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Spatial analysis of stunting determinants in 514 Indonesian districts/cities: Implications for intervention and setting of priority

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Abstract

While the national prevalence of stunting in Indonesia has decreased, the level remains high in many districts/cities and there is significant variation. This ecological study employed aggregated data from the Basic Health Research Report and the District/City Poverty Data from 2018. We investigated the determinants of stunting prevalence at the district/city level, including autocorrelation applying the spatial autoregressive (SAR) model. The analyses revealed stunting prevalence above the national average in 282 districts/cities (54.9%), *i.e.* ≥30% in 297 districts/cities (57.8%) and ≥40% in 91 districts/cities (17.7%). Autocorrelation was found between Sumatra, Java, Sulawesi as well as Bali, East Nusa Tenggara and West Nusa Tenggara (Bali NTT NTB). The SAR modelling revealed the following variables with significant impact on the stunting prevalence in various parts of the country: closet defecation, hand washing, at least four antenatal care visits during pregnancy, poverty, immunisation and supplementary food for children under 5 years.

Introduction

Indonesia has the fourth largest prevalence of stunting worldwide (National Team for Poverty Reduction Acceleration Indonesia, 2017). More positively, according to recent data from the Central Bureau of Statistics Indonesia, the national prevalence decreased from 37.2% in 2013 to 30.8% in 2018. However, based on data from the annual Nutrition Status Monitoring reports of the Ministry of Health of the Republic of Indonesia, the general distribution pattern indicates that many districts/cities are still experiencing a high level of stunting prevalence (Ministry of Health, 2015, 2016, 2017).

The national prevalence of stunting in children under 5 years in Indonesia decreased from 37.2% in 2013 to 30.8% in 2018 (Ministry of Health, 2018). However, a national decline does not necessarily reflect a decline in all districts/cities in every region. The threshold for high prevalence of stunting according to World Health Organization (WHO) is ≥30%. Figure 1 shows the distribution of stunting prevalence for each district/city in every province of Indonesia in comparison with the WHO threshold.

The current stunting prevalence exceeds 30% (the WHO threshold) in as many as 297 Indonesian districts/cities (57.8%) and even reaches 40% in 91 (17.7%) of districts/cities, with only 6.8% showing a stunting prevalence below 20%. At the provincial level, 21 provinces (62%) have an average stunting prevalence above 30%, while only 13 provinces have a prevalence below

30% (Figure 1). These results clearly demonstrate that many districts/cities in Indonesia still have a high stunting prevalence.

The alleviation of stunting in Indonesia is a challenge as the country is large and consists of 17,504 islands, with 34 provinces and 514 districts/cities. Regional sociocultural characteristics, behaviour and poverty vary from one island to the next and even within provinces. These factors should be considered when decisions are made about directives, policies and programmes for reducing stunting. Therefore, decision-makers require much information, *e.g.*, regarding economic and resource disparities across areas and nutrition data that reflects regional context and variation as well as knowledge of which areas have high prevalence of stunting. This would assist the National and regional governments to effectively prioritise intervention programmes to meet the National Medium-Term Development Plan target of achieving ≤20% of stunted children under 5 years by 2024, which is better than the aim of WHO's World Health Assembly that promotes ≤40% of stunted children by 2025 (WHO, 2014).

Spatial analysis would be particularly helpful in identifying areas where stunting occurs and what types of specific or priority interventions could be implemented there (Kandala *et al*., 2011; Di Cesare *et al*., 2015; Haile *et al*., 2016; Hagos *et al*., 2017; Development Initiatives, 2018; Menon *et al*., 2018). Spatial analysis of stunting has not been widely implemented in Indonesia. To the best of our knowledge, it has yet to be used to develop policies or programmes at national and regional levels.

To assist the government in developing contextual stunting interventions throughout Indonesia, this study conducted spatial analysis using Indonesian districts/cities as the units of analysis. The main research objectives were the following: i) to identify whether there is autocorrelation among districts/cities; and ii) to define a spatial model of risk factors for stunting prevalence in Indonesia.

