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Determinants of Pneumonia in Toddlers: Multivariate Analysis

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Pneumonia remains a leading cause of morbidity and mortality among toddlers aged 12-59 months at Cikande Health Center Serang Regency, with 89 cases reported from January to March 2025. This unmatched case-control study included 118 toddlers (59 pneumonia cases and 59 healthy controls from nearby households, 1:1 ratio, purposive sampling). Pneumonia was defined as cough ≥2 days with rapid breathing or chest indrawing. Data on toddler gender, maternal education/knowledge, bedroom ventilation (≥10% floor area), humidity (40-60% RH), occupancy density (≤2 persons/room) and cigarette smoke exposure were analyzed via Chi-Square (bivariate) and multiple logistic regression (multivariate, stepwise elimination, interaction tests) using SPSS. Bivariate analysis showed significant associations ($p < 0.05$) for all factors. Multivariate modelling retained maternal education (pv=0.041, OR=2.606, 95% CI: 1.042-6.518), maternal knowledge (pv=0.003, OR=3.916, 95% CI: 1.580-9.708), bedroom ventilation (pv=0.026, OR=2.771, 95% CI: 1.126-6.818), bedroom humidity (pv=0.001, OR=5.360, 95% CI: 2.077-13.835) and occupancy density (pv=0.006, OR=3.676, 95% CI: 1.464-9.228). Bedroom humidity was the most dominant factor. No significant interactions found. Modifiable environmental factors (humidity, density) and maternal factors are key pneumonia determinants. Interventions should target home environmental improvements and maternal education.

Keywords: Education, Humidity, Housing Density, Knowledge, Ventilation Area

INTRODUCTION

Pneumonia is an acute infection of the lung tissue (alveoli) caused by various microorganisms such as bacteria, viruses, fungi, and parasites. Pneumonia is dubbed "The Forgotten Killer of Children" because it can attack the respiratory tract in the lungs, weaken breathing, and lack of attention to address the problem can lead to death, especially in children (Indonesian Ministry of Health, 2023). Pneumonia can spread in various ways, one of which is through saliva droplets from the cough and sneeze of a person diagnosed with pneumonia. In addition, pneumonia does not only spread through the air via saliva droplets, but it can also spread through the bloodstream during childbirth. Pneumonia is generally characterized by symptoms of cough, flu, and difficulty breathing with or without fever. However, pneumonia has a distinctive symptom, namely gasping for breath or pulling of the lower chest wall when breathing (WHO, 2023). In Indonesia, pneumonia is also the leading cause of death among children under five. Based on data from the Indonesian Ministry of Health, in 2018, an estimated 19.000 children died from pneumonia, with at least 71 children in Indonesia contracting the disease every hour. From 2020 to 2021, deaths from pneumonia in infants aged 29 days to 11 months accounted for approximately 14.5% of deaths. Meanwhile, in children aged 12-59 months, pneumonia was the second leading cause of death after diarrhea (Indonesian Ministry of Health, 2022).

Based on data from the 2023 Indonesian Health Survey (SKI), the prevalence of pneumonia among toddlers in Banten Province is quite high, reaching 21,7% per 3.819 toddlers aged 12-23 months (SKI, 2023). In addition, according to data from the Banten Provincial Health Office, the coverage of pneumonia cases in infants in Banten Province in 2023 reached 68.9 percent, which is close to the national target for coverage of pneumonia cases in infants. However, the number of pneumonia cases in toddlers that were treated was still very low, only around 0.8%, which is far from the Minimum Service Standard (SPM) target of 100%(Banten Provincial Health Office, 2023). This condition indicates a gap between case detection and appropriate and effective treatment, meaning that many infants in Banten Province with pneumonia have not received adequate care. Based on data from the Serang District Health Office's P2PMTM in 2024, the number of pneumonia cases detected in toddlers in the Serang district (age group 1-<5 years) was 3.331 cases. Cikande Community Health Center is one of the primary health care facilities in Serang District with a relatively high number of pneumonia cases among

children in 2024, reaching 217 cases(Serang District Health Office, 2024). In 2025, according to the MTBS (Integrated Management of Sick Children) service data report at Cikande Community Health Center, the incidence of pneumonia in toddlers at the Cikande Community Health Center was still relatively high every month, starting from January with 30 cases, February with 28 cases, and March with 31 cases (Cikande Community Health Center, 2024).

Pneumonia can be caused by several factors. These factors are divided into intrinsic and extrinsic factors. Intrinsic factors are factors that originate from the individual, including the gender of the infant, the mother's education, and the mother's knowledge. Meanwhile, extrinsic factors are factors that originate from outside the individual, including bedroom ventilation, floor type, wall type, bedroom humidity, bedroom density, and exposure to cigarette smoke. Male children have a higher risk of developing pneumonia than female infants, because the diameter of male children's lungs is smaller than that of female children (Sangadji et al., 2022). Additionally, innate response in male toddlers tends to be weaker compared to females, testosterone hormone inhibits the release of interleukins and inflammatory responses, whereas estrogen in females enhances surfactant production in the lungs and alveologenesis (alveoli formation), compounded by higher environmental exposure due to less protective child-rearing patterns (Hudmawan et al., 2023). Education is one of the main factors that can indirectly affect the incidence of pneumonia in infants or toddlers, because the higher a mother's education, the higher her knowledge of caring for her child's health (Fajar et al., 2024). According to Notoatmodjo (2014), knowledge is the result of knowing that occurs after a person perceives an object. (Notoatmodjo (2014), in Masturoh & Anggita, 2018). Mothers who do not have sufficient knowledge about pneumonia will not support efforts to prevent pneumonia, resulting in higher rates of illness and death from pneumonia in toddlers (Mayaswari et al., 2024).

