



A National SKI-Based Child Stunting Risk Index for Concurrent Vulnerability Screening of Child Nutritional Risk in Indonesia

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Abstract

Indonesia has made progress in reducing child stunting, but current policy and surveillance systems largely identify children only after anthropometric growth deficits have occurred. This approach overlooks the accumulation of biological, infection, nutritional, and caregiving risks that precede measurable stunting. This study develops a Child Stunting Risk Index (CSRI) using the 2023 Indonesian Health Survey to support early and preventive risk prioritization among children aged 0–59 months. The CSRI is designed as a concurrent vulnerability screening tool rather than a diagnostic measure or an estimator of stunting prevalence. The formative index combines age-eligible proximal indicators within two dimensions: biological/infection risks and nutrition/care risks. Indicators are aggregated using nested equal weighting, subject to minimum data-coverage requirements. Risk categories are determined using a sample-relative traffic-light classification and assessed through leave-one-out known-group validation against established child growth risk markers. Among 82,678 children with valid scores, the weighted mean CSRI was 0.126 (12.56 on a 0–100 scale), with mean indicator coverage of 96.45%. Overall, 25.64% of children were classified as having high or very high risk. Risk was highest among children aged 6–23 months and in Maluku-Papua, Sumatra, and Sulawesi. Higher scores were consistently observed among children exposed to low birth weight, prematurity, incomplete immunization, inadequate dietary diversity, limited growth monitoring, and suboptimal breastfeeding and feeding practices. Theoretically, the study extends stunting assessment from outcome-based measurement to a multidimensional vulnerability framework. Practically, the CSRI provides a scalable tool for targeting preventive interventions before growth failure becomes observable.

Keywords *Stunting Risk, Vulnerability Screening, Child Nutrition, Composite Index, Indonesia*

INTRODUCTION

Stunting remains one of the most persistent forms of early-life deprivation because it reflects the cumulative effects of inadequate nutrition, recurrent infection, poor caregiving, and limited access to essential health services rather than a single episode of illness or food shortage. Globally, 150.2 million children under five were stunted in 2024, representing 23.2% of the global under-five population (UNICEF, WHO, & World Bank, 2025; World Bank, 2025). Indonesia has made substantial progress, with the national stunting prevalence declining to 19.8% in 2024. However, this level still represents a considerable public health burden and indicates the need for more precise prioritization of preventive services (Ministry of Health Republic of Indonesia, 2025). The 2023 Indonesian Health Survey (*Survei Kesehatan Indonesia* (SKI)), which integrates the functions previously performed by Riskesdas and the Indonesian Nutritional Status Survey, provides nationally representative health and nutrition information at the district and city levels. The survey therefore creates an opportunity to move national surveillance beyond prevalence reporting

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toward the earlier identification of children exposed to multiple proximal risks ([Ministry of Health Republic of Indonesia, 2024](#)).

Most epidemiological studies assess stunting using measured height-for-age z-scores or a binary indicator defined by the World Health Organization growth standard. These measures remain essential for estimating prevalence, identifying geographic disparities, and evaluating nutrition programs. Recent Indonesian research has expanded this evidence by examining social, environmental, maternal, household, and child-level determinants using national survey data, including SKI 2023 ([Arief et al., 2025](#)). Other studies have applied machine-learning algorithms to classify stunting and identify influential predictors from complex survey datasets ([Shen et al., 2023](#)). A recent meta-analysis also shows increasing use of machine-learning methods to predict childhood malnutrition from Demographic and Health Survey data ([Rao et al., 2025](#)). These developments improve explanations and predictions of anthropometrically defined outcomes.

Nevertheless, the current literature retains an important timing and operational limitation. Height-for-age measures identify growth failure only after biological, nutritional, infectious, and care-related disadvantages have accumulated sufficiently to produce an observable anthropometric deficit. Regression and machine-learning models generally treat measured stunting as the dependent outcome. Their primary purpose is therefore to explain or classify existing growth failure rather than to summarise a child's current exposure to modifiable risks before stunting becomes measurable. Complex predictive models may also be difficult to translate into transparent program rules, especially when health workers and policymakers need an interpretable tool that shows why a child requires preventive attention. Few national studies have converted routinely collected, age-specific child health and nutrition indicators into a multidimensional, child-level risk score that remains distinct from stunting diagnosis and prevalence estimation.

