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Review Article

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Risk analysis of temperature, humidity, ventilation, use of mosquito repellent, and smoking behaviour on the incidence of acute respiratory infections (ARI) in Toddlers

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ABSTRACT

Acute Respiratory Infections (ARI) are commonly experienced by children, infants, and toddlers. This study analysed the relationship of several factors that cause the occurrence of ARI in Toddlers, namely temperature, humidity, exposure to cigarette smoke, and the use of mosquito repellent.

This study used the meta-analysis method by doing a literature search and then finding the value of the effect size using JASP.

The research with meta-analysis showed that the smoking behaviour of family members is the highest risk of ARI in toddlers with a value of PR=E1.57=4,572 (95% CI 1.28-1.77). Furthermore, ventilation is the second highest risk of ARI in toddlers, with PR=E1.36=3.896. Then the humidity condition with the value of PR=E1.31=3.706. Other variables, such as air temperature risk increasing the incidence of ARI up to 2,829 times, and mosquito coils that had an impact up to 2,293 times increased the risk of ARI in Toddlers.

All variables can increase the risk of ARI in toddlers, with the three most potent variables being smoking behaviour, ventilation, and humidity. Other variables can still increase the risk of ARI in toddlers, but to a lesser extent.

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Review

Acute Respiratory Infections (ARI) pose a significant health threat, particularly to children under the age of five, as they can potentially result in fatalities [1]. According to data from the World Health Organization (WHO), the prevalence of ARI in developing countries stands at 0.29%, accounting for approximately 151 million cases, while in industrialized countries, it is only 0.05%, affecting nearly 5 million individuals. As stated by the Ministry of Health of the Republic of Indonesia, the number of deaths in toddlers aged 0-1 years caused by Acute Respiratory Infections (ARI) amounted to 12.4 million. As many as 80.3% of these deaths occur

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in developing countries [2]. Based on data from the DKI Jakarta Health Office, during the first half of 2023, there was a decrease in ARI cases in March with 119,734 patients, then decreased but increased again in June with 102,475 points. This increase coincided with a spike in cases of ARI in toddlers by about 24-31%, which suggests poor air pollution may be a contributing factor to the high rate of ARI [3]. This information indicates that ARI remains a severe problem for health systems in developing countries such as Indonesia, especially among children under five [4].

Acute Respiratory Infections (ARI) are commonly experienced by children, infants, and toddlers [5]. ARI is a condition that occurs when germs or microorganisms enter the respiratory system, both upper and lower. This condition can be transmitted from one person to another and has varying degrees of severity, ranging from asymptomatic to mild infections or even serious and potentially fatal ones. The seriousness of ARI depends on the type of pathogen causing it, environmental factors, and the infected individual's health. The infection can impact various regions of the respiratory system, spanning from the upper part, like the nose, to the lower part, including the alveoli. It can also affect structures such as the sinuses, middle ear cavity, and pleura [6].

In recent decades, health research has increasingly focused on environmental and behavioral factors that impact the incidence of ARI in children under five. One aspect that has become a significant focus is indoor air quality and its associated variables. Some factors that can influence the incidence of ARI in children under five include temperature, humidity, and ventilation in the home. In addition, mosquito coil use and family members' smoking behavior can also affect the incidence of ARI in children under five. This study aimed to identify and analyze the risks associated with temperature, humidity, ventilation, mosquito coil use, and smoking behavior on the incidence of ARI in children under five.

Methods

This study is a meta-analysis study using statistical techniques to quantify the results of studies on temperature, humidity, ventilation, mosquito coil use, smoking behavior, and their impact on ARI in toddlers in Indonesia from 2013-2023. Although this approach is objective and can quantitatively measure effects, journal selection with inclusion and exclusion criteria was necessary as the combined studies varied in quality, publication trends, and data limitations. After this selection, we chose a total of 27 articles. The following is an overview of the steps taken:

Next, the study results were entered, which included the values of treat positive, treat negative, outcome positive, and outcome negative. Then, Microsoft Excel calculated each article's Odds Ratio (OR), Log OR, and SE Log OR, and journals were grouped based on the same variables. After the data input stage, we conducted an analysis using Jeffrey's Amazing Statistics Program (JASP) application to evaluate bias and sensitivity in the study. The research's primary objective was to estimate the odds ratio using Mantel-Haenszel for the Fixed Effects model and DerSimonian-Laird for the random effects model. We used the random effects analysis model if there was significant variation between the variables or the heterogeneity p was less than 0.05.

The meta-analysis calculated the Prevalence Ratio (PR) that conveys:

1. If PR>1 and the confidence interval is not more than 1, the variable acts as a risk factor for ARI in children under five.
2. If PR<1 and the confidence interval exceeds 1, the variable is a protective factor against ARI in children under five.
3. The variable has no significant relationship if PR=1 and the confidence interval is not more than 1.

