Global Pediatric Health
Volume 11: 1–10

DOI: 10.1177/2333794X241227694
journals.sagepub.com/home/gph
Sage

Prediction of Toddlers Acute Respiratory Infection (ARI) to Become Pneumonia in Martapura Catchment Area, Banjar District, Indonesia

Leka Lutpiatina, MSi[1], Lilis Sulistyorini, MKes[2], Ririh Yudhastuti, Prof[2], and Hari Basuki Notobroto, MKes[2]

Abstract

Introduction. The pneumonia pattern in young children may vary across different catchment areas. Therefore, this study aims to analyze the predictive factors for toddlers with an Acute Respiratory Infection (ARI) developing into pneumonia in the catchment area of Banjar Regency, Indonesia. *Methods.* A case-control design, with 300 respondents, consisting of 106 cases and 194 controls. A questionnaire of interviews with mothers/caregivers of toddlers. Forty-one indicators data were analyzed using multiple logistic regression with backward stepwise regression to arrive at the final model. *Results.* The predictive factors for toddlers with pneumonia were the child's age (*P*-value .070), child development (*P*-value .007), breastfeeding (*P*-value .051), family income (*P*-value .026), and location of houses along the river (*P*-value .025). *Conclusion.* A prediction index for toddler pneumonia has been compiled, which can be applied to improve the health of lower middle-class toddlers requiring more government attention.

Keywords

catchment area, house on the banks of the river, low family income, stunted child development, toddler pneumonia

Received February 15, 2023. Received revised December 6, 2023. Accepted for publication January 5, 2024.

Introduction

Acute Respiratory Infection (ARI) is an acute infectious disease that attacks the upper respiratory tract and lower respiratory tract. ARI can cause mild symptoms such as coughing and runny nose, moderate symptoms such as shortness of breath and severe symptoms. ARI is severe if it attacks the lower respiratory tract, affecting lung tissue and can cause pneumonia. Pneumonia diagnosis is made by looking at clinical symptoms, namely the presence of fast breathing which is characterized by a respiratory frequency of 60 times or more/minute (for toddlers <2 months), 50 times or more/minute (for toddlers 2 months-<1 year) 40 times or more/ minutes (for toddlers 1-<5 years), or a strong inward pull on the lower chest wall.[1] Pneumonia is a major cause of morbidity and mortality from infectious diseases globally, leading to 740 180 deaths among children under 5 years old in 2019.[2] Most cases of death from respiratory infections are related to acute lower respiratory tract infections. However, upper respiratory infections, especially in children, are the most prevalent.[3] Acute Respiratory Infection is one of the main causes of consultation or hospitalization in healthcare facilities, especially in child care.[4]

The prevalence of pneumonia among toddlers in Indonesia is 2.1%.[5] In 2020, South Kalimantan recorded 1.8%, while Banjar district had a prevalence of 0.9% with the highest cases of toddler pneumonia deaths in

[1]Medical Laboratory Technology Poltekkes Kemenkes Banjarmasin, Banjarbaru, Indonesia
[2]Campus C Universitas Airlangga, Surabaya, Indonesia

Corresponding Author:
Leka Lutpiatina, Medical Laboratory Technology Poltekkes Kemenkes Banjarmasin, Jalan Mistar Cokrokusumo 4A, Banjarbaru, Indonesia.
Email: leka.lutpiatina-2021@fkm.unair.ac.id

the province.[6] Banjar Regency is a district in the Martapura catchment area,[7] with a height ranging from 0 to 1878 m above sea level. The low altitude causes the flow of rainwater to be less smooth, therefore, some areas are always inundated with water (29.93%) and others are periodically inundated with water (0.58%).[7] Since the catchment area collects, stores, and distributes water from rainfall to the lake or sea naturally,[8] this area has the potential for a high level of humidity and water flow. The characteristics of Banjar Regency located in a catchment area allow a unique pattern of the incidence of ARI pneumonia among children under 5 years old.

The condition of Banjar district that contributes to the ARI risk factors includes a dense population of 572 109 people and an increasing number of poor residents from 15 120 in 2020 to 18 070 in 2021, ranking third in South Kalimantan.[9] As a catchment area, Banjar district has several riverside settlements along the Martaputa river, with high humidity levels. During the day, the strong sun radiation causes evaporation from the river and most houses on the banks of the river use wood materials, which conduct moisture quickly due to their porous nature. This creates a hot and humid living environment along with the direct heat radiation from the sun.[10] Furthermore, residential areas along the river tend to be densely populated and the buildings are uninhabitable, making ISPA a disease that is often found in areas with high density areas with families living at or below the poverty line.[11,12] High population density accelerates the spread of respiratory viruses.[13]

Risk factors that are broadly related to ARI are demographic, socioeconomic, environmental, and nutritional factors.[14] In various countries, the risk factors include the characteristics of the child, mother, and father, exposure to cooking fuel, cigarettes, exclusive breastfeeding, child nutrition, school children, contact with someone who coughs, separate kitchen, number of family members, construction houses, mosquito coils, types of latrines, and sources of drinking water.[11,15-21] Research states that the risk factor for pneumonia in children under 5 is family income, occupancy density, mother's age, child's age, complimentary food, immunization, cooking fuel, living room ventilation, defecation habits, mixed breastfeeding, malnutrition, and parental education.[22-27]

