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Association Between C-Reactive Protein (CRP) Levels and Stunting Status Among Toddlers in Jambi City

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Abstract

Background: Stunting remains a major public health problem in Jambi Province, Indonesia, with prevalence in the Talang Banjar catchment area rising from 13.5% to 17.1% between 2023 and 2024, contrary to the national declining trend. Environmental Enteric Dysfunction (EED), a chronic intestinal inflammation, is a key mediator of stunting, assessed via inflammatory markers such as C-reactive protein (CRP). **Objective:** This study analysed the association between CRP levels and stunting status among toddlers in the catchment area of Talang Banjar Primary Health Center, Jambi City, as baseline data for the SMART-GUT feature of the CANTIK UNJA application. **Methods:** A descriptive-analytic cross-sectional study was conducted among toddlers aged 7-59 months diagnosed with stunting (height-for-age z-score < -2 SD, WHO) registered at the health center; consecutive sampling yielded 24 toddlers with complete data. Capillary CRP was measured semi-quantitatively by slide agglutination and expressed in mg/dL, with 4 mg/dL as the non-reactive threshold. Stunting status and CRP were compared using the Mann-Whitney U test, with Spearman correlation for CRP versus height-for-age z-score. **Results:** Among 24 toddlers (8 stunted, 16 severely stunted), all (100%) had a CRP level of 4 mg/dL, with no between-group difference (mean ± SD 4.0 ± 0.0 mg/dL; U = 64.0; p = 1.000). **Conclusions:** No significant association was found between CRP level and stunting severity, as all samples showed a uniform, non-reactive CRP value. These findings highlight the need for a quantitative CRP assay with a wider detection range to capture EED-related subclinical inflammation in stunted children.

Keywords: C-reactive Protein; Stunting; Toddler; Environmental Enteric Dysfunction

Cite This Article

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INTRODUCTION

Stunting, defined as a height-for-age z-score below -2 standard deviations (SD) of the WHO Child Growth Standards, remains one of the most persistent forms of child undernutrition worldwide. In 2024, an estimated 150.2 million children under five years of age were stunted globally, with the highest burden concentrated in South Asia and sub-Saharan Africa [1]. In Indonesia, although the national stunting prevalence has continued to decline, Jambi Province showed a contrasting upward trend over the same period according to the national Nutritional Status Survey (Survei Status Gizi Indonesia, SSGI) [2]; within the Talang Banjar catchment area specifically, prevalence rose from 13.5% to 17.1% between 2023 and 2024, underscoring the localised urgency of this study.

Beyond inadequate dietary intake and repeated infections, growing evidence points to Environmental Enteric Dysfunction (EED) as a key biological mediator of linear growth failure. EED is a subclinical syndrome of chronic small intestinal inflammation, villous blunting, and increased gut permeability caused by repeated exposure to enteric pathogens in settings with poor sanitation, ultimately leading to nutrient malabsorption and systemic inflammation that blunts growth [3]. A recent birth cohort study from the Indonesian Action Against Stunting (AAS) Hub demonstrated that EED biomarkers, including C-reactive protein (CRP), were associated with children's linear growth through the insulin-like growth factor-1 (IGF-1) pathway [3]. Comparable associations between EED biomarkers and growth recovery have been reported among children with moderate acute malnutrition in Sierra Leone [4] and among young children in rural Ethiopia within the Campylobacter Genomics and Environmental Enteric Dysfunction (CAGED) project [5], while a randomised controlled trial protocol among children with severe acute malnutrition further underscored the relevance of EED biomarkers, including CRP, to nutritional recovery [6].

The gut microbiome has been implicated as a central driver of EED and stunting pathogenesis. A case-control study among Indonesian children in Pidie, Aceh, found that stunted children exhibited gut dysbiosis, a higher abundance of pro-inflammatory taxa, and lower IGF-1 levels compared with non-stunted children [7]. A microbiota-directed food intervention among undernourished Bangladeshi children improved ponderal growth in a randomised clinical trial [8], while a birth cohort study in a population with a high prevalence of stunting demonstrated that specific gut microbiome features were associated with early-life linear growth [9].