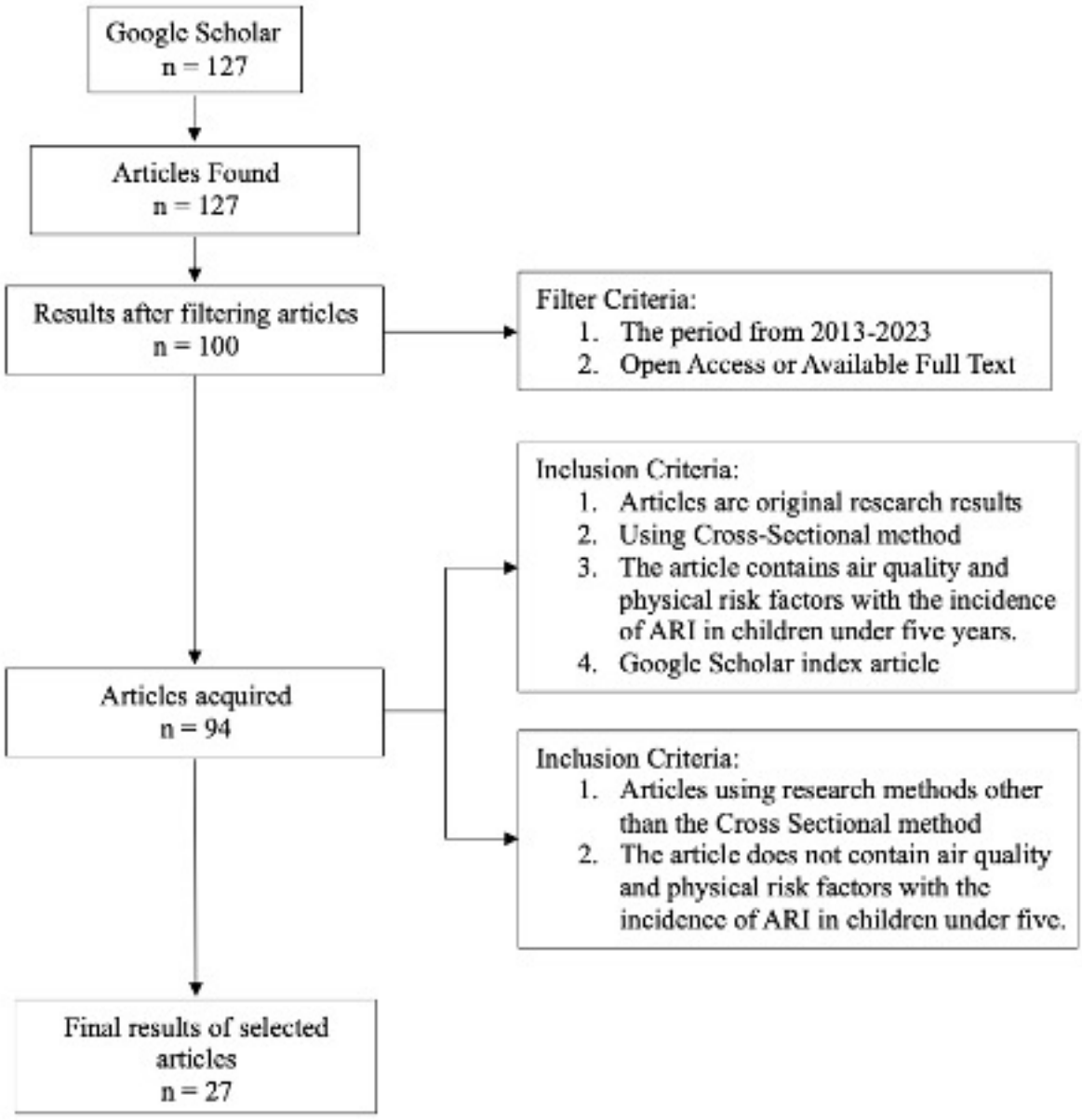

Fig. 1. Risk analysis of temperature, humidity, ventilation, use of mosquito repellent, and smoking behavior on the Incidence of ARI in Toddlers

Risk analysis of temperature with ARI in Toddlers

Table 1 reveals that the p-value in the heterogeneity test (0.710) is more significant than α, signifying that the study variation is homogenous. Therefore, the analysis employs the Fixed Effect model.

Table 1. Heterogeneity test of Fixed Effects method meta-analysis of temperature with ARI in Toddlers

	Q	df	p
Omnibus test of model coefficients	36.418	1	< .001
Test of residual heterogeneity	5.438	8	0.710

Note. *p* -values are approximate.
Note. The model was estimated using Fixed Effects method.

