Spatial Analysis Risk Factors of Pneumonia Incidence in Toddlers Gowa Regency

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Abstract: *Background*: Pneumonia is one of the highest causes of death in children under five years old in the world. Globally, the number of under-five deaths due to pneumonia is estimated to reach up to 700,000 cases per year.

Objectives: This study aimed to spatially analyze the risk factors for pneumonia incidence among under-fives in Gowa Regency in 2021-2023.

Methods: This study used an analytic observational with an ecological study design. The population in this study was all cases of pneumonia among under-fives in Gowa Regency in 2021-2023, totaling 1,634 cases. The sample size in this study was 18 subdistricts with the sample selection technique using the exhaustive sampling method.

Results: There was a relationship between population density (r=0.470 p=0.000), poor population (r=0.422 p=0.001) and incomplete immunization status (r=0.457 p=0.000) with the incidence of pneumonia among under-fives in Gowa Regency in 2021-2023. Meanwhile, there was no association between undernutrition status (r=0.250 p=0.068) with the incidence of pneumonia among under-fives in Gowa Regency in 2021-2023.

Conclusion: Although undernutrition status did not show a statistically significant association in this study, it remains an important risk factor in the susceptibility of under-fives to pneumonia and other infections. Children with undernutrition status have a weak immune system, making them susceptible to disease complications. Therefore, nutritional interventions such as the provision of supplementary food, increasing exclusive breastfeeding coverage, and nutrition education to parents still need to be developed in a sustainable manner.

Keywords: Population Density, Poor Population, Incomplete Immunization Status, Undernutrition Status, Children Under Five.

1. INTRODUCTION

Pneumonia is one of the highest causes of death among children under five years of age in the world. Globally, the number of under-five deaths from pneumonia is estimated to reach up to 700,000 cases per year [1]. Based on data from the World Health Organization (WHO), in 2019 there were 740,180 under-five deaths due to pneumonia [2]. Then based on data from the United Nations International Children's Emergency Fund (UNICEF), there are more than 1,400 cases per 100,000 children suffering from pneumonia or 1 case per 71 children each year suffering from pneumonia. Most of the highest incidences of pneumonia cases occur in developing countries, namely, in South Asia (2,500 cases) and West and Central Africa (1,620 cases) [3].

Indonesia is one of the 30 countries in the world with the highest burden of pneumonia [4]. Indonesia itself ranks seventh in Southeast Asia with the highest number of pneumonia cases [5]. Based on data from the Indonesian Health Profile in 2021, the number of pneumonia cases among under-fives was 278,261 cases or around 31.41% with the number of under-five deaths amounting to 444 cases or around 0.16% [6]. Meanwhile, in 2022 the number of pneumonia cases in children under five increased to 386,724 cases or around 38.78% with the number of under-five deaths amounting to 459 cases or around 0.12% [7]. This indicates that there was an increase in the number of pneumonia cases in children under five years old by 7.37% from the previous pneumonia cases.

The results of the Indonesian Health Survey (IHS) in 2023 showed that the prevalence of pneumonia among under-fives in South Sulawesi Province was 0.9% [8]. Then based on data from the Indonesian Health Profile in 2022, the number of pneumonia cases in children under five in South Sulawesi Province reached 4,872 cases or about 14.40% with the number of deaths of children under five as many as 9 cases or about 0.63% [7]. The highest number of pneumonia cases among under-fives in South Sulawesi Province was found in Bulukumba District, with 649 cases or 39.9%. Meanwhile, the incidence of pneumonia in Gowa Regency ranks fourth with 413 cases or 15.4% in 2022

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[9]. In 2023, the number of pneumonia cases among under-fives in Gowa Regency increased to 1,260 cases or 41.7%, making Gowa Regency the first district with the highest number of pneumonia cases among under-fives [10].

According to the World Health Organization (WHO) pneumonia is a form of acute respiratory infection that affects the lungs [11]. Pneumonia can be caused by various microorganisms such as viruses, fungi and bacteria. The main cause of pneumonia in toddlers is often Streptococcus pneumoniae and Haemophilus influenzae, followed by Staphylococcus aureus and Klebsiella pneumoniae in severe pneumonia cases [12]. Pneumonia can be transmitted through the air by the patient when coughing or sneezing. In addition, pneumonia can also spread through other fluids such as blood during childbirth or from objects contaminated by the patient [13]. Symptoms that are often found in children with pneumonia are coughing, fever, chills, headache and loss of appetite [12].

In several studies conducted previously by Nuraeni and Rahmawati it was found that temperature, humidity, occupancy density, population density and income level are risk factors for pneumonia in children under five years of age [14]. However, according to Mardani, Pradigdo and Mawarni there are two factors associated with the incidence of pneumonia, namely intrinsic factors and extrinsic factors [15]. Intrinsic factors include age, gender, low birth weight, nutritional status, immunization status, exclusive breastfeeding, and vitamin A. Extrinsic factors include elevation, population density, residential density, temperature, humidity, rainfall, ventilation, lighting, air pollution, fuel type, and family socioeconomic status.

The results of a study Amazihono, Adisanjaya and Wasita showed that toddlers living in dense settlements have a higher risk of pneumonia than toddlers living in uncrowded settlements. This is because microorganisms spread more easily in crowded places, increasing the risk of pneumonia transmission more quickly [16]. Another study also explained that the denser an area is, the greater the potential for disease spread. Population density can affect air circulation in an environment that has the potential for external contamination, which can increase the risk of infection and facilitate disease transmission [17].

The incidence of pneumonia is a very risky disease in vulnerable groups, namely infants and toddlers, so prevention needs to be done as early as possible [18]. According to Mardani, Pradigdo and Mawarni there are two ways to prevent deaths in toddlers from pneumonia. First, vaccination can help prevent infections that develop directly in the toddler's body that cause pneumonia, for example Haemophilus influenzae. Second, immunization can prevent infections that cause pneumonia as a complication of diseases such as measles and pertussis [15]. Immunization that can prevent pneumonia directly is the Pneumococcal Conjugate Vaccine (PCV). However, the PCV vaccine is not yet part of basic immunization for infants in Indonesia. However, there are several immunizations that can indirectly prevent pneumonia, namely DPT, HIB and measles [19].

The impact of pneumonia if not addressed or intervened can affect the stunted growth and development of toddlers and be life-threatening to the point of death in toddlers. For this reason, it is necessary to prevent pneumonia in toddlers by avoiding risk factors that cause pneumonia and implementing pneumonia management guidelines appropriately and quickly as well as increasing immunization, especially DPT, measles, HIB and pneumococcus [12]. Meanwhile, countermeasures that can be taken by the government to reduce pneumonia mortality include improving access to health care facilities for children under five, as well as increasing community participation in early detection and gradual expansion of Pneumococcal Conjugate Vaccine (PCV) immunization [20].

Risk factors for pneumonia incidence in an area can be explained using spatial data analysis. Spatial data analysis is a measurement result that contains information on the location of each pneumonia event and provides the distribution of pneumonia events within a region. Spatial data is data collected from different spatial locations and shows the relationship between data and location. The spatial approach is useful for knowing how a disease spreads, especially infectious diseases that are strongly influenced by the surrounding environment. An area that is close to each other will be at risk of contracting each other compared to areas that are far apart, so data about a disease will be more easily monitored by looking at the geography of an area with cases that occur in an area.