The physical conditions of the home environment include ventilation and humidity. Poor ventilation can cause the air to become humid due to evaporation. Humid air can cause bacteria to grow and can cause health problems, especially in the respiratory system (Yohana et al., 2020). The growth of bacteria or microorganisms is influenced by humidity conditions; these agents can multiply rapidly in very low and very high humidity conditions (Laliyanto et al., 2023). Overcrowding in infants' sleeping quarters can increase the risk of pneumonia in infants because pathogens can spread more quickly in crowded environments (Fataruba et al., 2022). Exposure to cigarette smoke is not a direct cause of pneumonia in toddlers, but it is an indirect factor in the incidence of pneumonia in toddlers. However, exposure to cigarette smoke can cause lung disease that will weaken the toddler's immune system (Pramei et al., 2022).

Research variables were selected based on strong epidemiological evidence, local clinical relevance and modification potential for public health interventions. Toddlers gender was chosen due to significant association with pneumonia (OR=3.043; pv=0.006) from immunological hormonal differences. Maternal education and knowledge variables were selected due to strong correlation with clinical decision making (OR=2.844 and 2.863; pv=0.010). Bedroom ventilation area (<10% floor area), humidity (>60% RH), occupancy density (>2 persons/room) and cigarette smoke exposure variables were chosen because each significantly increases risk (OR=2.780;3.919;2.283;2.453 times) according to Ministry of Health Decree No. 829/1999 and Minister of Health Regulation No. 2/2023 standards.

Based on the above description, this study aims to determine the relationship between the gender of toddlers, maternal education, maternal knowledge, physical conditions of the home environment (including the size of the bedroom ventilation and humidity of the bedroom), bedroom occupancy density, and exposure to cigarette smoke with the incidence of pneumonia in toddlers in the working area of the Cikande Community Health Center, Serang Regency, in 2025.

METHODS

This study employed a quantitative approach with an unmatched case-control design, where matching was based on the age range of 12-59 months to control for age confounding. The case population consisted of 59 toddlers diagnosed with pneumonia, while the community-based control group included 59 healthy toddlers (not diagnosed with pneumonia) selected from nearby households (<500m) to ensure similar environmental exposures and minimize selection bias. The total sample comprised 118 respondents with a 1:1 ratio, selected using purposive sampling. Pneumonia was operationally defined clinically as cough >2 days with rapid breathing frequency ≥50x/min or lower chest wall indrawing. Bedroom ventilation area was measured using a roll meter (adequate if ≥10% of floor area per Ministerial Decree of Health No. 829/1999), humidity using a digital hygrometer (adequate if 40-60% RH per Ministry of Health Regulation No.2/2023 and maternal education and knowledge via interviews and questionnaires.

Intsruments included structured interview quetionnaires and direct observation/measurement sheets. Data analysis involved univariate (frequency), bivariate (Chi-square) and multivariate (multiple logistic regression) methods using SPSS. The study received ethical approval from the Faculty of Health Sciences, Faletehan University (No.001960/2025) and permission from Cikande Community Health Center.

RESULTS AND DISCUSSION

Frequency Distribution of Variables Related to the Occurrence of Pneumonia in Infants

Based on Table 1 of the univariate analysis results, it can be seen that 37 (62.7%) of the cases were male infants, 39 (66.1%) of the cases had mothers with low education levels, 34 (57.6%) of the cases had mothers with poor knowledge, and 43 (72.9%) of the cases had

sleeping areas that did not meet ventilation requirements. case group was 43 (72.9%), humidity in the toddler's bedroom that did not meet the requirements in the case group was 43 (72.9%), housing density in the toddler's bedroom that did not meet the requirements in the case group was 36 (61.0%), and toddlers exposed to cigarette smoke from family members in the case group was 37 (62.7%).

Table 1.

Frequency Distribution of Variables Associated with Pneumonia in Infants at the Cikande Community Health Center Serang Regency in 2025

Variable	Pneumonia				Total	
	Pneumonia		No Pneumonia			
	N	%	N	%	N	%
Gender of Toddlers						
Male	37	62.7%	21	35.6%	58	49.2%
Female	22	37.3%	38	64.4%	60	50.8%
Mother's Education						
Low	39	66.1%	24	40.7%	63	53.4%
High	20	33.9%	35	59.3%	55	46.6%
Mother's Knowledge						
Poor	34	57.6%	19	32.2%	53	44.9%
Good	25	42.4%	40	67.8%	65	55.1%
Bedroom Ventilation Area						
Does Not Meet Requirements	43	72.9%	29	49.2%	72	61.0%
Meets Requirements	16	27.1%	30	50.8%	46	39.0%
Bedroom Humidity						
Does Not Meet Requirements	43	72.9%	24	40.7%	67	56.8%
Meets Requirements	16	27.1%	35	59.3%	51	43.2%
Bedroom Occupancy Density						
Does Not Meet Requirements	36	61.0%	24	40.7%	60	50.8%
Meets Requirements	23	39.0%	35	59.3%	58	49.2%
Exposure to Cigarette Smoke						
Exposed	37	62.7%	24	40.7%	61	51.7%
Not Exposed	22	37.3%	35	59.3%	57	48.3%

Relationship between Gender Variables in Toddlers and Incidence of Pneumonia in Infants

In general, gender refers to the biological category that distinguishes individuals as male or female based on anatomical and physiological characteristics inherent since birth. Gender differences in infants can be a cause of disease, for example, diseases that attack the respiratory tract (ISPA or pneumonia). Based on Table 2, it can be seen from the results of the Chi-Square test at α 5% that there is a significant relationship between the gender of toddlers and the incidence of pneumonia in toddlers with a pvalue of 0,006 and an *Odds Ratio* (OR) of 3.043 (95% CI: 1.438-6.442) meaning that male infants have a 3 times greater risk of developing pneumonia compared to female infants.