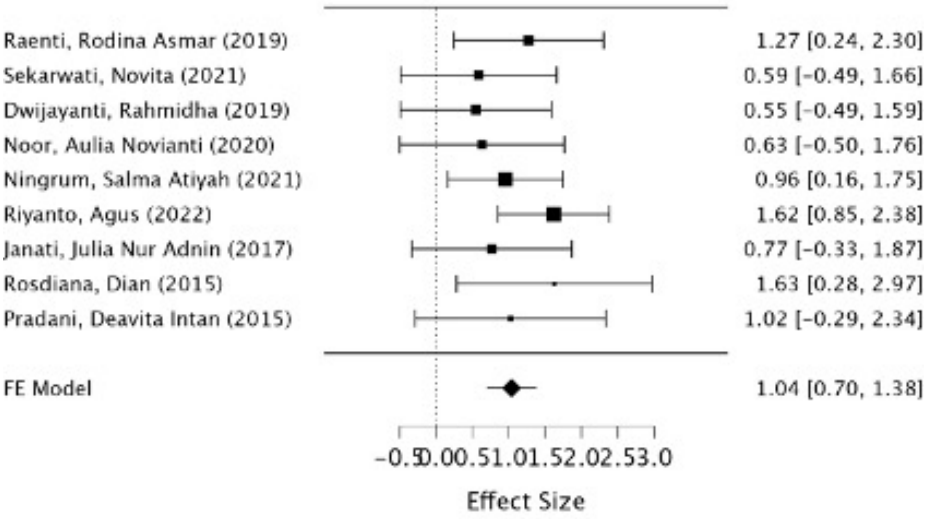

Fig. 2. Forest plot of temperature risk with ARI in Toddlers

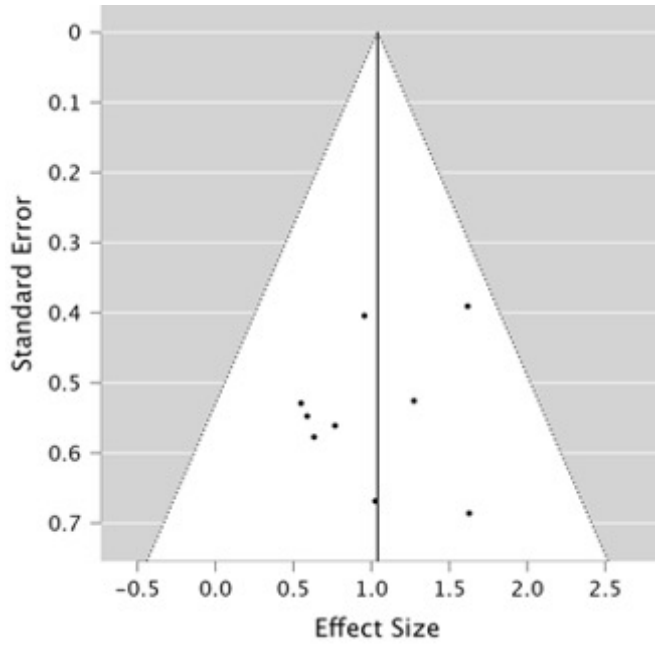

Fig. 3. Funnel Plot of Temperature Risk with ARI in Toddlers

The indoor temperature should kept within the range of 18°C-30°C. This temperature is affected by outside temperature, air humidity, and the temperature of objects around the room [7]. Variations in indoor temperature can arise from multiple sources, including insufficient ventilation, the density of occupants, building characteristics, and the geographical and topographical features of the region [8]. Based on the Fixed Effects (FE) Model in Fig. 2, the estimated Prevalence Ratio (PR) was 1.04 with a 95% CI between 0.70-1.38. The forest plot results show a PR of $E^{1.04}$=2.829, indicating that the risk of ARI in children under five increases about 2.829 times when conditions are not eligible compared to suitable needs. The funnel plot for the relationship between temperature and ARI among children under five shows no publication bias; this can be seen in Fig. 3 because the symmetrical pattern in the form of a black circle (plot) is within the triangle area. Furthermore, based on Egger's test, a p-value of 0.489 (p>α 0.05) was obtained, indicating no evidence of significant publication bias, as shown in Table 2.

The risk analysis results showed an association between unqualified house temperature and the risk of ARI in children under five. The risk of ARI in toddlers increases about 2,829 times if the temperature does not meet the requirements compared to the temperature that meets the requirements. Corresponding with findings from the Purwokerto Health Center area, which indicate a substantial association between temperature and ARI in toddlers (OR: 3.574, 95% CI: 1.275 - 10.014) [9]. However, these results contrast with other studies (p-value: 0.709, p>0.05) that investigated the connection between indoor air temperature and ARI occurrence and found no significant correlation among toddlers in the Spermonde Islands [10].

Table 2. Egger's Test Meta-Analysis of Temperature Risk with ARI in Toddlers

	z	p
sei	-0.691	0.489

Table 3. Heterogeneity test of Fixed Effects method meta-analysis of humidity with ARI in Toddlers

	Q	df	p
Omnibus test of model coefficients	65.841	1	< .001
Test of residual heterogeneity	17.268	10	0.069

Note. *p*-values are approximate.
Note. The model was estimated using Fixed Effects method.

Risk analysis of humidity with ARI in Toddlers

Table 3 reveals that the p-value in the heterogeneity test (0.069) is more significant than α, signifying that the study variation is homogenous. Therefore, the analysis employs the Fixed Effect model.