Based on the description of the problems above, considering that the prevalence of pneumonia among children under five years of age in Gowa Regency has increased every year, and that Gowa Regency has a high number of pneumonia cases among children

under five years of age, this study was conducted to determine the spatial analysis risk factors of pneumonia incidence in toddlers Gowa Regency.

2. MATERIAL AND METHODS

2.1. Study Design

The type of research used was analytic observational with an ecological study design. This study was conducted in Gowa Regency from September 31 to October 17, 2024. The population in this study was all cases of pneumonia among under-fives in Gowa Regency in 2021-2023, totaling 1,634 cases. The sample size in this study was all sub-districts in Gowa Regency in 2021-2023, namely 18 sub-districts including Bajeng, West Bajeng, Barombong, Biringbulu, Bontolempangan, Bonto-marannu, Bontonompo, South Bontonompo, Bungaya, Manuju, Pallangga, Parangloe, Parigi, Pattallassang, Somba Opu, Tinggimoncong, Tombolo Pao and Tompobulu. Then the sample selection was carried out using non probability sampling with exhaustive sampling method.

2.2. Data Collection

The data collection process in this study used secondary data obtained from the Gowa Regency Health Office, the Gowa Regency Statistics Agency and the Gowa Regency Social Service which included data on pneumonia incidence, population density, poor population, undernutrition status and incomplete immunization status. The collected data were then processed and analyzed using STATA and QGIS applications, and presented in the form of tables and graphs used to discuss the study.

2.3. Methods of Analyses

2.3.1. Statistical Analysis

Statistical tests are used as a method for analyzing descriptive data and estimating data to draw conclusions from research results. Descriptive research aims to explore health phenomena in the community related to risk factors and effects [21]. The statistical analysis used in this study is the Pearson Product Moment Correlation test which aims to determine the relationship between the dependent variable (pneumonia incidence) and the independent variables (population density, poor population, undernutrition status and incomplete immunization status) using the STATA application. The correlation test is a statistical method used to measure the magnitude of the relationship between two variables. The correlation value ranges from -1 to +1, where the correlation value below 0 to -1 indicates that the relationship between the two variables is a negative relationship, while the correlation value above 0 to +1 means that there is a positive relationship between the two variables, and a correlation value of 0 means that there is no relationship between the two variables [22]. Then if the data is normally distributed, the correlation test used is the Pearson Product Moment Correlation and if the data is not normally distributed, it uses the Spearman Rank Correlation.

2.3.2. Spatial Analysis

The spatial data analysis process was conducted using the QGIS application. The final result was a map of the distribution of pneumonia incidence among under-fives. Spatial analysis was used to determine trends in the distribution of the number of pneumonia cases among children under five years of age with population density, poor population, undernutrition status and incomplete immunization status by subdistrict. Data on the coordinates of pneumonia cases in children under five years of age were first obtained by collecting the complete addresses of pneumonia patients in all Puskesmas in Gowa Regency. The complete address of each patient was then entered into the Global Positioning System (GPS) to obtain the coordinate points. The coordinates of each case were inputted into Microsoft Excel before being analyzed using the QGIS application to map and display regional information based on data obtained from various agencies. Spatial analysis is done by combining two or more maps (overlay) to produce a new map.

3. RESULTS

3.1. Univariate Analysis

The results of the analysis showed that the mean pneumonia incidence, population density, poor population, undernutrition status and incomplete immunization status in Gowa Regency in 2021-2023 were 30.26, 1,016.63, 7,512.31, 97.57 and 732.59, with standard deviations of pneumonia incidence, population density, poor population, undernutrition status and incomplete immunization status of 71.07, 1,380.33, 4,711.41, 97.57 and 621.48. The results of the analysis can be seen in Table **1**.

Table 1: Statistical Distribution of Research Variables

Variables	Mean	SD	Min-Max	95% CI
Pneumonia Incidence	30.26	71.07	0-461	10.86-49.66
Population Density	1,016.63	1,380.33	85-5,697	639.87-1,393.39
Poor Population	7,512.31	4,711.41	1,900-19,426	6,226.35-8,798.28
Undernutrition Status	97.57	89.59	8-388	73.12-122.03
Incomplete Immunization Status	732.59	621.48	243-2,703	562.96-902.22

Source: Secondary Data, 2021-2023.
Note. SD = standard deviation; CI = confidence interval.

Table 2: Normality Test of Research Variables

Variables	Kolmogorov-Smirnov		Shapiro-Wilk	
	Statistic	Sig.	Statistic	Sig.
Population Density	0.117	0.993	0.687	0.000
Poor Population	0.139	0.975	0.837	0.000
Undernutrition Status	0.148	0.939	0.832	0.000
Incomplete Immunization Status	0.018	1.000	0.712	0.000

Source: Secondary Data, 2021-2023.
Note. Sig = significant; at sig < 0.05 data is not normally distributed.

3.2. Bivariate Analysis

The results of the normality test for population density, poor population, undernutrition status and incomplete immunization status in Gowa Regency in 2021-2023 using the Kolmogorov-Smirnov test obtained an average p-value (sig) > 0.05, namely 0.993, 0.975, 0.939 and 1.000. So it can be concluded that all data is normally distributed. Then the correlation test used is the Pearson correlation test. The results of the analysis can be seen in Table **2**.

The correlation test results show that there is a relationship between population density, poor population and incomplete immunization status with the incidence of pneumonia among children under five years old in Gowa Regency in 2021-2023 with p-value (sig) < 0.05, namely 0.000, 0.001 and 0.000. The relationship is moderate and positive (unidirectional), meaning that the higher the population density, poor population and incomplete immunization status, the higher the incidence of pneumonia. Meanwhile, there is no relationship between undernutrition status and the incidence of pneumonia among children under five in Gowa Regency in 2021-2023 with a p-value (sig) > 0.05, namely 0.068. The relationship is weak and positive (unidirectional), meaning that the higher the undernutrition status, the higher the incidence of pneumonia. The results of the analysis can be seen in Table **3**.

Table 3: Pearson Correlation Test of Research Variables with Pneumonia Incidence

Variables	r	p-value
Population Density	0.470	0.000
Poor Population	0.422	0.001
Undernutrition Status	0.250	0.068
Incomplete Immunization Status	0.457	0.000

Source: Secondary Data, 2021-2023.
Note. r = correlation value; it is not unidirectional if r is negative (-).