Materials and methods

This ecological study employed aggregate data (percentages) at the district/city level in Indonesia. We sourced data from the Basic Health Research Report and the District/City Poverty Data and Information Report for 2018, both issued by the Central Bureau of Statistics Indonesia. Indonesia's 514 districts/cities served as the unit of analysis. They were grouped into seven categories according to the islands on which they are located: Sumatra, Java, Kalimantan, Sulawesi, Maluku, Papua as well as Bali, East Nusa Tenggara and West Nusa Tenggara (Bali NTT NTB). This grouping was done to reduce the bias in determining neighbours arising from Indonesia's many small islands, which lack closely connected neighbours. It needs to be stated that this condition might disturb the analysis.

We used the conceptual framework of UNICEF 1998 that was adapted according to the availability of existing data in Indonesia. Immediate causes of stunting were grouped into two sets of variables: i) food intake consisting of percentages of pregnant women receiving supplementary food plus children under 5 years receiving supplementary food and/or vitamin A; and ii) health status consisting of percentages of children under 5 years with diarrhoea and/or with upper respiratory tract infection (URTI). Presumed underlying causes of stunting were grouped into two sets of variables: i) health services consisting of percentages of pregnant women receiving at least four antenatal care visits (ANC-K4); ii) completely immunized children under 5 years with access to sanitation and clean water; percentages of the >10-year-old population with access to hand washing with soap at five critical times during the day; and iii) of >3-year-old population using a closet for defecation. We also included household poverty in the analysis.

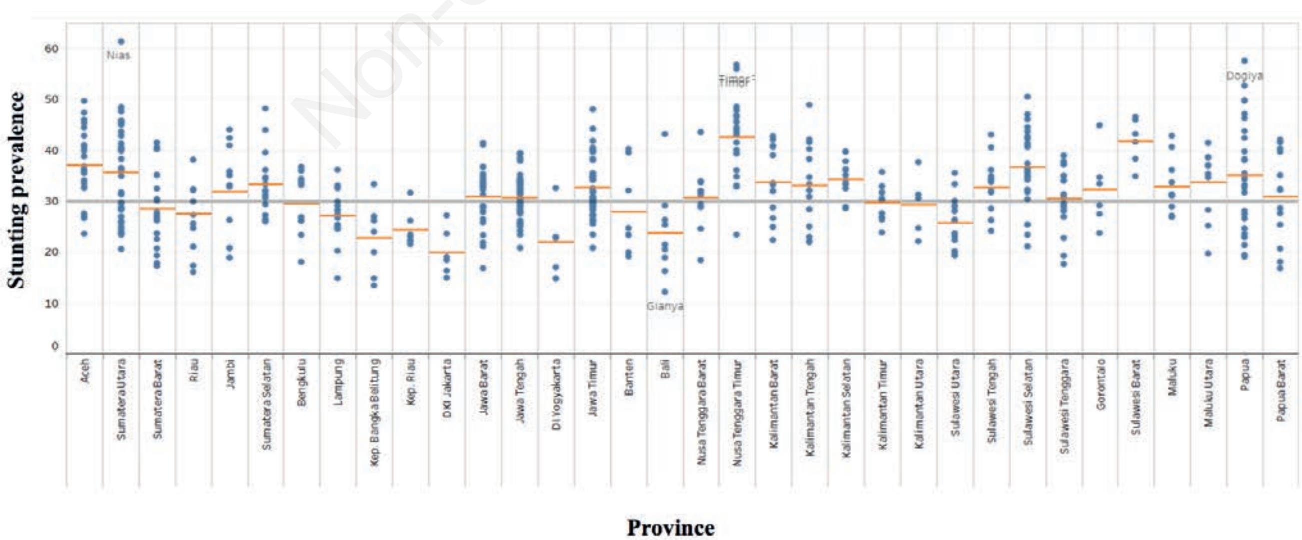

Figure 1. Distribution of stunting prevalence in Indonesia by province and district/city in 2018. The stunting prevalence for each district/city in every province of Indonesia is denoted by dots; The long grey line is the threshold for high prevalence of stunting according to the World Health Organization. The short orange lines represent the average value of stunting prevalence in each province.