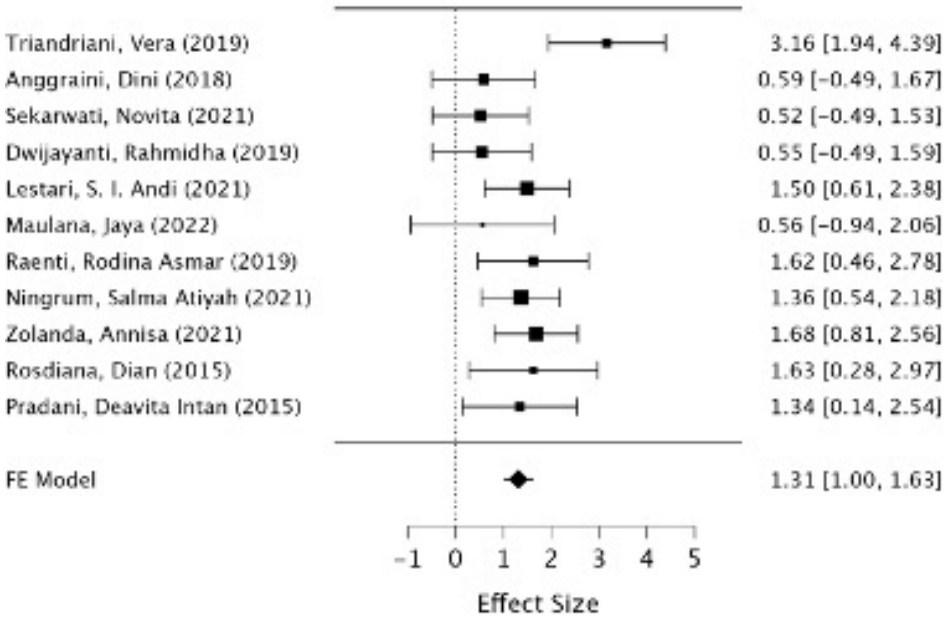

Fig. 4. Forest plot of humidity risk with ARI in Toddlers

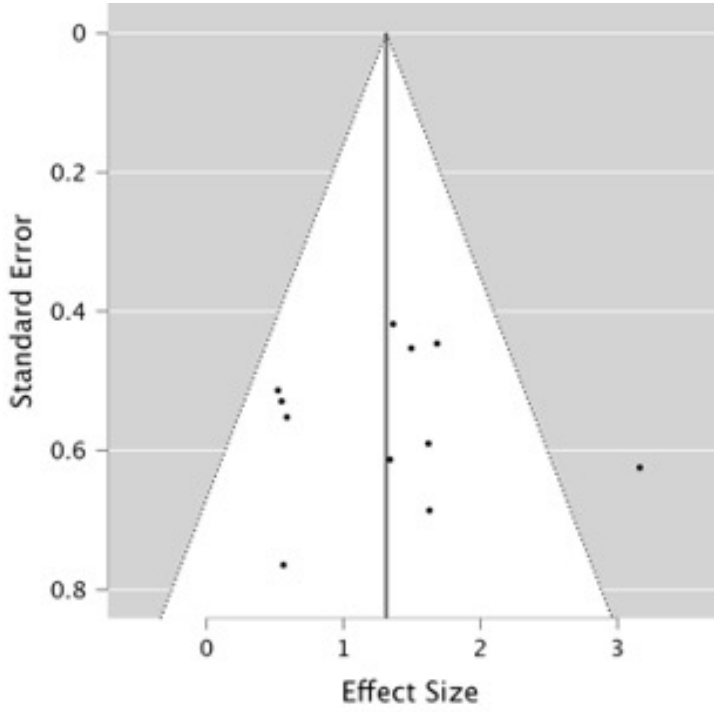

Fig. 5. Funnel Plot of Humidity Risk with ARI in Toddlers

High humidity will increase the spread of viruses and bacteria that cause ARI [11]. Fig. 4 shows that based on the Fixed Effects (FE) model, the estimated Prevalence Ratio (PR) is 1.31 with a 95% CI between 1.00-1.63. The Forest Plot results show a PR of $E^{1.31}$=3.706, indicating that the risk of ARI in children under five increases about 3.706 times when humidity conditions are not eligible compared to eligible humidity conditions. The Funnel Plot for the association between humidity and ARI among children under five indicates the absence of publication bias. Furthermore, based on Egger's test, a p-value of 0.928 (p > α 0.05) was obtained, indicating no evidence of significant publication bias, as shown in Table 4.

The risk analysis results showed an association between unqualified house moisture conditions and the risk of ARI in children under five. The risk of ARI in children under five increases about 3,706 times if the humidity conditions do not meet the requirements compared to those that meet the requirements. The Ministry of Health of Indonesia put forward health efforts regarding humidity in Regulation Number 1077/MENKES/PER/V/2011 concerning air health guidelines in home spaces with good humidity between 40%-60% [12]. In line with the research of Pradani (2015), the analysis established a connection between household humidity and the occurrence of ARI, yielding an odds ratio (OR) of 3.82 (with a 95% confidence interval of 1.15-12.7) and a statistically significant p-value of 0.024 [12]. Similarly, Triandriani and Hansen's research in 2019 identified a substantial association between ventilation in the bedrooms of toddlers within the Sidomulyo Health Center's jurisdiction and ARI incidence, supported by a very low p-value of <0.001 (0.009) and an OR of 4.779 [13].