Accordingly, this study aims to develop and validate a Child Stunting Risk Index (CSRI) for Indonesian children aged 0–59 months using SKI 2023. Guided by the child health production function and the UNICEF maternal and child nutrition framework, the CSRI treats birth outcomes, morbidity, feeding practices, immunization, supplementation, and health-service contact as proximal inputs that jointly shape child growth and development ([Grossman, 1972](#); [UNICEF, 2020](#)). The study contributes by constructing an age-eligible, non-overlapping formative index; introducing a transparent traffic-light classification for preventive prioritization; assessing content and construct validity through known-group comparisons; and identifying regional concentrations and program-relevant contributors to vulnerability. The CSRI is not designed to diagnose stunting, replace anthropometric assessment, or estimate prevalence. Instead, it provides a complementary surveillance instrument for identifying children who may require preventive attention before measurable linear growth failure occurs.

LITERATURE REVIEW

The conceptual starting point is the child health production function, in which child health emerges not only from clinical care but from a combination of household resources, caregiver time, service contact, environmental exposure, nutrition, and biological endowment. The child health production function treats child health as the result of accumulated investments, resources, care, nutrition, service contact, infection exposure, and biological endowment ([Grossman, 1972](#)). The nutrition literature provides specific content for this framework. The UNICEF conceptual framework distinguishes immediate determinants such as diets and care from underlying household, service, and social conditions ([UNICEF, 2020](#)), while the Lancet maternal and child undernutrition literature similarly highlights fetal growth, birth weight, infant and young child feeding, infections, and service delivery as central pathways into linear growth faltering ([Victora et](#)

al., 2021; Keats et al., 2021; Heidkamp et al., 2021).

The 6- to 23-month window is particularly important. WHO's 2023 complementary-feeding guideline focuses on children in this age range and emphasizes dietary diversity, animal-source foods, fruits and vegetables, and age-appropriate feeding frequency (World Health Organization, 2023), reflecting a high-leverage period in which inadequate complementary feeding can quickly translate into cumulative nutritional deficits, though this does not imply older children are no longer relevant. A useful screening index should therefore remain sensitive to age eligibility, applying exclusive breastfeeding to infants, complementary feeding to older infants and young children, and service-contact indicators to the full under-five population. Measurement is the second theoretical issue. CSRI is a formative index rather than a reflective psychometric scale. Where a reflective scale treats indicators as interchangeable manifestations of an underlying trait, a formative index treats indicators as defining the construct itself, so omitting one component changes the meaning of the index (Diamantopoulos & Winklhofer, 2001), a distinction that matters because stunting vulnerability is multidimensional and low birth weight, missing growth monitoring, no vitamin A supplementation, and low dietary diversity are distinct risk exposures rather than interchangeable symptoms of a single latent variable.

A methodological implication of the additive formative structure is full compensability, meaning a child with one extreme risk exposure can receive the same score as a child with several moderate exposures. The OECD and JRC Handbook on Constructing Composite Indicators discusses this trade-off extensively and reviews alternative aggregation approaches including geometric means, the Mazziotta-Pareto adjusted index, and counting-based methods such as the Alkire-Foster framework, which is explicitly non-compensatory (Nardo et al., 2008; Alkire & Foster, 2011). This paper uses nested equal weighting as a transparent, replicable default, though the compensability assumption should be kept in mind when interpreting individual scores for triage purposes; future work may compare the additive CSRI with non-compensatory alternatives to assess whether triaging implications differ in practice. The validation strategy follows construct validation rather than causal inference.

