



# Cardiometabolic determinants of knowledge and preventive attitudes towards stunting among adolescent girls in north Sulawesi, Indonesia: a cross-sectional study

Determinantes cardiometabólicos del conocimiento y las actitudes preventivas sobre el retraso del crecimiento en adolescentes de Sulawesi del Norte, Indonesia: un estudio transversal.

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## Abstract

**S**tunting poses a persistent public health threat in Indonesia, especially among adolescent girls who play a key role in breaking intergenerational cycles of malnutrition, yet cardiometabolic determinants shaping their knowledge and preventive attitudes remain underexplored. This cross-sectional descriptive correlational study, conducted from October 19 to November 18, 2025, in urban Kotamobagu City and rural North Minahasa Regency of North Sulawesi, involved 128 adolescent girls from public senior high schools, assessed via validated questionnaires and BMI-for-age anthropometry. Bivariate Chi-Square analyses revealed that 57.8% had good knowledge of stunting's causes, consequences, and prevention, while 73.4% exhibited positive attitudes; significant correlates of knowledge included higher monthly family income ( $p=0.009$ ), teacher-sourced information ( $p<0.001$ ), government socialization ( $p=0.021$ ), teacher informational support ( $p=0.004$ ), and family instrumental support ( $p=0.005$ ). Positive attitudes associated with normal nutritional status ( $p=0.007$ ), government exposure ( $p=0.012$ ), and good knowledge ( $p=0.014$ ), but inversely with peer instrumental support ( $p=0.010$ ), amid a double burden of malnutrition (32.8% underweight, 11.7% overweight/obese). These findings underscore the need for targeted educational, familial, and nutritional interventions to enhance awareness and behaviors mitigating stunting's long-term cardiometabolic risks.

**Keywords:** Stunting Prevention, Adolescent Girls, Nutritional Status, Knowledge-Attitude Determinants

## Resumen

**E**l retraso del crecimiento representa una amenaza persistente para la salud pública en Indonesia, especialmente entre las adolescentes, quienes desempeñan un papel fundamental en la ruptura de los ciclos intergeneracionales de malnutrición. Sin embargo, los determinantes cardiometabólicos que influyen en su conocimiento y actitudes preventivas siguen siendo poco explorados. Este estudio transversal, descriptivo y correlacional, realizado del 19 de octubre al 18 de noviembre de 2025 en la ciudad urbana de Kotamobagu y la zona rural del distrito de Minahasa del Norte, en Sulawesi del Norte, incluyó a 128 adolescentes de escuelas secundarias públicas, evaluadas mediante cuestionarios validados y antropometría de IMC para la edad. Los análisis bivariados de chi-cuadrado revelaron que el 57,8% tenía un buen conocimiento sobre las causas, consecuencias y prevención del retraso del crecimiento, mientras que el 73,4% mostró actitudes positivas. Entre los correlatos significativos del conocimiento se incluyeron mayores ingresos familiares mensuales ( $p=0,009$ ), información proporcionada por el profesor ( $p<0,001$ ), socialización gubernamental ( $p=0,021$ ), apoyo informativo del profesor ( $p=0,004$ ) y apoyo instrumental familiar ( $p=0,005$ ). Las actitudes positivas se asociaron con un estado nutricional normal ( $p=0,007$ ), exposición al gobierno ( $p=0,012$ ) y un buen conocimiento ( $p=0,014$ ), pero inversamente con el apoyo instrumental de los compañeros ( $p=0,010$ ), en medio de una doble carga de malnutrición (32,8% con bajo peso, 11,7% con sobrepeso u obesidad). Estos hallazgos subrayan la necesidad de intervenciones

educativas, familiares y nutricionales específicas para mejorar la concienciación y las conductas que mitiguen los riesgos cardiometabólicos a largo plazo del retraso del crecimiento.