Table 4. Egger's test meta-analysis of risk of humidity with ARI in Toddlers

	z	p
sei	0.091	0.928

Table 5. Heterogeneity test of fixed effects method meta-analysis of ventilation with ARI in Toddlers

	Q	df	p
Omnibus test of Model Coefficients	58.145	1	< .001
Test of Residual Heterogeneity	11.974	6	0.063

Note. p -values are approximate.
Note. The model was estimated using Fixed Effects method.

Risk analysis of ventilation with ARI in Toddlers

Table 5 reveals that the p-value in the heterogeneity test (0.063) is more significant than α, signifying that the study variation is homogenous. Therefore, the analysis employs the Fixed Effect Model.

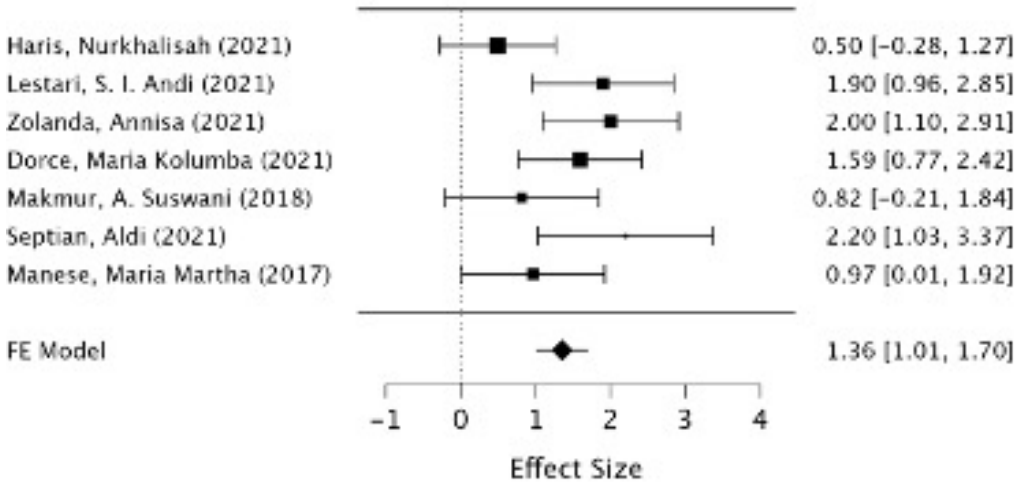

Fig. 6. Forest plot of ventilation risk with ARI in Toddlers

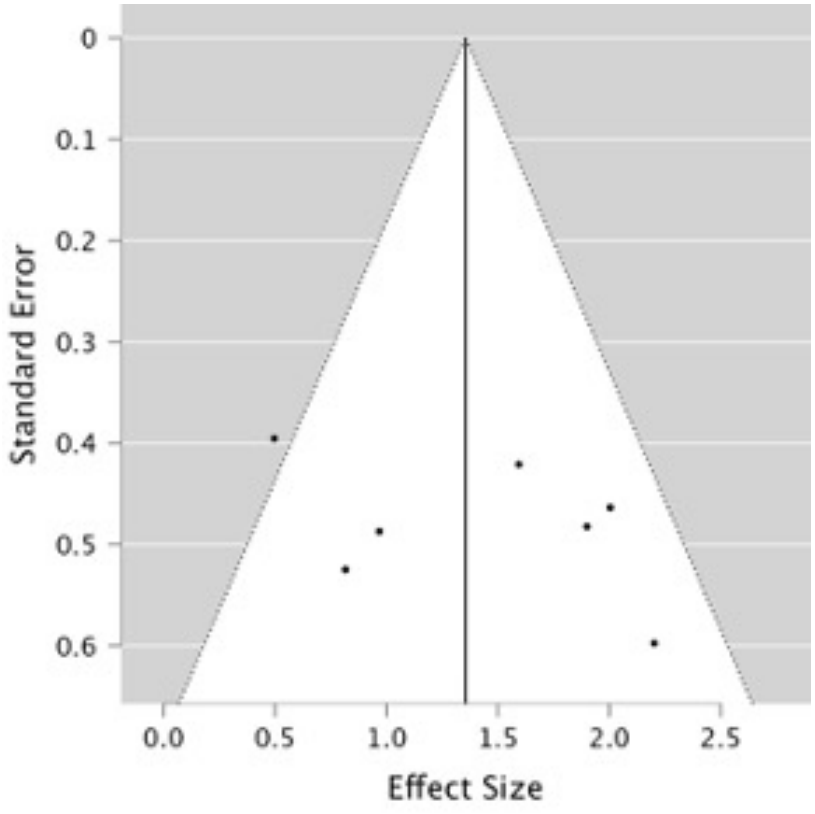

Fig. 7. Funnel plot of ventilation risk with ARI in Toddlers

Insufficient ventilation in rooms with toddlers raises the ARI risk. Poor airflow leads to indoor pollution build-up, including viruses, bacteria, and harmful particles, making it easier for children under five to be exposed to ARI-causing pathogens and breathe less fresh air [14]. Fig. 8 shows that based on the Fixed Effects (FE) Model, the estimated Prevalence Ratio (PR) is 1.36 with a 95% CI between 1.01 and 1.70. The Forest Plot results show a PR of $E^{1.36}$ =3.896, indicating that the risk of ARI in children under five increases about 3.896 times when ventilation conditions are not eligible compared to eligible ventilation conditions. The funnel plot in Fig. 9 indicated no publication bias for the connection between ventilation and ARI in children under five. Furthermore, based on Egger's test, a p-value of 0.112 (p>α 0.05) was obtained, indicating no evidence of significant publication bias, as shown in Table 6.

