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Effect of Food Security on Stunting Prevention via Protein Consumption Mediation

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Abstract

The value of potential GDP lost due to stunting varies between countries. Stunting is not only an indicator of well-being but also a prerequisite for increasing productivity. The problem of stunting can lead to a decrease in productivity, which, in turn, can lead to lower economic output. Indonesia is one of the countries that still faces stunting problems. This study aims to analyze the role of protein consumption in mediating the effect of food security on stunting prevention in Indonesia. The data used is panel data covering 34 provinces in Indonesia for the period 2018-2021, resulting in 136 observations. The model used in this study is path analysis. There are two models estimated using panel data regression analysis: the stunting prevention equation model and the protein consumption equation model. Stunting prevention is estimated against the variables of food security and protein consumption. In the second model, the effect of food availability for consumption is estimated on consumption through the food security approach. The results show that increasing food security and protein consumption influences stunting prevention. Increasing food security affects protein consumption. Protein consumption mediates the effect of food security on stunting prevention. Government policies to increase protein consumption can be achieved through formal and informal education. Fiscal policies such as a sugar tax and a tax on unhealthy foods or drinks with low nutritional value can be applied to create a substitution effect that impacts increased protein consumption. Labor-intensive economic policy in the agricultural sector is also needed to promote food security, protein consumption, and stunting prevention simultaneously.

Introduction

The quality of human resources is fundamental and very important for economic development [1]. If the quality of human resources is good, economic development will improve . Conversely, if the quality of human resources is poor, there will be a loss of economic development potential [2–6]. The quality of human resources can be shaped even before birth. Before a human is born, there is a pair of parents—man and woman. The human being born is expected to become a quality human resource so that optimal economic development potential can be achieved [7,8].

However, if the human being born turns out to be unqualified due to various factors such as malnutrition, which ultimately causes stunting, then achieving optimal economic development becomes difficult [9]. The economic loss due to stunting in the labor force in Indonesia is currently estimated at 10.5% of gross domestic product (GDP), equivalent to IDR 386 trillion [10,11]. Stunting is one of the growth and development disorders experienced by children due to a lack of nutrient intake, especially micronutrients, repeated infections, and inadequate psychosocial stimulation [12]. The World Health Organization (WHO) uses body length-for-age (PB/U) as an indicator of stunting in children aged 0-59 months, with a PB/U score below -2SD categorized as stunted children [13].

Stunting can be assessed by anthropometric measurements. Anthropometry is a procedure for assessing size, proportion, and body composition related to toddler growth. Anthropometric measurements include weight, height, and body mass index, with early detection of stunting

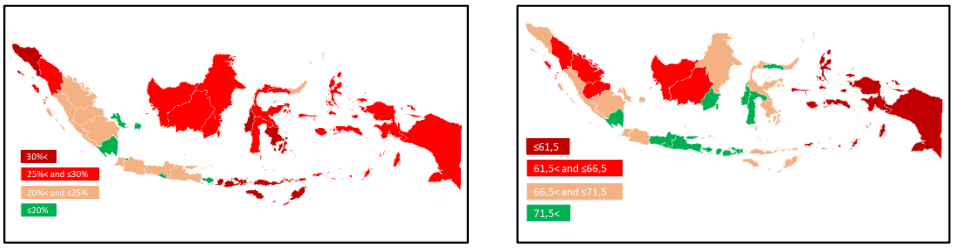
using measurements of children's height based on age [12]. Over the past few decades, anthropometric research has provided indicators of well-being based on human physique, facilitating the measurement of health development across social and regional groups and by gender [14].

Childhood stunting has long-term consequences for human capital, including reduced physical growth, lower educational attainment, impaired cognition, decreased labor productivity, and lower wages [15]. Stunting impedes economic growth and labor market productivity by reducing adult worker earnings by 20 percent, exacerbating inequality, reducing total lifetime earnings by 10 percent, and making poverty intergenerational [16,17].