Investigations of risk factors for pneumonia in toddlers have used the case-control method, where toddlers without symptoms of ARI/pneumonia serve as controls.[22] Meanwhile, other studies used cross-sectional methods, this is to ensure that the negative pneumonia group comparison is likely to be healthy toddlers or those with ARI non-pneumonia.[24-27] This makes it necessary to determine the predictors of pneumonia in ARI toddlers by using a control and a group of pneumonia cases. There is limited information on pneumonia in toddlers under 5 years old in the catchment area community. Therefore, this study aims to analyze the predictive factors for toddlers with ARI developing into pneumonia in the catchment area of Banjar Regency. The variable characteristics considered include child characteristics, psychomotor, health, and mother's characteristics, behavior, family's economic status, contact between individuals, house air pollution, sanitation, and physical condition.

Method and Material

This is an observational analytic study using a case-control design, comparing the case group (toddlers with pneumonia) to controls (toddlers with non-pneumonia ARI). It was conducted in the Martapura catchment area, Banjar district, Indonesia, in a unitary river with tributaries of 30 km from the main river. The sample size was 300 respondents, consisting of 106 cases and 194 controls, which were selected using a simple random sampling technique. The primary data were taken retrospectively regarding the risk factors for the occurrence of ARI pneumonia in children under 5 years old, which was taken in November 2022 to January 2023. Written informed consent from respondents was obtained prior to data collection, the data were collected using a questionnaire filled out by enumerators from the results of interviews with mothers/caregivers of toddlers. The toddler development questionnaire has obtained permission to use the questionnaire from the public health center in the research area, while the other questionnaires are instruments designed by the researchers themselves. The questionnaire included general data, child characteristics, psychomotor, health, as well as mother's characteristics, behavior, contact between individuals, family's economic status, house air pollution, sanitation, and physical condition. The physical conditions were measured directly from the respondent's house in form of temperature, humidity, airflow, lighting, and ventilation sizes of the toddler's bedroom. Subsequently, the bedroom and ventilation areas were measured using a measuring meter, lighting using a luxmeter, temperature and humidity were estimated with a thermohygrometer, while the wind speed was measured using an anemometer. In this study, a total of 41 indicators were collected and measured. All questionnaires have gone through content validity and criterion related validity tests.

The case population was selected before that of the control, based on the diagnosis of pneumonia by doctors at the Banjar district health center. Inclusion criteria were toddler patients diagnosed with pneumonia by a doctor at the Banjar district health center. The exclusion

criteria were those who refused or did not participate in part or all of the procedures. The control population was all toddlers who were diagnosed with non-pneumonic ARI. Meanwhile, the exclusion criteria were toddler patients diagnosed with non-pneumonic ARI but developed pneumonia.

The Child Development Pre-screening Questionnaire is used to measure child development indicators. This questionnaire was translated and modified from the Denver Prescreening Developmental Questionnaire by the Indonesian Ministry of Health team. Children's development monitored is language development, cognitive abilities, social-emotional skills and motor skills. The questionnaire is designed for initial examination of babies aged 3 months to children aged 6 years. At each particular age, there are 10 questions about the child's developmental abilities. If the answer ≤6 points is "yes," it means that the child's growth and development is hampered in the variable range of language development, cognitive abilities, social-emotional skills and motor skills.[28] The residential density indicator is evaluated based on: 1 person/4 m^2 (qualify) versus >1 person/4 m^2 (not eligible). House floors are made from: parquet/vinyl/ceramic/ tile/cement/brick and carpet (qualify) versus earth/sand/wood/board/bamboo/fronds (not eligible). House walls are made of: stone with cement/brick/plastered brick (qualify) vs bamboo/logs/boards and soil (not eligible). Room ventilation by area: ≥10% of floor area (qualify) vs <10% of floor area (not eligible). Room lighting: 60-120 lux (qualify) vs <60 lux/>120 lux (not eligible), room temperature: 18-30°C (qualify) versus <18°C/>30°C. Room humidity is evaluated based on: 40% to 70% (qualify) versus <40%/>70% (not eligible).[29]

Data processing was carried out using SPSS version 26. Simple logistic regression was used for inferential analysis to determine the effect of candidate indicators for pneumonia children under 5 years old with a *P*-value < .25. A predictive index model was constructed using multiple logistics regression for the incidence of pneumonia in children under 5 years old with a significance confidence level of 0.1 and backward stepwise regression to arrive at the final model. Receiver Operating Characteristic (ROC) analysis was carried out to determine the cut-off point value based on the obtained ROC curve.

Ethical Approval

This study has received ethical approval from the Research Ethics Committee of the Faculty of Public Health, Airlangga University with certificate number: 140/EA/KEPK/2022. The manuscript received written approval from all authors before starting the study and written informed consent from respondents was obtained prior to data collection.

Results

Table 1 showed that only 13 out of the 41 indicators tested using simple logistic regression had a *P*-value < .25. This revealed that they can be used as candidates for inclusion in the multiple logistic regression test. These indicators were the child's age (*P*-value = .070), child development (*P*-value = .002), breastfeeding (*P*-value = .058), occupancy density (*P*-value = .033), family income (*P*-value = .000), ownership of goods electronics (*P*-value = .032), house electricity capacity (*P*-value = .084), cooking fuel (*P*-value = .200), the distance between the house and main road (*P*-value = .135), toilet facilities (*P*-value = .041), walls the house (*P*-value = .431), the ceiling of the house (*P*-value = .074), the location of the house on the river bank (*P*-value = .032).