Regulation Number 1077/MENKES/PER/V/2011 mandates that ventilation should cover a minimum of 10% of the floor area. Inadequate ventilation can increase the house's O_2 and toxic CO_2 levels [15]. Risk analysis results indicated a link between unqualified home ventilation and the risk of ARI in children under five. ARI risk in toddlers rises by approximately 3,896 times when ventilation does not meet the requirements compared to when it does. These aligned with research in Surabaya city, showing that respondents with poor ventilation (less than 10%) have 2.85 times higher ARI risk than those with better ventilation (more than 10%) [16].

Table 6. Egger's test meta-analysis of ventilation risk with ARI in Toddlers

	z	p
sei	1.590	0.112

Table 7. Heterogeneity test of fixed effects method meta-analysis of mosquito coil use with ARI in Toddlers

	Q	df	p
Omnibus test of Model Coefficients	28.312	1	< .001
Test of Residual Heterogeneity	12.210	6	0.057

Note. p -values are approximate.

Note. The model was estimated using Fixed Effects method.

Risk analysis of mosquito coil use with ARI in Toddlers

Table 7 reveals that the p-value in the heterogeneity test (0.057) is more significant than α, signifying that the study variation is homogenous. Therefore, the analysis employs the Fixed Effect Model.

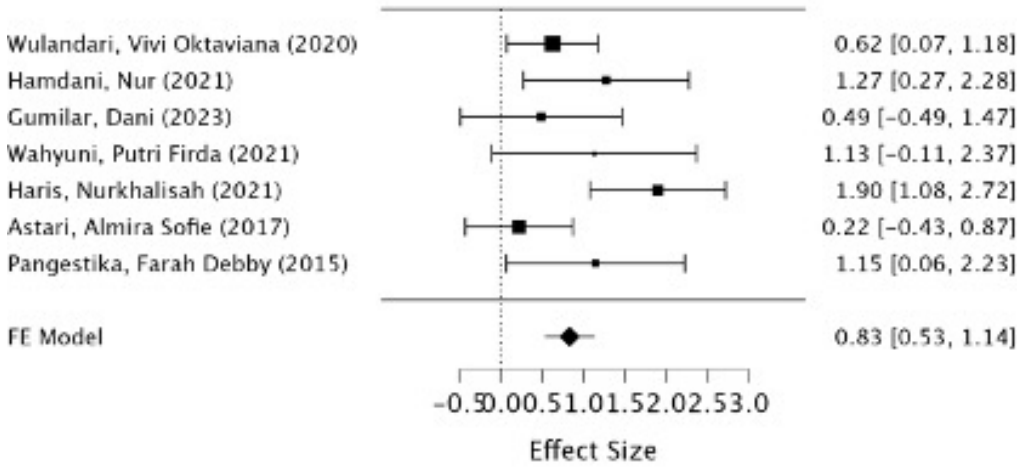

Fig. 8. Forest plot of risk of mosquito coil use with ARI in Toddlers

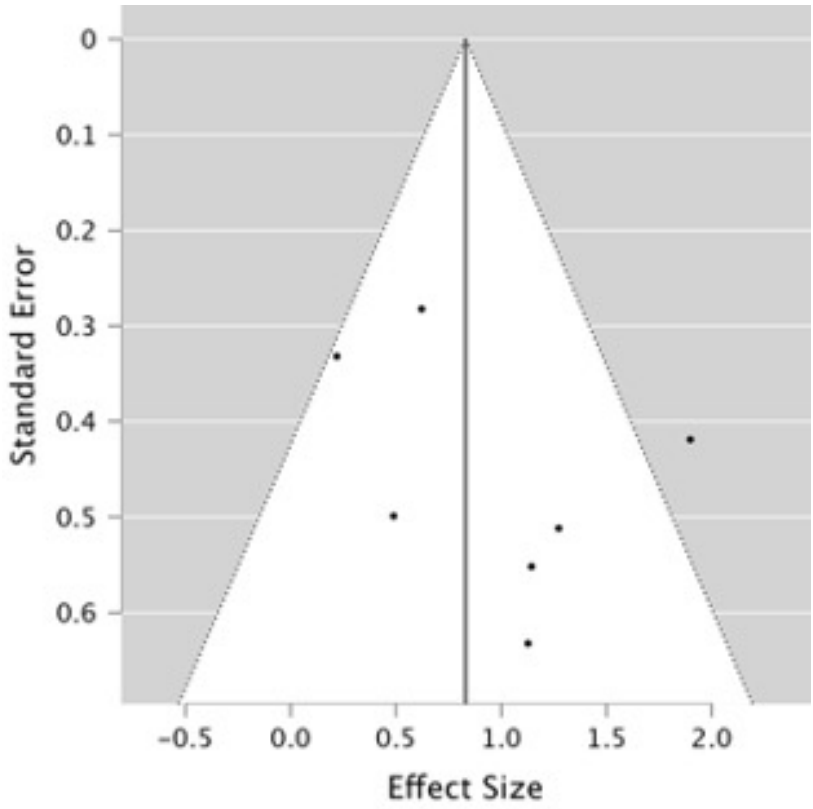

Fig. 9. Funnel plot of risk of mosquito coil use with ARI in Toddlers

Using mosquito coils as a mosquito-repelling incense product in rooms with toddlers can increase ARI risk, especially for those with sensitive respiratory systems, as some of these products emit chemicals that can be irritating [17]. Increased utilization of indoor spaces without proper ventilation can result in elevated indoor air pollution levels. This condition can create conditions conducive to the persistence of pathogens that cause ARI and increase the likelihood of transmission to toddlers [18]. Fig. 10 shows that based on the Fixed Effects (FE) Model, the estimated Prevalence Ratio (PR) is 0.83 with 95% CI between 0.53-1.14. The Forest Plot result reveals a PR of $E^{0.83}$=2.293, indicating that using