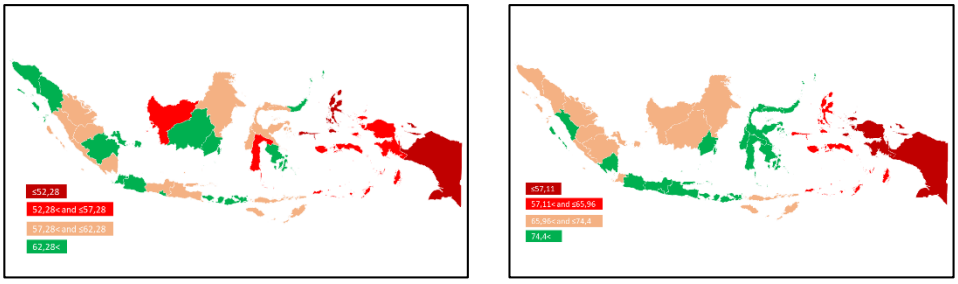
Stunting reflects a country's socioeconomic conditions [18]. High stunting rates are associated with poor socioeconomic conditions, while a decrease in national stunting rates typically indicates an improvement in overall socioeconomic conditions. Socioeconomic conditions are closely linked to the ability to provide adequate nutritional intake and health services for pregnant women and children under five [10]. The stunting prevalence threshold set by the WHO is 20 percent [13,19]. In 2021, 82 percent of provinces in Indonesia (28 out of 34 provinces) had a stunting prevalence above the threshold set by WHO. Detailed stunting prevalence per province in Indonesia can be seen in Figure 1(a).

Stunting does not only occur among the poor but also affects the richest households, with 29% of toddlers from the top 20% of households by socioeconomic status being stunted [10,20]. Preventing stunting is crucial as it is linked to the quality of human resources and impacts the nation's future development. By 2045, Indonesia will reach 100 years of independence. Approaching its centennial, Indonesia focuses on four pillars of development: 1. Human development and mastery of science and technology, 2. Sustainable economic development, 3. Equitable development, and 4. Strengthening national resilience and governance. These pillars form the 2045 Golden Indonesia Vision, which aims for a Sovereign, Advanced, Fair, and Prosperous nation [21].

To support the development pillars in the vision, especially Pillar 1, namely human development, the problem of stunting must be prevented to achieve Pillar 2 of the vision, which focuses on optimal economic development. In traditional neoclassical economic theory, GDP is considered the main index of development [22]. Several studies reveal that if stunting is not prevented, it can lead to potential GDP losses. The potential GDP loss due to stunting is estimated to be up to 1.2% [15]. Another study found it could be as high as 3.99% [23]. Additionally, GDP per capita losses can range from 5% to 7% [24]. In some cases, GDP losses may reach up to 8% [25]. The decrease in GDP due to stunting occurs because stunting is an aspect of health, which serves as an indicator of welfare. Health is a prerequisite for increasing productivity [22]. When stunting becomes an issue, productivity declines [26]. This decrease in productivity leads to lower economic output, which subsequently results in a reduced GDP value.



(a) (b)



(c) (d)

Figure 1. Indonesia's stunting prevalence map 2021 from (a) Ministry of Health and (b) Statistics Indonesia, (c) protein consumption per capita 2021 in grams (Statistics Indonesia), and (d) food security index 2021 (National Food Agency).

Thus, the problem of stunting is important to prevent. The condition of stunting prevention in Indonesia can be assessed through the Special Index for Handling Stunting approach [26]. In 2021, the Special Index for Handling Stunting in Indonesia was 71.5. There were 68% of provinces in Indonesia (23 out of 34 provinces) with a Special Index for Handling Stunting value below the national average. This can be seen in detail in Figure 1(b).

There are direct and indirect causes of stunting [27]. One of the direct causes of stunting is inadequate nutritional intake. Nutrient intake can be assessed from protein consumption [28–31]. Furthermore, protein consumption plays an important and positive role in height [32], so in this case, adequate protein consumption can help prevent stunting. The average daily per capita protein consumption in Indonesia in 2021 was 62.28 grams [33]. In 53% of provinces (18 out of 34 provinces) in Indonesia, the average daily per capita protein consumption is below the national figure. This can be seen in detail in Figure 1(c).