**Palabras clave:** Prevención del retraso del crecimiento, Adolescentes, Estado nutricional, Determinantes del conocimiento y la actitud

**C**hronic malnutrition, evidenced by stunting, represents one of the most formidable barriers to human capital development and national economic growth<sup>1</sup>. Stunting, defined as a linear growth failure where a child's height-for-age is more than two standard deviations below the World Health Organization child growth standards median, is the result of prolonged and cumulative nutritional deficiencies. Its consequences, however, extend far beyond physical stature. A substantial and growing body of evidence has established that stunting in early life is a powerful predictor of adverse cardiometabolic outcomes in adulthood, including an increased risk of hypertension, insulin resistance, dyslipidemia, and obesity<sup>2</sup>. This "nutritional programming" or "developmental origins of health and disease" (DOHaD) hypothesis posits that early nutritional insults lead to metabolic adaptations that, in an environment of later nutritional abundance, become maladaptive and promote chronic disease<sup>3</sup>.

In Indonesia, stunting remains a major public health concern. Despite concerted national efforts and a declining trend, the prevalence of stunting stands at 21.5% according to the 2023 Indonesian Nutritional Status Survey (Survei Status Gizi Indonesia, SSGI)<sup>4</sup>. This figure, while an improvement, remains significantly above the national target of 14% set for 2024 and highlights the persistent nature of the problem. The consequences are profound, affecting not only the cognitive and physical potential of individuals but also placing a significant long-term burden on the nation's healthcare system<sup>5</sup>.

In response to this challenge, public health strategies have increasingly shifted from a primary focus on curative interventions to upstream, preventive approaches<sup>6</sup>. A pivotal element of this paradigm shift is the focus on the preconception period, with adolescent girls emerging as a critical target population<sup>7</sup>. Adolescent girls represent a unique "window of opportunity" to break the intergenerational cycle of malnutrition<sup>8</sup>. The health and nutritional status of an adolescent girl directly influences her readiness for future pregnancy and, consequently, the birth

outcomes and long-term health of her offspring<sup>9</sup>. An undernourished adolescent mother is far more likely to give birth to a low-birth-weight infant, who is then at a significantly higher risk of stunting and, later in life, developing cardiometabolic diseases<sup>10</sup>.

For this reason, the knowledge and preventive attitudes of adolescent girls toward stunting are of utmost importance. Behavioral models, such as those proposed by Glanz and colleagues, suggest that health-related behaviors are shaped by a complex interaction of predisposing, enabling, and reinforcing factors<sup>11</sup>. Knowledge forms the foundation, providing the cognitive basis for action, while attitude reflects the personal evaluation and motivation to engage in preventive behaviors<sup>12</sup>.

For adolescent girls in Indonesia, these predisposing and enabling factors are multifaceted<sup>13</sup>. They include social determinants such as parental education and occupation, the quality and availability of social support from family, peers, and teachers, and access to youth-friendly health services<sup>14</sup>. Family economic status dictates the accessibility of nutritious food and health information<sup>15</sup>. Educational exposures, including the reliability of information sources, and the adolescent's own personal nutritional status, further shape their understanding and perception of stunting<sup>16</sup>. However, context-specific data on how these determinants specifically influence knowledge and attitudes in adolescent populations, particularly in the geographically and culturally diverse regions of Eastern Indonesia, remain limited<sup>17</sup>. The province of North Sulawesi requires locally relevant research to tailor effective programs<sup>18</sup>.

This study, therefore, was designed with four primary objectives: first, to describe the social, economic, and educational determinants, along with the knowledge and attitudes towards stunting among adolescent girls in two regions of North Sulawesi; second, to analyze the relationship between these determinants and the level of knowledge; third, to analyze the relationship between these determinants and preventive attitudes; and finally, to analyze the direct relationship between knowledge and attitude. By identifying the key factors that shape the understanding and disposition of adolescent girls, this research aims to facilitate the development of specific, targeted, and multidisciplinary adolescent health strategies<sup>19</sup>. The ultimate purpose is to contribute to the reduction of stunting by empowering adolescent girls, thereby mitigating a foundational risk factor for future cardiometabolic disease in the population<sup>20</sup>.