Following Cronbach and Meehl (1955), this paper distinguishes three layers of validity evidence. Content validity is established by grounding each CSRI component in the UNICEF framework, the Lancet undernutrition literature, and WHO complementary-feeding guidance, with the item pool designed to represent the domain of proximal stunting risk exposures observable in SKI 2023. Internal construct coherence is evaluated through known-group validation, where children with established risk markers should show higher CSRI scores on the remaining components, demonstrating that the index captures a coherent risk gradient. Criterion validity, the correlation between CSRI and a measured outcome such as height-for-age z-scores or a binary stunting classification, has not been tested here because the R07 analytical file contains no anthropometric outcomes, so the validation exercise is limited to content and construct-internal evidence and is not designed to estimate the causal effect of immunization, vitamin A, breastfeeding, or diet on stunting. External criterion validation against measured HAZ remains an essential next step.

RESEARCH METHOD

This study uses the 2023 Indonesian Health Survey (SKI) microdata to construct a national Child Stunting Risk Index (CSRI) for children aged 0 to 59 months. The child serves as the unit of analysis. Child records were linked to household and member information to obtain age, sex, household location, and relevant health indicators. The analytical R07 file contains 86,275 children aged 0 to 59 months. Of these, 82,678 children have a valid non-overlap CSRI score. A child receives a valid score when at least one observed item exists in both CSRI dimensions, namely biological or

infection risk and nutrition or care risk. Children who do not meet this minimum coverage rule are excluded from the analysis.

Each component is coded as 1 when the child is exposed to a proximal risk and 0 when no observed risk exists, conditional on age eligibility. The index applies nested equal weighting. First, age-eligible items are averaged within each dimension. Second, the biological or infection dimension and the nutrition or care dimension are averaged with equal weights. The main score is defined as:

$$CSRI_i = 0.5B_i + 0.5N_i$$

where B_i represents the biological or infection dimension and N_i represents the nutrition or care dimension for the child i . The score ranges from 0 to 1 and is also reported on a 0-100 scale. Higher values indicate greater proximal vulnerability.

The biological/infection dimension captures birth and morbidity risks, while the nutrition/care dimension captures feeding, micronutrient, service-contact, and care-continuity risks. The index also classifies children into traffic-light vulnerability groups. The high-risk group uses the 75th percentile cutoff, equal to $CSRI \geq 0.200$ in the R07 analytical sample. The very-high-risk group uses the 90th percentile cutoff, equal to $CSRI \geq 0.306$. These thresholds serve as sample-relative screening cutoffs for monitoring, counseling, and follow-up prioritization.

The analysis constructs the CSRI, describes its weighted distribution, profiles risk by demographic and regional groups, and assesses construct validity through leave-one-out known-group validation and robustness checks. Known-group validation uses a leave-one-out approach to avoid mechanical circularity. For each risk marker (k), the study recomputes the index by excluding that marker and estimates:

$$CSRI_i(-k) = \alpha + \beta RiskMarker_{ik} + \gamma X_i + \epsilon_i$$

where $CSRI_i(-k)$ is the leave-one-out score, $RiskMarker_{ik}$ is the excluded risk marker, and X_i includes age group, sex, and urban-rural residence. A positive β indicates that children exposed to a specific risk marker also tend to carry a higher burden of other proximal risks. The coefficient does not represent a causal effect.

Several robustness checks assess the sensitivity of the index. The first excludes short length at birth because this indicator may reflect an early growth outcome rather than a pure risk exposure. The second compares nested equal weighting with equal item weighting. The third compares alternative screening cutoffs at the 70th, 75th, 80th, and 90th percentiles.

FINDINGS AND DISCUSSION

Sample Profile and CSRI Descriptive Statistics

The weighted national profile shows a large sample with high item coverage. The mean CSRI is 0.126, equivalent to 12.56 on a 0–100 scale, and 25.64% of children with a valid score fall above the preferred P75 screening threshold. This figure should be interpreted as a vulnerability screening signal, not as a stunting prevalence estimate.