The next indirect factor for stunting prevention is food security [27]. Food security refers to the supply of food to meet protein consumption demand [34]. Research has estimated the effect of food security on food consumption, with results showing a positive and statistically significant effect [35]. Food security can be measured using the food security index approach. The minimum food security index for a province to be considered to have the best resilience is 74.4 [36]. As many as 50% (17 out of 34) provinces in Indonesia have a food security index below 74.4. A map of the food security index per province in Indonesia is presented in Figure 1(d).

Several studies on the relationship between direct and indirect factors and stunting have been conducted to inform policymakers in planning economic development through human development. However, the research conducted so far has been limited to descriptive analysis, qualitative studies, and literature reviews [37–43]. In addition, previous quantitative research has been limited to analyzing the relationship between direct and indirect risk factors for stunting without examining these factors at the country level. Previous studies have only analyzed observations in small areas. This contrasts with earlier studies that have only explored the risk relationships of stunting factors and focused on observations in small areas. According to Haile & Headey [44], research on stunting is still limited to non-experimental evidence based on cross-sectional surveys.

This study aims to examine the effect of indirect factors, specifically food security, on stunting prevention through the mediating role of protein consumption as a direct factor, with observations at a larger scale, namely at the country level, in this case, Indonesia. The study uses secondary data and panel data for all provinces in Indonesia, which enhances the accuracy of the analysis. Based on the introduction provided, the objectives of this research are to investigate the effect of protein consumption and food security on preventing stunting in Indonesia, assess the impact of food security on protein consumption in Indonesia, and explore the mediating effect of protein consumption in the relationship between food security and

stunting prevention in Indonesia. The findings of this analysis will provide valuable information to the government on efforts to prevent stunting, which is closely related to human resources and economic development.

Materials and Methods

Data and Variables

This study aims to analyze the role of protein consumption in mediating the effect of food security on stunting prevention in Indonesia. The variables used in this study are protein consumption, food security, and stunting prevention. The type of data used in this study is panel data, which is a combination of cross-section and time-series data. The cross-section data contains 34 provinces (n=34), and the time-series data covers a 4-year period from 2018 to 2021 (T=4), resulting in a total of 136 observations (N=136). The total of 136 observations is due to data availability obtained from several sources, and it remains relevant for analyzing panel data because the number of observations is greater than 90 [45]. Data on protein consumption and stunting prevention were obtained from the Central Bureau of Statistics, while data on food security were obtained from the National Food Agency. Table 1 describes the variables, their resources, and respective sources. It is balanced panel data with available data for all units within the period under investigation.

Table 1. Description of variables, units of measurement, and data sources.

Status	Variable Name	Symbol	Variable Definition	Units	Data Sources
Dependent	Stunting Prevention	SP	Stunting prevention is measured through multidimensional factors such as nutrition, health, housing, education, and social security.	Point	Statistics Indonesia
Mediator	Protein Consumption	PC	Grams of protein consumed per capita per day.	Grams	Statistics Indonesia
Independent	Food Security	FS	Food security is measured through food availability, food affordability, and food utilization.	Point	National Food Agency

Method

In economic development theory by Todaro and Smith, health is considered an output of economic development [22]. In this study, we approach health via stunting prevention. Economic development can be measured through consumption, especially in Indonesia, where the majority of gross domestic product by expenditure is contributed by consumption [46]. According to the literature, protein consumption has a direct effect on stunting prevention [19,28–31,47]. Thus, the initial function of this research is shown in Equation 1, as follows:

$$SP_{it} = \beta_0 + \beta_1 PC_{it} + \varepsilon_{it} \quad (1)$$

Where SP_{it} represents stunting prevention in the i-th province and t-th year, PC_{it} denotes protein consumption the i-th province and t-th year, β_0 is the intercept, β_1 is the regression coefficient, and ε_{it} is the error term for the i-th province and t-th year. An additional factor affecting stunting prevention is food security [48–52]. Hence, the Stunting Prevention Equation Model in this research is formulated in Equation 2, as follows:

$$SP_{it} = \beta_0 + \beta_1 PC_{it} + \beta_2 FS_{it} + \varepsilon_{it} \quad (2)$$