The graph of the correlation test results of population density, poor population, undernutrition status and incomplete immunization status with the incidence of pneumonia in children under five can be seen in the following Figure **1**:

3.3. Spatial Analysis

3.3.1. Population Density

The results of overlaying population density with the incidence of pneumonia among children under five in Gowa Regency in 2021-2023 show that there are 25 sub-districts with high population density (> 400 people/km^2), 5 sub-districts with medium category (201-400 people/km^2) and 24 sub-districts with low category (< 200 people/km^2). Population density of more than 400 people/km^2 with a high incidence of pneumonia in children under five in 2021-2023 is in

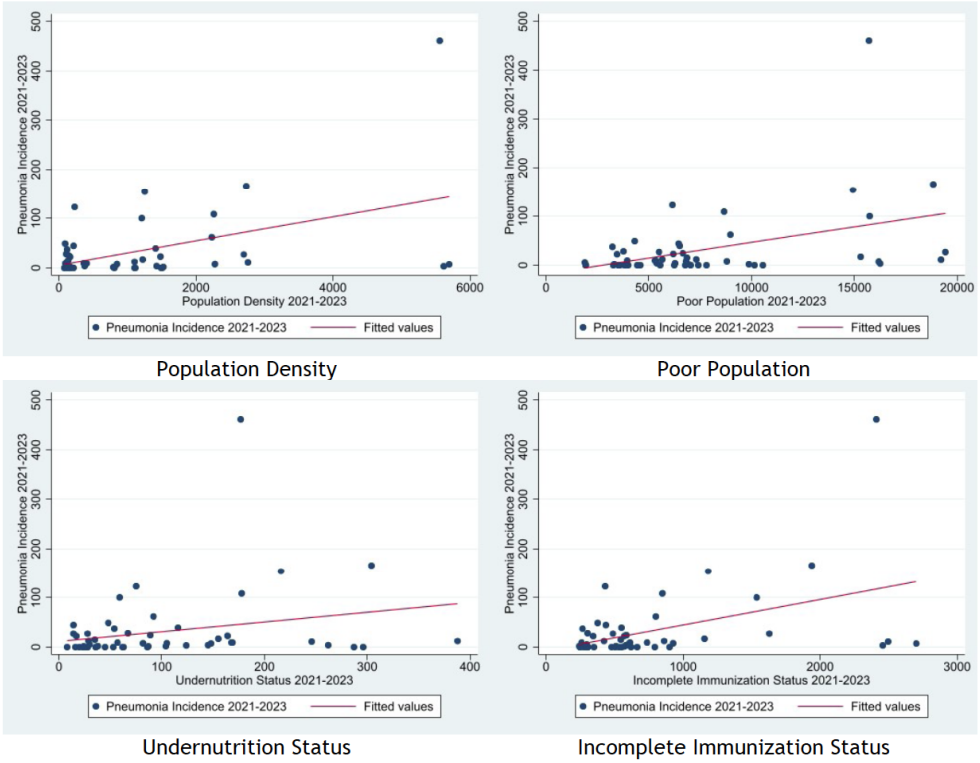

Figure 1: Scatter Plot of Research Variables with Pneumonia Incidence.

Somba Opu sub-district with 471 cases. Meanwhile, population density of less than 200 people/km^2 with a high incidence of pneumonia in children under five years 2021-2023 is found in Parangloe sub-district with 49 cases.

Based on the spatial analysis map between population density and the incidence of pneumonia among under-fives, it was found that Gowa Regency has high and low population density. However, the distribution of pneumonia cases is more prevalent in areas with high population density than low population density. The highest incidence of pneumonia in Gowa Regency was in 2023 with an average population density in the high category (> 400 people/km^2). Meanwhile, the highest population density reached 5,697 people/km^2 in 2022 with 51 pneumonia cases among children under five. Some areas with a high population density also have a high number of poor population. The results of the analysis can be seen in Figure **2**.

3.3.2. Poor Population

The results of overlaying the poor population with the incidence of pneumonia among children under five in Gowa Regency in 2021-2023 show that there are 11 sub-districts with a high category of poor population (> 10,000 people), 25 sub-districts with a medium category (5,001-10,000 people) and 18 sub-districts with a low category (< 5,000 people). The poor population of more than 10,000 with a high incidence of pneumonia in children under five in 2021-2023 is found in Somba Opu sub-district with 471 cases. Meanwhile, the poor population of less than 5,000 with a high incidence of pneumonia in children under five in 2021-2023 is found in Parangloe sub-district with 49 cases.

Based on the spatial analysis map between the poor population and the incidence of pneumonia among under-fives, the average area of Gowa Regency has a moderate poor population. However, the distribution of pneumonia cases is more prevalent in areas with a high poor population than a low poor population. The highest incidence of pneumonia in Gowa Regency was in 2023 with an average poor population in the medium category (5,001-10,000 people). Meanwhile, the highest poor population reached 19,426 people in 2021 with the incidence of pneumonia in children under five years old as many as 323 patients. Some areas that have a low poor population also have a low population density. The results of the analysis can be seen in Figure **3**.

3.3.3. Undernutrition Status

The results of the overlay of undernutrition status with the incidence of pneumonia among children under

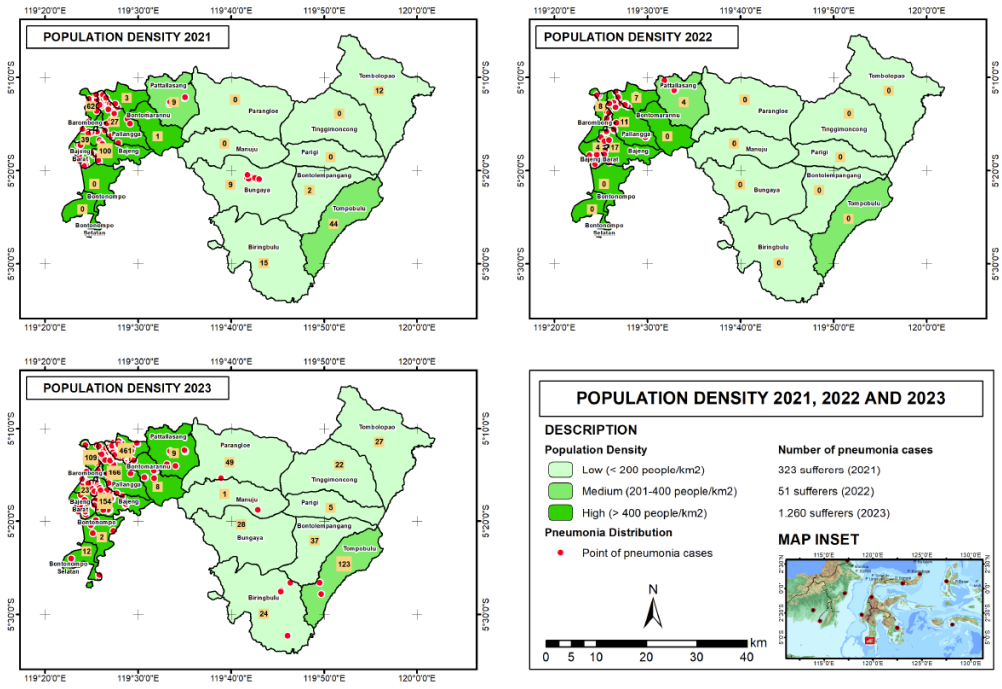

Figure 2: Map of Population Density with Pneumonia Incidence.