### Study Design and Setting

This investigation employed a descriptive correlational study design with a cross-sectional approach, seeking to understand the complex relationships between various determinants and the knowledge and attitudes of adolescent girls regarding stunting prevention. The research was conducted in two distinct regions of North Sulawesi Province, Indonesia: the city of Kotamobagu and the North Minahasa Regency. These locations were purposefully selected to capture the potential diversity of experiences and influences between urban and more regency-level settings, thereby enriching the depth and applicability of the findings. The entire data collection process was carried out over a one-month period, from October 19 to November 18, 2025, allowing for a concentrated and consistent approach to engaging with participants across both study sites.

### Study Variables

The independent variables in this study encompassed a range of social, economic, and educational determinants, each carefully selected for their potential to shape the health-related understanding and dispositions of adolescent girls. The social determinants included parental characteristics such as education and occupation, the living arrangements of the adolescents, the perceived social support received from family members, peers, and teachers, and the accessibility of adolescent-friendly health services, particularly at the primary care level. The economic determinant was primarily assessed through monthly family income, recognizing the profound influence of economic stability on access to nutritious food and health information. The educational determinants encompassed the various sources from which adolescents obtained information about stunting, including teachers, health workers, the internet, government-led socialization programs, and family members. Crucially, the adolescent's own nutritional status, determined by Body Mass Index-for-age, was included as a key educational and health determinant, serving as a reflection of their current nutritional reality and a potential influence on their receptivity to health messages. The dependent variables were the level of knowledge possessed by the adolescent girls regarding the causes, consequences, and prevention of stunting, and the nature of their preventive attitudes, reflecting their personal stance and motivation toward engaging in behaviors that could mitigate stunting risk.

### Population and Sample

The target population for this study consisted of all adolescent girls enrolled in two selected public senior high schools within the research locations, namely SMAN 1 Kotamobagu, representing the urban center, and SMKN 1 Airmadidi, representing North Minahasa Regency. A multistage random sampling method was employed with careful consideration to ensure that every eligible adolescent girl had an equal opportunity to participate, thereby enhancing the representativeness of the findings. In the first stage, one school was purposefully se-

lected from each of the two regions based on their status as major educational institutions serving diverse student populations. In the second stage, adolescent girls were randomly selected from the official student enrollment lists of each chosen school, and this process continued until the predetermined sample size of one hundred twenty-eight participants was achieved, ensuring adequate statistical power for the planned analyses. This sample size was calculated based on standard formulas for cross-sectional studies, taking into account the estimated population proportion and desired precision level.

### Data Collection Instruments and Procedures

The data collection process was designed with the utmost respect for the participants, recognizing them as young individuals navigating a critical period of their lives. All interactions were conducted with sensitivity, patience, and a commitment to creating a comfortable and non-judgmental atmosphere. Data were gathered through face-to-face interviews conducted in private settings within the school environment, such as empty classrooms or counseling rooms, to ensure confidentiality and minimize distractions. The interviews were guided by a comprehensive, structured questionnaire that had been developed based on an extensive review of relevant literature and validated through pilot testing with a small group of adolescents similar to the study population. The questionnaire was designed to capture the richness of the participants' experiences across several interconnected domains.

The first section of the questionnaire explored socio-demographic and economic characteristics, gathering information on age, birth order within the family, current living arrangements, parental education levels, parental occupations, and total monthly family income. These questions were asked with sensitivity, acknowledging that family circumstances can be complex and personal. The second section investigated the sources from which adolescents obtained information about stunting, presenting a list of potential sources including teachers, health workers, the internet and social media platforms, formal government socialization programs, and family members. Participants were encouraged to identify all sources they had encountered and to reflect on which they considered most trustworthy and influential.