Here, FS_{it} represents food security in the i-th province and t-th year, and β_2 is the regression coefficient in the stunting prevention equation model. Food security reflects the supply side of

protein consumption [34]. The fundamental law of demand states that price and quantity move in opposite directions when other factors remain unchanged [53]. Price is sensitive to the availability of supply. Therefore, we hypothesize that food security, acting as the supply factor, influences protein consumption, which serves as the demand factor, and formulate The Protein Consumption Equation Model as shown in Equation 3, as follows:

$$PC_{it} = \alpha_0 + \alpha_1 FS_{it} + \varepsilon_{it} \quad (3)$$

Food security not only affects stunting prevention directly, but also indirectly through protein consumption [54–56]. To test the role of protein consumption as a mediator in the relationship between food security and stunting prevention, we use equation models (2) and (3), as well as one mediation hypothesis test. The mediation hypothesis test in this research is conducted using the Sobel test. The Sobel test is used to determine the significance level of the mediating variables in path analysis, as path analysis primarily measures the magnitude of the direct effect of the independent variable on the mediating variable and its impact on the dependent variable [57]. The mediating variable in this study is protein consumption. This Sobel test provides evidence of whether the mediating variables used in the study significantly mediate the indirect relationship between the independent variable and the dependent variable [58]. The mediation hypothesis test using the Sobel test formula assesses the significance of the following coefficient, as shown in Equation 4.

$$z_{jk} = \frac{\alpha_j \beta_k}{\sqrt{(\beta_k^2 + \mathrm{SE}_{aj}^2) + (\alpha_j^2 + \mathrm{SE}_{\beta k}^2)}}, \text{ for j=1, k=1, and j=k.} \quad (4)$$

Where aj is the j-th coefficient of regression in the protein consumption equation model, β_k is the k-th coefficient of regression in the stunting prevention equation model, $SE_{\alpha j}$ is the standard error of estimation for the j-th coefficient of regression in the protein consumption equation model, and $SE_{\beta k}$ is the standard error of estimation for the k-th coefficient of regression in the stunting prevention equation model. If the calculated z_{jk} value is greater than the critical value of the z-table at a significance level of 5 percent, then the protein consumption variable significantly mediates the relationship between the food security variable and the stunting prevention variable.

Model Selection Test

Chow test, Hausman test, and LM test are sequentially conducted in stages to determine the best model selection in panel data regression in this research. in this research. To determine whether the FEM model is better than the CEM model, the Chow test is used. By using the Chow test, the significance of the intercept αi is assessed to see whether it is different in each sector (FEM) or the same (CEM). The hypothesis used is H0: CEM model, Ha: FEM model. If the p-value < 0.05, then H0 is rejected, meaning that the FEM model is selected, and vice versa. The Hausman test is used to choose between the FEM and REM models. The hypothesis of this test is H0: REM model, Ha: FEM model. If the p-value < 0.05, then H0 is rejected, meaning the FEM model is selected, and vice versa. The LM test is used to determine the best model between CEM and REM by testing the REM model based on the residual value. The hypothesis is H0: CEM model, Ha: REM model. If the p-value < 0.05, then H0 is rejected, meaning that the FEM model is selected, and vice versa. In linear regression with the OLS approach, classical assumption tests are required, including Multicollinearity, Heteroskedasticity, Normality, and Autocorrelation [45].

Results and Discussion

Descriptive Statistics

In Table 2, we present the between cross-section, within time series, and overall summary statistics for stunting prevention, protein consumption, and food security. A balanced panel data with 34 cross-sectional units (the 34 provinces in Indonesia) over 4 years is used for the empirical analysis. There are no missing observations among the variables and across provinces, resulting in 136 observations. The standard deviation of the variables in Table 2 suggests that there are significant differences in the between and within variations in stunting prevention, protein consumption, and food security, with most of these differences accounted for by between variances.