Table 2. Sample profile and CSRI descriptive statistics

Indicator/group	Unweighted N	CSRI (0-1)	CSRI (0-100)	Interpretation
Full child sample aged 0-59 months	86,275	-	-	All observed children in the R07 analytical file

Indicator/group	Unweighted N	CSRI (0-1)	CSRI (0-100)	Interpretation
Children with valid CSRI score	82,678	-	-	Children contributing to the non-overlap CSRI
Weighted mean CSRI	-	0.126	12.56	Average proximal stunting vulnerability
Mean item coverage	-	0.965	96.45%	Average observed share of age-applicable items
High/very-high risk share	-	0.256	25.64%	Children above the P75 screening threshold
Age 0-5 months	6,739	0.096	9.61	High/very-high risk: 17.25%
Age 6-23 months	23,594	0.142	14.15	High/very-high risk: 24.93%
Age 24-59 months	55,942	0.122	12.23	High/very-high risk: 26.96%
Sex: Male	44,583	0.126	12.59	High/very-high risk: 25.94%
Sex: Female	41,692	0.125	12.53	High/very-high risk: 25.32%
Residence: Urban	43,824	0.126	12.58	High/very-high risk: 25.93%
Residence: Rural	42,451	0.125	12.52	High/very-high risk: 25.24%

Traffic-Light Vulnerability Screening Classification

The traffic-light classification translates the index into an operational triage rule. Low-risk children account for 48.23% of the valid weighted sample, and moderate-risk children account for 26.14%. The combined high and very-high groups account for 25.64%, with 10.01% falling in the very-high category. These children should not be labeled as stunted based on CSRI alone. They should be prioritized for growth monitoring, feeding counseling, immunization review, vitamin A checks, and MCH handbook follow-up.

Table 3. Traffic-light vulnerability screening classification

Risk category	Unweighted N	Weighted share (%)	Mean CSRI	Mean CSRI (0-100)	Coverage (%)
Low risk	36,161	48.23	0.025	2.50	98.38
Moderate risk	22,289	26.14	0.136	13.60	96.79
High risk	14,070	15.63	0.240	24.05	96.35
Very high risk	10,158	10.01	0.404	40.36	94.10

Age, Regional, and Provincial Risk Profiles

The age profile highlights the continued importance of the complementary-feeding period. Children aged 6-23 months have the highest mean CSRI, at 14.15 on the 0-100 scale. Yet children aged 24-59 months have the highest high- or very-high-risk share, at 26.96%, indicating that service gaps, missed growth monitoring, and care-practice risks remain relevant after infancy. Policy attention should therefore remain focused on the first 1,000 days while continuing to monitor older under-five children.

Regional gaps are more pronounced than sex or urban-rural differences. Maluku-Papua shows the highest mean CSRI and high or very-high risk share, followed by Sumatra and Sulawesi. Java-Bali records lower average risk but contains more than half of the weighted child population, making it important for program scale. These results suggest that eastern and outer-island regions need more intensive risk reduction, while Java-Bali remains central for broad program coverage.

Table 4. Weighted regional profile of CSRI and high/very-high risk

Region	Unweighted N	Weighted sample share (%)	Mean CSRI (0-100)	High/very-high (%)	Very high (%)	Biological/infection	Nutrition/care
Maluku-Papua	7,405	3.03	21.16	46.85	26.18	10.23	32.09
Sumatra	25,955	23.99	16.29	37.08	16.08	7.74	24.83
Sulawesi	13,283	7.77	15.14	33.62	13.84	8.50	21.77
Kalimantan	8,097	6.60	12.37	25.78	9.63	6.34	18.40
Java-Bali	21,941	53.92	10.33	18.93	6.33	8.22	12.44
Nusa Tenggara	5,997	4.69	9.47	17.09	5.06	6.75	12.19

Leave-One-Out Known-Group-Validation

The known-group validation supports the construct validity of the CSRI. Children with established risk markers have higher leave-one-out CSRI scores, indicating that each marker reflects a broader clustering of proximal risks. The strongest gradients relate to immunization, birth weight, vitamin A, growth monitoring, MCH handbook availability, breastfeeding, and animal-source food consumption. Recent acute respiratory infection is the main exception. Its validation signal is weak, suggesting that recent ARI captures short-term illness or reporting variation rather than accumulated stunting-related vulnerability.