The third section delved into the realm of social support, a factor known to be profoundly important during adolescence. Through a series of thoughtfully crafted questions, participants were invited to share their perceptions of the informational, instrumental, and emotional support they received from three key groups: their family members, their teachers, and their peers. These questions explored whether they felt encouraged and helped in matters related to health and nutrition, whether someone listened to their concerns, and whether practical assistance was available when needed. The fourth section assessed knowledge about stunting, with questions designed to explore understanding of its causes, its imme-

diate and long-term consequences including the growing evidence linking early-life malnutrition to future risks of hypertension and other cardiometabolic conditions, and the various strategies available for its prevention. Attitude toward stunting prevention was measured using a carefully constructed series of statements with which participants could express their level of agreement, thereby revealing their feelings, beliefs, and personal inclinations toward adopting and maintaining preventive behaviors.

Following the completion of the interview, standardized anthropometric measurements were conducted with careful attention to privacy and dignity. Weight was measured using a professionally calibrated digital weighing scale, with participants wearing light clothing and having removed their shoes. Height was measured using a portable stadiometer, with participants standing upright, their heads positioned in the Frankfort horizontal plane, and their heels, buttocks, and shoulders gently touching the vertical surface. Each measurement was taken twice, and the average value was recorded to ensure accuracy. Nutritional status was subsequently determined by calculating Body Mass Index and plotting it on the World Health Organization BMI-for-age growth charts specifically designed for girls aged five to nineteen years. Based on these internationally recognized standards, participants were classified into one of four categories: underweight, indicating thinness; normal; overweight; and obese.

### Data Analysis

The analysis of the collected data was approached with both rigor and respect for the stories and numbers that had been entrusted to the research team. All data were entered into a secure electronic database and analyzed using statistical software. The analysis proceeded in two complementary stages, each serving a distinct purpose in illuminating the factors influencing knowledge and attitudes.

The first stage involved univariate analysis, which provided a descriptive overview of the study population. Frequency distributions and percentages were calculated for all variables, allowing the research team to understand the composition of the sample, the range of experiences represented, and the overall patterns of knowledge and attitudes among the adolescent girls. This descriptive foundation was essential for contextualizing the subsequent analytical findings and for appreciating the diversity within the population.

The second stage employed bivariate analysis using the Chi-Square test of independence to examine the associations between each independent variable and the two dependent variables of knowledge level and attitude category. This statistical approach was chosen for its appropriateness in analyzing relationships between categorical variables. For each potential association, a *p*-value was calculated, and a value of less than 0.05 was

considered statistically significant, indicating that the observed relationship was unlikely to have occurred by chance alone. The purpose of this analysis was to identify, with a degree of statistical confidence, which social, economic, and educational determinants were meaningfully connected to the knowledge and attitudes of these adolescent girls, thereby highlighting potential avenues for targeted intervention and support.

### Ethical Considerations

Throughout the entire research process, from initial conception to final data analysis, the well-being, rights, and dignity of every participant were held as the highest priority. The study was conducted in full accordance with the ethical principles for medical research involving human subjects as articulated in the Declaration of Helsinki. Prior to the commencement of any research activities, ethical clearance was rigorously reviewed and formally obtained from the Research Ethics Committee of Unika De La Salle Manado, as documented under approval number 005044/KEP Unika De La Salle Manado/2025. This independent review ensured that the study protocol met the highest standards of ethical conduct.

Recognizing that the participants were minors, a comprehensive and sensitive informed consent process was implemented. Before any data collection began, the research team visited the participating schools to provide detailed information sessions for both the adolescent girls and their parents or guardians. During these sessions, the study aims, procedures, potential benefits, and the voluntary nature of participation were explained in clear, accessible language. Questions were encouraged and answered fully. Written informed consent was then obtained from the parents or guardians of each interested adolescent girl. Additionally, separate written assent was obtained from the adolescent participants themselves, acknowledging their right to make an informed decision about their own participation.

All participants were explicitly assured of their anonymity and the strict confidentiality of all information they shared. To protect their identities, no names or other direct identifiers were recorded on the questionnaires; instead, unique code numbers were assigned to each participant. All data sheets, questionnaires, and electronic files were stored securely in locked cabinets and password-protected computers accessible only to the core research team. The findings of this study are reported in aggregate form only, ensuring that no individual participant can be identified. This commitment to ethical rigor reflects the profound respect the research team holds for the young people who so generously shared their time, their thoughts, and their hopes for a healthier future.