The results of the stage 1 multiple logistic regression test were presented in Table 2. It was discovered that indicators of child age have a *P*-value = .112, child development *P*-value = .022, breastfeeding *P*-value = .063, occupancy density *P*-value = .142, family income *P*-value = .003, ownership of electronic goods *P*-value = .900, house electricity capacity *P*-value = .665, cooking fuel *P*-value = .252, the distance between the house and main road *P*-value = .139, toilet facilities *P*-value = .453, walls of the house *P*-value = .643, house ceiling *P*-value = .830, house location on the river bank *P*-value = .147.

Table 3 showed the final results of the multiple logistic regression test, which obtained 5 indicators with *P*-value < .1. This included the child's age with a *P*-value = .076, child development *P*-value = .010, breastfeeding *P*-value = .056, family income *P*-value = .001, and the location of the house along the river has a *P*-value = .037. Based on the results of the double logistic regression test, a prediction index formula for the incidence of ARI pneumonia in toddlers can be prepared, namely the beta coefficient value at constant is added to the beta coefficient value for each prediction variable (Table 3), so that it can be formulated as follows: −1.610 + 0.517 × child's age (12-59 months) + 1.505 × child development (delayed) + 0.628 × breastfeeding (predominance of infant formula) + 1.198 × family income (<wages minimum) + 0.576 × home location in river banks (distance < 15 m from the river banks). The ROC analysis also obtained a sensitivity value of 78.3%, 42.3% specificity, an area under the curve of 0.673 with a significance value of .000, and a cut-off point value of −0.7275.

Table 1. Indicators of Risk Factors for Toddlers With Pneumonia.

No.	Indicators	*P*-value
1	Child age	.070*
2	Child gender	.754
3	Order of birth of children	.553
4	Child development	.002*
5	Motor activity	.807
6	Breastfeeding	.058*
7	Intake of vitamin A	.500
8	Nutritional status	.278
9	Basic immunization	.325
10	Mother's age	.464
11	Mother's job	.653
12	Mother's education	.618
13	Mother's knowledge	.882
14	Mother's attitude	.899
15	Mother's actions	.896
16	Occupancy density	.033*
17	History of close contact with sufferers of ARI before	.437
18	Family history of respiratory tract disease	.304
19	Family income	.000*
20	Home ownership status	.854
21	Ownership of electronic goods	.032*
22	House electricity capacity	.084*
23	Cooking fuel	.200*
24	Family members smoke in the house	.717
25	Use of mosquito coils/electric	.764
26	The distance between the house and the road	.135*
27	Smoke burning garbage/household industry	.714
28	Clean water source	.488
29	Toilet facilities	.041*
30	Waste water disposal facilities	.646
31	Waste disposal	.967
32	House floor	.431
33	House wall	.070*
34	Roof	.692
35	House ceiling	.024*
36	Ventilation	.875
37	Temperature	.459
38	Humidity	.803
39	Lighting	.599
40	Airflow	.862
41	Location of the house from the river bank	.032*

*P-value $<$ .25, can be used as a candidate for inclusion in the multiple logistic regression test.

Discussion

Based on Table 1, only 13 out of the 41 indicators used met the requirements as candidates. The indicators were selected according to the conditions of the respondents in the Banjar district catchment area. Previous studies have produced different risk factors for the incidence of toddler pneumonia, such as maternal age by Cardoso et al[22] and immunization with house ventilation by Kasundriya et al.[25] However, these indicators were not found to be significant risk factors According to Rodriguez,[30] the risk factors for childhood infection are unique in each region due to individual demographic and socioeconomic patterns.[30]

In this study, ownership of electronic goods, home electricity capacity, cooking fuel, distance from the

Table 2. Results of the Multiple Logistic Regression Test Stage 1 of the Risk Factors for Pneumonia Children Under 5 Years Old.