Table 5. Leave-one-out known-group validation

Risk marker	Domain	N	Mean difference	Adjusted coefficient	SE	p-value
No immunization history	Care	83,895	0.141	0.125***	(0.003)	<0.001
Low birth weight	Biological	79,383	0.079	0.083***	(0.003)	<0.001
No vitamin A supplementation	Nutrition	79,520	0.092	0.079***	(0.002)	<0.001
No recent growth monitoring	Care	82,944	0.078	0.076***	(0.002)	<0.001
Pneumonia diagnosis in the previous year	Infection	85,891	0.065	0.064***	(0.008)	<0.001

Risk marker	Domain	N	Mean difference	Adjusted coefficient	SE	p-value
Never breastfed	Nutrition	30,100	0.069	0.060***	(0.006)	<0.001
Missing or unavailable MCH handbook	Care	86,256	0.063	0.060***	(0.002)	<0.001
No animal-source food consumption	Nutrition	23,590	0.058	0.058***	(0.003)	<0.001
Premature birth	Biological	81,494	0.065	0.053***	(0.002)	<0.001
Minimum dietary diversity not met	Nutrition	23,590	0.048	0.046***	(0.002)	<0.001
Inappropriate timing of complementary feeding	Nutrition	22,439	0.031	0.030***	(0.003)	<0.001
Short length at birth	Biological	64,602	0.027	0.027***	(0.002)	<0.001
Non-exclusive breastfeeding	Nutrition	6,708	0.027	0.026***	(0.004)	<0.001
Minimum meal frequency not met	Nutrition	16,980	0.024	0.022***	(0.003)	<0.001
Recent diarrhoea	Infection	86,256	0.020	0.017***	(0.003)	<0.001
Recent acute respiratory infection	Infection	86,256	0.001	0.010**	(0.003)	0.005

Programme-Relevant Risk Contributors

Contributor profiling shifts attention from statistical validation to program action. Among high/very-high risk children, non-exclusive breastfeeding, low dietary diversity, inappropriate timing of complementary feeding, no recent growth monitoring, low meal frequency, missing MCH handbook, and no vitamin A supplementation are the most prevalent contributors. These items are not causal claims. They identify common modifiable risks among children already flagged by CSRI and provide practical entry points for frontline intervention.

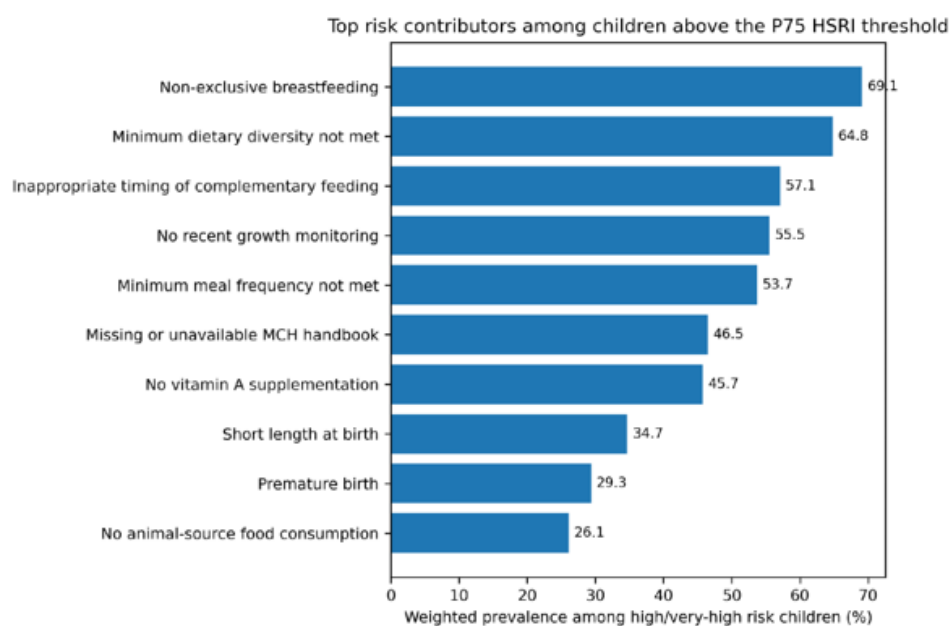


Figure 1. Top risk contributors among high/very-high risk children. Bars show weighted prevalence of each risk item among children above the P75 CSRI threshold