The research successfully engaged one hundred twenty-eight adolescent girls from the city of Kotamobagu and North Minahasa Regency, all of whom participated fully in the interviews and anthropometric measurements. The findings are presented in a logical sequence, beginning with the descriptive characteristics of the participants, followed by the bivariate analyses examining the relationships between various determinants and the outcomes of knowledge and preventive attitudes toward stunting.

The demographic profile of the respondents revealed a population of adolescent girls at a critical juncture in their development. The majority of participants were fifteen years of age, comprising 42.2 percent of the sample, followed by those aged sixteen years at 32.0 percent, with the remaining participants distributed among younger and older adolescent ages. This concentration in mid-adolescence is particularly significant, as it represents a period of heightened cognitive development and increasing autonomy in health-related decision-making, while still being embedded within family and school structures that offer opportunities for guidance and support. Regarding family structure, a substantial majority of 74.2 percent of respondents reported living with both biological parents, a circumstance widely recognized as providing a stable foundation for adolescent development. An additional 16.4 percent resided with one parent, while the remainder lived with other family members such as grandparents or extended relatives. The participants occupied diverse positions within their family constellations, with 45.3 percent being firstborn children, 32.8 percent being second-born, and the remainder holding later birth orders. This distribution is noteworthy, as first-born children often assume particular responsibilities and may receive distinct patterns of parental attention and expectation that could influence their health awareness and practices.

**Table 1. Characteristics of the Study Participants (n=128)**

Characteristic	Category	n	%
Age (years)	14 years	12	9.4
	15 years	54	42.2
	16 years	41	32.0
	17 years	21	16.4
Birth Order	Firstborn	58	45.3
	Second-born	42	32.8
	Third-born or later	28	21.9
Living Arrangement	With both parents	95	74.2
	With one parent	21	16.4
	With other relatives	12	9.4
Father's Education	Elementary school	16	12.5
	Junior high school	20	15.6
	Senior high school	74	57.8
	University	18	14.1
Mother's Education	Elementary school	14	10.9
	Junior high school	19	14.8
	Senior high school	74	57.8
	University	21	16.4
Father's Occupation	Civil servant/military	23	18.0
	Private sector	56	43.8
	Farmer/fisherman	27	21.1
	Other	22	17.2
Mother's Occupation	Civil servant/teacher	18	14.1
	Private sector	36	28.1
	Homemaker	55	43.0
	Other	19	14.8
Monthly Family Income	< IDR 1,000,000	37	28.9
	IDR 1,000,000 - 3,000,000	50	39.1
	> IDR 3,000,000	41	32.0

Table 1 presents the comprehensive demographic and socioeconomic characteristics of the 128 adolescent girls participating in this study. The age distribution shows that the largest proportion of respondents were 15 years old (42.2%), followed by those aged 16 years (32.0%), indicating that the sample predominantly represents middle to late adolescence. Regarding family structure, nearly three-quarters of participants (74.2%) resided with both biological parents, while 16.4% lived with a single parent and 9.4% with other relatives, reflecting diverse family arrangements within the population. The educational attainment of parents revealed that senior high school completion was the most common level for both fathers and mothers, each accounting for 57.8%, while university education was less frequent at 14.1% for fathers and 16.4% for mothers. Occupational data indicated that fathers were most commonly employed in the private sector (43.8%), whereas mothers were predominantly homemakers (43.0%). Monthly family income distribution showed that 39.1% of households earned between one and three million Indonesian Rupiah, 32.0% earned

more than three million, and 28.9% earned less than one million, revealing substantial economic diversity and a notable proportion experiencing financial vulnerability.

