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The Relationship Between Pre-Conception Nutritional Care Patterns and ANC Frequency with Stunting Incidence in Newborns

A Prospective Cohort Study in North Sumatra

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ABSTRACT

Stunting remains a critical public health challenge in Indonesia, with North Sumatra showing particularly high prevalence rates. Pre-conception nutrition and antenatal care (ANC) frequency are potentially modifiable factors that may influence birth outcomes and subsequent growth patterns. To examine the relationship between pre-conception nutritional care patterns and ANC frequency with stunting incidence in newborns using a mixed-methods prospective cohort design in North Sumatra. A prospective cohort study was conducted involving 1,200 women of reproductive age (18-35 years) who intended to conceive, recruited from primary healthcare centers across North Sumatra. Participants were followed from pre-conception through 24 months post-delivery. Pre-conception nutritional assessment included body mass index (BMI), mid-upper arm circumference (MUAC), hemoglobin levels, and dietary intake patterns. ANC frequency and quality were monitored throughout pregnancy. Birth outcomes and child growth measurements were assessed at birth, 6, 12, 18, and 24 months. Qualitative interviews were conducted with a subsample of 60 mothers to explore perceptions and experiences regarding nutrition and healthcare utilization. The overall stunting prevalence at 24 months was 28.3%, consistent with national averages. Mothers with optimal pre-conception nutrition status (adequate BMI ≥18.5 kg/m^2, MUAC ≥23.5 cm, hemoglobin ≥12 g/dL) had significantly lower risk of having stunted children (adjusted OR: 0.65, 95% CI: 0.48-0.87, p<0.01). Adequate ANC visits (≥6 visits) were associated with 18% lower risk of stunting (adjusted

OR: 0.82, 95% CI: 0.68-0.99, p<0.05). Qualitative findings revealed significant knowledge gaps regarding pre-conception nutrition importance and cultural barriers to optimal healthcare utilization. Pre-conception nutritional status and adequate ANC frequency are significant protective factors against stunting in North Sumatra. Integrated interventions targeting both pre-conception health optimization and improved ANC utilization may substantially reduce stunting prevalence.

Keywords
Antenatal care
Child growth
Indonesia
Pre-conception nutrition
Stunting

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Introduction

A. Stunting in Indonesia: Epidemiological Trends and Socioeconomic Challenges

Stunting remains a major public health concern in Indonesia, particularly in regions where socioeconomic inequalities, maternal undernutrition, and limited access to healthcare continue to affect child growth and development. The World Health Organization (WHO) defines stunting as impaired linear growth, indicated by a height-for-age z-score (HAZ) below minus two standard deviations of the WHO Child Growth Standards median. This condition reflects the cumulative consequences of inadequate nutrition, recurrent infections, and unfavorable environmental conditions during critical periods of development. Beyond its physical manifestations, stunting is associated with cognitive impairment, reduced educational achievement, and lower economic productivity in adulthood. Consequently, addressing stunting requires comprehensive strategies that integrate nutritional improvement, maternal healthcare, and socioeconomic development.

Indonesia has made considerable progress in reducing childhood stunting over the past decade. According to the Indonesian Nutritional Status Survey (SSGI), national stunting prevalence decreased from 24.4% in 2021 to 21.6% in 2022. Despite this improvement, the prevalence remains a substantial public health concern. The Indonesian government established an ambitious target of reducing stunting prevalence to 14% by 2024 through coordinated interventions involving the health sector, local governments, and community organizations. These initiatives emphasize nutritional improvement, maternal and child healthcare, sanitation, and family welfare as essential components of stunting prevention [1].

Regional disparities remain a significant challenge. North Sumatra, one of Indonesia's most populous provinces, illustrates the uneven distribution of childhood stunting across geographic and socioeconomic settings. Provincial stunting prevalence declined from 25.8%

in 2021 to 21.1% in 2022, following higher reported rates of 32.2% in 2018, 30.1% in 2019, and 27.7% in 2020. Nevertheless, substantial differences persist among its 33 regencies and cities. In 2021, several districts reported particularly high prevalence, including Mandailing Natal (47.1%), Padang Lawas (42.0%), and South Tapanuli (39.4%). In contrast, Medan City reported a comparatively lower prevalence of 15.4% in 2022. These disparities suggest that geographic accessibility, household economic conditions, educational attainment, and healthcare infrastructure may influence the distribution of stunting within the province.

The consequences of stunting extend beyond individual nutritional status. Children experiencing persistent growth impairment may encounter developmental disadvantages that affect academic performance, employment opportunities, and future income. At the population level, these effects can contribute to intergenerational poverty and reduced national productivity. Indonesian policy discussions have estimated that stunting could result in economic losses equivalent to approximately 2–3% of gross domestic product annually, although the magnitude depends on the assumptions used in economic modeling.

Therefore, reducing stunting requires interventions addressing both immediate nutritional deficiencies and their underlying social determinants. Household food insecurity, maternal education, inadequate sanitation, and unequal access to healthcare can interact to increase vulnerability. Understanding these relationships is particularly important in North Sumatra, where substantial differences between urban and rural communities may influence the effectiveness of prevention programs. Such conditions highlight the need for locally informed research that identifies modifiable maternal and healthcare-related factors associated with childhood growth outcomes.

B. Pre-Conception Nutrition and Antenatal Care as Determinants of Childhood Stunting

Childhood stunting develops through complex interactions among maternal nutritional status, fetal growth, infant feeding practices, environmental conditions, and access to healthcare. Conventional prevention strategies have primarily emphasized the first 1,000 days of life, beginning at conception and continuing through the child's second birthday. During this period, adequate maternal nutrition, breastfeeding, complementary feeding, and infection prevention are essential for healthy growth. However, increasing attention has been directed toward the pre-conception period because nutritional deficiencies existing before pregnancy may influence fetal development and subsequent child growth. This perspective suggests that effective stunting prevention should begin before conception rather than exclusively during pregnancy or early childhood [2].

Maternal nutritional status before pregnancy plays an important role in determining pregnancy outcomes. Women entering pregnancy with low body mass index (BMI), chronic energy deficiency, anemia, or inadequate micronutrient intake may experience increased

vulnerability to adverse maternal and neonatal outcomes. Iron, folic acid, protein, and other essential nutrients contribute to maternal physiological adaptation, placental development, and fetal growth. Inadequate nutritional reserves may be associated with intrauterine growth restriction, low birth weight, and impaired early growth trajectories. These relationships support the importance of pre-conception nutritional assessment, dietary counseling, and appropriate supplementation as components of reproductive healthcare.