Table 2. Descriptive statistics of variables.

Variable		Mean	Std. Dev.	Min.	Max.	Observations
Stunting Prevention	Overall	67.673	6.712	46.400	84.300	N = 136
	Between		6.704	49.975	83.925	n = 34
	Within		0.645	66.797	68.341	T = 4
Protein Consumption	Overall	60.946	6.020	44.037	76.788	N = 136
	Between		5.963	45.039	73.193	n = 34
	Within		0.304	60.533	61.266	T = 4
Food Security	Overall	69.254	11.284	25.130	85.150	N = 136
	Between		10.067	34.783	83.760	n = 34
	Within		3.523	65.634	72.433	T = 4

Unit Root Test and Panel Regression Model Selection

The result in Table 3 shows that stunting prevention, protein consumption, and food security achieved stationarity at levels for Levin, Lin, and Chu, and Fisher's unit root tests. Therefore, the null hypothesis that all panels contain unit roots for these variables is rejected.

Table 3. Panel unit root tests on variables at the level.

Variables	Levin, Lin, and Chu	Fisher Augmented Dickey Fuller	Decision
Stunting Prevention	-21.824***	166.470***	I (0)
	(0.000)	(0.000)	
Protein Consumption	-49.953***	113.705***	I (0)
	(0.000)	(0.000)	
Food Security	-41.595***	167.857***	I (0)
	(0.000)	(0.000)	

Note: P-values in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 4 is the result of the best model selection test on both the stunting prevention regression model and the protein consumption regression model conducted in this study. Based on Table 4, it can be observed that the p-value of the Chow test on the stunting prevention model is smaller than 0.01. The null hypothesis in the Chow test is the common effect model. Based on the p-value of the Chow test results, with a 99% confidence level or 1% error rate, the null hypothesis is rejected and the alternative hypothesis is the fixed effect model.

The next step is to conduct a Hausman test on the stunting prevention model. The p-value of the test is greater than 0.01. The null hypothesis in the Hausman test is the random effect model. Based on the p-value of the Hausman test results, the null hypothesis is rejected and the alternative hypothesis, namely the fixed effect model, is accepted.

The next stage, the LM test, needs to be done again because the Chow test and the Hausman test have different results. The LM test has a null hypothesis of the common effect model. The result of the LM test is to reject the null hypothesis with an error rate of 1% and accept the

alternative hypothesis, namely the random effect model. Thus, the best model for estimating the stunting prevention regression model is the random effect model. In contrast to the stunting prevention equation, the protein consumption model obtained the result that the fixed effect model is the best, both at the Chow test stage and the Hausman test stage. Thus, the best model for estimating the protein consumption regression model is the fixed effect model.

Table 4. Model selection test.

Test	*P-Value*	
	Stunting Prevention Model	Protein Consumption Model
Chow Test	0.0000	0.0986
Hausman Test	1.0000	0.0420
LM Test	0.0000	-
Conclusion	Random Effect Model	Fixed Effect Model

Classical Assumption Test

The purpose of the multicollinearity test is to determine whether or not there are independent variables that are linearly correlated. If the independent variables are linearly correlated, it will be difficult to distinguish the effect of each independent variable on the dependent variable. The method for detecting the presence or absence of multicollinearity is by examining the correlation value.

According to Gujarati and Porter [45], if the correlation between independent variables is greater than 0.8, then multicollinearity occurs; if the correlation is less than 0.8, then multicollinearity does not occur. In Table 5, it can be observed that none of the independent variables have a correlation value greater than 0.8 with other independent variables. Therefore, it is concluded that there is no multicollinearity among the independent variables, both in the stunting prevention equation and the protein consumption equation.

Table 5. Multicollinearity test.

Variable	Protein Consumption Protein	Food Security
Protein Consumption	1.00	0.61
Food Security	0.61	1.00

The purpose of the heteroscedasticity test is to determine whether or not there is inequality in the variance of the residuals from one observation to another in the regression equation model. If the residual variance is constant across observations, then there is no heteroscedasticity, which is referred to as homoscedasticity. However, if the residual variance differs across observations, then heteroscedasticity occurs.