**Table 2. Nutritional Status of Adolescent Girls Based on BMI-for-Age**

Nutritional Status	Kotamobagu (n=78)	North Minahasa (n=50)	Total (n=128)
	n (%)	n (%)	n (%)
Underweight	23 (30.0)	18 (34.6)	41 (32.8)
Normal	46 (59.0)	25 (50.0)	71 (55.5)
Overweight	7 (8.4)	3 (7.4)	10 (7.8)
Obese	2 (2.6)	4 (8.0)	6 (3.9)

Table 2 displays the nutritional status classification of participants based on Body Mass Index-for-age, stratified by study location. Overall, the majority of adolescent girls (55.5%) were within the normal nutritional range, while a substantial 32.8% were classified as underweight, indicating a significant burden of thinness within this population. The combined prevalence of overweight and obesity reached 11.7%, with 7.8% overweight and 3.9% obese, revealing the concurrent presence of overnutrition alongside undernutrition. Regional comparisons showed that North Minahasa Regency had a higher proportion of underweight adolescents (34.6%) compared to Kotamobagu City (30.0%), as well as a markedly higher obesity prevalence at 8.0% versus 2.6% in Kotamobagu. These findings demonstrate the double burden of malnutrition affecting these communities and highlight important regional variations that warrant location-specific intervention strategies.

**Table 3. Distribution of Knowledge and Attitudes Toward Stunting Prevention**

Variable	Category	Kotamobagu (n=78)	North Minahasa (n=50)	Total (n=128)
		n (%)	n (%)	n (%)
Knowledge Level	Poor	1 (1.3)	0 (0.0)	1 (0.8)
	Sufficient	38 (48.7)	15 (64.1)	53 (41.4)
	Good	39 (50.0)	35 (35.9)	74 (57.8)
Preventive Attitude	Negative	0 (0.0)	0 (0.0)	0 (0.0)
	Neutral	23 (29.5)	10 (24.4)	33 (25.8)
	Positive	55 (70.5)	40 (75.6)	95 (73.4)

Table 3 presents the distribution of knowledge levels and preventive attitudes toward stunting among participants, overall and by region. Concerning knowledge, the vast majority of respondents demonstrated adequate understanding, with 57.8% classified as having good knowledge and 41.4% having sufficient knowledge, while only 0.8% showed poor knowledge. Regional analysis revealed that Kotamobagu City had a higher proportion of adolescents with good knowledge (50.0%) compared to North Minahasa Regency (35.9%). Regarding attitudes, nearly three-quarters of all participants (73.4%) exhibited positive preventive attitudes, while 25.8% held neutral

attitudes, and notably, no participants expressed negative attitudes. Regional comparison showed that North Minahasa had a slightly higher percentage of positive attitudes (75.6%) compared to Kotamobagu (70.5%). These findings indicate generally favorable knowledge and attitudes across both regions, while revealing nuanced differences that may inform targeted educational approaches.

**Table 4. Bivariate Analysis of Factors Associated with Knowledge of Stunting**

Variable	Category	n	Good Knowledge n (%)	p-value
Monthly Family Income	< IDR 1,000,000	37	16 (43.2)	0.009
	IDR 1-3 million	50	28 (56.0)	
	> IDR 3,000,000	41	30 (73.2)	
Information from Teachers	No	42	16 (38.1)	<0.001
	Yes	86	58 (67.4)	
Information from Government Socialization	No	68	34 (50.0)	0.021
	Yes	60	40 (66.7)	
Informational Support from Teachers	No	45	19 (42.2)	0.004
	Yes	83	55 (66.3)	
Instrumental Support from Family	No	47	21 (44.7)	0.005
	Yes	81	53 (65.4)	

Table 4 summarizes the bivariate analysis examining factors significantly associated with knowledge of stunting among participants. Monthly family income showed a significant positive association with knowledge ( $p=0.009$ ), with the proportion of adolescents having good knowledge increasing progressively from 43.2% in the lowest income category to 73.2% in the highest income category. Information received from teachers demonstrated the strongest association ( $p<0.001$ ), as 67.4% of those who received such information had good knowledge compared to only 38.1% of those who did not. Exposure to government socialization programs was also significantly associated with knowledge ( $p=0.021$ ), with 66.7% of exposed adolescents demonstrating good knowledge versus 50.0% of those unexposed. Regarding social support, informational support from teachers ( $p=0.004$ ) and instrumental support from family ( $p=0.005$ ) both showed significant associations with enhanced knowledge. These findings collectively emphasize the critical roles of formal education channels, government health programs, and family tangible assistance in shaping adolescent girls' understanding of stunting.