Table 2.

Relationship between Gender Variables in Toddlers and Incidence of Pneumonia in Toddlers

Variable	Pneumonia				Total		*P value*	OR (95% CI)
	Pneumonia		No Pneumonia					
	N	%	N	%	N	%		
Gender of Toddlers								3.043
Male	37	62.7%	21	35.6%	58	49.2%	0.006	(1.438-6.442)
Female	22	37.3%	38	64.4%	60	50.8%		

Source: Primary Data 2025

The results of this study are in line with the research by Chairunnisa et al., (2021) which showed a significant relationship between infant gender and the incidence of pneumonia in infants in the Cinere Community Health Center working area in Depok City with a pvalue of 0.033. The results of this study are also supported by the research of Sangadji et al., (2021) which states that there is a significant relationship between infant gender and the incidence of pneumonia in infants at the Cibodasari Community Health Center with a pvalue of 0.027. Hormonal and physiological differences in the respiratory system between males and females are one of the risk factors. Women have larger lung diameters and estrogen hormones that stabilize and enhance the immune response when infection occurs by releasing mediators that are very useful during the inflammatory response when infection occurs. Meanwhile, males have smaller lung diameters, and the testosterone hormone in males has little activity to inhibit the release of interleukin, which will interfere with the inflammatory response when an infection occurs (Hudmawan et al., 2023). In addition, based on observations, mothers of toddlers tend to be more protective of female toddlers. This difference in parenting patterns is due to mothers' perception that male infants have stronger physiques and immune systems, so mothers do not need to be as strict with their male infants. This is why female infants tend to stay at home more often than male infants, who engage in more outdoor play activitie.

The Relationship Between Mother's Education and The Incidence of Pneumonia in Toddlers

Education is a conscious and planned learning process to develop an individual's potential and increase their knowledge so that they can contribute positively to social life. Education does not only take place in an academic environment, but also within the family and community (Fajar et al., 2024). Based on Table 3, the results of the chi-square test at α 5% show that there is a significant relationship between maternal education and the incidence of pneumonia in toddlers with a pvalue of 0.010 and an *Odds Ratio* (OR) of 2.844 (95% CI: 1.345-6.012) this means that mothers with low education have a 2.844 times greater risk of their infants developing pneumonia compared to mothers with high education.

Table 3.

Relationship Between Maternal Education Variable and Incidence of Pneumonia in Infants

Variable	Pneumonia				Total		*P value*	OR (95% CI)
	Pneumonia		No Pneumonia					
	N	%	N	%	N	%		
Mother's Education								
Low	39	66.1%	24	40.7%	63	53.4%	0.010	2.844 (1.345-6.012)
High	20	33.9%	35	59.3%	55	46.6%		

Source : Primary Data

The results of this study are consistent with the research by Fajar et al., (2024) which states that there is a significant relationship between maternal education and the incidence of pneumonia in toddlers in the Baloi Permai Community Health Center Working Area in Batam City with a pvalue of 0.002, which means that the pvalue is smaller than α (0.05). The results of this study are also supported by the research of Hudmawan et al., (2023) which states that there is a significant relationship between maternal education and the incidence of pneumonia in toddlers at the Cilembang Community Health Center in Tasikmalaya City with a pvalue of 0.032. Based on the interview results, low education among mothers whose toddlers suffered from pneumonia was

due to the fact that their average highest level of education was junior high school (24 or 40.7%), while high education among mothers whose toddlers did not suffer from pneumonia was due to the fact that their highest level of education was senior high school/vocational high school (33 or 55.9%). This, education is closely related to a person's knowledge. Where knowledge and broad insight are obtained from education, mothers with low education often have limited knowledge about child health, so they do not understand the signs and symptoms, prevention, and treatment of pneumonia. This situation causes them to delay seeking medical help. On the other hand, higher education among mothers makes them more concerned and knowledgeable about caring for their toddlers' health, so they are much more aware of how to prevent and treat diseases such as pneumonia. Maternal education also serves as a proxy for socio-economic status and structural healthcare access. Higher-educated mothers typically have better economic resources, live in improved housing condition and are more likely to seek timely medical care for their children. Lower education often correlates with limited financial means and reduced access to health information and services, indirectly increasing pneumonia risk through structural determinants.

Relationship Between Mother's Knowledge and The Incidence of Pneumonia in Infants

Knowledge is everything related to the process of recognizing, either through direct observation using the five senses or the results of a person's thoughts about a particular object or event. Knowledge is the basis for a person in forming attitudes and behaviors (Notoatmodjo (2014) in Masturoh & Anggita, 2018). Based on Table 4, it can be seen from the results of the Chi-Square test at α 5% that there is a significant relationship between maternal knowledge and the incidence of pneumonia in toddlers with a pvalue of 0.010 and an *Odds Ratio* of 2.863 (95% CI: 1.350-6.071) meaning that infants cared for by mothers with poor knowledge have a 2.86 times greater risk of developing pneumonia.

Table 4.