mosquito coils in the house raises the ARI risk in children under five by about 2.293 times compared to those without their use. The funnel plot for the association between mosquito coils and ARI use among children under five indicates the absence of publication bias, as shown in Fig. 11. Furthermore, based on Egger's test, the p-value of 0.099 (p>α 0.05) indicates the absence of evidence of significant publication bias, as shown in Table 8.

The presence of family members using mosquito coils at home is associated with ARI risk in toddlers. Meta-analysis results indicated that ARI risk in children under five increased by around 2,293 times when family members used mosquito coils at home compared to those who did not. Likewise, a study conducted in Banjar City revealed a notable increase in ARI risk among toddlers residing with family members who smoke indoors, showing an odds ratio (OR) of 12.00, with a 95% confidence interval (CI) ranging from 3.66 to 39.32 [19]. The safety of mosquito repellents depends on the concentration of the active ingredients and the frequency of use. Among these products, mosquito coils, especially when their smoke is inhaled, carry a higher risk due to their higher concentration. Conversely, liquid mosquito repellents change into gas with varying concentrations, while electric mosquito coils, powered by electricity to produce smoke, have different concentration levels and are typically less risky [17]. A study in Jember District found that 75% of children diagnosed with ARI had families who used mosquito coils daily [18].

Table 8. Egger's test meta-analysis of the risk of mosquito coil use with ARI in Toddlers

	z	p
sei	1.648	0.099

Table 9. Heterogeneity test of fixed effects method meta-analysis of smoking behavior with ARI in Toddlers

	Q	df	p
Omnibus test of model coefficients	150.366	1	< .001
Test of residual heterogeneity	20.058	12	0.066

Note. *p* -values are approximate.

Note. The model was estimated using Fixed Effects method.

Risk analysis of smoking behavior with ARI in Toddlers

Table 9 reveals that the p-value in the heterogeneity test (0.066) is more significant than α, signifying that the study variation is homogenous. Therefore, the analysis employs the Fixed Effect Model.