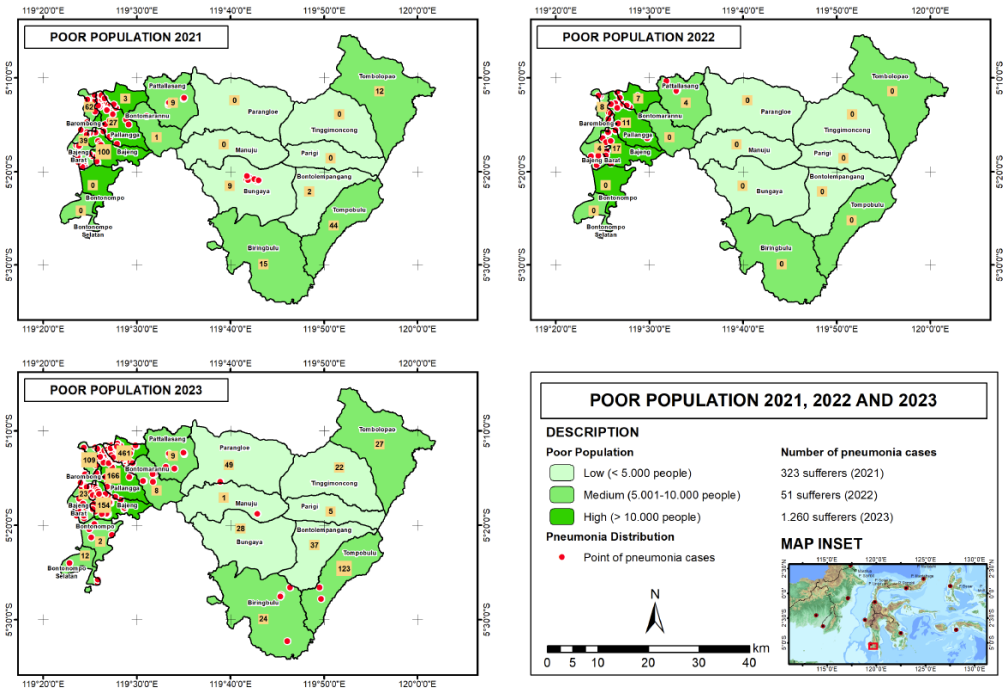

Figure 3: Map of Poor Population with Pneumonia Incidence.

five in Gowa Regency in 2021-2023 show that there are 19 sub-districts with high undernutrition status (> 100 people), 13 sub-districts with medium category (51-100 people) and 22 sub-districts with low category (< 50 people). Undernutrition status of more than 100 people with a high incidence of pneumonia in children under five in 2021-2023 is found in Somba Opu Sub-district with 471 cases. Meanwhile, the undernutrition status of less than 50 people with a high incidence of pneumonia in children under five in 2021-2023 is found in Parangloe sub-district with 49 cases.

Based on the spatial analysis map between undernutrition status and the incidence of pneumonia among under-fives, the average area of Gowa

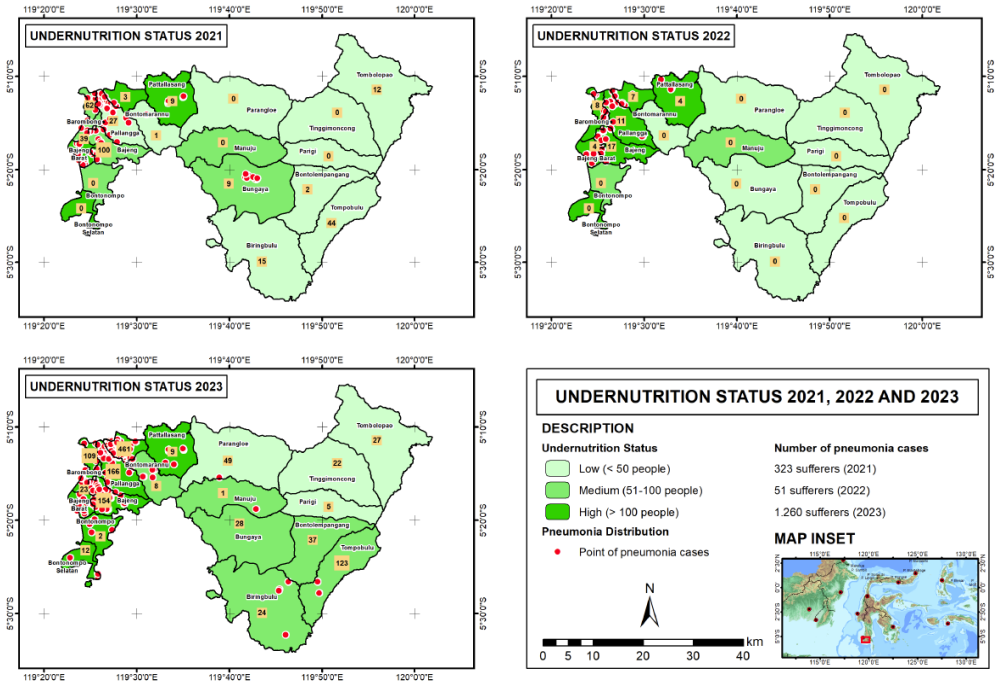

Figure 4: Map of Undernutrition Status with Pneumonia Incidence.

Regency has a low undernutrition status. However, the distribution of pneumonia cases is more prevalent in areas with high undernutrition status than low undernutrition status. The highest incidence of pneumonia in Gowa Regency was in 2023 with the average undernutrition status in the high category (> 100 people). Meanwhile, the highest undernutrition status reached 388 people in 2023 with a pneumonia incidence of 1,260 people under five. The results of the analysis can be seen in Figure **4**.

3.3.4. Incomplete Immunization Status

The results of overlaying incomplete immunization status with the incidence of pneumonia among children under five in Gowa Regency in 2021-2023 show that there are 9 sub-districts with high incomplete immunization status (> 1,000 people), 22 sub-districts with medium category (501-1,000 people) and 23 sub-districts with low category (< 500 people). Incomplete immunization status of more than 1,000 people with a high incidence of pneumonia in toddlers in 2021-2023 is found in Bajeng sub-district with 271 cases. Meanwhile, incomplete immunization status of less than 500 people with a high incidence of pneumonia in children under five in 2021-2023 is found in Somba Opu sub-district with 471 cases.

Based on the spatial analysis map between incomplete immunization status and the incidence of pneumonia among under-fives, the average area of Gowa Regency has a low incomplete immunization status. However, the distribution of pneumonia cases was more prevalent in areas with high incomplete immunization status than low incomplete immunization status. The highest incidence of pneumonia in Gowa Regency was in 2023 with an average incomplete immunization status in the low category (< 500 people). Meanwhile, the highest incomplete immunization status reached 2,703 people in 2022 with 51 pneumonia cases among under-fives. The results of the analysis can be seen in Figure **5**.

4. DISCUSSION

4.1. Population Density

The results of the bivariate analysis between population density and the incidence of pneumonia among under-fives using the Pearson correlation test showed that H0 was rejected and Ha was accepted, meaning that there is a significant relationship between population density and the incidence of pneumonia among under-fives in Gowa Regency in 2021-2023. The correlation value (r) is 0.470, which means that the higher the population density, the higher the incidence of pneumonia. The spatial analysis showed that the highest population density in Gowa Regency with the highest incidence of pneumonia among under-fives in 2021-2023 was in Somba Opu Sub-district with a population density of more than 400 people/km^2.