Table 6. Heteroscedasticity test.

Model	Variable	Coeff.	Std. Error	t-Stat.	P-Value
Stunting Prevention	PC	-0.0766	0.0593	-1.2913	0.1988
	FS	0.0086	0.0171	0.5061	0.6136
Protein Consumption	FS	-0.0336	0.0261	-1.2871	0.2003

A good regression model is one that does not experience heteroscedasticity. According to Glejser [59], to test the residuals of the regression equation, one can regress the absolute value of the residuals on the independent variables. The null hypothesis in the Glejser test is homoscedasticity, while the alternative hypothesis is heteroscedasticity. In Table 6, it can be observed that all independent variables for both the stunting prevention equation and the protein consumption equation have a p-value of more than 0.1, meaning that they fail to reject the null hypothesis or accept the null hypothesis. Based on these results, it is concluded that there is no heteroscedasticity in the residuals for both the stunting prevention equation and the protein consumption equation.

Table 7. Normality test.

Model	Std. Dev	Skewness	Kurtosis	Jarque-Bera	*P-Value*
Stunting Prevention	5.0139	0.0340	3.5810	1.9391	0.3793
Protein Consumption	5.7807	-0.1724	3.4322	1.2861	0.5257

Normality is one of the assumptions that must be met in regression analysis. This assumption is tested on the residuals of the regression equation; violation of the normality assumption will lead to inaccurate statements in the inferential analysis [60]. The normality test on the residuals of the regression equation can be conducted using the Jarque-Bera test [45]. The Jarque-Bera test has a null hypothesis stating that the residuals are normally distributed, and the alternative hypothesis is that the residuals are not normally distributed. In Table 7, both the stunting prevention equation and the protein consumption equation have a p-value above 0.1, meaning that the null hypothesis is not rejected or is accepted. Based on this, the assumption of residual normality for both equations can be met.

Table 8. Autocorrelation test.

Model	Durbin-Watson	Conclusion
Stunting Prevention	1.7488	No Autocorrelation
Protein Consumption	1.5429	Positive Autocorrelation, can be ignored [61]

Table 8 contains information about the Durbin-Watson (DW) value for the regression results of the stunting prevention equation, which is 1.748787. The DW value is compared with the DW table value, containing the dL and dU values. If dU < DW < 4 - dU, then there is no positive or negative autocorrelation [62]. The DW table value, with 136 observations, 3 total variables, and a 1% significance level, gives dL = 1.57321, dU = 1.63295, and 4 - dU = 2.36295 [45]. Thus, for the stunting prevention equation, the value of dL < DW < 4 - dU, so there is no positive or negative autocorrelation in the equation. The protein consumption equation has a DW value of 1.542946. The DW table value, with 136 observations, 2 total variables, and a 1% significance level, gives dL = 1.58811, dU = 1.61776, and 4 - dU = 2.38224. If the DW value is less than dL, then it is concluded that there is positive autocorrelation [62]. Thus, for the protein consumption equation, the value of DW < dL, indicating positive autocorrelation in the equation. However, due to the panel data used in this research, the autocorrelation result can be ignored because autocorrelation is relevant to time series data only and is not meaningful to cross-sectional data or panel data [61].

Estimation Result

The value of the F-statistic presented in Table 9 is significant for both models, suggesting that all independent variables together affect the dependent variable. The effects of protein consumption and food security on stunting prevention are partially significant in the stunting prevention model. This shows that an increase of 1 gram of protein consumption per capita per day significantly increases stunting prevention by 0.358 points. An increase of 1 point in food security significantly increases stunting prevention by 0.063 points. The results for the protein consumption model reveal that a 1-point increase in food security significantly increases protein consumption by 0.195 grams per capita per day.

Table 9. Estimation on both model.