Spatial analysis is the use of locational information to better understand observed attribute values (Pfeiffer *et al*., 2008; Fotheringham *et al*., 2009). In the health sector, spatial analysis serves to provide an overview of spatial patterns, identification of disease clusters and risk factors (Waller and Gotway, 2004; Pfeiffer *et al*., 2008; Bhunia and Shit, 2019). The first step of spatial analysis is to decide on spatial weighting to define neighbours, which was done using the Euclidean distance method that defines neighbours if the two areas are within a radius of <1 degree from each other or at a distance of ≤111 km. Autocorrelation between regions was tested using Moran's *I*, with the null hypothesis (H_0) that there is no spatial autocorrelation (I=0) with a=0.05 (*i.e*. the probability of making the wrong decision when H_0 is true). The spatial model of risk factors was identified using spatial autoregressive (SAR) analysis (Fotheringham and Rugerson, 2018). All the statistical assumptions (normality, independence, multicollinearity and homoscedasticity) must be fulfilled to proceed with further analysis using classical linear regression. Accordingly, the following steps were applied: i) the Anderson-Darling (AD) test of residual normality (Myers, 2000); ii) the Durbin-Watson (DW) test of independence (Myers, 2000); iii) a multicollinearity test using variance inflation factor (VIF) values (Myers, 2000); iv) the Breusch-Pagan (BP) a test of homoscedasticity (Myers, 2000); v) an autocorrelation test; vi) SAR modelling; vii) a comparison of the Akaike information criterion (AIC) value of classical linear regression and the SAR model; and viii) a decision and assumption test.

The SAR analysis was conducted to test the hypothesis r (spatial lag)=0. The value of r indicates whether regions are related in terms of stunting prevalence. SAR modelling can be done if there is spatial autocorrelation and no heteroscedasticity is found. The AIC value was used to determine which model had the best fit for the data. Data were analysed using R i386 (version 3.6.1) and Tableau Public 2020 software (https://www.tableau.com). Missing data were replaced by estimates, calculated by averaging the values from neighbouring areas. However, where an area had >5% missing data for a particular variable, that variable was excluded for that area. Consequently, not all variables could be studied on all islands or island groups.

Assumption test

Prior to identifying the spatial autocorrelation, several tests were run to evaluate statistical assumptions of the stunting prevalence residual. In each test, the P-value was compared with a=0.05. If the P-value is less than a, then H_0 is rejected. We employed classic regression to test the assumptions on the residual of stunting variable as well as to define its AIC value in the next step. Table 1 presents the results of the four tests.

The AD test result confirmed that the stunting prevalence residual was normally distributed, the DW test result that it was independent, and the BP test result that it was homogeneous (with no heteroscedasticity), as the P-value of each test was >0.05. Moreover, the VIF value indicated that there is no multicollinearity among the independent variables. Accordingly, with all assumptions verified, further analysis could proceed.

Results

Missing data

During the data management process, five of the study areas were found to have >5% missing data for at least one variable. Only Java and Bali NTT NTB had sufficient data to analyse all 10 variables. The following variables were excluded in some of the regions as follows:

- for Sumatra: i) supplementary food for pregnant women; ii) supplementary food for children under 5 years; iii) supplementary vitamin A for children under 5 years;
- for Kalimantan and Papua: i) supplementary food for pregnant women; ii) supplementary food for children under 5 years; and
- for Sulawesi and Maluku: supplementary food for pregnant women.

It is important to highlight these differences in the number of variables for each area to avoid bias in interpreting the SAR model.

Spatial autocorrelation

The autocorrelation test results for the districts/cities of each major island (group) are reported in Table 2. The results indicate the presence of spatial autocorrelation in stunting prevalence at the district/city level in Sumatra, Java, Sulawesi and Bali NTT NTB at

Table 1. Statistical test results for residual assumptions.

Island/ island group	Statistical test result (P-value) Anderson-Darling	Durbin-Watson	Breusch-Pagan	VIF
Sumatra	0.5379 (0.166)	2.052 (0.832)	3.562 (0.829)	<10
Java	0.714 (0.060)	1.754 (0.154)	10.253 (0.419)	<10
Sulawesi	0.4696 (0.241)	1.868 (0.48)	6.604 (0.678)	<10
Bali NTT NTB	0.669 (0.075)	1.727 (0.34)	11.809 (0.298)	<10
Kalimantan	0.42 (0.315)	1.868 (0.56)	4.851 (0.773)	<10
Maluku	0.149 (0.956)	2.393 (0.516)	7.608 (0.5471)	<10
Papua	0.243 (0.751)	2.655 (0.02)	5.851 (0.664)	<10

VIF, variance inflation factor.

P<0.05. On this basis, we performed further statistical analysis (classical regression and SAR) using the data of these four islands/island groups.