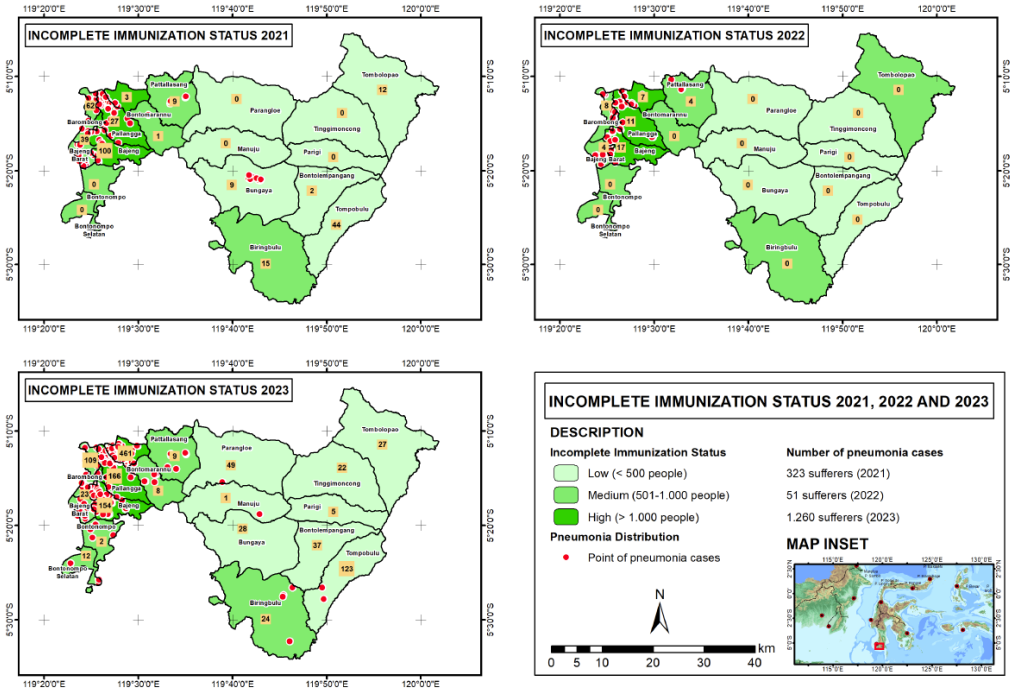

Figure 5: Map of Incomplete Immunization Status with Pneumonia Incidence.

This study is in line with the results conducted by Abdul-Aziz *et al*., that population density contributed to the high incidence of lower respiratory tract infections (LRTIs), including pneumonia among under-fives in Kirkuk City, Iraq [23]. Similarly, a study by Savitri *et al*., found that population density had a significant effect on under-five mortality due to pneumonia in Indonesia [24]. However, this study is not in line with Permatasari *et al*., which showed that population density did not have a significant relationship with the incidence of pneumonia at the Kedungkandang Health Center [25]. Similarly, a study by Juni *et al*., showed that there was no significant relationship between residential density and the incidence of pneumonia at the Banjarmangu Health Center [26].

The denser the population in an area, the greater the potential for the spread of disease in that area. Population density can affect airflow in the surrounding environment and have an impact on increasing the risk and intensity of infections that facilitate disease transmission [27]. Pneumonia is a disease that attacks the respiratory tract where transmission can occur through the air. The population density of an area makes it easier for the disease to spread from one person to another. Thus, densely populated conditions can increase the risk for pneumonia transmission [24].

Transmission of pneumonia through the respiratory tract in toddlers is caused by the growth of bacteria and viruses in a home environment whose physical conditions and occupancy density do not meet the requirements. Ideally, there is a match between the ratio of the area of a house and the total number of residents in a house who live in it. The imbalance between the number of residents and the size of the house makes the criteria for the density of occupancy of a house unqualified. This is one of the risks of pneumonia in children under five, as infants and toddlers are more susceptible to contracting viruses and bacteria that cause pneumonia [28].

High housing density can increase indoor air pollution. In addition, a healthy home requires adequate lighting. Appropriate lighting can help kill disease bacteria. The house as a place of residence must be able to provide a healthy life so that the occupants of the house can have and feel a healthy life both physically, mentally and socially. In urban areas, the fulfillment of healthy homes is difficult to implement. The reason is due to the imbalance of the problem of narrow land, high land prices, expensive building materials with the increasing needs of community housing. Thus growing slums [29].

Human health can be compromised due to air pollution in the home or room because humans spend more time indoors. Home as a microenvironment that has a close relationship with air pollution. The state of health or not the air in the room of the house can be

influenced by various components of the house, building structure, activities in the house and air quality outside the house. The number of occupants in a house also plays an important role in the speed of transmission of microorganisms in the environment [30]. Microbes are the main agents of pneumonia that cause infection. Pneumonia that occurs in the community is mostly caused by gram-positive bacteria, while nosocomial pneumonia is usually caused by gram-negative bacteria and aspiration pneumonia is usually caused by anaerobic bacteria [31].

Based on the results of the study, there are differences between toddlers living in areas with high and low population density. Children living in areas with high population density suffered more pneumonia than children living in areas with low population density. This is because areas with high population density can facilitate the spread of viral bacteria that cause pneumonia through droplets when coughing or sneezing. Houses in densely populated areas are often poorly ventilated, leading to suboptimal air circulation. Densely populated neighborhoods also often have poor drainage and sanitation systems that can increase the risk of infection due to exposure to bacteria and viruses.

4.2. Poor Population

The results of the bivariate analysis between the poor population and the incidence of pneumonia among under-fives using the Pearson correlation test showed that H0 was rejected and Ha was accepted, meaning that there is a significant relationship between the poor population and the incidence of pneumonia among under-fives in Gowa Regency in 2021-2023. The correlation value (r) is 0.422, which means that the higher the poor population, the higher the incidence of pneumonia. Meanwhile, the spatial analysis results show that the highest poor population in Gowa Regency with the highest incidence of pneumonia among children under five in 2021-2023 is in Pallangga Subdistrict with a poor population of more than 10,000 people.

This study is in line with the results conducted by Olatunde *et al*., that high poverty rates contribute to the high mortality rate due to pneumonia among under-fives in Nigeria [32]. Similarly, a study by Savitri *et al*., found that the poor had a significant effect on under-five mortality due to pneumonia in Indonesia [24]. However, this study is not in line with Firmansyah which showed that poverty levels were not significant to the spread of pneumonia cases in East Java Province [33]. Similarly, a study by Rahmawati *et al*., found that there was no significant relationship between socioeconomic factors and the incidence of pneumonia among under-fives in Surakarta [34].

The poor are more susceptible to disease due to various conditions they experience, such as an unhealthy living environment, food consumption that does not meet nutritional standards and low access to medical services. This allows the poor to experience health problems more easily [24]. Toddlers in poor families have a tendency to utilize health services less than toddlers in non-poor families. This may indicate that despite the implementation of the National Health Insurance (JKN) in Indonesia, poverty is still a barrier to accessing health facilities, especially in children [35]. The high cost of obtaining health services makes poor people prefer alternative medicine and low education makes limited knowledge in dealing with a disease [36].

Based on the results of the study, there are differences between toddlers living in areas with high and low poverty. Children living in high-poverty areas suffered more pneumonia than children living in low-poverty areas. This is due to the undernutrition or poor nutrition of toddlers who find it difficult to obtain nutritious food, unhealthy environmental conditions with poor sanitation, as well as narrow residential densities and low air quality. So that efforts are needed to increase awareness and understanding of mothers of toddlers about health, make improvements to environmental sanitation and provide good nutritional intake in toddlers.