Dependent Variabel	Independent Variable					
	Protein Consumption	Food Security	Constant	Obs.	R^2	F-Stat.
Stunting Prevention	0.358***	0.063***	41.532***	136	0.220	18.694***
	(0.073)	(0.020)	(4.610)			
Protein Consumption		0.195***	47.454***	136	0.188	7.576***
		(2.694)	(2.694)			

Note: Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The mediating effect of protein consumption on the relationship between food security and stunting prevention is shown in Table 10. We can conclude that protein consumption partially mediates the relationship between food security and stunting prevention. This is because food security directly affects stunting prevention, as discussed earlier in the stunting prevention model in Table 9, and food security directly affects stunting prevention via protein consumption significantly, with a 99% level of confidence. As a mediating effect for food security, protein consumption significantly increases stunting prevention by 0.070 points for each 1-point increase in food security.

Table 10. Summary of mediating effect test.

Food Security Effect on Stunting Prevention	Coeff.	t-Stat.	Std. Error	P-Value
Direct	0.063	3.193	0.020	0.002
Indirect via Protein Consumption	0.070	3.532	0.020	0.000

Discussion

We find that protein consumption positively impacts stunting prevention. This result is similar to the findings of a study by Soofi et al. [63], which found that nutritional interventions, including protein consumption, were significantly related to reduced stunting. The results are also similar to the study by Fahmida et al. [64], which concluded that the problem of protein consumption was directly linked to stunting issues in 10 districts/cities in Indonesia. The implication of these results is the need for government policies to increase protein consumption in the community, so that conditions for stunting prevention can be achieved. This policy could take the form of education regarding the importance of nutritional intake for the body, particularly protein consumption. Such education could begin in educational institutions, starting from pre-school and continuing through elementary school, middle school, and even college if necessary, by including education on the importance of protein consumption in the curriculum.

Education, in addition to that in educational institutions, can also be carried out in family institutions by providing knowledge of protein consumption to prospective couples during pre-marital consultations at the Religious Affairs Office. Fahmida et al. [64] found scientific evidence regarding the importance of ensuring adequate nutritional intake, including sufficient protein consumption, especially for pregnant women, as this allows for more appropriate and timely interventions to prevent stunting. This education is also provided at community health centers (puskesmas) during pregnancy and at integrated service posts (posyandu) when the child is born and under the age of five (toddlers).

Another policy that can be implemented by the government is fiscal policy through the application of taxes or excise duties on unhealthy foods or drinks with low nutritional value. An example of this is the application of excise duties on packaged, high-sugar sweetened beverage products, with the aim of creating a substitution effect that encourages increased protein consumption through other beverage products, such as high-protein milk. Pineda et al. [65] found evidence of a decrease in sales, purchases, and consumption of high-sugar foods or drinks subject to excise duties, especially when the excise is combined with subsidies for healthy foods, including those containing protein. Excise duties on high-sugar sweetened beverages will reduce both the volume and calories purchased, with the greatest impact on low-income households, while subsidies will increase purchases of healthier drinks [66]. Sugar excise, in particular, is a powerful tool to encourage healthier food consumption among consumers [67].

Another finding is that food security has a positive impact on stunting prevention. These results are similar to the research conducted by Tiwari et al. [51] in Nepal, which found empirical evidence of a strong relationship between food insecurity and stunting. The same results were also observed by Hackett et al. [52] in Colombia, who found that the risk of stunting increases as food insecurity worsens. Thus, food security is strongly related to stunting prevention. Food

security must take local factors into account, particularly regarding food availability, as conditions such as geography, culture, and knowledge differ from one region to another. In Indonesia, red beans (Phaseolus vulgaris), oyster mushrooms (Pleurotus ostreatus), catfish (Clarias gariepinus), and fermented soybeans (tempeh) are widely available in local communities for consumption. These foods contain high nutritional value, including high-quality protein [19]. Food aid is necessary for ensuring food security, which in turn helps prevent stunting, but evidentiary analysis of cost-effective options is needed [55]. Climate variability and extremes, conflict, economic slowdowns and downturns (e.g., the COVID-19 pandemic), and increasing costs of healthy food are identified as the main causes of rising malnutrition, including stunting and food insecurity [48].