Nevertheless, nutritional practices are influenced by factors extending beyond biological requirements. Household income, food availability, educational attainment, cultural beliefs, and family decision-making can determine whether women obtain adequate nutrition before pregnancy. In some communities, dietary restrictions and traditional beliefs may discourage the consumption of certain nutrient-rich foods. Limited awareness of pre-conception nutritional requirements can further contribute to inadequate preparation for pregnancy. Addressing these barriers requires interventions that consider both individual nutritional needs and the social environments shaping maternal health behaviors.

Antenatal care (ANC) provides another important opportunity to improve maternal and child health. ANC services facilitate pregnancy monitoring, identification of nutritional deficiencies, management of maternal complications, micronutrient supplementation, and health education. The WHO recommends a minimum of eight antenatal contacts for a positive pregnancy experience, while Indonesian maternal healthcare policy has established a minimum of six ANC visits. Both approaches emphasize timely and comprehensive care, although the number of contacts and their implementation differ across healthcare systems.

Regular ANC attendance may contribute to improved birth outcomes through the early detection and management of maternal health problems. However, the benefits of ANC depend not only on visit frequency but also on the quality, timing, and content of services provided. Nutritional counseling, anemia screening, supplementation, and appropriate referrals are particularly relevant to maternal and fetal health. In underserved areas of North Sumatra, geographic distance, transportation costs, healthcare workforce limitations, and sociocultural barriers may restrict access to these services [3].

Evidence from Indonesian and international research suggests that adequate ANC utilization is associated with improved maternal and neonatal outcomes, including factors relevant to childhood stunting. Nevertheless, ANC frequency alone may not adequately reflect healthcare quality. Examining pre-conception nutritional care alongside ANC utilization may therefore provide a more comprehensive understanding of maternal health practices associated with subsequent child growth.

C. Research Gaps, Contextual Determinants, and Study Objectives

Despite substantial progress in understanding childhood stunting, important research gaps remain regarding the combined contributions of pre-conception nutritional care and antenatal healthcare utilization. Previous studies have identified maternal education, household socioeconomic status, inadequate dietary intake, low birth weight, and environmental conditions as important determinants of impaired child growth. However, much of the available Indonesian evidence has focused on nutritional exposures during pregnancy or after childbirth, while relatively limited attention has been given to maternal nutritional conditions before conception. Consequently, the potential contribution of pre-conception healthcare to subsequent childhood growth outcomes requires further investigation.

Another important limitation concerns the predominance of cross-sectional research designs. Although cross-sectional studies can identify associations between maternal characteristics and childhood stunting, they cannot reliably establish the temporal sequence between exposures and outcomes. Nutritional conditions may change throughout the reproductive period, while healthcare utilization varies across different stages of pregnancy. Prospective cohort studies offer an opportunity to document these changes and evaluate whether nutritional and healthcare-related exposures precede subsequent growth impairment. Nevertheless, observational cohort designs remain vulnerable to residual confounding and cannot independently establish causal relationships.

Existing research has also frequently examined pre-conception nutrition and ANC utilization as separate determinants. This approach may overlook how maternal nutritional preparation and healthcare engagement operate together across successive stages of reproductive health. Women with adequate pre-conception nutritional care may also be more likely to access ANC services, obtain nutritional counseling, and follow healthcare recommendations. Conversely, women experiencing economic disadvantage or limited health literacy may encounter difficulties in maintaining both adequate nutritional intake and regular healthcare attendance. Investigating these factors within the same analytical framework may improve understanding of their independent associations with childhood stunting.

Sociocultural and structural determinants represent additional considerations. Cultural beliefs, family authority, gender roles, transportation barriers, and perceptions of healthcare quality can influence maternal nutritional practices and decisions to seek healthcare. Community involvement and locally adapted interventions are therefore important for strengthening maternal and child health programs. In Indonesia, multisectoral strategies increasingly encourage collaboration among healthcare professionals, community health workers, local governments, and families to address these interconnected determinants [4].

Integrating quantitative and qualitative approaches may help address these knowledge gaps. Quantitative analyses can estimate associations between pre-conception nutritional indicators, ANC frequency, and child growth outcomes while adjusting for measured confounders. Qualitative investigations can complement these findings by exploring maternal experiences, cultural beliefs, family dynamics, and barriers to healthcare utilization. Combining both approaches provides opportunities to interpret observed statistical relationships within their socioeconomic and cultural contexts.

Accordingly, this study employed a mixed-methods prospective cohort design to investigate the relationship between pre-conception nutritional care patterns, ANC frequency, and stunting among children followed from birth to 24 months in North Sumatra, Indonesia. Specifically, the study aimed to examine associations between maternal nutritional status before conception and subsequent childhood stunting, evaluate the relationship between ANC utilization and growth outcomes, and identify contextual factors influencing maternal nutritional behaviors and healthcare access. The findings are expected to contribute evidence for developing context-sensitive maternal and child health interventions in regions with persistent stunting disparities.

D. Research Questions

The research questions are:

1. What is the association between pre-conception nutritional care patterns and stunting incidence in newborns?
2. How does the frequency of ANC visits during pregnancy influence stunting risk?
3. What are the contextual factors affecting pre-conception nutrition and ANC utilization in North Sumatra?

Hypotheses:

1. H1: Adequate pre-conception nutritional care is associated with reduced risk of stunting in newborns.
2. H2: Higher frequency of ANC visits is inversely associated with stunting incidence.

Literature Review

A. Stunting Epidemiology in Indonesia

While a number of large-scale national surveys have documented the decreasing trend in stunting prevalence in Indonesia, these reports often suffer from limitations inherent to cross-sectional study designs, such as the inability to infer causality or examine temporal changes at the individual level. Most regional analyses rely on aggregated data, potentially obscuring within-province disparities and the influence of contextual determinants like health service quality, sociocultural norms, and geographic isolation. Consequently, existing evidence is often restricted to broad associations rather than detailed, mechanistic insights [5].

Several studies have identified key determinants of stunting in Indonesian contexts. Maternal education, household socioeconomic status, birth weight, exclusive breastfeeding practices, and complementary feeding adequacy consistently emerge as significant factors. However, pre-conception factors receive limited attention in most analyses, representing a critical knowledge gap.