Spatial autoregressive model

As the stunting prevalence residual was found to have no heteroscedasticity (see Table 1), we determined that SAR analysis would be the most appropriate spatial modelling (Anselin, 2005; Grekousis, 2020). Prior to SAR modelling, we performed a classical regression test to evaluate the residual assumption and the AIC value, which could subsequently be compared with the AIC value of the SAR model. The comparison of AIC is shown in Table 3, which presents the comparison of AIC values for each area between the classical regression and SAR models. The AIC values for Sumatra and Java are almost the same in both models. We thus decided to continue using the SAR model. To evaluate that all assumption of SAR model were fulfilled, an all-assumption test was performed (Table 4).

As reported in Table 4, the tests of the SAR model's statistical assumptions produced the following results for the four islands/island groups: the stunting prevalence residual was normally distributed (the AD test), independent (the DW test), the residual variance was homogeneous (the BP test) and there was no multicollinearity between the independent variables. Thus, the SAR model met the statistical assumptions (Table 5).

For Sumatra, the SAR model identified closet defecation, hand washing and ANC-K4 as significant negative determinants meaning that higher values of these three variables were associated with lower stunting prevalence. Specifically, the prevalence decreased by 0.13% with 1% increase in closet defecation, by 0.14% with 1% increase in hand washing and by 0.12% with 1% increase in ANC-K4. By contrast, the correlation with poverty was positive, *i.e.* higher poverty percentages were associated with a higher stunting prevalence. Specifically, the prevalence increased by 0.33% with 1% increase in the poverty percentage.

For Java, the SAR model identified only ANC-K4 as a significant, negative determinant of stunting prevalence. Specifically, the prevalence decreased by 0.22% with 1% increase in ANC-K4. By contrast, poverty showed a positive correlation where the stunting prevalence increased by 0.73% with 1% increase in the poverty percentage.

The SAR model also identified two significant determinants of stunting prevalence in Sulawesi: closet defecation and ANC-K4. The correlation between stunting prevalence and closet defecation was negative. Specifically, the prevalence decreased by 0.38% with 1% increase in closet defecation. By contrast, the correlation with ANC-K4 was positive; specifically, stunting prevalence increased by 0.13% with 1% increase in ANC-K4.

For Bali NTT NTB, the SAR model identified four significant variables of stunting prevalence: poverty, hand washing, immunisation and supplementary food for children under 5 years. The correlations of stunting prevalence with hand washing, immunisation and supplementary food for children under 5 years were negative. Specifically, the prevalence decreased by 0.19% with 1% increase of hand washing, by 0.16% with 1% increase in immunisation and by 0.15% with 1% increase in supplementary food for children under five. By contrast, the correlation with poverty was positive showing an increase of 0.31% stunting prevalence with 1% increase in poverty.

Table 2. Autocorrelation test results.

Island group	Moran's *I*	P-value
Sumatra	0.299	1.522e-10
Java	0.105	1.246e-06
Kalimantan	0.104	0.073
Sulawesi	0.303	2.038e-09
Bali NTT NTB	0.633	4.127e-15
Maluku	–0.128	0.4103
Papua	0.126	0.55

Table 3. Comparison of Akaike information criterion values between classical regression and spatial autoregressive models.

Model	AIC			
	Sumatra	Java	Sulawesi	Sunda Islands
Classical regression	1008.184	745.9121	564.9081	277.2694
SAR	1009.3	746.16	547.91	276.16

AIC, Akaike information criterion; SAR, spatial autoregressive.

Table 4. Test results of the spatial autoregressive model's statistical assumptions.

Island group	Statistical test result (P-value)			
	Anderson-Darling	Durbin-Watson	Breusch-Pagan	VIF
Sumatra	0.5379 (0.166)	2.052 (0.832)	3.562 (0.829)	<10
Java	0.714 (0.0609)	1.754 (0.154)	10.253 (0.419)	<10
Sulawesi	0.4696 (0.241)	1.868 (0.48)	6.604 (0.678)	<10
Bali NTT NTB	0.669 (0.075)	1.727 (0.34)	11.809 (0.298)	<10

VIF, variance inflation factor.