We also find that food security has a positive impact on protein consumption. These results are related to the findings of Andreoli et al. [49] which showed that food security, measured by the proxy of average temperature, has a significant and negative effect on animal protein consumption. The interpretation of this study is that residents in areas with temperate climates (lower temperatures) tend to consume more animal protein compared to residents in tropical climates (higher temperatures). Areas with lower temperatures are more conducive to grain production, and surplus grain production is important for intensive livestock production. As a result, residents in tropical areas consume less animal protein due to the natural characteristics of tropical soil conditions and other ecological factors that inhibit grain production. This is confirmed by data from Statistics Indonesia [33], which shows that the top source of protein consumption among Indonesian residents, according to food commodity groups in both urban and rural areas, comes from grains. Locally available, nutrient-dense food security is essential to achieving adequate protein consumption. Indonesia has a diverse population with varying food patterns and food availability, and these differences in food security can affect the nutritional adequacy of protein consumption from locally available foods [64].

The final finding in this research is that protein consumption mediates the effect of food security on stunting prevention. These results are in line with the conclusions of the study by Fahmida et al. [64], which concluded that strengthening locally available food security, including nutrient-dense foods such as protein, should be incorporated into stunting prevention strategies. Nikiema et al. [55] conducted a study comparing the cost-effectiveness of various food supplies for food security to prevent stunting. The conclusion was that food security produced from legumes (such as soy), which contain vegetable protein, has cost-effectiveness in promoting protein consumption for stunting prevention. Other similar results were obtained by Tiwari et al. [51], whose research in Nepal showed that residents in hilly areas were significantly less likely to suffer from stunting compared to those in mountainous areas. This discrepancy may be due to differences in food security between the two areas, affecting food access, eating patterns, and protein consumption, leading to varying levels of stunting prevention. Food prices contribute significantly to the problem of stunting [19,68]. To reduce malnutrition, including stunting and food insecurity worldwide, a transformation of the food system is needed to address nutritional deficiencies, including protein consumption, for stunting prevention [48].

Policies that can be implemented to increase food security, and thereby enhance stunting prevention both directly and through protein consumption, include creating government policies that support labor-intensive economies in the agricultural sector. The government can implement policies that stimulate the development of the agricultural sector by guaranteeing the marketing of agricultural products produced by farmers, such as through government purchases of crops. This approach is expected to increase employment opportunities, raise incomes, and reduce inequality. The government, after purchasing agricultural products from these producers, can distribute the products by selling them at subsidized prices. This is expected to create an income effect by reducing the costs consumers must pay for agricultural

products. As food security improves, protein consumption is anticipated to increase, which will, in turn, contribute to enhanced stunting prevention.

Conclusions

Based on the results of this study, it can be concluded that protein consumption has a positive effect on preventing stunting. Increased protein consumption leads to greater stunting prevention. Food security also influences stunting prevention, with higher food security contributing to better stunting outcomes. Furthermore, food security positively affects protein consumption, as increased food security leads to greater protein intake. Protein consumption mediates the effect of food security on stunting prevention, meaning that improved food security, through the mediation of protein consumption, will enhance stunting prevention.

Government policies on formal education curricula and pre-marital consultations at the religious affairs office, which provide knowledge about the importance of protein consumption, are necessary. Fiscal policies such as a sugar tax are also needed to create a substitution effect that encourages increased protein consumption. Additionally, labor-intensive economic policies in the agricultural sector, along with government-guaranteed purchases of agricultural products and the distribution of these products at subsidized prices, are important for increasing food security, protein consumption, and stunting prevention.

This study has limitations, including the lack of disaggregated data on the sources of protein consumption (e.g., animal-based or plant-based protein). Another limitation is that the data collected is restricted to the provincial level. Additionally, this study's scope is limited to the perspective that stunting prevention is driven primarily by protein consumption and food security. Further research should expand the analysis to include more detailed data at the municipality or regency level and explore a broader range of factors that contribute to stunting prevention.

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