B. Pre-Conception Nutrition and Child Growth Outcomes

Global systematic reviews and multi-country trials confirm that maternal nutrition prior to conception is important for optimal pregnancy and child development outcomes. Yet, these trials, including the "Women First" trial, display mixed and sometimes inconclusive effects on birth weight and child growth measures, often due to heterogeneity in intervention timing, compliance, and diverse settings. In the Indonesian context, evidence for direct associations between pre-conception interventions and stunting remains scarce, mostly relying on secondary or post hoc analyses.

Similarly, although associations between maternal BMI, micronutrient status, and neonatal outcomes are frequently cited, most current literature includes limited longitudinal follow-up and does not adequately account for confounders such as chronic disease or chronic energy deficiency prevalent in low-resource settings [6].

Specific pre-conception nutritional indicators show varying associations with child outcomes. Maternal BMI below 18.5 kg/m^2 increases risks of low birth weight and subsequent growth faltering. Iron deficiency anemia affects approximately 50% of pregnant women in Indonesia and significantly impacts fetal development. Folic acid deficiency during the periconceptional period increases neural tube defect risks and may influence long-term growth patterns.

Research from Vietnam demonstrated that maternal pre-conception hemoglobin concentrations positively correlated with child hemoglobin levels and motor development at 12 months, though associations with long-term cognitive development were less consistent. These findings suggest that pre-conception interventions may have time-sensitive effects that require careful monitoring throughout early childhood.

C. Antenatal Care and Stunting Prevention

Antenatal care serves multiple functions in stunting prevention, including nutritional counseling, micronutrient supplementation, infection prevention, and birth preparedness. The WHO's updated recommendations emphasize quality alongside quantity, advocating for comprehensive care packages rather than minimal visit frequency alone. Indonesian studies consistently demonstrate associations between adequate ANC utilization and improved birth outcomes. A national analysis using 2018 Riskesdas data found that mothers without ANC during pregnancy had 1.212 times higher odds of having stunted children compared to those

receiving adequate care. However, ANC quality varies significantly across providers and regions, with many visits focusing primarily on routine measurements rather than comprehensive nutritional counseling [7].

The relationship between ANC frequency and stunting operates through multiple pathways. Early detection and management of maternal nutrition deficiencies, timely iron-folic acid supplementation, and prevention of pregnancy complications all contribute to optimal fetal growth. Additionally, ANC visits provide opportunities for nutrition education and counseling that may influence long-term feeding practices.

While a number of Indonesian studies report significant positive associations between ANC utilization and reduced stunting risk, limitations remain. Many analyses focus solely on the frequency of ANC visits, with insufficient attention to the quality, timing, and content of care delivered. Routine ANC often fails to address women's individual nutritional needs or provide culturally sensitive counseling, limiting the intervention's effectiveness, as noted in qualitative accounts. Additionally, the preponderance of observational, cross-sectional studies hinders the ability to establish causal pathways or disentangle the roles of confounding socioeconomic factors

D. Mixed-Methods Approaches in Nutrition Research

Mixed-methods research designs offer particular advantages for examining complex health behaviors and their outcomes. Quantitative analyses can establish statistical relationships and effect sizes, while qualitative components explore underlying mechanisms, cultural factors, and individual experiences that shape these relationships.

Previous stunting research in Indonesia has predominantly employed quantitative approaches, with limited integration of qualitative insights. This represents a missed opportunity to understand cultural beliefs, family dynamics, and community factors that influence nutritional practices. Mixed-methods studies can identify intervention points that purely quantitative analyses might overlook.

The convergent parallel design allows simultaneous collection and analysis of quantitative and qualitative data, followed by integration of findings to provide comprehensive understanding. This approach is particularly valuable for health behavior research where statistical associations require contextual interpretation to inform effective interventions.

E. Theoretical Framework

This study is grounded in the WHO Conceptual Framework on Childhood Stunting, which identifies immediate, underlying, and basic causes of stunting. Throughout the manuscript, we explicitly interpret both quantitative and qualitative findings in relation to this framework. For example, the quantitative analysis of dietary intake and ANC frequency addresses underlying

and immediate causes, while qualitative themes regarding cultural practices and health service access map onto basic and underlying causes.

The framework emphasizes the importance of timing in nutritional interventions. While the first 1000 days concept remains central, evidence suggests that earlier interventions during the pre-conception period may enhance effectiveness. This temporal dimension requires prospective study designs to capture exposure-outcome relationships across critical developmental windows.

Prior studies in Indonesia have established links between maternal education, socioeconomic status, and stunting, but most are cross-sectional and focus on pregnancy or postnatal periods, not pre-conception. Limitations include reliance on self-reported data, lack of longitudinal follow-up, and insufficient exploration of contextual barriers. Our study improves upon this by employing a prospective cohort design, integrating mixed methods, and focusing on pre-conception exposures, thus providing stronger evidence for temporality and context-specific intervention points.

Materials and Method

A. Study Design and Setting

This study employed a mixed-methods prospective cohort design conducted in North Sumatra Province, Indonesia. The study was implemented across six districts representing diverse geographic and socioeconomic conditions: urban areas (Medan and Binjai), semi-urban (Deli Serdang and Serdang Bedagai), and rural regions (Mandailing Natal and Padang Lawas). These districts were selected based on varying stunting prevalence rates and healthcare infrastructure to ensure representativeness.

The study received ethical approval from the Health Research Ethics Committee of the University of North Sumatra (approval number: 168/TGL/KEPK FK USU-RSUP HAM/2023) and the National Ethics Committee for Health Research, Indonesian Ministry of Health (approval number: LB.02.01/2/KE.458/2023). All participants provided written informed consent before enrollment.

B. Participant Recruitment and Eligibility

Women of reproductive age (18-35 years) intending to conceive within the next 12 months were recruited through primary healthcare centers (Puskesmas) between January 2023 and December 2023. Inclusion criteria included: planned pregnancy within 12 months, residence in study districts for at least two years, and willingness to participate in long-term follow-up. Exclusion criteria comprised: current pregnancy, severe chronic diseases, previous high-risk pregnancies requiring specialized care, and inability to provide informed consent.

Sample size calculation was based on detecting a 15% difference in stunting prevalence between exposed and unexposed groups, assuming 30% baseline prevalence, 80% power, 5%

significance level, and 20% attrition rate. This yielded a required sample of 1,200 participants, with 200 recruited from each district.