Discussion

Indonesia is a vast country and a large archipelago as reflected by the overall variation of the significant stunting determinant correlations. Each region has its own characteristics that must be considered by the government when designing invention strategies. The national-level decline of stunting notwithstanding, we noted the occurrence of wide variations among districts/cities within provinces, among provinces within island groups and across the country. Sumatra has the heaviest burden, with over 80% of its districts/cities with still high stunting prevalence according to the most recent, available data. Such variations are not only found in Indonesia but also in many other countries where the stunting prevalence has decreased at the national level, such as India, Ethiopia and Peru (Haile *et al*., 2016; Hernandez-Vasquez and Tapia-Lopez, 2017; Menon *et al*., 2018; Development Initiatives, 2018).

Moran's *I* showed a significant spatial autocorrelation in stunting prevalence among districts/cities in Sumatra, Java, Sulawesi and Bali NTT NTB. This indicates that the stunting prevalence in one area - either high or low - does not occur randomly but is related to the stunting prevalence in neighbouring districts/cities. We found a tendency for the stunting prevalence of an area to be more similar to that in closer areas than that in more distant areas, a fundamental concept of geography that '*everything is related to everything else, but near things are more related than distant thing*' stated by Tobler's Law long ago (Souris, 2019). However, spatial autocorrelation in stunting prevalence was not found to occur in Kalimantan and Papua, which emphasizes that large regions can present differences over significant distances. In addition, different geographical situations with regions separated by sea, such as in Maluku, also showed less autocorrelation. These results suggest that the size of an area and the geographical conditions within and between districts (*e.g*., separation by water) greatly affect the distance between areas and consequently affect neighbouring variables, in turn resulting in presence or absence of spatial autocorrelation. In the context of spatial analysis, autocorrelation denotes a similarity that varies with the distance between locations (Fotheringham *et al*., 2009).

Poverty was found to be a statistically significant risk factor in Sumatra, Java and Bali NTT NTB. The relationship between poverty and stunting has been confirmed by many studies, including those conducted in Sri Lanka, India, Brazil, Indonesia, Peru,

Table 5. Modelling results for spatial autoregressive.

Variable	SAR	Sumatra	Java	Sulawesi	Bali NTT NTB
Intercept	Coefficient	53.794	53.102	48.345	47.053
	z-value	12.047	6.289	3.863	3.763
	Pr(>lzl)	<2.2e-16	3.184e-10	0.000	0.000
Diarrhoea	Coefficient	−0.035	−0.016	0.043	−0.354
	z-value	−0.336	−0.139	0.253	−1.651
	Pr(>lzl)	0.737	0.889	0.8002	0.098
URTI	Coefficient	−0.001	0.063	−0.103	0.189
	z-value	−0.017	0.828	−0.665	1.490
	Pr(>lzl)	0.987	0.408	0.5057	0.136
Closet defecation	Coefficient	−0.132	−0.091	−0.382	−0.133
	z-value	−2.939	−1.349	−3.256	−1.264
	Pr(>lzl)	0.003	0.177	0.0011	0.206
Handwashing	Coefficient	−0.140	0.040	0.025	−0.187
	z-value	−3.461	0.821	0.447	−2.811
	Pr(>lzl)	0.0005	0.412	0.6546	0.005
ANC-K4	Coefficient	−0.120	−0.224	0.133	0.111
	z-value	−2.696	−2.439	2.083	0.903
	Pr(>lzl)	0.007	0.015	0.0372	0.367
Immunisation	Coefficient	−0.047	−0.057	−0.271	−0.158
	z-value	−1.778	−1.468	−0.567	−2.098
	Pr(>lzl)	0.075	0.142	0.5705	0.036
Poverty	Coefficient	0.334	0.732	0.320	0.314
	z-value	3.158	5.614	1.419	2.006
	Pr(>lzl)	0.002	1.976e-08	0.1556	0.045
Supplementary Vitamin A	Coefficient	-	−0.077	0.031	0.080
	z-value	-	−1.376	0.491	1.437
	Pr(>lzl)	-	0.169	0.6231	0.151
Supplementary food_pregnant women	Coefficient	-	0.005	-	0.120
	z-value	-	0.132	-	1.419
	Pr(>lzl)	-	0.895	-	0.155
Supplementary food_children	Coefficient	-	−0.018	−0.018	−0.148
	z-value	-	−0,553	−0,361	−2.823
	Pr(>lzl)	-	0.580	0.7179	0.005

SAR, spatial autoregressive; URTI, upper respiratory tract infection; ANC-K4, at least four antenatal care visits.