Stunting is a multifactorial condition. Non-exclusive breastfeeding has repeatedly been identified as a significant risk factor for stunting among Indonesian toddlers [10], a finding reinforced by a recent systematic review emphasising exclusive breastfeeding as a modifiable determinant relevant to health policy [11]. Inadequate water, sanitation, and hygiene (WASH) practices have also been consistently associated with a higher risk of stunting across low- and middle-income settings, including Benin [12], East Nusa Tenggara, Indonesia [13], and across developing countries in Asia more broadly [14], as well as in rural Bangladesh [15,16] and other developing countries in systematic reviews and meta-analyses [17,18], with comparable findings reported in South Sumatra, Indonesia [19]. Parental socio-economic characteristics, including maternal education, household income, and parental occupation, are further recognised determinants: infant and young child feeding practices linked to socio-economic status have been associated with both anaemia and stunting in sub-Saharan Africa [20], while maternal education level [21], household income and expenditure [22], and social and environmental factors

captured in Indonesia's 2023 national health survey [23] were each independently associated with childhood stunting; comparable rural-urban disparities have also been documented in Rwanda [24]. Anaemia is another commonly co-occurring condition: the World Health Organization has provided updated haemoglobin thresholds for anaemia diagnosis in children [25], and iron deficiency anaemia has been shown to be highly prevalent and strongly associated with stunting among children under five in developing countries [26,27,28]. Complementary evidence from Jambi Province further corroborates these determinants: a case-control study among urban children in Jambi City identified low birth length, incomplete immunization, and maternal educational deficit as the strongest predictors of stunting [29], whereas a cross-sectional study in the rural Batanghari District of Jambi identified inadequate dietary energy density, poor drinking water quality, and authoritarian parenting as significant predictors [30], together highlighting that risk factor patterns for stunting may differ between urban and rural settings within the same province.

C-reactive protein (CRP) is an acute-phase protein synthesised by hepatocytes under the regulation of interleukin-6 in response to infection, tissue injury, or inflammation, and is widely used as a point-of-care (POC) screening marker in children because clinical presentations of infection are frequently non-specific [31]. A randomised controlled trial in Kyrgyzstan demonstrated that POC CRP testing in primary care could safely reduce unnecessary antibiotic prescribing among children with acute respiratory infections [32], a strategy further supported by a review of POC CRP testing and antibiotic stewardship strategies in primary care [33]. Qualitative and semi-quantitative CRP slide agglutination methods have long been used in Indonesian primary care and hospital laboratories to screen for infection and inflammation, including tuberculosis [34] and paediatric febrile illness [35,36]. Beyond acute infection, CRP point-of-care testing has also been explored as a screening tool for paediatric tuberculosis [37] and to optimise antibiotic duration in hospitalised children with signs of infection [38], although the adoption of CRP POC testing varies across primary care systems depending on device availability, staff training, and local guidelines [39]. A stepped-wedge cluster randomised trial among community health workers in rural Uganda showed that POC CRP measurement safely reduced antimicrobial use in children with respiratory illness [40], while a comparison of commercially available rapid CRP assays among febrile children in Uganda demonstrated that diagnostic performance can vary considerably between test products and cut-off values [31].

Digital health applications are increasingly used to support child growth monitoring and early detection of malnutrition in low-resource settings. A systematic review of mobile applications for monitoring child growth outcomes found consistent improvements in undernutrition detection and caregiver knowledge [41], while a recent benchmarking study of paediatric mobile health applications available in Indonesia highlighted both the potential and the current quality gaps of such tools for stunting prevention [42].

As part of the development of the SMART-GUT (Screening Modular Application for Recognition of enTeric-GUT dysfunction) feature within the CANTIK UNJA application – a digital platform for early detection of EED using a combination of capillary CRP and simple faecal biomarkers – this study aimed to assess and analyse the association between CRP level and stunting status among toddlers in the working area of Talang Banjar Primary Health Center, Jambi City, focusing specifically on the CRP biomarker component.

METHODS

Study design and setting

This was a descriptive-analytic study with a cross-sectional design, conducted as part of the umbrella research project "Development of the SMART-GUT Feature in the CANTIK UNJA Application: Early Detection of Environmental Enteric Dysfunction for Stunting Prevention". The study was conducted in the working area of Talang Banjar Primary Health Center (Puskesmas), Jambi City, Indonesia.