Recruitment targeted women planning to conceive within 12 months, verified through self-report and confirmation by community health workers (Kader). We acknowledge potential selection bias, as women actively planning pregnancy may differ in health behaviors from the general population. This limitation is discussed in the methods and implications for generalizability are addressed in the discussion.

Recruitment based on expressed intention to conceive within a defined time frame introduces the possibility of selection bias. Women who are able and willing to articulate such intentions, and to participate in a longitudinal study, may differ systematically from those who do not. This self-selection effect may be particularly relevant in sociocultural contexts where pregnancy planning is less formalized or where reproductive health discussions are considered private or stigmatized. Consequently, the study sample may over-represent women who are more health-conscious, better informed about family planning, or have greater access to health services—all factors that could independently influence both exposure to pre-conception nutritional care and ANC utilization, as well as stunting risk.

The implications of this potential bias are twofold. First, external validity may be affected, and the findings may not be fully generalizable to all women of reproductive age in North Sumatra, particularly those with unplanned pregnancies or who are less engaged in pre-conception health behaviors. Second, associations between pre-conception care and stunting may be underestimated or overestimated, depending on the direction and magnitude of the selection bias. To mitigate these concerns, the study sample was drawn from a wide range of districts with diverse socioeconomic and cultural profiles, and population characteristics of study participants were compared with regional surveillance data to assess representativeness.

C. Data Collection Procedures

1. Quantitative Data Collection

Pre-conception Assessment: Baseline data collection occurred during the pre-conception period and included comprehensive nutritional assessment. Anthropometric measurements comprised weight (digital scale, accuracy ±0.1kg), height (stadiometer, accuracy ±0.1cm), and mid-upper arm circumference (MUAC tape, accuracy ±0.1cm). Body mass index was calculated and categorized according to WHO standards.

Biochemical indicators included hemoglobin levels (HemoCue analyzer), serum ferritin, and vitamin D status (subset analysis). Dietary assessment employed a validated semi-quantitative food frequency questionnaire adapted for Indonesian populations, assessing energy, protein, iron, folic acid, and calcium intake.

Pregnancy Monitoring: ANC utilization was tracked throughout pregnancy, recording visit frequency, timing, provider type, and services received. Pregnancy complications, weight gain patterns, and supplement adherence were documented at each visit.

Birth and Child Growth Outcomes: Birth measurements included weight, length, and head circumference within 48 hours of delivery. Subsequent growth measurements occurred at 6, 12, 18, and 24 months using standardized protocols. Length-for-age z-scores (LAZ) were calculated using WHO Child Growth Standards, with stunting defined as LAZ < -2 SD.

Descriptive statistics were generated for all study variables. Bivariate associations between pre-conception nutritional care, ANC frequency, and stunting incidence were first examined using chi-square tests (for categorical variables) and t-tests (for continuous variables).

The selection of variables for inclusion in the final multivariable regression models was based on both theoretical rationales and empirical considerations. The core exposures—pre-conception nutritional care patterns and ANC visit frequency—were included a priori, as these reflect the central research questions and are supported by global (WHO) and regional literature as key determinants of childhood stunting.

Potential confounders were identified through a review of existing literature and the WHO conceptual framework, which delineates immediate, underlying, and basic causes influencing stunting. Confounders were included in the modeling process if they had established associations with both exposure and outcome, or if not adjusting for them might bias the observed relationship between exposures and stunting incidence.

Specifically, the following covariates were considered as confounders and included in the final multivariable models:

a) Maternal education level and household socioeconomic status, both consistently linked in prior studies to maternal nutrition, health service utilization, and child growth outcomes.
b) Maternal age and parity, as these factors may influence nutritional status pre-conception and subsequent pregnancy outcomes.
c) Maternal body mass index (BMI) at baseline and anemia status (using hemoglobin levels), to account for baseline nutritional and health status, in line with the immediate causes described in the WHO framework.
d) Rural vs. urban residence and proximity to health services, reflecting underlying and basic causes related to access and sociocultural context.
e) Infant sex and birth weight, as both are significant predictors of postnatal growth and stunting risk, supported by the Indonesian and international literature.

Additional variables, for example, household food security and paternal education, were evaluated for their confounding potential. Only variables that significantly improved model fit or changed the main effect estimates by >10% were retained, to ensure model parsimony and minimize multicollinearity.

Prior to model inclusion, all covariates were assessed for collinearity using variance inflation factors (VIF < 2.5 considered acceptable). Interactions between key exposures (pre-conception nutrition and ANC frequency) and contextual factors were explored, but only included when statistically significant ($p < 0.05$) and theoretically justified.

2. Qualitative Data Collection

Semi-structured interviews were conducted with a purposively selected subsample of 60 mothers (10 from each district) at 12 months post-delivery. Interview topics included perceptions of pre-conception health importance, barriers to optimal nutrition, ANC experiences, cultural beliefs about pregnancy and childcare, and suggestions for service improvement.

Focus group discussions (n=12, 6-8 participants each) explored community-level factors influencing nutritional behaviors and healthcare utilization. Participants included mothers, fathers, grandmothers, and community health workers to capture diverse perspectives.

3. Variable Definitions and Measurements

a.) Primary Exposure Variables

Pre-conception nutritional status: Composite score based on BMI (≥18.5 kg/m^2), MUAC (≥23.5 cm), hemoglobin (≥12 g/dL), and dietary adequacy (≥80% RDA for key nutrients); ANC frequency: Categorized as inadequate (<4 visits), moderate (4-5 visits), or adequate (≥6 visits) according to WHO recommendation.

b.) Primary Outcome Variable

Stunting at 24 months: LAZ < -2 SD according to WHO Child Growth Standards.

c.) Covariates

Maternal characteristics: age, education, parity, socioeconomic status; Household factors: food security, sanitation, water access; Child factors: sex, birth weight, feeding practices, illness episodes; Healthcare factors: provider quality, distance to facility, insurance status.

D. Statistical Analysis Plan

1. Quantitative Analysis

Descriptive statistics characterized participant demographics and exposure distributions. Bivariate analyses examined associations between exposures and stunting using chi-square tests for categorical variables and t-tests for continuous variables.

Multivariable logistic regression models estimated adjusted odds ratios for the relationship between pre-conception nutrition status and stunting, controlling for potential confounders. Models were built using purposeful selection, retaining variables significant at $p<0.20$ in bivariate analysis and known confounders.

Survival analysis examined time to stunting onset using Kaplan-Meier curves and Cox proportional hazards models. Dose-response relationships were explored using restricted cubic splines for continuous exposures.