Prediction indicators	ARI not Pneumonia		Pneumonia		Total		OR (95%CI)	*P*-value	β
	n	%	n	%	n	%			
Child age									
<12 months	65	33.5	25	23.6	90	30.0	References	.112	.476
12-59 months	129	66.5	81	76.4	210	70.0	1.610 (0.894-2.899)		
Amount	194	100	106	100	300	100			
Child development									
Well developed	189	97.4	94	88.7	283	94.3	References	.022	1.383
Stunted	5	2.6	12	11.3	17	5.7	3.986 (1.225-12.975)		
Amount	194	100	106	100	300	100			
Breastfeeding									
Breastfeeding dominance	164	84.5	80	75.5	244	81.3	References	.063	.625
Infant formula dominance	30	15.5	26	24.5	56	18.7	1.868 (0.966-3.610)		
Amount	194	100	106	100	300	100			
Occupancy density									
Qualify	45	23.2	14	13.2	59	19.7	References	.142	.523
Not eligible	149	76.8	92	86.8	241	80.3	1.688 (0.840-3.392)		
Amount	194	100	106	100	300	100			
Family income*									
>Wages minimum	61	31.4	12	11.3	73	24.3	References	.003	1.104
<Wages minimum	133	68.6	94	88.7	227	75.7	3.015 (1.445-6.290)		
Amount	194	100	106	100	300	100			
Ownership of electronic goods									
Has a fridge/washing machine	134	69.1	60	56.6	194	64.7	References	.900	.037
Have TV/radio/none	60	30.9	46	43.4	106	35.3	1.037 (0.586-1.836)		
Amount	194	100	106	100	300	100			
Household electricity capacity									
Electrical power900 watts/more	97	50.0	42	39.6	139	46.3	References	.665	.121
There is no electricity/electricity from neighbors/450 W	97	50.0	64	60.4	161	53.7	1.129 (0.652-1.955)		
Amount	194	100	106	100	300	100			
Cooking fuel									
Electricity/LPG/kerosene	182	93.8	95	89.6	277	92.3	References	.252	.552
Wood/twigs/straw	12	6.2	11	10.4	23	7.7	1.737 (0.675-4.467)		
Amount	194	100	106	100	300	100			
The distance of the house from the road									
>100 m	118	60.8	55	51.9	173	57.7	References	.139	.396
<100 m	76	39.2	51	48.1	127	42.3	1.485 (0.880-2.508)		
Amount	194	100	106	100		100			
Toilet facilities									
Private toilet	174	89.7	86	81.1	260	86.7	References	.453	.292
Public toilet	20	10.3	20	18.9	40	13.3	1.338 (0.625-2.868)		
Amount	194	100	106	100	300	100			
House wall									
Qualify	65	33.5	28	26.4	93	31.0	References	.643	.149
Not eligible	129	66.5	78	73.6	207	69.0	1.160 (0.619-2.175)		
Amount	194	100	106	100	300	100			
House ceiling									
There is a ceiling	116	59.8	52	49.1	168	56.0	References	.830	.063
No ceiling	78	40.2	54	50.9	132	44.0	1.065 (0.0602-1.882)		
Amount	194	100	106	100	300	100			

(continued)

Table 2. (continued)

Prediction indicators	ARI not Pneumonia n	%	Pneumonia n	%	Total n	%	OR (95%CI)	*P*-value	β
Location of the house from the river bank									
Distance >15 m from the river bank	144	74.2	66	62.3	210	70.0	references	.147	.436
Distance <15 m from the river bank	50	25.8	40	37.7	90	30.0	1.547 (0.858-2.791)		
Amount	194	100	106	100	300	100			
Constant							0.047	.000	−3.066

*Family income with regional minimum wage = 2 906 473 rupiah.

Table 3. Final Results of the Multiple Logistic Regression Test on the Risk Factors for Pneumonia in Children Under 5 Years Old.

Prediction indicators	OR (95%CI)	*P*-value	Beta coefficient (β)*
Child age (12-59 months)	1.678 (0.948-2.970)	.076	0.517
Child development (stunted)	4.503 (1.435-14.135)	.010	1.505
Breastfeeding (predominance of infant formula)	1.874 (0.985-3.567)	.056	0.628
Family income (<wages minimum)	3.313 (1.664-6.594)	.001	1.198
Location of the house on the river bank (distance <15 m from the river bank)	1.779 (1.034-3.059)	.037	0.576
Constant	0.098	.000	−1.610

*The beta coefficient value is used to compile the prediction index formula.

house to the main road, toilet facilities, house walls, and house ceilings are indicators that are included in the candidate risk factors for pneumonia children under 5 years old. Although these 8 indicators were not included in the final model, they were in the pneumonia ARI group with the highest percentage in the category that supports the incidence of pneumonia (category 2) compared to the non-pneumonia ARI group, as presented in Table 2. According to some literature, these indicators have been linked to increased risk factors for the incidence of ARI in children under 5 years old. These included the possession of valuable (electronic) items is an indicator of the family's economic level,[31] the use of electricity has an impact on children's ARI,[32] cooking fuel,[33] distance from the house to the main road,[34] toilet facilities,[35] house walls, and roof of the house.[36]

The results in the final model showed that the child's age, child development, breastfeeding, family income, and the location of the house on the banks of the river were predictive indicators for toddlers with ARI pneumonia in the catchment area, as presented in Table 3. The pneumonia predictive index formula can be used to predict ARI in toddlers that may develop into pneumonia. Indicators for children aged 12 to 59 months have a beta coefficient of 0.517, *P*-value .076, OR (95%Cl) 1.678 (0.948-2.970). This indicated that children aged 12 to 59 months have the possibility of pneumonia 1.684 times compared to children aged <1 year. Acharya et al[21] and Sulistyorini et al[37] stated that ARI symptoms appear most frequently in children aged 1 to 2 years.[21,37] However, Dagne et al[34] reported that children under 1 year have higher ARI. According to Harerimana et al,[23] children aged 24 to 59 months compared to 0 to 11 months were associated with a lower risk of developing pneumonia, namely 0.53 times (OR: 0.53, 95% CI: 0.40-0.69). Abebaw and Damtie[26] showed that toddler pneumonia was highest in children under 1 year of age with a proportion of 33.6%. Children under 1 year are less likely to be at risk of infection because they are more protected from air pollution, as parents generally place them in a room safe from pollution.[38] Breastfeeding also supplies babies with immunoglobulin, which protects them from ARI.[39]