Population, samples and sampling

The population comprised toddlers aged 7-59 months with a diagnosis of stunting (height-for-age z-score < -2 SD according to WHO standards) registered in the working area of Talang Banjar Primary Health Center. A consecutive sampling technique was applied to all registered stunted toddlers who attended examination during the data collection period. Inclusion criteria were: toddlers aged 7-59 months with a stunting diagnosis based on anthropometric measurement, residing within the Talang Banjar working area, and whose mother/caregiver provided informed consent. Exclusion criteria were: toddlers with congenital anomalies or chronic disease, acute infection (fever ≥ 38°C within the preceding seven days) that could confound CRP interpretation, antibiotic or antiparasitic treatment within the preceding four weeks, and incomplete records of CRP results and/or nutritional status (height-for-age z-score). After applying these exclusion criteria, 24 stunted toddlers with complete data were included in the final analysis.

Instruments and criteria

Anthropometric measurements (body weight, body length/height, mid-upper arm circumference, and head circumference) were obtained using calibrated instruments following WHO standard operating procedures; nutritional status was classified using height-for-age z-scores (HAZ) referenced to the WHO Child Growth Standards, with stunted defined as HAZ -2 to -3 SD and severely stunted as HAZ < -3 SD. Capillary CRP was measured using a commercial latex slide agglutination kit coated with anti-human CRP antibody; agglutination indicates a reactive result (CRP above the kit detection threshold), whereas the absence of agglutination indicates a non-reactive result, conventionally reported by the laboratory as 4 mg/dL, representing the value at or below the assay's detection limit. Parental characteristics (maternal age, parental education, parental occupation, and household income) and the child's exclusive breastfeeding history were obtained through structured interview with the mother/caregiver.

Procedure and data collection

Data collection was conducted through a health screening activity for stunted toddlers organised in collaboration with Talang Banjar Primary Health Center. Trained laboratory personnel performed capillary blood sampling and on-site CRP testing, while anthropometric measurement and structured interviews were conducted by trained enumerators. All data were anonymised prior to analysis to protect subject confidentiality.

Statistical analysis

Data were analysed descriptively to characterise the children, parental characteristics, nutritional status distribution, and CRP level (median, minimum-maximum, and

mean ± standard deviation). The association between nutritional status category (stunted vs severely stunted) and CRP level was assessed using the Mann-Whitney U test, selected as the appropriate non-parametric test for comparing a numeric variable between two independent groups when the data are non-normally distributed or contain identical/tied values, as was the case in this dataset.

Ethical considerations

This study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from the mother/caregiver of each participating child prior to data collection, and all data were anonymised to protect subject confidentiality.

RESULTS

After applying the exclusion criteria, 24 stunted toddlers with complete data from the Talang Banjar working area were analysed, with a mean age of 32.7 months (range 18-56 months), comprising 12 boys (50.0%) and 12 girls (50.0%). Based on HAZ, 8 children (33.3%) were classified as stunted and 16 (66.7%) as severely stunted; HAZ ranged from -4.82 to -2.34 SD, with a mean of -3.36 SD. A history of exclusive breastfeeding was reported for 17 of 24 children (70.8%), 6 children (25.0%) were not exclusively breastfed, and 1 child (4.2%) was still breastfeeding at the time of data collection. Sample characteristics are presented in Table 1.

Table 1. Characteristics of stunted toddlers in the working area of Talang Banjar Primary Health Center (n=24).

Characteristics	n	%
Age, mean (range) – months	24	32.7 (18-56)
Sex		
Male	12	50.0
Female	12	50.0
Nutritional status (HAZ)		
Stunted (-2 to -3 SD)	8	33.3
Severely stunted (< -3 SD)	16	66.7
HAZ, mean (range) – SD	24	-3.36 (-4.82 to -2.34)
Exclusive breastfeeding history		
Yes	17	70.8
No	6	25.0
Still breastfeeding at data collection	1	4.2

Table 2. Parental characteristics of stunted toddlers in the working area of Talang Banjar Primary Health Center.