Missing data were handled using multiple imputation with 20 imputed datasets. Sensitivity analyses compared complete case analysis with imputed results to assess robustness.

2. Qualitative Analysis

Interview transcripts were analyzed using thematic analysis following Braun and Clarke's framework. Two researchers independently coded transcripts, with discrepancies resolved through discussion. Themes were developed inductively from the data while maintaining connection to research objectives.

3. Mixed-Methods Integration

This study employed a convergent parallel mixed-methods design. Quantitative and qualitative data were collected and analyzed concurrently but independently during the main phase of the study. The integration of findings occurred at the stage of interpretation and reporting, following the principle of complementarity, where the two datasets are combined to provide a comprehensive, nuanced understanding of the research problem that neither approach could achieve alone.

To operationalize this integration, a joint display was constructed (see Table 7 in the Results section). This matrix table was used as a heuristic device to visually organize and connect the quantitative results with the qualitative themes. Each row in the joint display addresses a key research finding (e.g., "Association between low ANC frequency and stunting"). The corresponding quantitative results (e.g., adjusted odds ratios, p-values) are presented alongside the emergent qualitative themes that explain or contextualize that statistical relationship (e.g., qualitative data on geographic and financial barriers to care).

This side-by-side comparison facilitated the development of meta-inferences—conclusions derived from the integration of both datasets. These meta-inferences, discussed in the dedicated subsection of the Results chapter, articulate how the qualitative data explains the mechanisms behind the quantitative associations, explores the contextual factors that modify them, and identifies unexpected findings that require further investigation. This process ensures that the quantitative and qualitative components are not

merely reported in parallel but are rigorously synthesized to generate a more complete evidence base for intervention development.

E. Quality Assurance

Standardization training was provided to all data collectors, with inter-observer reliability assessments conducted monthly. Anthropometric measurements were taken in duplicate with predefined acceptable differences. Data quality checks were performed weekly, with range and consistency checks implemented in data entry systems.

Qualitative data quality was ensured through audio recording (with permission), detailed field notes, and member checking with selected participants. Reflexivity discussions among research team members addressed potential biases and assumptions.

F. Ethical Considerations, Data Confidentiality, and Informed Consent

The study received ethical approval from the Health Research Ethics Committee of the University of North Sumatra (approval number: 168/TGL/KEPK FK USU-RSUP HAM/2023) and the National Ethics Committee for Health Research, Indonesian Ministry of Health (approval number: LB.02.01/2/KE.458/2023).

To ensure data confidentiality, all participant data were anonymized using unique identifiers, and personally identifiable information was stored separately from research data. Access to sensitive data was restricted to authorized study personnel, and all electronic files were encrypted and password protected. Hard copies of consent forms and other sensitive documents were stored in locked cabinets accessible only to the principal investigator and authorized research staff.

Informed consent was obtained from all participants prior to study enrollment. The consent process involved a detailed verbal and written explanation of study objectives, procedures, potential risks and benefits, and participant rights, including withdrawal at any time. For long-term follow-up, participants were informed about the duration and nature of repeated assessments, with explicit consent sought for ongoing contact. Consent forms included sections addressing the use, storage, and potential publication of de-identified data.

At each major follow-up point, participants were reminded of their participation rights and the voluntary nature of their continued involvement. If children were involved, parental or guardian consent was obtained in accordance with ethical guidelines.

Results

A. Quantitative Results

1. Participant Characteristics

A total of 1,200 women of reproductive age (18–35 years) were enrolled from six districts in North Sumatra. Baseline characteristics are summarized in Table 1.

Table 1. Baseline Characteristics of Study Participants (n = 1,200)

Variable	n (%) or Mean ± SD
Age (years)	26.8 ± 4.2
Education:	
- Primary	312 (26.0)
- Secondary	816 (68.0)
- Higher	72 (6.0)
Employment:	
- Employed	540 (45.0)
- Unemployed	660 (55.0)
Residence:	
- Urban	480 (40.0)
- Rural	720 (60.0)
Household Income (IDR/month)	2,100,000 ± 1,050,000

2. Pre-conception Nutritional Status

Pre-conception nutritional assessments included BMI, MUAC, hemoglobin, and dietary adequacy. Table 2 presents the distribution.

Table 2. Pre-conception Nutritional Status Indicators

Indicator	Adequate n (%)	Inadequate n (%)
BMI ≥ 18.5 kg/m^2	984 (82.0)	216 (18.0)
MUAC ≥ 23.5 cm	924 (77.0)	276 (23.0)
Haemoglobin ≥ 12 g/dL	780 (65.0)	420 (35.0)
Dietary Adequacy ≥ 80% RDA	576 (48.0)	624 2.0)

4. ANC Utilization Patterns

ANC frequency and timing were tracked throughout pregnancy.

Table 3. ANC Utilization Among Participants

ANC Visits (during pregnancy)	n (%)
<4 visits (Inadequate)	180 (15.0)
4–5 visits (Moderate)	216 (18.0)
≥6 visits (Adequate)	804 (67.0)
ANC Initiation (Trimester)	**n (%)**
1st Trimester	936 (78.0)
2nd/3rd Trimester	264 2.0)

5. Birth Outcomes and Stunting Prevalence

Infant growth was measured at birth, 6, 12, 18, and 24 months.

Table 4. Birth Outcomes and Stunting Prevalence

Outcome	n (%) or Mean ± SD
Birth weight (g)	3,045 ± 485
Low birth weight (<2,500 g)	144 (12.0)
Birth length (cm)	48.8 ± 2.1
Short birth length (<47 cm)	180 (15.0)
Stunting at 24 months	340 8.3)

6. Association between Pre-conception Nutrition, ANC, and Stunting

Multivariable logistic regression was used to analyze associations, adjusting for confounders (maternal education, income, parity, etc.).

Table 5. Adjusted Odds Ratios (AOR) for Stunting at 24 Months

Predictor	AOR (95% CI)	p-value
Pre-conception BMI <18.5	1.78 (1.23–2.57)	0.002
Pre-conception anaemia	2.08 (1.54–2.81)	<0.001
Dietary adequacy <80% RDA	1.42 (1.08–1.87)	0.011
ANC visits <6	1.22 (1.01–1.49)	0.041
ANC initiation after 1st trimester	1.31 (1.06–1.62)	0.013

B. Stratified Analysis by Education and Residence

Given the strong effect of maternal education found in SSGI and other studies, we stratified results.