The development of stunted children had a beta coefficient of 1.505, *P*-value .010, OR (95% Cl) 4.503 (1.435-14.135). This indicated that stunted children had 4.709 times the possibility of pneumonia 4 compared to those with normal development. Ramani et al[40] also discovered that child development at a rate of 34.82% was a significant risk factor for developing ARI in children under 5 years old. Child development can be related to nutrient intakes such as protein, energy, certain fats,

iron, zinc, copper, iodine, selenium, vitamin A, choline, and folate, which have a significant influence on brain, cognitive, and social-emotional development.[41,42] Malnutrition in childhood can affect the function of the Central Nervous System (CNS) and the Structural development of the CNS[41] as well as neurotransmitter systems.[42] In this study, it was discovered that the risk factors for nutritional status were only not related to pneumonia in children under 5 years old but also included child development, as illustrated in Tables 1 and 3, respectively. This was due to the influence of nutritional factors and other conditions of the development of children. According to Walker et al,[43] child development is influenced by the development and function of the central nervous system, as well as psychosocial risk factors and biological factors. Psychosocial and biological factors can involve parenting patterns, maternal depression, and an unhealthy environment.[43] Therefore, the interaction between these factors can lead to stunted child development and significantly affect the incidence of toddler pneumonia.

Breastfeeding (predominance of infant formula) had a beta coefficient of 0.628, a *P*-value of .056, OR (95% Cl) 1.874 (0.985-3.567). Children who are given infant formula have the possibility of pneumonia 1.877 times compared to those given breast milk. In line with Abebaw and Damtie[26] who stated that children who were given mixed breast milk were associated with a 5.229 times higher risk of developing pneumonia (AOR 5.229; *P* .001). Fakih et al[27] reported that the duration of breastfeeding had a significant effect on the incidence of toddler pneumonia. Other studies showed that children who are not exclusively breastfed had the possibility of developing ARI (OR = 2.18; CI 0.96-4.97 *P* = .06).[44] This is because breastfeeding plays a very significant role in protection against infection. The main nutrients needed for an efficient immune response include vitamins A and Fe, which are present in breast milk.[45] Breast milk is the best nutrition for babies as it contains the microbiota and biologically active components that aid mucosal immune system. The mother's gut bacteria can also be transferred to the baby through breast milk, which protects against several respiratory and diarrheal diseases.[46]

Family income below the minimum wages had a beta coefficient of 1.198, *P*-value 0.001, OR (95% Cl) 3.313 (1.664-6.594). This indicated that children in families with income below the minimum wage (<2 906 473 rupiah) had 1.989 times the likelihood of pneumonia compared to those with higher income. Another study stated that children with a monthly income of less than 1000 Ethiopian Birr (<19.03 USD) (27.8%)[26] had a potential for pneumonia. Low and stable monthly per capita household income (<US$30.00 = OR: 2.77, 95% CI: 1.51-5.10; no income = OR: 1.88, IC95%: 1.02-3.47) was associated with a higher risk of developing pneumonia (Cardoso et al.[22] It was also reported that family income affected the susceptibility to infection and transmission of ARI among toddlers.[44] Generally, income determines the strength of resources over some time. This showed that families with high incomes are more likely to have the means to pay for health care and afford better nutrition, such as fresh fruit and vegetables of more quality and variety, as well as choosing homes, schools, and recreation.[47]

The location of the house on the banks of the river had a beta coefficient of 0.576, *P*-value .037, OR (95% Cl) 1.779 (1.034-3.059). This showed that children with a house location <15 m from the riverbank with high humidity had 1.846 times the likelihood of pneumonia compared to those with >15 m from the riverbank. The strong sun radiation during the day causes evaporation from the river and most of the houses on the river banks use wood materials, which quickly become moisture conductors.[10] Humidity is an environmental factor that can influence transmission by supporting the survival and persistence of respiratory viruses in droplets or fomites.[48,49] Other studies also showed that the temperature and humidity of the area around rivers in China correlated with the distance of the river. It was discovered that with increasing distance, the temperature gradually increases but the humidity decreases significantly.[50] The width of urban rivers is the main factor affecting temperature and humidity in the nearest area.[51] Riverside areas with a distance of <15 m will have a high level of humidity compared to those farther away. Therefore, this study proves that houses along river banks are associated with a higher risk of developing pneumonia in toddlers.

Besides potential flooding and landslides, the Indonesian government has stipulated regulations prohibiting the construction of buildings on riverbanks in Article 157 of the 2011 State Gazette Law and Supplement to State Gazette Number 1 concerning Housing and Settlements. This prohibitions construction in the area that may cause environmental damage. This is supported by Government Regulation Number 35 of 1991 concerning Rivers in Article 7 paragraph (2) and Law Number 32 of 2009 on Environmental Protection and Management in Article 69 paragraph (1) letter a, prohibiting any activity in rivers that can harm the environment.