Relationship Between Mother's Knowledge and Incidence of Pneumonia in Toddlers

Variable	Pneumonia				Total		*P value*	OR (95% CI)
	Pneumonia		No Pneumonia					
	N	%	N	%	N	%		
Mother's Knowledge								
Poor	34	57.6%	19	32.2%	53	44.9%	0.010	2.863 (1.350-6.071)
Good	25	42.4%	40	67.8%	65	55.1%		

Source : Primary Data

The results of this study are in line with Wijayanti (2020) study, which states that there is a significant relationship between maternal knowledge and the incidence of pneumonia in toddlers in Bantul Regency, Yogyakarta, with a pvalue of 0.002. Mothers with poor knowledge typically only completed junior high school, which makes it difficult for them to receive health information about what pneumonia is, its signs and symptoms, how to prevent it, and how to treat it. Barriers to receiving health information and not actively seeking health information about pneumonia caused respondents to be less concerned. As a result, toddlers cared for by mothers with poor knowledge had a higher risk factor of delayed treatment if they contracted pneumonia. Meanwhile, mothers with good knowledge generally found it easier to receive health information, including about pneumonia. In addition, they are more responsive and able to recognize the signs and symptoms of the disease earlier and know the appropriate prevention and treatment measures. This attitude of concern plays a very important role in reducing the risk of complications from pneumonia in toddlers. Maternal knowledge is structurally linked to socio-economic factors. Mother with higher education and better economic status have greater access to health education programs, media information and healthcare facilities. Poor knowledge often reflects limited socio-economic opportunities rather than individual deficiency, acting as a structural determinant of pneumonia incidence.

Relationship Between Bedroom Ventilation Area Variables and the Incidence of Pneumonia in Infants

Ventilation is the process of circulating air from outside into a room or from inside to outside, so that the air inside the room remains fresh and not stuffy. With ventilation, dirty air, dust, and excess moisture can be removed and replaced with clean air. This will improve the air quality inside the room. According to Minister of Health Decree No. 829/MENKES/SK/VII/1999 concerning Health Requirements for Housing and Residential Environments, one of the health requirements for indoor air is to have air circulation and exchange which in this case means that the air conditioning or ventilation system must ensure good air exchange in the room with a cross ventilation system and a minimum ventilation area of

10% of the floor area or using artificial ventilation(Kepmenkes No. 829, 1999). Based on Table 5, it can be seen from the results of the chi-square test at α 5% shows that there is a significant relationship between the ventilation area of the bedroom and the incidence of pneumonia in toddlers with a pvalue of 0.014 and an *Odds Ratio* of 2.780 (95% CI: 1.290-5.993), meaning that toddlers who sleep in rooms with inadequate ventilation have a 2.78 times greater risk of contracting pneumonia.

Table 5.

Relationship Between Bedroom Ventilation Area and Incidence of Pneumonia Toddlers

Variable	Pneumonia				Total		*P value*	OR (95% CI)
	Pneumonia		No Pneumonia					
	N	%	N	%	N	%		
Bedroom Ventilation Area								
Does Not Meet Requirements	43	72.9%	29	49.2%	72	61.0%	0.014	2.780 (1.290-5.993)
Meets Requirements	16	27.1%	30	50.8%	46	39.0%		

The results of this study are in line with the research by Sa'diyah et al., (2022) which states that there is a significant relationship between the ventilation area of toddlers' bedrooms and the incidence of pneumonia in toddlers in the Baturraden II Community Health Center Working Area with a pvalue of 0.002, which means that the pvalue is smaller than α (0.05). The results of this study are also supported by the research of Nilamsari & Putri (2022)which states that there is a significant relationship between the ventilation area of toddlers' bedrooms and the incidence of pneumonia in toddlers in Tropodo Village, Krian District, Sidoarjo Regency, East Java Province, with a pvalue of 0.049. Based on the observations conducted, it was found that the ventilation area did not meet the requirements because the overall ventilation area was less than the established standard, which is a minimum of 10% of the floor area to obtain comfort and fresh air, which is very necessary in an infant's bedroom. In addition, the type of ventilation was non-functional, making it difficult to adjust according to needs because there were no openings to open and close it. Furthermore, the respondents' habit of covering air vents and windows with wood, paper, or cloth reduces the amount of air entering the infant's bedroom. This can increase the risk factors for the infant's respiratory health, making them susceptible to pneumonia.

Relationship Between Bedroom Humidity Variables and the Incidence of Pneumonia in Infants

Humidity is a measure of the amount of water vapor contained in the air. Humidity is often used as an indicator of environmental health in the air to determine whether it meets health standards or not. If a house or room has humidity that is too high or too low, it will be very easy for pathogenic microorganisms to grow and cause illness among its occupants. According to Minister of Health Regulation No. 2 of 2023 on Environmental Health in the Prevention of Air Quality Degradation, humidity that meets standards ranges from 40% to 60%. If the air humidity is less than 40% (then it is categorized as dry) and if the air humidity is more than 60% (then it is categorized as humid) (Minister of Health Regulation No. 2, 2023). Based on Table 6, the results of the chi-square test at α 5% show that there is a significant relationship between bedroom humidity and the incidence of pneumonia in toddlers with a pvalue of 0.001 and an *Odds Ratio* of 3.919 (95% CI: 1.807-8.500). meaning that infants sleeping in rooms with humidity levels that do not meet the requirements have a 3.91 times greater risk of contracting pneumonia.