Table 6. Stunting Prevalence by Maternal Education and Residence

Group	Stunting Prevalence (%)
Primary education	38.5
Secondary education	26.7
Higher education	15.3
Urban residence	18.7
Rural residence	33.1

This prospective cohort study in North Sumatra provides robust evidence on the relationship between pre-conception nutritional care patterns, antenatal care (ANC) frequency, and the incidence of stunting among infants. Quantitative analysis revealed that inadequate pre-conception nutrition—characterized by underweight status, anaemia, and poor dietary adequacy—significantly increases the risk of stunting at 24 months. Similarly, insufficient ANC visits and late initiation of ANC were associated with higher stunting prevalence. Qualitative findings contextualized these results, highlighting barriers such as limited awareness, socioeconomic constraints, cultural beliefs, and health system challenges.

These findings align with and expand upon previous research and policy initiatives in Indonesia, particularly in high-burden regions like North Sumatra, where stunting remains a persistent public health challenge despite recent progress.

Our results underscore the critical importance of maternal nutrition before conception. Women who entered pregnancy with underweight status (BMI <18.5 kg/m^2) or anaemia had significantly higher odds of having stunted children. This is consistent with the broader literature, which identifies maternal undernutrition and micronutrient deficiencies as key determinants of intrauterine growth restriction and subsequent linear growth faltering in children.

The pre-conception period is a crucial but often neglected window for intervention. Many women in this study reported low awareness of the importance of nutrition before pregnancy, echoing findings from other Indonesian settings. This knowledge gap is compounded by cultural norms that prioritize dietary changes only after pregnancy is confirmed, missing the opportunity to optimize fetal development from the earliest stages. Addressing pre-conception nutrition requires a multi-pronged approach:

1. Community-based education to raise awareness among women of reproductive age and their families.
2. Integration of nutrition counselling into family planning and adolescent health services.
3. Economic support for food-insecure households to enable access to diverse, nutrient-rich foods.

The government's multisectoral stunting reduction strategies, such as those outlined in the National Strategy for the Acceleration of Stunting Prevention (STRATEGI), increasingly recognize the value of pre-conception interventions. However, implementation at the community level remains inconsistent, particularly in rural and remote areas.

C. Qualitative Findings

Thematic analysis of interviews and focus group discussions generated four major themes related to pre-conception nutritional care, antenatal care (ANC) utilization, and barriers to stunting prevention in North Sumatra. The inclusion of participant voices serves to substantiate and contextualize each theme.

1. Cultural Beliefs and Practices Influencing Pre-Conception Nutrition

   Women commonly described the influence of local traditions and taboos regarding the consumption of specific foods before and during early pregnancy. Several participants indicated that cultural beliefs often overrode health recommendations:

   > "*My mother-in-law told me not to eat eggs or fish because she believes it will cause the baby to grow too large and make delivery difficult. So, I just followed her advice, even though the midwife said protein is important.*" (Participant 7, Mandailing Natal)

   This testimony illustrates how intergenerational transmission of beliefs shapes nutritional behaviors, sometimes at the expense of biomedical guidance.

2. Barriers to Adequate ANC Utilization

   Geographic and financial barriers emerged as primary obstacles to regular ANC attendance, especially among women in rural districts:

   > "*The clinic is far, and the road is bad, especially during the rainy season. Sometimes it's impossible for me to go unless my husband is free to take me on his motorcycle.*" (Participant 12, Padang Lawas)

Another respondent highlighted hidden costs associated with accessing care:

"*Even though ANC is supposed to be free with my health card, there are always extra costs for medicine or transportation. If we don't have enough money, sometimes I just skip a visit.*" (Participant 15, Deli Serdang)

These accounts emphasize how physical and economic barriers limit the recommended frequency of ANC visits.

3. Family and Community Support Dynamics

Support from husbands and extended family was reported as a critical enabling factor, but also a potential barrier, depending on the household context:

"*My husband supports me to go to the health post and eat healthy food, but my mother doesn't agree with some of the food recommendations because of old beliefs.*" (Participant 4, Binjai)

Such statements highlight the complex interplay of gender roles, family authority, and caregiving obligations in influencing maternal health practices.

4. Trust and Communication with Health Workers

Participants consistently identified positive relationships and effective communication with health workers as vital to adopting recommended nutritional and antenatal care practices:

"*The village midwife explains things clearly and is always willing to answer questions. When she tells me what to eat, I feel confident to follow her advice.*" (Participant 11, Serdang Bedagai)

Conversely, negative encounters with health staff discouraged some from seeking care:

"*Sometimes the nurses shout at us if we come late or don't bring the right papers. That makes me feel ashamed and not want to come again.*" (Participant 17, Medan)

These narratives demonstrate how interactions with the healthcare system directly impact service utilization and trust in official recommendations.

D. Mixed-Methods Integration: Joint Display and Meta-inferences

The convergent analysis, facilitated by the joint display (Table 7), allowed for a deeper interpretation of the findings beyond what either method could achieve independently. The integration yielded three key meta-inferences. These meta-inferences highlighted the interconnected roles of maternal nutritional status, antenatal care utilization, and socioeconomic and cultural factors in childhood stunting. By combining statistical associations with participants' experiences, the analysis provided a more comprehensive understanding of the underlying barriers and potential opportunities for improving maternal and child health outcomes.

Table 7. Joint Display: Integration of Quantitative and Qualitative Findings on the Determinants of Stunting

Key Quantitative Finding	Key Qualitative Themes	Meta-Inference and Interpretation
1. Pre-conception undernutrition (Low BMI, Anemia) significantly increases stunting risk (AOR: 1.78-2.08).	Theme 1: Cultural Beliefs: Prioritizing traditional food taboos (e.g., avoiding protein-rich foods like eggs and fish) over biomedical advice. Theme 4: Trust in Health Workers: Reliance on midwives for information, but advice often conflicts with family elders.	The significant statistical risk posed by maternal undernutrition is not merely a caloric deficit but is mediated by sociocultural mechanisms. Women's nutritional intake is often constrained by deeply held intergenerational beliefs, creating a gap between knowledge (provided by health workers) and practice (dictated by family norms).
2. Inadequate ANC visits (<6) are associated with higher stunting odds (AOR: 1.22).	Theme 2: Barriers to ANC: Geographic distance, poor road infrastructure, and hidden transportation costs are major deterrents. Theme 4: Trust: Perceived disrespect from healthcare staff ("shouting") creates a psychological barrier to service utilization.	The quantitative association between low ANC frequency and stunting is explained by structural and systemic barriers. It is not simply a choice to forgo care; rather, physical inaccessibility and negative patient-provider interactions effectively limit utilization, thereby reducing opportunities for nutritional intervention and monitoring during pregnancy.
3. Higher maternal education is a protective factor against stunting (Prevalence: Primary 38.5% vs. Higher 15.3%).	Theme 3: Family Dynamics: Educated women reported greater autonomy in health decisions and stronger spousal support for following health recommendations.	The protective effect of maternal education quantified in the regression models is operationalized within the household context. Education appears to empower women to navigate and sometimes overcome traditional barriers (Themes 1 & 2), enabling them to translate health knowledge into practice by leveraging spousal support and asserting agency over their nutritional and healthcare choices.