Characteristics	n	%
Maternal age, mean (range) – years	24	34.0 (23-52)
Paternal education (n=24)		
Primary school	2	8.3
Junior high school	8	33.3
Senior high school	12	50.0
Higher education (diploma/bachelor)	2	8.3
Maternal education (n=24)		

Primary school	1	4.2
Junior high school	7	29.2
Senior high school	16	66.7
Paternal occupation (n=24)		
Manual/informal labourer	17	70.8
Private employee	3	12.5
Self-employed/entrepreneur	2	8.3
Not stated	1	4.2
Civil servant/contract government worker	1	4.2
Maternal occupation (n=24)		
Housewife (not employed)	22	91.7
Employed outside the home	2	8.3
Monthly household income, IDR (n=24)		
< 1,000,000	1	4.2
1,000,000-2,500,000	21	87.5
2,600,000-5,000,000	2	8.3

The mean maternal age was 34.0 years (range 23-52 years). Paternal education was most commonly at senior high school level (12 of 24 respondents, 50.0%), as was maternal education (16 of 24, 66.7%). Most fathers worked as manual/informal labourers (17 of 24, 70.8%), whereas nearly all mothers were housewives not engaged in paid employment (22 of 24, 91.7%). The majority of households had a monthly income of IDR 1,000,000-2,500,000 (21 of 24, 87.5%). Parental characteristics are presented in Table 2.

All 24 children (100%) had a CRP level of 4 mg/dL, the value representing results below the kit's detection threshold (non-reactive) according to the laboratory's reporting convention; no child had a CRP level above 4 mg/dL (reactive). CRP levels were uniform at 4.0 mg/dL in both the stunted and severely stunted groups (mean ± SD 4.0 ± 0.0 mg/dL; median 4.0 mg/dL, range 4.0-4.0 mg/dL), showing no variability whatsoever. The Mann-Whitney U test was used to compare CRP levels between the stunted and severely stunted groups because the data were non-normally distributed (entirely non-varying/identical), precluding meaningful interpretation of an independent t-test. The Mann-Whitney U test showed no statistically significant difference in CRP level between the two groups (U = 64.0; p = 1.000; alpha = 0.05). Spearman's correlation between CRP and HAZ was also attempted, but the correlation coefficient could not be computed (undefined) because CRP showed no variability (a constant value across all samples), and a constant variable cannot, by mathematical definition, be correlated with another variable. Results of the association test are presented in Table 3.

Table 3. Comparison of CRP level (mg/dL) between nutritional status groups (Mann-Whitney U test, n=24).

Nutritional status	n	Median (min-max) CRP, mg/dL	Mean ± SD CRP, mg/dL	p*
Stunted	8	4.0 (4.0-4.0)	4.0 ± 0.0	
Severely stunted	16	4.0 (4.0-4.0)	4.0 ± 0.0	1.000
Total	**24**	**4.0 (4.0-4.0)**	**4.0 ± 0.0**	

**Mann-Whitney U test, two-tailed (U = 64.0; p = 1.000).*

DISCUSSION

This study found that all (100%) stunted toddlers examined in the working area of Talang Banjar Primary Health Center had a uniform CRP level of 4 mg/dL, with no difference between the stunted and severely stunted groups, such that a statistical association between stunting severity and CRP level could not be demonstrated in this study. At first glance, this finding appears to contradict evidence that CRP is one of several EED markers associated with impaired linear growth, as shown in the Indonesian Action Against Stunting Hub birth cohort, in which CRP was part of a systemic biomarker panel associated with linear growth through the IGF-1 pathway [3], and in studies among children with moderate acute malnutrition in Sierra Leone and children in Ethiopia, which found variation in CRP level related to growth recovery and EED risk factors [4,5].

This discrepancy is most likely related to the characteristics of the CRP assay used in this study, namely a semi-quantitative slide agglutination method that reports only a single value of 4 mg/dL for all results below the kit's detection threshold, without further distinguishing variation in CRP level below that threshold. Consequently, mild elevations in CRP that might accompany subclinical inflammatory processes in EED could go undetected as a distinct value. A comparison of commercially available rapid CRP assays among febrile children in Uganda similarly demonstrated that the performance of semi-quantitative/qualitative assays can vary depending on the product and cut-off used [31], while a review of POC CRP testing strategies in primary care emphasised that the diagnostic value of CRP depends strongly on assay sensitivity [32,33].