The results of this study are in line with the research by Indah et al., (2022) which states that there is a significant relationship between room humidity and the incidence of pneumonia in toddlers in the Sidorejo Community Health Center Working Area, Pagar Alam City, with a pvalue of 0.000 (<0.05). The results of this study are also supported by the research of Sa'diyah et al., (2022) which states that there is a significant relationship between humidity and the incidence of pneumonia in toddlers in the Working Area of the Baturraden II Community Health Center with a pvalue of 0.012. The humidity in the toddlers' bedrooms that did not meet the requirements was caused by an average humidity of 63.9% RH, which exceeds the ideal humidity limit in a room, which is 40-60% RH. High humidity is influenced by several factors, such as the area of ventilation or the insufficient number of vents in the toddler's bedroom, and the respondents' habit of closing air vents and windows, which also limits air circulation and sunlight entering the bedroom. High relative humidity creates optimal conditions for bacterial and fungal growth, as most pathogen thrive between 60-90% RH. High humidity also prolongs the survival of virus-carrying aerosol droplets in indoor air. Poor ventilation combined with high humidity causes air stagnation, trapping respiratory irritants and microorganisms that trigger pneumonia in toddlers. This condition resulted in high humidity and supported the growth of microorganisme that could potentially pose health risks, particularly respiratory tract infections such as pneumonia.

Table 6.

Relationship Between Bedroom Humidity and the Incidence of Pneumonia in Infants

Variable	Pneumonia				Total		*P value*	OR (95% CI)
	Pneumonia		No Pneumonia					
	N	%	N	%	N	%		
Bedroom Humidity								
Does Not Meet Requirements	43	72.9%	24	40.7%	67	56.8%	0.001	3.919 (1.807-8.500)
Meets Requirements	16	27.1%	35	59.3%	51	43.2%		

Source: Primary Data

Relationship Between Housing Density Variables Sleeping Room and the Occurrence of Pneumonia in Infants

Housing density is the ratio between the number of occupants and the floor area of the living space occupied, usually measured in square meters per person (m²/person). Housing density also reflects the population density in a house or room, which describes how crowded or spacious the living space is in relation to the number of occupants (Fataruba et al., 2022). According to Minister of Health Decree No. 829/MENKES/SK/VII/1999 concerning Health Requirements for Housing and Residential Environments, housing density in toddler bedrooms can be determined using the room area indicator. Sleep for at least 8 hours and it is not recommended for more than 2 people to sleep in one bedroom, except for children under 5 years of age (Minister of Health Decree No. 829, 1999). Based on Table 7, the results of the chi-square test at 5% α show that there is a significant relationship between the density of occupants in the bedroom and the incidence of pneumonia in toddlers, with a pvalue of 0.043 and an *Odds Ratio* of 2.283 (95% CI: 1.092-4.771). meaning that infants who sleep in rooms with substandard occupancy density have a 2.28 times greater risk of contracting pneumonia.

Table 7.

Relationship between Bedroom Density Variables and Incidence of Pneumonia in Toddlers

Variable	Pneumonia				Total		*P value*	OR (95% CI)
	Pneumonia		No Pneumonia					
	N	%	N	%	N	%		
Bedroom Occupancy Density							0.043	2.283
Does Not Meet Requirements	36	61.0%	24	40.7%	60	50.8%		
Meets Requirements	23	39.0%	35	59.3%	58	49.2%		

The results of this study are consistent with the research by Nurjayanti et al., (2022) which states that there is a significant relationship between room occupancy density and the incidence of pneumonia in infants in the Tawang Community Health Center working area in Tasikmalaya City with a pvalue of 0.000 (<0.05). The occupancy density does not meet the requirements because the average floor area of the infant bedroom is 10.79 m^2 with a minimum floor area of 5.83 m^2 and a maximum floor area of 32.80 m^2. In addition, the average number of occupants in one infant bedroom was 2 to 3 adults, with a minimum of 1 adult and a maximum of 4 adults. These conditions indicate that toddler bedrooms tend to experience overcrowding that exceeds recommended health standards. Overcrowded housing has the potential to increase the risk of disease transmission, especially pneumonia in toddlers, because the more occupants in a confined space, the higher the levels of carbon dioxide and air pollutants in the room. Inadequate ventilation area and number of available vents, as well as respondents' habit of closing vents and windows, also exacerbate the condition of densely populated rooms. This has an impact on the quality of air in the sleeping area, slowing down air exchange and increasing humidity, which is a risk factor for the growth of microorganisms that cause respiratory tract infections such as pneumonia.

The Relationship Between Cigarette Smoke Exposure and Pneumonia Incidence in Infants

Cigarette smoke exposure is smoke that comes from smokers and smoking near individuals. Cigarette smoke exposure is one of the main risk factors that negatively impact health, especially in toddlers. The nicotine and other harmful chemicals contained in cigarettes can cause respiratory system dysfunction (Kusparlina & Wasito, 2022). Based on Table 8, the results of the chi- square test at 5% significance level shows that there is a significant relationship between exposure to cigarette smoke and the incidence of pneumonia in toddlers with a pvalue of 0.027 and an *Odds Ratio* of 2.453 (95% CI: 1.170-5.143), meaning that toddlers exposed to cigarette smoke from family members have a 2.45 times greater risk of developing pneumonia.

Table 8.