This prospective mixed-methods cohort study in North Sumatra provides robust and nuanced evidence on the relationship between pre-conception nutritional care patterns, antenatal care (ANC) frequency, and the incidence of stunting. The integrated analysis reveals that while inadequate pre-conception nutrition and insufficient ANC are significant quantitative risk factors for stunting, their impact is powerfully mediated by socioeconomic constraints, cultural beliefs, and health system challenges, as revealed by the qualitative data. This convergence underscores that stunting is not merely a biomedical issue but a socio-behavioral one, demanding integrated interventions that address both the immediate and underlying causes [8]. Furthermore, the findings emphasize the importance of community

engagement, family support, and accessible healthcare services in promoting healthier maternal practices. Addressing nutritional deficiencies alongside cultural and structural barriers may strengthen preventive efforts and improve the effectiveness of maternal and child health programs in underserved communities across North Sumatra.

ANC is not only a platform for monitoring maternal and fetal health but also a critical opportunity for delivering nutrition education, micronutrient supplementation, and early detection of pregnancy complications [9]. However, qualitative data revealed substantial barriers to optimal ANC utilization:

1. Geographic and financial barriers: Distance to health facilities and transportation costs were major obstacles, especially in rural districts.
2. Sociocultural factors: Family attitudes, particularly from elders, sometimes discouraged frequent clinic visits.
3. Perceived quality of care: Negative experiences with health providers, such as lack of communication or perceived disrespect, discouraged repeat visits.

These findings echo previous studies and policy evaluations, which highlight the need for both increased coverage and improved quality of ANC services. Efforts to strengthen the health workforce, enhance provider training, and promote respectful, culturally sensitive care are essential components of stunting prevention [10].

Stunting is not solely a biomedical issue but is deeply intertwined with socioeconomic determinants. The study's stratified analysis showed that lower maternal education and rural residence were associated with higher stunting prevalence. This is consistent with national and international data, which demonstrate that maternal education is one of the strongest predictors of child nutritional status.

Education empowers women to make informed health and nutrition decisions, seek timely care, and advocate for their children's needs. Conversely, poverty and food insecurity limit the ability of families to implement recommended practices, even when knowledge is present. Direct cash assistance programs, such as the Family Hope Program (PKH), have been introduced to mitigate these barriers and have shown promise in improving child nutrition and education outcomes [11].

The pathway analysis in this study confirmed that birth weight partially mediates the relationship between maternal pre-conception nutrition and stunting. Infants born to undernourished mothers were more likely to have low birth weight, which in turn increased the risk of stunting. This finding reinforces the importance of interventions that begin before and continue throughout pregnancy to optimize both maternal and fetal health [12].

North Sumatra has implemented a range of promotive, preventive, curative, and rehabilitative strategies to address stunting. These include:

1. Specific nutrition interventions: Provision of supplementary food for pregnant women with chronic energy deficiency (KEK), underweight toddlers, and school children.
2. Nutrition-sensitive interventions: Outreach on parenting, sanitation, and environmental health, often leveraging village funds for local food initiatives.
3. Capacity building: Training health workers and community cadres to deliver nutrition education and promote infant and young child feeding (IYCF) best practices.
4. Behavioral change campaigns: Promoting the consumption of protein-rich foods, such as fish and eggs, and advocating for clean and healthy living behaviors (PHBS).

These efforts are supported by multisectoral collaboration, involving local governments, health services, educational institutions, and community organizations. The convergence of these actions—known as the "Eight Convergence Actions for Stunting Reduction"—has been recognized as a best practice in several districts, contributing to significant declines in stunting prevalence [13]. Such collaboration also creates opportunities to align nutrition-specific interventions with improvements in sanitation, social protection, and maternal healthcare. Regular coordination, transparent monitoring, and active community participation may help local stakeholders identify implementation gaps, allocate resources more effectively, and sustain prevention activities across diverse geographic and socioeconomic settings over time.

In this study, dietary adequacy during the pre-conception period was operationalized as meeting ≥80% of the Recommended Dietary Allowance (RDA) for energy and essential nutrients, consistent with approaches to categorizing dietary intake relative to nutrient reference values [14], [15]. However, we recognize that the threshold of 80% RDA may be perceived as arbitrary, as there is limited consensus in the literature regarding a universally accepted cut-off. In particular, the RDA is designed to cover the needs of nearly all healthy individuals in a specified group, whereas the Estimated Average Requirement is generally preferable for estimating the prevalence of inadequacy in populations [14], [15]. The choice of this threshold was informed by broader evidence linking maternal undernutrition and micronutrient deficiencies with adverse maternal and birth outcomes in low- and middle-income settings, rather than by evidence establishing 80% as a universal clinical threshold [9], [16], [17]. Nevertheless, as the sensitivity of results to the cut-off point is an important consideration for interpretability and generalizability, post-hoc sensitivity analyses employing alternative thresholds (e.g., 70% and 90% RDA) were conducted. These analyses indicated that while effect sizes varied, the direction and statistical significance of associations between pre-conception nutrition and stunting risk remained robust, lending support to the stability of our main findings under the evaluated definitions [18].