Robustness Checks and Structural Interpretation

The main index is stable to reasonable alternative specifications. Excluding short length at birth yields a correlation of 0.979 with the main CSRI, and equal item weighting yields 0.981. Threshold robustness shows that the size of the flagged group naturally changes with the chosen cutoff, from 33.00% at P70 to 20.38% at P80 and 10.01% at P90. This supports the P75 threshold as a pragmatic balance between selectivity and program reach.

Table 6. Robustness checks

Check	Role	Threshold/value	Flagged N	Share or correlation
P70	Sensitivity only	0.167	30,098	33.00
P75	Preferred main threshold	0.200	24,228	25.64
P80	Sensitivity threshold	0.225	19,774	20.38
P90	Very-high-risk threshold	0.306	10,158	10.01
CSRI excluding short length at birth	Specification correlation	-	-	corr. with main CSRI = 0.979
Equal item-weighted CSRI	Specification correlation	-	-	corr. with main CSRI = 0.981
Biological/infection dimension	Specification correlation	-	-	corr. with main CSRI = 0.480
Nutrition/care dimension	Specification correlation	-	-	corr. with main CSRI = 0.890

The nutrition and care dimension dominates the CSRI. Its scores are consistently higher across regions and correlate more strongly with the composite index than the biological and infection dimension, 0.890 versus 0.480. Although nested equal weighting gives both dimensions equal weight in the mean, higher prevalence and wider dispersion make nutrition and care the main driver of risk ranking. In its current form, the CSRI therefore captures mainly nutrition and care-practice vulnerability. However, the biological and infection dimension contributes less to differentiation across children. Future refinements should consider variance-adjusted weighting or report both sub-indices alongside the composite score.

A related concern is the MCH handbook. Because it records immunization, growth monitoring, and vitamin A information, its absence may cause several care indicators to appear missing or at risk at the same time. This structured missingness may inflate the nutrition and care dimension and strengthen apparent co-occurrence in validation tests. Future checks should restrict the sample to children with an available MCH handbook to assess whether the known-group gradients remain stable.

CONCLUSIONS

This study constructs a national Child Stunting Risk Index (CSRI) using SKI 2023 child health and nutrition indicators. Under the preferred P75/P90 traffic-light rule, 25.64% of children with valid scores are classified as high or very high risk, with the greatest burden among children aged 6–23 months and in Maluku-Papua, Sumatra, and Sulawesi. Robustness checks and known-group

validation support the CSRI as a transparent and replicable preventive prioritization tool that complements, but does not replace, anthropometric assessment.

The findings should be interpreted within several research boundaries: the index has not been validated against measured height-for-age z-scores, relies on cross-sectional data, applies a compensatory additive structure, is influenced mainly by the nutrition and care dimension, and may overstate selected care risks when Buku KIA records are missing. Future studies should validate the CSRI using linked anthropometric or longitudinal data and assess its sensitivity, specificity, calibration, and predictive performance to strengthen its use in identifying vulnerable children before visible growth failure occurs.

LIMITATIONS & FURTHER RESEARCH

This study has two important limitations. First, the R07 dataset used in this analysis does not include measured height-for-age z-scores or a binary stunting outcome. Therefore, the study cannot test criterion validity against measured anthropometric status. The CSRI should be interpreted as a concurrent vulnerability screening index, not as a stunting diagnosis or prevalence estimate. Second, the number of age-eligible items differs across children because of age rules and item availability. This may reduce strict comparability across individual scores. Future work should report the distribution of observed items per child, profile excluded children by age, region, and urban-rural residence, and validate the index against measured HAZ, linked SSGI or SKI anthropometric data, or provincial stunting prevalence.

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