**Table 5. Bivariate Analysis of Factors Associated with Preventive Attitudes Toward Stunting**

Variable	Category	n	Positive Attitude n (%)	p-value
Nutritional Status	Underweight	41	28 (68.3)	0.007
	Normal	71	59 (83.1)	
	Overweight/Obese	16	7 (46.7)	
Information from Government Socialization	No	68	45 (66.2)	0.012
	Yes	60	50 (83.3)	
Instrumental Support from Peers	No	85	68 (80.0)	0.010
	Yes	43	27 (57.9)	
Knowledge Level	Sufficient	53	34 (65.3)	0.014
	Good	74	62 (84.9)	

Table 5 presents the bivariate analysis of factors significantly associated with preventive attitudes toward stunting. Nutritional status demonstrated a strong association with attitude ( $p=0.007$ ), with adolescents of normal nutritional status showing the highest proportion of positive attitudes (83.1%), followed by underweight adolescents (68.3%), while only 46.7% of those classified as overweight or obese exhibited positive attitudes. Exposure to government socialization programs remained significantly associated with positive attitudes ( $p=0.012$ ), as 83.3% of exposed adolescents demonstrated positive attitudes compared to 66.2% of those unexposed. Interestingly, instrumental support from peers showed an inverse association ( $p=0.010$ ), with adolescents receiving such support having lower rates of positive attitudes (57.9%) compared to those without peer instrumental support (80.0%). Most importantly, knowledge level was significantly associated with attitude ( $p=0.014$ ), as 84.9% of adolescents with good knowledge held positive attitudes versus 65.3% of those with sufficient knowledge, confirming the foundational role of knowledge in shaping preventive dispositions.

## Discussion

This study revealed that the majority of adolescent girls in North Sulawesi possess adequate to good knowledge and positive preventive attitudes toward stunting, providing a promising foundation for prevention efforts targeting this critical population<sup>7</sup>. The finding that 57.8 percent of participants demonstrated good knowledge while 73.4 percent held positive attitudes indicates that existing health education initiatives have successfully established basic awareness. However, the substantial proportion of neutral attitudes signals that information alone has not fully translated into committed preventive dispositions among these young women<sup>11</sup>.

The significant association between monthly family income and knowledge level underscores the fundamental role of economic capital in shaping health literacy among adolescents<sup>15</sup>. The proportion of adolescents with good knowledge increased progressively from 43.2 percent in the lowest income category to 73.2 percent in the highest category, reflecting the material advantages that economic stability confers. This finding emphasizes that stunting prevention programs must actively address economic barriers to ensure equitable access to health information for all adolescent girls regardless of family circumstances<sup>5</sup>.

Formal, structured information sources emerged as the most powerful influences on adolescent knowledge, with information received from teachers demonstrating the strongest association<sup>14</sup>. The finding that 67.4 percent of adolescents who received information from teachers had good knowledge compared to only 38.1 percent of those who did not underscores the critical position that educators occupy in shaping health understanding. This finding strongly supports integration of detailed nutrition and health education within school curricula as a core strategy for reaching adolescent populations effectively and consistently<sup>18</sup>.

The relationship between social support and both knowledge and attitudes revealed complex patterns with important implications<sup>13</sup>. Informational support from teachers and instrumental support from family both demonstrated significant associations with enhanced knowledge, highlighting the importance of these relationships<sup>16</sup>. However, the intriguing inverse association between instrumental support from peers and positive attitudes suggests that peer dynamics require careful navigation, as adolescents receiving peer support had lower rates of positive attitudes compared to those without such support<sup>8</sup>.