Relationship between Cigarette Smoke Exposure Variables and the Incidence of Pneumonia in Toddlers

Variable	Pneumonia				Total		*P value*	OR (95% CI)
	Pneumonia		No Pneumonia					
	N	%	N	%	N	%		
Exposure to Cigarette Smoke							0.027	2.453 (1.170-5.143)
Exposed	37		24		61	51.7%		
No Exposed	22	62.7%37.3%	35	40.7%59.3%	57	48.3%		

Source: Primary Data

The results of this study are in line with the research by Kusparlina and Wasito (2022) which states that there is a significant relationship between exposure to cigarette smoke and the incidence of pneumonia in toddlers in the Banjarejo Community Health Center Working Area, Madiun City, with a pvalue of 0.025, which means that the pvalue is smaller than α (0.05). The results of this study are also supported by research by Hudmawan et al., (2023) which states that there is a significant relationship between exposure to cigarette smoke and the incidence of pneumonia in toddlers in the Cilembang Community Health Center Working Area in Tasikmalaya City with a pvalue of 0.028. In toddlers exposed to cigarette smoke from family members, this is caused by the habits of the toddler's closest family members, such as their father or grandfather, who smoke inside the house and sometimes smoke near the toddler. The habit of smoking inside the house and around infants is caused by various factors, such as lack of knowledge, difficulty in receiving information, and lack of awareness about the effects of smoking inside the house and when cigarette smoke is inhaled by infants. Direct and indirect exposure to cigarette smoke causes infants to become passive smokers, which has a particular impact on respiratory health, such as pneumonia. This, controlling exposure to cigarette smoke is a crucial step in efforts to reduce the incidence of pneumonia in infants.

Multivariate Analysis of Disease Incidence Varibales Pneumonia in Infants

Bivariate Selection

Multivariate analysis was conducted on all independent variables with a pvalue <0.25. The analysis in this study aimed to determine the most dominant variables related to the type of infant gender, maternal education, maternal knowledge, bedroom ventilation area, bedroom humidity, bedroom occupancy density, and exposure to cigarette smoke with the incidence of pneumonia in infants in the Cikande Community Health Center Working Area, Serang Regency, in 2025. Based on Table 9, after bivariate selection of several candidate independent variables, the variables included in the multivariate modeling because (pvalue <0.25) were infant gender (pvalue=0.04), maternal education (pvalue=0.06), maternal knowledge (pvalue=0.06), bedroom ventilation area (pvalue = 0.09), bedroom humidity (pvalue = 0.01), bedroom occupancy density (pvalue = 0.028), and exposure to cigarette smoke (pvalue = 0.018).

Table 9.

Bivariate Selection of Independent Variables with Dependent Prediction Model

No	Variable	*p-value*	Description
1	Infant Gender	0.04	Candidate
2	Mother's Education	0.06	Candidate
3	Mother's knowledge	0.06	Candidate
4	Bedroom Ventilation Area	0.09	Candidate
5	Bedroom Humidity	0.01	Candidate
6	Bedroom Occupancy Density	0.028	Candidate
7	Cigarette Smoke Exposure	0.018	Candidate

Initial Multivariate Modelling

After the candidate variables were obtained, they were then entered into the initial stage of multivariate prediction modeling. Based on Table 10 of the statistical test results, the variable of infant gender had a pvalue = 0.126 > 0.05 and the variable of cigarette smoke exposure had a pvalue = 0.130 > 0.05, so both variables had to be removed from the model. This shows that gender and exposure to secondhand smoke are not significantly related to the incidence of pneumonia in toddlers. Therefore, in the process of modeling logistic regression with the gradual elimination method, the variable with the largest p-value is excluded from the model to obtain fewer (simple) models.

Table 10.

Initial Multivariate Prediction Modeling

No	Variable	*p-value*	*Odds Ratio* (OR)	(95% CI)
1	Infant Gender	0.126	2.061	0.816-5.207
2	Mother's Education	0.040	2.694	1.045-6.946
3	Mother's knowledge	0.008	3.620	1.409-9.299
4	Bedroom Ventilation Area	0.036	2.664	1.064-6.673
5	Bedroom Humidity	0.005	4.056	1.518-10.837
6	Bedroom Occupancy Density	0.013	3.340	1.285-8.679
7	Cigarette Smoke Exposure	0.130	2.037	0.811-5.114

Source: Primary Data 2025

After removing the variables of infant gender and exposure to cigarette smoke from the model, the next step was to reanalyze the variables with a pvalue > 0.05. Based on Table 11 of the statistical test results, the variables of maternal education had a pvalue = 0.041 < 0.05, maternal knowledge had a pvalue = 0.003 < 0.05, bedroom ventilation area pvalue=0.026< 0.05, bedroom humidity pvalue=0.001 < 0.05, and bedroom occupancy density pvalue=0.006 < 0.05, so no variables were removed from the model. It can be concluded that there is a joint relationship between the variables of maternal education, maternal knowledge, bedroom ventilation area, bedroom humidity, and bedroom occupancy density with the incidence of pneumonia in toddlers.

Table 11.

Initial Multivariate Analysis Model

No	Variable	*p-value*	*Odds Ratio* (OR)	(95% CI)
1	Mother's Education	0.041	2.606	1.042-6.518
2	Mother's knowledge	0.003	3.916	1.580-9.708
3	Bedroom Ventilation Area	0.026	2.771	1.126-6.818
4	Bedroom Humidity	0.001	5.360	2.077-13.835
5	Bedroom Occupancy Density	0.006	3.676	1.464-9.228

Prediction Model Interaction Test

After conducting initial multivariate modeling and obtaining the final results, the next step is to perform an interaction test. The interaction test is used to identify the effect of one independent variable on the dependent variable depending on the level or category of another independent variable. Based on Table 12 of the statistical test results, there is no interaction between the mother's education variable and the mother's knowledge (sig omnibus=0,876>0,05). Meanwhile, Table 13 shows that statistically there is no interaction between bedroom

ventilation area and the humidity variable (sig omnibus=0,513>0,05). Interaction testing in this multivariate analysis was only carried out on two combinations of variables, namely maternal education and maternal knowledge. The findings of this study showed that 39 people (66.1%) had low education in toddlers, while 40 people (67.8%) had good maternal knowledge in non-pneumonia toddlers. According to Nasrudin's theory (2021), each person's knowledge is different depending on how each person senses objects. The results of research that have been conducted by Sary et al., (2024), there is a significant relationship (pvalue 0.021) between maternal knowledge and pneumonia. And based on the results of research by Pratiwi and Wildayanti (2023) (pvalue 0.253).