The discovery of the pneumonia predictive index in this study can help health workers to screen toddlers with ARI against the possibility of developing pneumonia. The sensitivity value is 78.3%, the specificity value

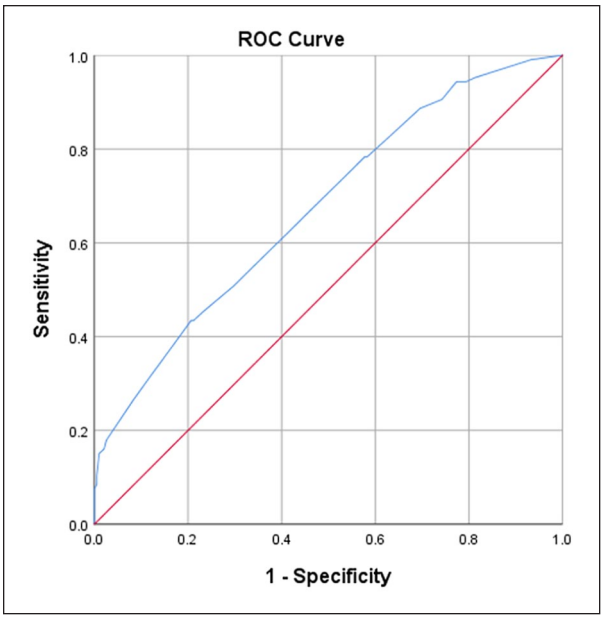

Figure 1. ROC curve of the risk factors for toddler pneumonia.

is 42.3% as shown in Figure 1. This shows that the prediction index can predict toddlers who really have pneumonia among the sick population, which is 78.3%. The limitations of this study include the retroactive nature of the interview data collected from mothers/caregivers of toddlers, which can lead to subjectivity in the respondents' answers. The physical conditions of the house, namely temperature, humidity, lighting, and airflow were measured once at the time of observation of the respondent's house. Meanwhile, the strength of this study is the predictions for toddlers with ARI developing pneumonia in catchment area settlements. The results also showed that 75.7% of the community belonged to the lower middle class with a monthly family income below the minimum wage, as shown in Table 2. Therefore, these results are relevant and valuable in improving the health of lower middle class communities which require more attention from the government in terms of improving toddler nutrition and improving sanitation facilities such as toilet facilities.

Conclusion

The predictive factors for children with ARI developing into pneumonia in the catchment area are the child's age, child development, breastfeeding, family income, and the location of the house on the riverbank. The predictive index formula for toddler pneumonia is expressed as $-1.610 + 0.517 \times$ child's age (12-59 months) $+ 1.505 \times$ child development (delayed) $+ 0.628 \times$ breastfeeding (predominance of infant formula) $+ 1.198 \times$ family income ($<$wages minimum) $+ 0.576 \times$ home location in river banks (distance <15 m from the river banks). This prediction model can be applied to improve the health of toddlers in the lower middle class, who require more attention from the government.

Acknowledgments

The authors are grateful to promoters, co-promoters, examiner lecturers, all lecturers of the Airlangga University public health study program, enumerators, health workers at the Banjar district health center, and the academic community of the Poltekkes of the Ministry of Health of Banjarmasin for supporting the success of this study.

Author Contributions

LL: contributed to conception and design, contributed to analysis, drafted the manuscript. LS: contributed to conception and design, critically revised the manuscript. RY: critically revised the manuscript. HBN: contributed to analysis, critically revised the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Study obtains National Competitive Research Program Funding (Doctoral Dissertation Research) from the Indonesian Directorate General of Higher Education, Research and Technology.

ORCID iD

Leka Lutpiatina https://orcid.org/0000-0003-3349-4978

Supplemental Material

Supplemental material for this article is available online.

References

1. Ministry of Health of the Republic of Indonesia. *Pedoman pengendalian infeksi saluran pernapasan akut*, Jakarta: Kementerian Kesehatan RI. 2011. Accessed February 6, 2023. https://galihendradita.files.wordpress.com/2019/11/pedoman-pengendalian-ispa-2011.pdf
2. WHO. *Pneumonia*. World Health Organization. 2021. Accessed February 6, 2023. https://www.who.int/news-room/fact-sheets/detail/pneumonia
3. Bhuyan GS, Hossain MA, Sarker SK, et al. Bacterial and viral pathogen spectra of acute respiratory infections in under-5 children in hospital settings in Dhaka city. *PLoS One*. 2017;12(3):1-21. doi:10.1371/journal.pone.0174488