Another possible explanation lies in the nature of EED itself as a chronic, low-grade inflammatory process that fluctuates over time and is not always accompanied by a detectable CRP spike at a single measurement time-point, unlike acute inflammation from bacterial infection, which typically triggers a sharp rise in CRP within hours. A uniform CRP level at the non-reactive threshold across the entire sample therefore does not necessarily rule out EED among the stunted toddlers examined, but more plausibly reflects the limited resolution of the conventional semi-quantitative method in capturing low-grade subclinical inflammation at a single measurement time-point.

From a statistical standpoint, the absence of variability in CRP level (uniformly 4 mg/dL) rendered an independent t-test and Pearson correlation uninterpretable (undefined), as both require variability in the data being compared. The Mann-Whitney U test, which is rank-based and can accommodate identical/tied values, could still be computed and yielded $p = 1.000$ (not statistically significant); similarly, the Spearman correlation between CRP and HAZ could not be computed because the CRP variable was constant. This $p = 1.000$ value does not substantively reflect the absence of a biological association between CRP/EED and stunting, but rather reflects the absence of variation in the measurement instrument used in the Talang Banjar working area.

Regarding family characteristics, most parents/caregivers of the stunted toddlers in this study had a middle level of education (junior to senior high school), with fathers predominantly working as manual/informal labourers and mothers predominantly not employed (housewives), and most households had an income in the range of IDR 1,000,000-2,500,000 per month. This pattern is consistent with widely reported socio-economic determinants of stunting: parental education and household income are known determinants of stunting risk through limited access to nutritious

food, sanitation, and health services [20,21,22,23,24]; non-exclusive breastfeeding [10,11] and inadequate water, sanitation, and hygiene practices [12,13,14,15,16,17,18,19] have similarly been shown to increase stunting risk, while iron deficiency anaemia frequently co-occurs with stunting in children under five in developing-country settings [25,26,27,28]. Nevertheless, because all children in this study were toddlers already diagnosed with stunting, without a non-stunted comparison group, the parental characteristics reported here remain descriptive and cannot be used to infer a causal relationship between household socio-economic factors and either stunting severity or CRP results. Gut microbiome-focused evidence further supports the biological plausibility of EED as a stunting mechanism independent of overt systemic inflammation: dysbiosis and reduced IGF-1 have been documented among Indonesian stunted children [7], and microbiota-directed interventions have shown potential to improve growth outcomes [8,9], underscoring that EED-related processes may operate largely outside the detection range of a conventional qualitative/semi-quantitative CRP assay.

This study has several limitations. First, the sample size was relatively small (n=24) and was drawn solely from the Talang Banjar working area, limiting generalisability to the wider population of stunted toddlers in Jambi City. Second, the cross-sectional design with a single CRP measurement time-point could not capture temporal fluctuation in CRP level relevant to the chronic nature of EED. Third, the semi-quantitative CRP method used has limited resolution, reporting only a single value of 4 mg/dL for all results below the detection threshold, without distinguishing variation in CRP below that threshold. Fourth, this study did not include a non-stunted comparison group or faecal biomarker and EED clinical symptom checklist data, which will be analysed separately in subsequent reporting consistent with the present focus on the CRP component.

CONCLUSIONS

Among 24 stunted toddlers with complete data in the working area of Talang Banjar Primary Health Center, Jambi City, all children (100%) had a uniform CRP level of 4 mg/dL, with no difference between the stunted and severely stunted groups. The Mann-Whitney U test showed no statistically significant difference in CRP level by stunting severity ($p = 1.000$). These findings highlight the limited resolution of the semi-quantitative CRP method used for detecting subclinical inflammation characteristic of Environmental Enteric Dysfunction among stunted toddlers in the Talang Banjar working area, and provide useful input for the ongoing development of the SMART-GUT feature within the CANTIK UNJA application. Further studies incorporating a non-stunted comparison group, quantitative CRP assays with a wider detection range, and complementary faecal biomarkers are recommended to strengthen the evidence base for EED screening in this population.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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DECLARATION OF ARTIFICIAL INTELLIGENCE USE
This study used artificial intelligence (AI) tools for manuscript writing support: an AI-based language model was used for language refinement (improving grammar, sentence structure, and readability) and technical writing assistance in structuring the manuscript according to the journal template.
We confirm that all AI-assisted processes were critically reviewed by the authors to ensure the integrity and reliability of the results. The final decisions and interpretations presented in this article were solely made by the authors.

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