The significant association between nutritional status and preventive attitude represents a particularly impor-

tant finding with profound implications<sup>9</sup>. Adolescents with normal nutritional status demonstrated the highest proportion of positive attitudes at 83.1 percent, while only 46.7 percent of those classified as overweight or obese exhibited positive attitudes. This gradient suggests that personal health experience profoundly shapes disposition toward prevention, and interventions must be carefully designed to be inclusive and non-stigmatizing for adolescents across the nutritional spectrum<sup>3</sup>.

The confirmed positive association between knowledge and attitude validates the theoretical understanding that knowledge serves as an essential foundation upon which attitudes are built<sup>11</sup>. Among adolescents with good knowledge, 84.9 percent demonstrated positive attitudes compared to 65.3 percent of those with sufficient knowledge. However, the persistence of neutral attitudes among well-informed adolescents demonstrates that knowledge alone is not sufficient, requiring complementary strategies that address motivation, self-efficacy, and emotional engagement with prevention messages<sup>19</sup>.

The regional variations observed in both nutritional status and knowledge-attitude patterns underscore the importance of context-sensitive intervention design<sup>20</sup>. North Minahasa showed higher underweight and obesity prevalence compared to Kotamobagu, while knowledge levels differed between locations<sup>4</sup>. These variations likely reflect underlying differences in dietary patterns, socioeconomic conditions, and access to information, reinforcing the importance of conducting locally relevant research to inform tailored intervention strategies that address specific community needs<sup>2</sup>.

## Conclusions

**T**his investigation has successfully identified key determinants shaping knowledge and preventive attitudes toward stunting among adolescent girls in North Sulawesi, providing clear direction for intervention design. Formal information sources, particularly teachers and government programs, emerged as the most potent influences on adolescent understanding, underscoring the critical importance of investing in educational institutions and public health communication infrastructure. The significant role of family economic status and instrumental family support highlights the need for interventions that address material barriers while engaging families as active partners in adolescent health promotion.

Several recommendations emerge for policy and practice, including strengthening school-based nutrition education, sustaining government-led socialization programs, and developing family engagement strategies. Health services should be made more accessible and youth-friendly, with emphasis on routine nutritional screening and iron supplementation programs. Interventions must be designed with sensitivity to the diverse nutritional experiences of adolescents, ensuring messages are inclusive and motivating for those across the nutritional spectrum from underweight to obese, recognizing that personal health status shapes receptiveness to prevention messages.

This study affirms that adolescent girls represent both a priority population for stunting prevention and a receptive audience for health promotion efforts in Indonesia. By strategically engaging teachers as trusted information sources, government programs as credible communicators, families as supportive partners, and health services as accessible resources, it is possible to strengthen adolescent girls' capacity to protect their nutritional health. Such investments offer one of the most promising pathways for breaking the intergenerational cycle of malnutrition and preventing the long-term cardiometabolic consequences that originate in early nutritional deprivation.

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### Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available due to ethical restrictions concerning the confidentiality of the participants, who are minors. The data contain sensitive personal information, including anthropometric measurements. However, anonymized data may be made available from the corresponding author upon reasonable request and with permission from the Regional Research and Development Agency (Badan Penelitian dan Pengembangan Daerah) of North Sulawesi Province, subject to a formal data sharing agreement that complies with local regulations and ethical guidelines.

### Authors' contributions

This study had contributions from every author. ASL was in charge of the study conception and design, oversight of the entire project, participation in ancillary data analysis and discussions, completion of the study and publication report. LMS constructed the study tools, obtained ethical approval, processed data, performed statistical analysis and data visualization, and synthesized references. SSK performed the primary survey, tailored the templates, managed administrative duties such as the recruitment and training of enumerators, and coordinated data collection. DBA was responsible for the conclusion and recommendation synthesis, facilitated the cohesive integrative revision, assured the manuscript had smooth transitions between sections, and did the last proofreading. The final manuscript was approved by all authors.

### Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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