4. Berman S. Epidemiology of acute respiratory infections in children of developing countries. *Rev Infect Dis*. 1991;13:S454-S462.
5. Riskesdas. *Laporan Nasional Riset Kesehatan Dasar 2018*, Badan Penelitian dan Pengembangan Kesehatan Kementerian Kesehatan RI, Jakarta. 2018. Accessed February 13, 2023. https://repository.badankebijakan.kemkes.go.id/id/eprint/3514/
6. Dinas Kesehatan Provinsi Kalsel. Profil Kesehatan Provinsi Kalimantan Selatan 2020. Dinkes Kalsel. 2021. Accessed February 13, 2023. http://dinkes.kalselprov.go.id/profil-kesehatan-tahun-2020.html
7. Sobatnu F, Irawan FA, Salim A. Identifikasi dan pemetaan morfometri daerah aliran sungai Martapura menggunakan teknologi GIS. *J Gradasi Tek Sipil*. 2017;1(2):45-52.
8. Peraturan Pemerintah No. 37 Tahun. tentang Pengelolaan Daerah Aliran Sungai. 2012. Accessed February 13, 2023. https://peraturan.bpk.go.id/Home/Details/5249
9. Badan Pusat Statistik Kabupaten Banjar. *Kabupaten Banjar dalam Angka Banjar Regency in Figures 2022*. Karya Bintang Musim. 2022. Accessed February 13, 2023. https://banjarkab.bps.go.id/publication/2022/02/25/50ca2371e0ba72816c6c1c84/kabupaten-banjar-dalam-angka-2022.html
10. Toding J, Kindangen J, Sangkertadi. Kenyamanan termal rumah tepi sungai, studi kasus rumah tepi sungai kahayan, palangka raya, indonesia. *Radial J Peradaban Sains Rekayasa dan Teknologi*. 2015;3(2):103-111. doi:10.37971/radial.v3i2.72
11. Adesanya O, Chiao C. Environmental risks associated with symptoms of acute respiratory infection among preschool children in North-Western and south-Southern Nigeria Communities. *Int J Environ Res Public Health*. 2017;14(11):1396-1410. doi:10.3390/ijerph14111396
12. Kolawole O, Oguntoye M, Dam T, Chunara R. Etiology of respiratory tract infections in the community and clinic in Ilorin, Nigeria. *BMC Res Notes*. 2017;10(1):712. doi:10.1186/s13104-017-3063-1
13. Rocklöv J, Sjödin H. High population densities catalyse the spread of COVID-19. *J Travel Med*. 2020;27(3):1-3. doi:10.1093/jtm/taaa038
14. Bhat RY, Manjunath N. Correlates of acute lower respiratory tract infections in children under 5 years of age in India. *Int J Tuberc Lung Dis*. 2013;17(3):418-422. doi:10.5588/ijtld.12.0117
15. Tazinya AA, Halle-Ekane GE, Mbuagbaw LT, et al. Risk factors for acute respiratory infections in children under five years attending the Bamenda Regional Hospital in Cameroon. *BMC Pulm Med*. 2018;18(1):7-8. doi:10.1186/s12890-018-0579-7
16. Addisu A, Getahun T, Deti M, Negesse Y, Mekonnen B. Association of acute respiratory infections with indoor air pollution from biomass fuel exposure among under-five children in Jimma Town, southwestern Ethiopia. *J Environ Public Health*. 2021;2021:7112548-7112549. doi:10.1155/2021/7112548
17. Fathmawati F, Rauf S, Indraswari BW. Factors related with the incidence of acute respiratory infections in toddlers in Sleman, Yogyakarta, Indonesia: evidence from the Sleman Health and Demographic Surveillance System. *PLoS One*. 2021;16(9):e0257881. doi:10.1371/journal.pone.0257881
18. Mulambya NL, Nanzaluka FH, Sinyangwe NN, Makasa M. Trends and factors associated with acute respiratory infection among under five children in Zambia: evidence from Zambia's demographic and health surveys (1996-2014). *Pan Afr Med J*. 2020;36(197):197.
19. Akinyemi JO, Morakinyo OM. Household environment and symptoms of childhood acute respiratory tract infections in Nigeria, 2003-2013: a decade of progress and stagnation. *BMC Infect Dis*. 2018;18(1):296-312. doi:10.1186/s12879-018-3207-5
20. Rana J, Uddin J, Peltier R, Oulhote Y. Associations between indoor air pollution and acute respiratory infections among under-five children in Afghanistan: do SES and sex matter? *Int J Environ Res Public Health*. 2019;16:1-13.
21. Acharya P, Mishra SR, Berg-Beckhoff G. Solid fuel in kitchen and acute respiratory tract infection among under five children: evidence from Nepal demographic and health survey 2011. *J Comm Heal*. 2015;40(3):515-521.
22. Cardoso AM, Coimbra CEA, Werneck GL. Risk factors for hospital admission due to acute lower respiratory tract infection in Guarani indigenous children in southern Brazil: a population-based case-control study. *Trop Med Int Health*. 2013;18(5):596-607.
23. Harerimana J-M, Nyirazinyoye L, Thomson DR, Ntaganira J. Social, economic and environmental risk factors for acute lower respiratory infections among children under five years of age in Rwanda. *Arch Public Health*. 2016;74(1):1-7. doi:10.1186/s13690-016-0132-1
24. Nirmolia N, Mahanta TG, Boruah M, et al. Prevalence and risk factors of pneumonia in under five children living in slums of Dibrugarh town. *Clin Epidemiol Glob Health*. 2018;6(1):1-4. doi:10.1016/j.cegh.2017.07.004
25. Kasundriya SK, Dhaneria M, Mathur A, Pathak A. Incidence and risk factors for severe pneumonia in children hospitalized with pneumonia in Ujjain, India. *Int J Environ Res Public Health*. 2020;17(13):1-16. doi:10.3390/ijerph17134637
26. Abebaw B, Damtie D. Pneumonia prevalence and associated risk factors among under-five children in Goncha Siso Enesie District, Northwest Ethiopia. *Adv Public Health*. 2022;2022:1-8. doi:10.1155/2022/6497895
27. Fakih A, Okafor C, Yusuf S, et al. Evaluation of risk factors of pneumonia in children under five years old at Mnazi Mmoja Hospital-Zanzibar. *Bull Environ Pharmacol Life Sci*. 2021;10:69-75.
28. Soedjatmiko S. Deteksi Dini Gangguan Tumbuh Kembang Balita. *Sari Pediatri*. 2016;3(3):175-188.
29. Keputusan Menteri Kesehatan Nomor 829 Tahun. tentang Persyaratan Kesehatan Perumahan. 1999. Accessed February 13, 2023. https://vdocuments.site/kepmenkes-ri-no-829-tahun-1999-persyaratan-kesehatan-perumahan.html?page=1
30. Rodriguez M. Covariates of acute respiratory infection in children under-five: the 2013 Philippine National