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Table 12.

Interaction Test of the Predictive Factor Model Between the Mother's Education Variable and Maternal Knowledge

No	Variable	*p-value*	*Odds Ratio* (OR)	(95% CI)
1	Mother's Education	0.618	2.093	0.115-38.010
2	Mother's knowledge	0.408	3.185	0.204-49.602
3	Bedroom Ventilation Area	0.026	2.779	1.128-6.844
4	Bedroom Humidity	0.001	5.358	2.075-13.834
5	Bedroom Occupancy Density	0.006	3.673	1.463-9.223
6	Mother's Education by Mother's Knowledge	0.876	1.152	0.194-6.825

Prior to final multivariate modeling, correlation analysis between environmental variables was conducted to assess multicollinearity risik. Pearson correlation analysis revealed a strong positive correlation between bedroom ventilation area and humidity (r=0.62, pvalue<0.01), where inadequate ventilation contributes to elevated humidity through reduced air exchange and moisture accumulation.

Final Multivariate Analysis Model

Based on Table 14, the bedroom humidity variable is the most dominant variable associated with the incidence of pneumonia in toddlers with a pvalue of 0.001 and an *Odds Ratio* (OR) of 5.360, meaning that toddlers who sleep in rooms with unsatisfactory humidity are 5.360 times more likely to contract pneumonia than toddlers who sleep in rooms with satisfactory humidity.

The Most Dominant Variable Related With The Occurrence Of Pneumonia In Infants

Based on the results of the statistical tests conducted, it was found that the humidity level in the sleeping area is the most dominant variable associated with the incidence of pneumonia in infants in the service area of the Cikande Health Center, Serang District, in 2025 with a pvalue of 0,001 and an *Odds Ratio* (OR) 5.360 with a 95% CI of 2.077-13.835, meaning that toddlers who sleep in a room with unqualified humidity have a greater chance of 5.360 to get pneumonia.

Table 14.

Final Multivariate Analysis Model

No	Variable	*p-value*	*Odds Ratio* (OR)	(95% CI)
1	Mother's Education	0.041	2.606	1.042-6.518
2	Mother's knowledge	0.003	3.916	1.580-9.708
3	Bedroom Ventilation Area	0.026	2.771	1.126-6.818
4	Bedroom Humidity	0.001	5.360	2.077-13.835
5	Bedroom Occupancy Density	0.006	3.676	1.464-9.228

CONCLUSIONS

Multivariate analysis indetified bedroom humidity (pvalue 0.001, OR= 5.360, 95%CI: 2.077-13.835) as the most dominant factor associated with pneumonia incidence in toddlers at Cikande Health Center, Serang Regency 2025, after controlling for maternal and occupancy density. Maternal knowledge (pvalue 0.003, OR=4.006) and bedroom occupancy density (pvalue 0.005, OR= 3.726) emerged as significant independent predictors, while maternal education remained protective (pvalue 0.050, OR= 2.516). bedroom ventilation was non-significant in final model (pvalue 0.913) after adjustment. Gender and cigarette exposure were excluded from final modeling (pvalue>0.25). These findings emphasize modifiable environmental factors (humidity, density) and maternal factors (knowledge) as primary intervention targets for pneumonia prevention in this setting.

SUGGESTION

The Cikande Community Health Center is advised to strengthen its promotional and preventive services by educating the community, especially on managing proper ventilation and humidity levels in accordance with health standards, prohibiting families from smoking inside the house and around infants, prohibiting families from sleeping with infants in a room with more than two adults, and implementing clean and healthy living behaviors to prevent pneumonia in infants. The community, especially mothers with infants, are also encouraged to increase awareness of the importance of environmental health in their homes.

REFERENCES

Akbar, H., B, H., Hamzah, R., Paundanan, M., & Reskiaddin, L. O. (2021). The Relationship Between the Physical Environment of the Home and the Incidence of Pneumonia in Infants in the Plumbon Community Health Center Working Area. *Jambi Public Health Journal (JKMJ)*, *5* (2), 1–8. [Crossref] [Publisher]

Chairunnisa, P., Nugrohowati, N., & Chairani, A. (2021). Analysis of Risk Factors for Pneumonia Incidence in Toddlers in the Cinere Community Health Center Working Area. *IKRA-ITH Humaniora*, *5* (2), 1–10. [Publisher]

Serang District Health Office. (2024). *Report on the Number of Pneumonia Cases in Toddlers in Serang District in 2024.*

Banten Provincial Health Department. (2023). *Health Profile of Health in Banten Province for the Year 2023.* [Publisher]

Fajar, Sembiring, F. Y., Panca Hendri, M., & Rozali, R. (2024). Determinants of Pneumonia Incidence in Toddlers in the Baloi Permai Community Health Center Working Area in Batam City. January 2024, *5* (1), 65-79. [Crossref] [Publisher]

Fataruba, I., Dusra, E., Lihi, M., Umar, C. B. P., & Umamity, S. (2022). The Relationship Between Physical Environmental Factors in the Home and the Incidence of Pneumonia in Children Under Five Years of Age in the Sirimau District Health Center Working Area in Ambon City. *Maluku Husada Health Journal*, *1* (2), 7–10. [Crossref] [Publisher]

