinct measures were used to assess the availability and quality of facilities, all of which showed independent and consistent links to the risk of stunting. Furthermore, children and adolescents with a flush toilet in the household had an approximately 60% decreased risk of stunting versus those with a bucket, hanging or no latrine (RRR for flush toilet with septic tank: 0.38; 95%CI: 0.18–0.84; p=0.017) [50].

No other longitudinal studies have been found investigating the relationship between unimproved sanitation and CAS in these age groups; however, several observational studies have explored similar associations [28,51,52]. Previous cross-sectional studies have reported significant links between poor sanitation, stunting, and anemia [12,28,52]. These findings highlight the need for further longitudinal research to understand the causal mechanisms driving these relationships and evaluate the effectiveness of interventions aimed at reducing both conditions across various age groups. Understanding the interdependence of these factors is critical for designing policies and programs that ensure optimal child growth and development.

To the best of our knowledge, this is the first study to examine the co-occurrence of stunting and anemia among Indonesian children at the individual level during three different age periods (1–5 years, 8–12 years, and 15–19 years). This age range is critical for identifying undernutrition in children and before the second window of opportunity or adolescence, which includes growth spurts in both boys and girls, as well as menarche in girls. Due to regional disparities in Indonesia, the impact of sanitation improvements on child health outcomes may vary across provinces. Findings from the Maternal and Young Child Nutrition Security Initiative in Asia (MYCNSIA) project in December 2014 from three districts in Indonesia, namely, Jayawijaya District in Papua Province, Klaten District in Central Java Province, and Sikka District in Nusa Tenggara Timur (NTT) Province showed that improved household sanitation facilities were significantly associated with lower odds of stunting among children under three years old, with the presence of a household toilet facility reducing the odds of stunting by 29%. Notably, this reduction occurred in areas where stunting prevalence had already declined by 23% within three years due to the scaling up of essential nutrition interventions. However, MYCNSIA findings also indicated that household access to improved drinking water sources or piped water was not associated with either stunting or anemia, and child anemia was not linked to household sanitation [53].

A key strength of this study is its longitudinal design, which allows for the examination of trends over time that specifically focused on the effect of improved sanitation and CAS among children and adolescents in Indonesia using a large dataset. Comparison with other longitudinal studies indicates similar associations between poor sanitation and childhood undernutrition, although differences in study design and population characteristics should be considered when interpreting results. The large sample size and extended follow-up period in IFLS enhance the external validity of our findings, suggesting that the observed relationships between sanitation, anemia, and stunting are likely applicable to broader populations in Indonesia and similar settings. By leveraging a robust longitudinal dataset and advanced analytical methods, this study contributes valuable insights into the long-term impacts of inadequate sanitation on child growth and health. These findings support the need for integrated public health policies that prioritize improved sanitation alongside nutritional and socio-economic interventions to break the cycle of malnutrition. Despite these strengths, the study also has several limitations. The IFLS dataset lacks specific maternal health data collected during pregnancy that may influence stunting, such as maternal anemia, nutritional status, and dietary intake during pregnancy. Additionally, data on certain behavioral and dietary factors, such as children's food intake and smoking habits, are not available for younger children, as the relevant IFLS questionnaire items are only administered to household members aged 15 years and above. Selection bias may also be present due to the exclusion of participants with missing anthropometric or hemoglobin data, potentially limiting the generalizability of the findings.

Conclusion

Based on the findings, the prevalence of CAS experienced a sharp decline from 2000 to 2014. The findings indicated that improved sanitation was associated with a lower risk of CAS, with the association remaining significant after adjusting for various confounding factors. Although the risk of anemia and CAS was higher among children with unimproved sanitation, its impact on stunting alone was not significant after adjustment. These findings highlight the critical role of improved sanitation interventions in addressing child nutritional issues, particularly in reducing anemia and CAS prevalence. Expanding access to safe WASH should be prioritized through integrated programs that combine nutrition and sanitation. Encouraging partnerships between health, nutrition, and sanitation sectors is essential to break the vicious cycle of malnutrition and diarrheal diseases. Establishing platforms for knowledge-sharing and collaboration can also ensure that these synergies are leveraged in addressing child health challenges. Furthermore, future research should investigate the synergistic effects of WASH interventions on nutritional outcomes and ensure that the full range of WASH is incorporated into nutritional strategies.

Ethics approval

The Ethical Committee of the Faculty of Public Health, Universitas Indonesia (Number: Ket-572/UN2.F10. D11/PPM.00.02/2024, September 12, 2024) provided ethical clearance. The IFLS surveys and their procedures were reviewed and approved by the Institutional Review Boards (IRBs) in the United States at RAND and in Indonesia at the University of Gadjah Mada (UGM) for IFLS waves 3, 4, and 5, while approvals for waves 1 and 2 were provided by the Universitas Indonesia.

Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

The data underlying the results presented in the study are available from the IFLS website through this link: https://www.rand.org/well-being/social-and-behavioral policy/data/FLS/IFLS/access.html. The supplementary material is available through this link: https://doi.org/10.6084/m9.figshare.28425467.v1

Declaration of artificial intelligence use

We hereby confirm that no artificial intelligence (AI) tools or methodologies were utilized at any stage of this study, including during data collection, analysis, visualization, or manuscript preparation. All work presented in this study was conducted manually by the authors without the assistance of AI-based tools or systems.

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