Demographic and Health Survey. *Up Los Baños Journal*. 2018;16:80-92.
31. Imas Joan A, Yulianto F, Lissa H, Felicia J, Rahmadhani P. Hubungan status sosial Ekonomi Orang Tua terhadap self-esteem Anak Usia 5-6 Tahun. *Indones J Educ Learn*. 2019;2(2):255.
32. Barron M, Torero M. Household electrification and indoor air pollution. *J Environ Econ Manag*. 2017;86:81-92.
33. Nsoh M, Mankollo BOY, Ebongue M, et al. Acute respiratory infection related to air pollution in Bamenda, North West Region of Cameroon. *Pan Afr Med J*. 2019;32(99):99.
34. Dagne H, Andualem Z, Dagnew B, Taddese AA. Acute respiratory infection and its associated factors among children underfive years attending pediatrics ward at University of Gondar Comprehensive Specialized Hospital, Northwest Ethiopia: institution-based cross-sectional study. *BMC Pediatr*. 2020;20(1):1-7.
35. Johnson D, Lynch R, Marshall C, Mead K, Hirst D. Aerosol generation by modern flush toilets. *Aerosol Sci Technol*. 2013;47:1047-1057.
36. Sunarsih E, Purba I. Risk factor analysis of acute respiratory infection on children under five years old in Tanjung Pering Village Ogan Ilir. *J Sci Basic Appl Res*. 2015;22(1):21-30.
37. Sulistyorini L, Li C-Y, Lutpiatina L, Utama RD, Nurlailah. Gendered impact of age, toilet facilities, and cooking fuels on the occurrence of acute respiratory infections in toddlers in Indonesia and the Philippines. *Int J Environ Res Public Health*. 2022;19(21):1-17. doi:10.3390/ijerph 192114582
38. Lutpiatina L, Sulistyorini L, Notobroto HB, et al. Multilevel analysis of lifestyle and household environment for toddlers with symptoms of acute respiratory infection (ARI) in Indonesia in 2007, 2012 and 2017. *Glob Pediatr Health*. 2022;9:2333794X221078700-2333794X221078713.
39. Ujunwa F, Ezeonu C. Risk factors for acute respiratory tract infections in under-five children in Enugu Southeast Nigeria. *Ann Med Health Sci Res*. 2014;4(1):95-99.
40. Ramani VK, Pattankar J, Puttahonnappa SK. Acute respiratory infections among under-five age group children at urban slums of Gulbarga City: a longitudinal study. *J Clin Diagn Res*. 2016;10(5):LC08-LC13. doi:10.7860/JCDR/2016/15509.7779
41. Georgieff MK. Nutrition and the developing brain: nutrient priorities and measurement. *Am J Clin Nutr*. 2007;85(2):614S-620S.
42. Beard JL, Connor JR. Iron status and neural functioning. *Annu Rev Nutr*. 2003;23:41-58.
43. Walker SP, Wachs TD, Gardner JM, et al. International Child Development Steering Group. Child development: risk factors for adverse outcomes in developing countries. *Lancet*. 2007;369(9556):145-157.
44. Shibata T, Wilson J, Watson L, et al. Childhood acute respiratory infections and household environment in an eastern Indonesian urban setting. *Int J Environ Res Public Health*. 2014;11(12):12190-12203. doi:10.3390/ijerph111212190
45. Calder PC, Jackson AA. Undernutrition, infection and immune function. *Nutr Res Rev*. 2000;13:3-29.
46. Le Doare K, Holder B, Bassett A, Pannaraj PS. Mother's milk: a purposeful contribution to the development of the infant microbiota and immunity. *Front Immunol*. 2018;9:361. doi:10.3389/fimmu.2018.00361
47. Shavers VL. Measurement of socioeconomic status in health disparities research. *J Natl Med Assoc*. 2007;99(9):1013-1023.
48. Pica N, Bouvier NM. Environmental factors affecting the transmission of respiratory viruses. *Curr Opin Virol*. 2012;2:90-95.
49. Weber TP, Stilianakis NI. Inactivation of influenza A viruses in the environment and modes of transmission: a critical review. *J Infect*. 2008;57:361-373.
50. Liu GC, Huang Y, Gao SQ. The influence of Lanzhou reach of Yellow River to temperature-humidity effect on surrounding lawn and brick underlying surface. *Adv Mater Res*. 2014;989-994:1236-1239. doi:10.4028/www.scientific.net/AMR.989-994.1236
51. Ji P, Zhu CY, Li SH. [Effects of urban river width on the temperature and humidity of nearby green belts in summer]. *Ying Yong Sheng Tai Xue Bao*. 2012;23(3):679-684.