Hapsari, A. A (2024). The Relationship Between Home Conditions and the Incidence of Pneumonia in Toddlers at the Lontar Community Health Center, Surabaya. *Promotif Preventif Journal, 7* (3), 545-552. [Crossref] [Publisher]

Hudmawan, Z. A., Abdurrahmat, A. S., & Annashr, N. N. (2023). The Relationship Between Host and Environmental Factors and the Incidence of Pneumonia in Toddlers in the Working Area of the Cilembang Community Health Center, Tasikmalaya City. *Indonesian Journal of Community Health*, *19* (2), 127–148. [Crossref] [Publisher]

Indah, N., Suryani, L., & Rosalina, S. (2022). Analysis of Risk Factors for Pneumonia in Toddlers in the Working Area of the Sidorejo Community Health Center in Pagar Alam City. *Saelmakers Perdana Health Journal*, *5* (2), 370-381. [Crossref] [Publisher]

Ministry of Health of the Republic of Indonesia. (2022). Indonesia Health Profile *2022*.

Ministry of Health of the Republic of Indonesia. (2023). Indonesia Health Profile *2023.*

Ministry of Health Regulation No. 829/MENKES/SK/VII/1999. Health Requirements for Housing and Residential Environments.

Kusparlina, & Wasito Eddy. (2022). Intrinsic and Extrinsic Factors Associated with the Occurrence of Pneumonia. *Communication and Social Dynamics (CSD)*,*7* (4),149–155. [Crossref] [Publisher]

Laliyanto, Nurjazuli, & Suhartono. (2023). The Influence of Physical Environmental Factors in the Home on the Incidence of Pneumonia in Toddlers. *Journal of Health Research, Bandung Health Polytechnic, 15* (2), 343-352. [Crossref] [Publisher]

Masturoh, I., & Anggita, N. (2018). *Health Research Methodology* (Priyati Yayuk Rini Dr, Ed.; 1st ed.). Center for Health Human Resources Education.

Mayaswari, K., G., Erni Sipahutar, I., & P Yunianti Suntari Cakera, N. L. (2024). The Relationship Between Mothers' Knowledge of Pneumonia and the Incidence of Pneumonia in Toddlers. *Journal of Nursing Echoes*, *17* (2), 137–149. [Crossref] [Publisher]

Nurjayanti, T. N., Maywati, S., Gustaman, R. A., Masyarakat, P. K., & Kesehatan, I. (2022). The Relationship Between Physical Conditions of Homes and the Incidence of Pneumonia in Toddlers in Densely Populated Areas of Tasikmalaya City (Case Study in the Tawang Community Health Center Working Area). *Indonesian Journal of Community Health*, *18* (1), 395–405. [Publisher]

Pramei, A. R., Andi Tihardimanto, & Syatirah Jalaluddin. (2022). The Relationship Between Exclusive Breastfeeding and Exposure to Cigarette Smoke on the Incidence of Pneumonia in Toddlers at Labuang Baji Regional General Hospital, Makassar, July 2018–July 2019. *Alami Journal (Alauddin Islamic Medical) Journal*, *6* (2), 6–12. [Crossref] [Publisher]

Pratiwi, Y., & Wildayanti. (2023). The Relationship of Education, Occupation and Knowledge with Preventive Behavior Againts Pneumonia in Children and Toddlers in Kandangmas Villages, Kudus Regency. *Cendikia Journal of Pharmacy, 7*(2), 140-149. [Crossref] [Publisher]

Cikande Health Center (2025). *Report on the Number of of Pneumonia Cases in Infants in Cikande Subdistrict Area.*

Sa'diyah, A., Utomo, B., & Hikmandari. (2022). Risk Factors of Physical Conditions at Home with Incidence of Pneumonia in Toddlers. *Semarang Health Polytechinic*, *41*(1), 23–31. [Crossref] [Publisher]

Sangadji, N. W., Okta Vernanda, L., Muda, A. K., & Veronika, E. (2022). The Relationship Between Gender, Immunization Status, and Nutritional Status with the Incidence of Pneumonia in Toddlers (0-59 months) at the Cibodasari Community Health Center in 2021. *JCA Health Science*, *2* (2), 66–74. [Publisher]

Sary, R. N., Kusumastuti, I., & Sugesti, R. (2024). The Relationship of Mothers' Knowledge, Attitudes, Physical Environment and Midwives' Role with Mothers' Behavior in Preventing Pneumonia in Toddlers with ARI at Kita Clinic, Depok, West Java in 2023. *SENTRI: Scientific Research Journal*, *3*(9), 4257-4271.

Shiddiq, Azizah R, Jalaludin, J., Sulistyorini, & Novi, D., (2022). Analysis of Family Behavior and the Incidence of Acute Respiratory Infections (ARI) in Toddlers in Indonesia. *21*, 442–448.

SKI. (2023). *Indonesian Health Survey (SKI) 2023.* [Publisher]

WHO. (2023) *Pneumonia In Children.* [Publisher]

Wijayanti, N. (2020). Factors Related to the Occurrence of Pneumonia in Toddlers in Bantul Regency, Yogyakarta. *Public Health Journal*, *11*(1), 19. [Publisher]

Yohana, B., Ayuningtya, O., & Suryandari, A. E. (2020). The Relationship Between Healthy Home Status and the Occurrence of Pneumonia in Toddlers at the Piyungan Community Health Center. *Bina Cipta Husada Journal*, *16*, 72–8. [Publisher]