Regarding the composite nutritional status score, each component (macronutrient and key micronutrient adequacy) was weighted equally when constructing the global index. This

approach was adopted for simplicity and in alignment with initial exploratory factor analyses, which did not reveal a dominant single predictor and indicated roughly equal contributions of the included components to overall nutritional status variance. Equal weighting can be a transparent approach to constructing a composite measure, although its appropriateness depends on the underlying conceptual and empirical structure [19], [20]. Nonetheless, equal weighting does not account for the differential biological impact that individual nutrients may have on fetal growth and stunting risk [17], [21]. To address this, we conducted additional analyses using principal component analysis-derived weights and nutrient-specific scores. These results were broadly consistent with our primary analyses, suggesting that while the weighting approach may influence relative contributions, the composite score as utilized provided a reasonable summary measure for the purposes of this study (see Supplementary Methods). We acknowledge, however, that more nuanced weighting, potentially guided by evidence on nutrient-specific risks, may strengthen future work [20], [21].

This prospective cohort study investigated the relationships between pre-conception nutritional care patterns, frequency of antenatal care (ANC) visits, and the incidence of stunting in newborns in North Sumatra. While the study design allows for the assessment of temporality, it is important to interpret observed associations with caution and avoid making strong causal claims, given the observational nature of the research [22], [23].

Our findings indicate that adequate pre-conception nutritional care and more frequent ANC visits are associated with lower odds of stunting during early childhood. Specifically, women who reported consistent pre-conception nutritional support and achieved the recommended number of ANC visits tended to have infants with improved growth profiles compared to those with less optimal care patterns. These results support prior research suggesting that maternal health and service utilization during the pre-conception and pregnancy periods may play a role in child growth outcomes [6], [7], [24], [25], [26].

However, it is essential to recognize that these observed associations do not necessarily imply direct causality. Although the prospective design permits us to infer temporal sequence, unmeasured confounding variables, such as underlying household socioeconomic characteristics, genetic factors, paternal health status, or additional community-level determinants, could contribute to or even explain the relationships identified [22], [27], [28].

The qualitative findings further enrich our understanding by highlighting the influence of cultural beliefs, family dynamics, and structural barriers, factors that may mediate or modify the association between maternal behaviors and child health [29], [30]. For example, the observed relationship between ANC visit frequency and stunting risk could be partly explained by greater health literacy or improved access to health information among women who regularly utilize these services [25], [30].

While the study adds to the evidence base supporting a link between maternal nutritional and health care practices and childhood stunting, the limitations inherent to observational research, including the potential for residual confounding and reporting biases, necessitate prudence in interpreting the results [23], [31]. Further interventional and mechanistic studies are warranted to more definitively clarify the causal pathways involved [16], [24].

Policy Implications

The policy recommendations drawn from this study aim to address the specific factors identified within North Sumatra regarding pre-conception nutrition and antenatal care (ANC) frequency in relation to childhood stunting. Our findings suggest that tailored interventions, rather than broad national directives, are necessary for effective stunting prevention in this region. Based on the quantitative and qualitative findings, six policy recommendations are proposed.

A. Strengthening Pre-Conception Nutritional Care

Provincial and district health authorities should prioritize pre-conception nutritional assessment and counseling for women of reproductive age, particularly in rural districts with persistently high stunting prevalence. Community health centers should integrate nutritional screening, including body mass index, mid-upper arm circumference, hemoglobin levels, and dietary adequacy, into routine reproductive healthcare services. Appropriate nutritional supplementation and dietary education should be provided according to individual needs. These measures may help identify nutritional deficiencies before pregnancy and improve maternal preparedness for conception.

B. Improving Antenatal Care Accessibility and Quality

The findings highlight the importance of ensuring at least six quality ANC visits, consistent with Indonesian maternal healthcare standards. However, increasing visit frequency alone may be insufficient without improving service quality. Healthcare providers should strengthen nutritional counseling, anemia screening, supplementation monitoring, and pregnancy-related health education. Additional efforts should address geographical barriers through community outreach services, mobile healthcare programs, and improved referral systems, particularly for women living in remote areas.

C. Integrating Sociocultural Considerations into Maternal Health Programs

The qualitative findings demonstrate that cultural beliefs, family dynamics, and traditional dietary restrictions influence maternal nutritional practices and healthcare utilization. Therefore, health education programs should involve husbands, family members, community leaders, and local health volunteers. Culturally sensitive communication strategies may improve understanding of maternal nutritional requirements while encouraging families to support healthy pregnancy preparation and regular ANC attendance.

D. Strengthening Community-Based and Multisectoral Collaboration

Effective stunting prevention requires coordination among healthcare institutions, local governments, educational organizations, and community groups. Existing community health platforms, including *Posyandu* and *Puskesmas*, can support nutritional education, early identification of vulnerable women, and continuous maternal health monitoring. Collaboration with social protection programs may also help address economic barriers that limit access to nutritious foods and essential healthcare services.

E. Developing Context-Specific Monitoring and Evaluation Systems

Provincial and district authorities should establish measurable indicators for monitoring pre-conception nutritional care, ANC attendance, service quality, and childhood growth outcomes. Regular evaluations should identify implementation gaps and differences in service accessibility between urban and rural communities. These findings can inform adjustments to local programs and improve resource allocation based on community needs and existing healthcare infrastructure.

F. Supporting Further Research and Evidence-Based Policy Development

Given the regional scope and observational design of this study, the recommendations should be interpreted cautiously. Although the findings demonstrate significant associations, they do not establish direct causal relationships. Further longitudinal, interventional, and multi-regional studies are necessary to evaluate the effectiveness of integrated pre-conception nutrition and ANC interventions. Larger investigations may provide stronger evidence for broader policy implementation.

Conclusion

This study confirms that stunting prevention must begin before conception and continue through pregnancy and early childhood. Pre-conception nutritional status and ANC frequency are both significant, modifiable risk factors for stunting, but their influence is mediated by socioeconomic, cultural, and health system factors. Efforts to reduce stunting in North Sumatra—and Indonesia more broadly—require integrated, multisectoral strategies that address the full spectrum of determinants, from individual knowledge and behavior to community norms and structural barriers. The government's commitment to stunting reduction, as reflected in national and regional policies, provides a strong foundation. Continued innovation, community engagement, and investment in health and social systems will be essential to achieve the ambitious targets set for 2024 and beyond. By centering interventions on women's health before and during pregnancy, and by addressing the broader context in which families live, Indonesia can make significant strides toward a stunting-free generation.

Limitation and Suggestions

Self-reported data on diet and ANC utilization may be subject to recall or social desirability bias. Loss to follow-up, particularly in rural areas, may underestimate stunting prevalence in the most vulnerable groups. The qualitative sample, while diverse, may not capture the full range of cultural variation across the province.

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Conflict of Interest

There is no conflict of interest.

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