Ethiopia, Bangladesh, Nepal, Pakistan and Kenya. Various studies have found that poverty is associated with low family income, which affects access to nutritious food (Monteiro *et al*., 2010; Sujendran *et al*., 2015; Gupta, 2017; Huicho *et al*., 2017; Tariku *et al*., 2017; Wirth *et al*., 2017; Jonah *et al*., 2018; Titaley *et al*., 2019).

Closet defecation and hand washing was found to be statistically significant variables in Sumatra, while in Sulawesi, only closet defecation was important and in Bali NTT NTB only hand washing. Closet defecation and hand washing are health-related behaviours that can prevent the occurrence of infectious diseases in children, and they reflect the community's access to sanitation and clean water (UNICEF, 1998; Monteiro *et al*., 2010; Schmidt, 2014; Saxton *et al*., 2016). Lack of access to clean water and good sanitation is an important underlying cause of stunting. Research in India and Cameroon found significantly higher stunting prevalence in children without access to good sanitation (Spears *et al*., 2013; Rah *et al.,* 2015; Aguayo and Menon, 2016). Similarly, hygiene and sanitation have been shown to impact on stunting prevalence in children under 2 years in Indonesia: specifically, the combination of poor toilet facilities and unsafe drinking water has been found to be associated with an increased likelihood of stunting (Torlesse *et al*., 2016; Badriyah and Syafiq, 2017). In an analysis of data from 34 developing countries (including results from the Indonesian Demographic Health Survey), Bauza and Guest (2017) concluded that improving defecation behaviour could reduce the number of children experiencing stunting, rather than just improving toilet access.

ANC-K4 was determined to be statistically significant factor in Sumatra, Java and Sulawesi, while in Bali NTT NTB, it was immunisation and supplementary food for children. The negative association between ANC-K4 and stunting prevalence has also been reported in several studies conducted in Latin America, Ethiopia, Bangladesh, Indonesia, Peru, Vietnam, and India (Ramirez *et al*., 2012; Di Cesare and Sabates, 2013; Talukder *et al*., 2018; Wirth *et al*., 2017). A study in Ethiopia found that mothers who did not receive ANC services during pregnancy had a 1.5 times greater risk of pre-lacteal feeding, a 2.8 times greater risk of feeding children with minimal dietary diversity and a 1.9 times greater risk of feeding children at a frequency below the minimum standard (Tessema *et al*., 2013).

In Indonesia, children living outside (compared to those living in) Java and Bali were predicted to have a higher likelihood of experiencing stunting due to the limited resources and facilities, including access to health workers and services (as well as immunisation) available outside those two regions (Titaley *et al*., 2019; Rahmawati and Umbul, 2014; Sugiharto and Budisuari, 2017; Sulistiyani *et al*., 2017).

Research limitations

This study is somewhat prone to ecological fallacy, whereby aggregate data representing an area are applied/inferred at the individual level. Another limitation is the availability and quality of secondary data. Published data at the regional level, in the form of either ethnographic or quantitative studies, is very limited, making it difficult to obtain comprehensive information. In particular, no relevant data are available on maternal and child diets, dietary diversity or parenting matters, variables that are vital predictors of stunting (UNICEF, 1991; WHO, 2013; Leroy & Frongillo, 2019).

Conclusions

In this study, spatial analysis identified autocorrelation in stunting prevalence in four of the seven major islands/island groups. This indicates that stunting prevalence is more similar among adjacent districts/cities than among those separated by a greater geographical distance. The SAR model results identified the following significant determinants of stunting prevalence: closet defecation, hand washing, ANC-K4 and poverty in Sumatra; ANC-K4 and poverty in Java; closet defecation and ANC-K4 in Sulawesi; and hand washing, immunisation, poverty and supplementary food for children under five in Bali NTT NTB.

This study primarily focused on improving the effectiveness and efficiency of evidence-based policies. By identifying the significant determinants of stunting prevalence for every main island/island group, especially the four big islands of Indonesia, the types of interventions can be adjusted accordingly. To improve on this study, we recommend repeating our method but for smaller administrative areas, for example at the village level in each district. In addition, this study's method can be used to identify appropriate policies and interventions for other health issues tailored according to the evidence for each regional context. Such an approach would be more effective than applying a uniform policy for all regions in Indonesia.

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