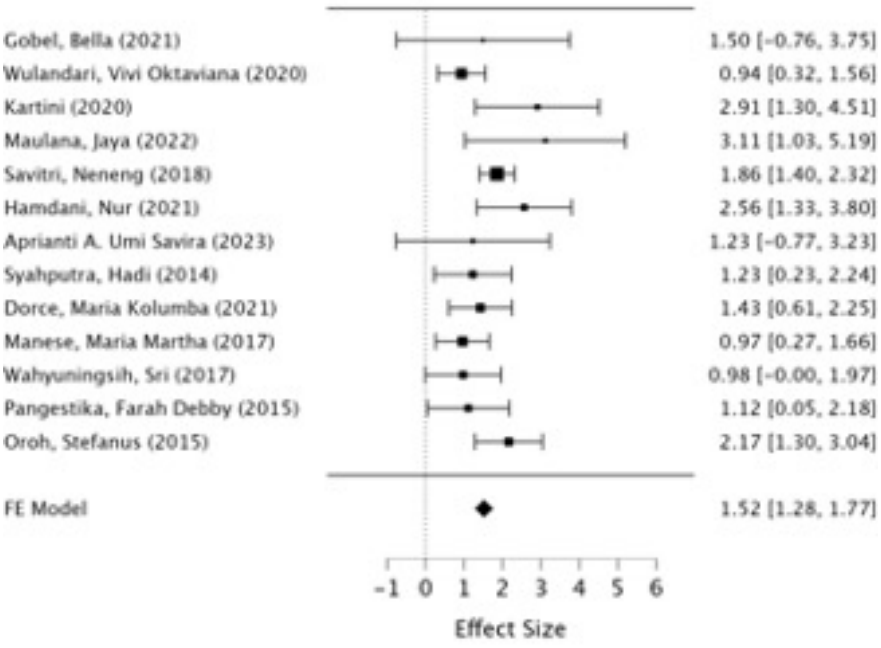

Fig. 10. Forest plot of risk of smoking behavior with ARI in Toddlers

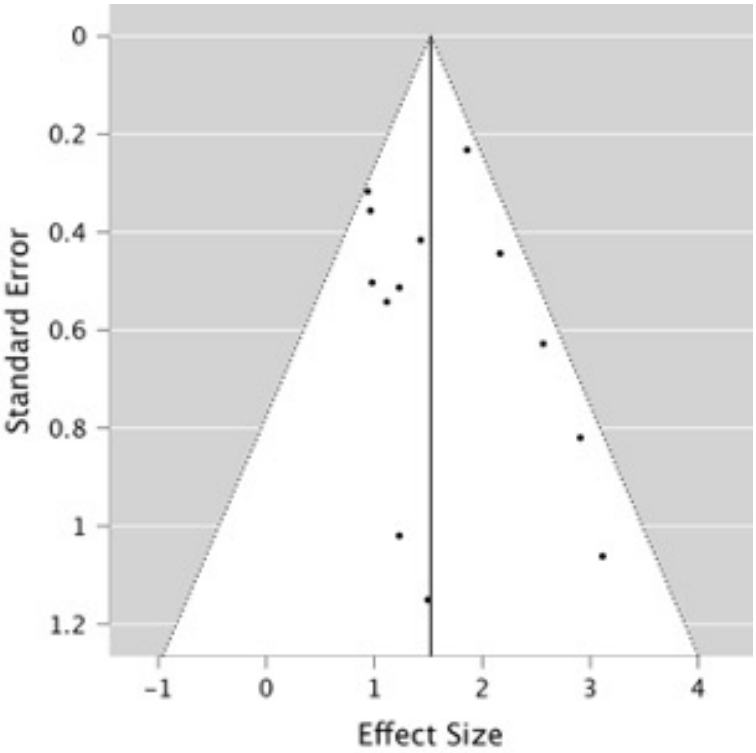

Fig. 11. Funnel Plot of Risk of Smoking Behavior with ARI in Toddlers

Smoking increases ARI risk in toddlers due to harmful substances in cigarette smoke, including indoor pollutants like carbon monoxide and toxic compounds. Smoke exposure weakens toddlers' immune systems and triggers respiratory tract inflammation, making them more susceptible to respiratory infections [20]. Children under five who inhale second-hand smoke from adult smokers are at an elevated risk of ARI, which can manifest as symptoms including coughs, colds, and respiratory infections [21].Fig. 12 shows that based on the Fixed Effects (FE) Model, the estimated Prevalence Ratio (PR) is 1.57 with a 95% CI between 1.28-1.77. The Forest Plot results reveal a cumulative PR of $E^{1.57}$=4.572, signifying that ARI risk in children under five is approximately 4.572 times higher when family members smoke than those who do not. The funnel plot for the relationship between smoking behavior and ARI in children under five reveals no publication bias, as shown in Fig. 13. Furthermore, based on Egger's test, the p-value of 0.348 (p>α 0.05) indicates the absence of evidence of significant publication bias, as shown in Table 10.

Smoking behavior carried out by family members around toddlers can result in exposure to cigarette smoke and significantly increase the risk of ARI up to 4,572 times higher than toddlers who live in a smoke-free environment. This risk increase was highlighted in a study conducted by Aprianti A. in 2023, emphasizing the association between smoking and elevated ARI risk in toddlers [22]. In alignment with a 2020 study by Kartini & Aripa, the research reveals that the case group predominantly included individuals with family members who were smokers (93.3%), while the control group primarily consisted of individuals who did not have family members who smoked (56.7%) [23].

Table 10. Egger's test meta-analysis of risk of smoking behavior with ARI in Toddlers

	z	p
sei	0.938	0.348

Table 11. Risk factors for the incidence of ARI in Toddlers

Independent variables	n (Articles)	Eksponential Fixed Effects (FE) models	Egger test
Smoking Behavior	13	1.52 (4.572)	0.348 (Unbiased)
Ventilation	7	1.36 (3.896)	0.112 (Unbiased)
Humidity	11	1.31 (3.706)	0.928 (Unbiased)
Temperature	9	1.04 (2.829)	0.489 (Unbiased)
Use of Mosquito Coils	7	0.83 (2.293)	0.099 (Unbiased)

Referring to the table of ARI risk factors in toddlers, the top three factors are smoking behaviour (4.572), ventilation (3.896), and humidity (3.706).

Conclusion

The meta-analysis results indicate that family members' smoking behaviour carries the highest risk for ARI in children under five, increasing the risk by approximately 4,572. Inadequate ventilation ranks as the second-highest risk, with a PR of roughly 3,896 times higher, followed by humidity, with a PR of approximately 3,706 times higher. Other variables, including temperature and the use of mosquito coils, also show significant associations with ARI in children under five, although the results may vary. It is advisable to prevent indoor smoking, control humidity, and ensure proper home ventilation to lower ARI rates. Health services can prioritize educating families about maintaining healthy indoor air.

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Competing interests

The authors assert that they have no competing interests.

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Ethical considerations

The authors have thoroughly addressed all ethical concerns, including plagiarism, informed consent, data integrity, publication duplication, and other related issues.

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