4.3. Undernutrition Status

The results of the bivariate analysis between undernutrition status and the incidence of pneumonia among under-fives using the Pearson correlation test showed that H0 was accepted and Ha was rejected, meaning that there was no significant relationship between undernutrition status and the incidence of pneumonia among under-fives in Gowa Regency in 2021-2023. The correlation value (r) is 0.250, which means that the higher the undernutrition status, the higher the incidence of pneumonia. The spatial analysis shows that the highest undernutrition status in Gowa Regency with the highest incidence of pneumonia among under-fives in 2021-2023 is in South Bontonompo Sub-district with an undernutrition status of more than 100 people.

This study is in line with the results conducted by Hudmawan *et al*., that there is no relationship between nutritional status and the incidence of pneumonia in toddlers at the Cilembang Health Center [36]. Similarly, a study by Talarima & Orno found that there was no relationship between the nutritional status of toddlers and the incidence of pneumonia in toddlers at the Benjina Inpatient Health Center [37]. However, this study is not in line with Srivastava *et al*., which showed that undernutrition was the main determinant of the incidence of pneumonia in toddlers in India [38]. Similarly, a study by Sidabutar *et al*., showed that undernutrition is a major risk factor for pneumonia in toddlers in Makassar, Indonesia [39].

Toddlers who suffer from pneumonia have poor nutritional status compared to toddlers who suffer from pneumonia who have normal nutritional status, statistically there is a close relationship between nutritional status and the incidence of pneumonia [40]. In theory, malnourished children are more susceptible to diseases, one of which is pneumonia. Malnutrition is the result of malnutrition that can reduce the body's ability to function in fighting various infectious diseases. Malnutrition is a major contributor to the incidence of pneumonia in under-fives [41]. Lack of nutritional intake makes the body vulnerable to disease, especially in the under-five years [42]. Undernutrition can weaken the immune system and weaken the respiratory muscles so that undernourished toddlers are more susceptible to pneumonia than those with normal nutrition [15].

Undernutrition and poor nutritional status can compromise the immune system. The thymus is one of the primary lymphoid organs. T cells produced by the thymus in toddlers play a role in the body's defense mechanism against foreign bodies. The thymus is very sensitive to malnutrition because it can cause thymic anthropy. So that almost all body mechanisms will deteriorate when malnutrition occurs. Malnutrition caused by lack of protein energy and vitamins A, E and C leads to antioxidant deficiency. Antioxidant deficiency leads to immune suppression which affects T cell mediation and adaptive immune responses. The immune system is incomplete or compressed, causing malnourished toddlers to be easily infected chronically and repeatedly. Infection of toddlers due to malnutrition is due to the effect on the mucosa and the protective function against pathogen invasion changes [43].

Based on the results of the study, there were differences between toddlers living in areas with high and low undernutrition status. Children living in areas with high undernutrition status had more pneumonia than children living in areas with low undernutrition status. This is due to the provision of complementary foods that are not in accordance with the nutritional needs of toddlers, toddlers do not get a balanced nutritious diet and have a history of chronic or congenital diseases in toddlers. So that efforts are needed to increase exclusive breastfeeding for 6 months in toddlers and nutrition education to mothers of toddlers.

4.4. Incomplete Immunization Status

The results of the bivariate analysis between incomplete immunization status and the incidence of pneumonia among under-fives using the Pearson correlation test showed that H0 was rejected and Ha was accepted, meaning that there is a significant relationship between incomplete immunization status and the incidence of pneumonia among under-fives in Gowa Regency in 2021-2023. The correlation value (r) is 0.457, which means that the higher the incomplete immunization status, the higher the incidence of pneumonia. The spatial analysis showed that the highest incomplete immunization status in Gowa Regency with the highest incidence of pneumonia among under-fives in 2021-2023 was in Somba Opu sub-district with an incomplete immunization status of more than 1,000 people.

This study is in line with the results conducted by Sutriana *et al*., that incomplete immunization is a risk factor for pneumonia in toddlers in Indonesia [44]. Similarly, a study by Tesema *et al*., found that the low status of complete basic immunization among under-fives in East Africa was one of the main factors for the high number of pneumonia cases in the country [45]. However, this study is not in line with Sangadji *et al*., which showed that there was no association between immunization status and the incidence of pneumonia among under-fives at the Cibodasari Health Center [46]. Similarly, a study by Lailla *et al*., showed that there was no association between complete basic immunization and the incidence of pneumonia among under-fives at Zainoel Abidin Hospital in Banda Aceh City [19].

High or low immunization status is caused by several factors such as rumors circulating in the community about immunization, knowledge and motivation of parents to bring their children to immunization, the role of health workers in channeling information, and promotive efforts that have an

influence on the immunization status of children under five [19]. The immunization status of children under five in rural areas is influenced by the distance between the house and health services supported by low knowledge, as well as the placement of health workers in the area which will be a motivator for the community which causes low immunization coverage [47]. The mother's level of education can also affect a person's knowledge about child immunization, as well as the husband and mother-in-law, which can then affect their decision to immunize their children [48].

Toddlers with incomplete immunization status are more susceptible to pneumonia because immunization plays an important role in protecting the body from bacteria and viruses that cause pneumonia. Incomplete immunization can make a toddler's body unable to receive protection against pathogens that cause pneumonia, resulting in a weaker immune system to fight infection. Immunizations available to directly prevent pneumonia are DPT (Diphtheria, Pertussis, Tetanus) immunization, HIB (Haemophilus Influenzae Type B) immunization and PCV (Pneumococcal Conjugate Vaccine) immunization [12]. Immunization of toddlers can help protect the body of toddlers from various dangerous diseases that can cause disability or death [49].

Based on the results of the study, there were differences between toddlers living in areas with high and low incomplete immunization status. Children living in areas with high incomplete immunization status suffered more pneumonia than children living in areas with low incomplete immunization status. This is due to the low level of knowledge and awareness of mothers in providing immunization to toddlers. Some mothers of toddlers do not provide immunization because of the side effects after immunization for their toddlers (fever, vomiting and decreased appetite). So that efforts are needed to increase awareness and understanding of mothers of toddlers about immunization, and increase the mobile immunization program to make it easier for the community to immunize.

5. CONCLUSION

Based on the results of research conducted in Gowa Regency with reference to the formulation of problems and research hypotheses, the following conclusions can be drawn:

a. There is a spatial relationship between population density and the incidence of pneumonia among children under five years of age in each subdistrict in Gowa Regency in 2021-2023.

b. There is a relationship between the poor population and the incidence of pneumonia among children under five spatially in each subdistrict in Gowa Regency in 2021-2023.

c. There is no relationship between undernutrition status and the spatial incidence of pneumonia among under-fives in each subdistrict in Gowa Regency in 2021-2023.

d. There is a relationship between incomplete immunization status and the spatial incidence of pneumonia among under-fives in each subdistrict in Gowa Regency in 2021-2023.

ETHICAL APPROVAL

This study has received ethical approval from the Health Research Ethics Committee (KEPK) of the Faculty of Public Health, Hasanuddin University, with approval number 2175/UN4.14.1/TP.01.02/2024 dated September 24, 2024.

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REFERENCES

[1] UNICEF. United Nations International Children's Emergency Fund 2023. A Child Dies of Pneumonia Every 43 Seconds.

[2] WHO. World Health Organization. Pneumonia in Children 2022.

[3] UNICEF. Pneumonia in Children Statistics [Internet]. United Nations International Children's Emergency Fund; 2021 [cited 2021 Dec 11]. Available from: https://data.unicef.org/topic/child-health/pneumonia/

[4] UNICEF. Every Child's Right to Survive: an Agenda to End Pneumonia Deaths. United Nations International Children's Emergency Fund 2020.

[5] Dadonaite B, Roser M. Our World in Data. Pneumonia 2024.

[6] Kemenkes RI. Profil Kesehatan Indonesia 2021. 1st ed. Sibuea F, Hardhana B, Widiantini W, editors. Jakarta: Pusat Data dan Informasi Kementerian Kesehatan Republik Indonesia 2022; pp. 1-538.

[7] Kemenkes RI. Profil Kesehatan Indonesia 2022. 1st ed. Sibuea F, editor. Jakarta: Pusat Data dan Informasi Kementerian Kesehatan Republik Indonesia 2023; pp. 1-550.

[8] Kemenkes RI. Survei Kesehatan Indonesia 2023. 1st ed. Tim BKPK, editor. Jakarta: Kementerian Kesehatan Republik Indonesia 2024; pp. 1-965.

[9] Dinkes Provinsi Sulsel. Laporan Program Pengendalian ISPA Provinsi Sulawesi Selatan Tahun 2022. Tim Program Pengendalian ISPA, editor. Makassar: Dinas Kesehatan Provinsi Sulawesi Selatan 2023; p. 1. https://doi.org/10.26858/pjser.v0i0.38707

[10] Dinkes Kabupaten Gowa. Laporan Data Rutin ISPA Kabupaten Gowa Tahun 2023. Tim Program Pengendalian ISPA, editor. Makassar: Dinas Kesehatan Kabupaten Gowa 2024; p. 1.

[11] WHO. Pneumonia [Internet]. World Health Organization; 2021 [cited 2021 Apr 25]. Available from: https://www.who.int/news-room/fact-sheets/detail/pneumonia

[12] Kemenkes RI. Situasi Pneumonia Balita di Indonesia. Buletin Jendela Epidemiologi 2010; 3: 1-36.

[13] UNICEF. Childhood Pneumonia: Everything you Need to Know [Internet]. United Nations International Children's Emergency Fund; 2020 [cited 2022 Jan 23]. Available from: https://www.unicef.org/stories/childhood-pneumonia-explained

[14] Nuraeni T, Rahmawati A. Pneumonia pada Balita dan Faktor yang Mempengaruhinya: Studi Kasus di Salah Satu Puskesmas di Indramayu. Gema Wiralodra 2019; 10(2): 155-64. https://doi.org/10.31943/gemawiralodra.v10i2.73

[15] Mardani RA, Pradigdo SF, Mawarni A. Faktor Risiko Kejadian Pneumonia pada Anak Usia 12-48 Bulan (Studi di Wilayah Kerja Puskesmas Gombong II Kabupaten Kebumen Tahun 2017). Jurnal Kesehatan Masyarakat 2018; 6(1): 581-90.

[16] Amazihono B, Adisanjaya NN, Wasita RRR. Pemetaan dan Pola Penyebaran Kasus Pneumonia pada Balita Berdasarkan Faktor Resiko Berbasis Sistem Informasi Geografis di Kota Denpasar Tahun 2022. Bali Health Published Journal 2023; 5(2): 59-68. https://doi.org/10.47859/bhpj.v5i2.332

[17] Syani F El, Budiyono, Raharjo M. Hubungan Faktor Risiko Lingkungan Terhadap Kejadian Penyakit Pneumonia Balita dengan Pendekatan Analisis Spasial di Kecamatan Semarang Utara. Jurnal Kesehatan Masyarakat 2015; 3(3): 732-44.

[18] Purimahua SL, Arsin AA, Daud A, Thaha RM, Darmawangsa, Birawida AB. Biomarkers of pneumonia disease in under five children in "grill culture." Gac Sanit [Internet] 2021; 35: S435-7. https://doi.org/10.1016/j.gaceta.2021.10.070

[19] Lailla A, Andayani H, Ismy J, Bakhtiar, Salawati L. Hubungan Imunisasi Dasar Lengkap dengan Kejadian Pneumonia pada Balita di RS Zainoel Abidin Banda Aceh. Jurnal Kedokteran Nanggroe Medika 2020; 3(1): 6-15. https://doi.org/10.29103/averrous.v6i1.2659

[20] Kemenkes RI. Kementerian Kesehatan Republik Indonesia 2020 [cited 2022 Jan 22]. Pneumonia pada Anak Bisa Dicegah dan Diobati. Available from: https://www.kemkes.go.id/article/view/20111500001/pneumonia-pada-anak-bisa-dicegah-dan-diobati.html

[21] Noor NN, Arsin A. Epidemiologi Dasar: Disiplin Ilmu dalam Kesehatan Masyarakat. 1st ed. Rasyid B, Elisafitri R, editors. Makassar: Unhas Press 2022; pp. 1-553.

[22] Machali I. Metode Penelitian Kuantitatif. 3rd ed. Habib AQ, editor. Yogyakarta: Fakultas Ilmu Tarbiyah dan Keguruan Universitas Islam Negeri (UIN) Sunan Kalijaga Yogyakarta 2021; pp. 1-270.

[23] Abdul-Aziz ZM, Ahmed AE, Hasan MD. Epidemiological and Clinical Insights into Pediatric Lower Respiratory Tract Infections in Kirkuk City-Iraq. Pakistan Journal of Life and Social Sciences (PJLSS) 2024; 22(1): 2527-38. https://doi.org/10.57239/PJLSS-2024-22.1.00189

[24] Savitri N, Azizah, Sitorus IMA, Andini NLE, Husna NL. Determinan Jumlah Kematian Balita Akibat Pneumonia di Indonesia Tahun 2019 dengan Pendekatan Generalized Poisson Regression. MEDIAN 2022; 5(1): 40-50.

[25] Permatasari MD, Winarno ME, Tama TD. Faktor Risiko yang Berhubungan dengan Kejadian Pneumonia pada Balita di Wilayah Puskesmas Kedungkandang Tahun 2017-2018. Sport Science and Health 2019; 1(1): 51-8. https://doi.org/10.33854/heme.v1i1.215

[26] Juni M, Nurjazuli, Suhartono. Hubungan Faktor Kualitas Lingkungan Rumah dengan Kejadian Pneumonia pada Bayi di Wilayah Kerja Puskesmas Banjarmangu 1 Kabupaten Banjarnegara. Jurnal Kesehatan Lingkungan Indonesia 2016; 15(1): 6-13. https://doi.org/10.14710/jkli.15.1.6-13

[27] Delfiyanti R, Eryando T. Analisis Spasial Pemetaan Prioritas Penanganan Pneumonia pada Balita di Provinsi Jawa Timur Tahun 2022. Media Publikasi Promosi Kesehatan Indonesia 2024; 7(5): 1226-34. https://doi.org/10.56338/mppki.v7i5.5026

[28] Bahri, Raharjo M, Suhartono. Hubungan Kondisi Fisik Lingkungan Rumah dan Angka Kuman Udara Dengan Kejadian Pneumonia Balita (Studi di Wilayah Kerja Puskesmas Baturraden II Banyumas). Jurnal Kesehatan Lingkungan Indonesia 2022; 21(2): 170-9. https://doi.org/10.14710/jkli.21.2.170-179

[29] Sari DA, Budiyono, Darundiati YH. Hubungan antara Kualitas Udara dalam Ruang dengan Kejadian Pneumonia pada Bayi di Wilayah Kerja Puskesmas Bandarharjo Kota Semarang. Media Kesehatan Masyarakat Indonesia 2019; 18(3): 12-8.

[30] Laliyanto, Nurjazuli N, Suhartono. Faktor-Faktor Lingkungan Rumah Yang Berhubungan Dengan Kejadian Pneumonia Pada Balita : Sebuah Kajian Sistematis. Sanitasi: Jurnal Kesehatan Lingkungan 2022; 15(1): 20-8. https://doi.org/10.29238/sanitasi.v15i1.1288

[31] Rahmawati FN. Hubungan Sanitasi Rumah dan Angka Kuman Udara Kamar Tidur dengan Kasus Pneumonia Balita di Kecamatan Kenjeran Surabaya. Jurnal Kesehatan Lingkungan 2018; 10(3): 306-12. https://doi.org/10.20473/jkl.v10i3.2018.306-312

[32] Olatunde OV, Adewale OS, Thulasiraman P, Daramola OA. Beyond Binary Diagnostics of Pneumonia Detection with Deep Learning. International Journal of Applied Information Systems (IJAIS) 2024; 12(44): 22-8.

[33] Firmansyah MR. Analisis Regresi Non Linear Terhadap Penyebaran Penyakit Pneumonia di Provinsi Jawa Timur. Jurnal Jendela Matematika 2025; 3(1): 1-6. https://doi.org/10.57008/jjm.v3i01.1089

[34] Rahmawati O, Hanim D, Sumardiyono. Hubungan Faktor Sosial Ekonomi dengan Kejadian Pneumonia pada Anak Bawah Lima Tahun di Surakarta. Nexus Kedokteran Komunitas 2014; 3(1): 42-9.

[35] Sari RK, Handayani D. Healthcare Utilization on Indonesian's Children: The Effect of Poverty and Maternal Characteristics. Media Kesehatan Masyarakat Indonesia 2020; 16(3): 305-16. https://doi.org/10.30597/mkmi.v16i3.9709

[36] Hudmawan ZA, Abdurrahmat AS, Annashr NN. Hubungan Antara Faktor Host Dan Environment Dengan Kejadian Pneumonia Pada Balita Di Wilayah Kerja Uptd Puskesmas Cilembang Kota Tasikmalaya. Jurnal Kesehatan Komunitas Indonesia 2023; 19(2): 127-48. https://doi.org/10.37058/jkki.v19i2.8644

[37] Talarima B, Orno S. Penyebab Terjadinya Penyakit Pneumonia Pada Balita di Wilayah Kerja Puskesmas Rawat Inap Benjina Kecamatan Aru Tengah Kabupaten Kepulauan Aru. Moluccas Health Journal 2020; 2(1): 49-58. https://doi.org/10.54639/mhj.v2i1.430

[38] Srivastava AD, Awasthi S, Jauhari S. Prevalence of persistent pneumonia among severe pneumonia and nutritional status as its associated risk factor: A prospective observational study among under-five children. J Family Med Prim Care 2024; 13(5): 1911-6. https://doi.org/10.4103/jfmpc.jfmpc_1480_23

[39] Sidabutar E, Ansariadi, Wahiduddin, Bustan N, Stang, Birawida AB. Analysis of risk factor for pneumonia in children less than five years in Makassar. J Educ Health Promot 2024; 13(16): 1-8. https://doi.org/10.4103/jehp.jehp_727_23

[40] Umar KF, Noor NN, Maria IL, Bustan MN, Abdullah MT, Thaha RM. Risk Factor of Paediatric Community-Acquired Pneumonia in Wajo Regency, Indonesia. National Journal of Community Medicine 2024; 15(2): 98-104. https://doi.org/10.55489/njcm.150220243601

[41] Mustikarani YA, Rahardjo SS, Qadridjati I, Prasetya H. Contextual Effect of Village on the Risk of Pneumonia in Children Under Five in Magetan, East Java. Journal of Epidemiology and Public Health 2019; 4(2): 117-26. https://doi.org/10.26911/jepublichealth.2019.04.02.07

[42] Mokoginta D, Arsin A, Sidik D. Faktor Risiko Kejadian Pnemonia pada Anak Balita di Wilayah Kerja Puskesmas Sudiang Kota Makassar core.ac.uk 2014; 1-12.

[43] Nurnajiah M, Rusdi, Desmawati. Hubungan Status Gizi dengan Derajat Pneumonia pada Balita di RS. Dr. M. Djamil Padang. Jurnal Kesehatan Andalas 2016; 5(1): 250-5. https://doi.org/10.25077/jka.v5i1.478

[44] Sutriana VN, Sitaresmi MN, Wahab A. Risk factors for childhood pneumonia: a case-control study in a high prevalence area in Indonesia. Clin Exp Pediatr 2021; 64(11): 588-95. https://doi.org/10.3345/cep.2020.00339

[45] Tesema GA, Tessema ZT, Tamirat KS, Teshale AB. Complete basic childhood vaccination and associated factors among children aged 12-23 months in East Africa: a multilevel analysis of recent demographic and health surveys. BMC Public Health 2020; 20(1): 1-14. https://doi.org/10.1186/s12889-020-09965-y

[46] Sangadji NW, Okta Vernanda L, Muda CAK, Veronika E. Hubungan Jenis Kelamin, Status Imunisasi, dan Status Gizi Dengan Kejadian Pneumonia Pada Balita (0-59 Bulan) Di Puskesmas Cibodasari 2021. JCA Health Science [Internet] 2022; 2(2): 66-74. Available from: https://jca.esaunggul.ac.id/index.php/jhea/article/view/240

[47] Thaha ILM, Rismayanti, Kasnar H. Faktor yang berhubungan dengan rendahnya cakupan imunisasi hepatitis B-1 pada Bayi 0-7 hari di wilayah kerja Puskesmas Siompu Kabupaten Buton tahun 2009. Jurnal MKMI [Internet] 2010; 6(4): 4-9. Available from: https://media.neliti.com/media/publications/27402-ID-faktor-yang-berhubungan-dengan-rendahnya-cakupan-imunisasi-hepatitis-b-1-pada-ba.pdf

[48] Sugita P, Arsin AA, Maria IL, Ansariadi, Ishak H, Syam A. Effectiveness of Mhealth on Immunization Target Tracking Which Affects Drop Out and Left Out Numbers in Rural and Urban Areas at The Public Health Center Level, Indonesia'. National Journal of Community Medicine 2023; 14(8): 491-8. https://doi.org/10.55489/njcm.140820233143

[49] Kemenkes RI. Profil Kesehatan Indonesia 2019. 1st ed. Hardhana B, Sibuea F, Widiantini W, editors. Jakarta: Pusat Data dan Informasi Kementerian Kesehatan Republik Indonesia 2020; pp. 1-487.

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https://doi.org/10.6000/1929-6029.2025.14.21