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Research article

Association between indoor environmental risk factors and pneumonia among preschool children in Urumqi : A case-control study

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ABSTRACT

Background: Pediatric pneumonia presents a significant global health challenge, particularly in low- and middle-income countries. This study aimed to investigate the incidence of pneumonia in preschool children in Urumqi and its association with indoor environmental factors.
Methods: This case-control study collected data from December 2018 to December 2019 on 1522 preschool children in Urumqi (779 boys and 743 girls) who were diagnosed with pneumonia by a physician. A control group of children who had never had pneumonia was matched in a 1:1 ratio based on gender, age, and ethnicity. Using questionnaires, data were collected on children's general characteristics, passive smoking, types of housing, flooring materials, and indoor dampness, analyzing potential factors associated with the incidence of pediatric pneumonia.
Results: Multivariate analysis revealed that cesarean birth (odds ratio [OR] = 1.27; 95 % confidence interval [95%CI] = 1.08–1.48), being an only child (OR = 1.32; 95%CI = 1.13–1.55), antibiotic treatment during the first year of life (OR = 2.51; 95%CI = 1.98–3.19), passive smoking during the mother's pregnancy (OR = 1.62; 95%CI = 1.24–2.13), living in multi-family apartment housing (OR = 1.64; 95%CI = 1.28–2.10) and other types of housing (OR = 1.47; 95%CI = 1.09–1.99), laminate flooring (OR = 1.31; 95%CI = 1.01–1.72), and tile/stone/cement flooring flooring (OR = 1.31; 95%CI = 1.06–1.61), and dampness in dwelling (during first year of

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mother's pregnancy) (OR = 1.30; 95%CI = 1.04–1.63) were risk factors for pediatric pneumonia. The use of fresh air filtration systems in children's residences (OR = 0.66; 95%CI = 0.50–0.86) was identified as a protective factor.

Conclusion: This study underscores the importance of indoor environmental factors in the prevention of pediatric pneumonia. Public health strategies should consider these factors to reduce the incidence of pneumonia in children. Future research needs to be conducted over a broader geographical range and consider a more comprehensive range of factors influencing pediatric pneumonia.

1. Background

Pneumonia remains a prevalent Lower respiratory infections among preschool children globally. In 2010, an estimated 120 million children under five were afflicted worldwide, leading to approximately 1.4 million fatalities [1]. The latest reports from 2022 indicate that, in 2019, the mortality rate due to lower respiratory infections in children under the age of five was 13.9 %. Although specific mortality rates attributable to pneumonia were not reported, this data suggests a downward trend in fatalities [2]. A significant health survey, China, Children, Homes, Health (CCHH), was conducted across ten Chinese cities in September 2010. This survey revealed that the incidence of pneumonia in Chinese preschoolers varied from 25.5 % to 41.7 % [3]. Concurrently, our focused study in Urumqi indicated a concerning prevalence rate of 40.9 % among this demographic [4]. A decade later, a follow-up CCHH national cross-sectional study encompassing seven Chinese cities was executed. Our analysis of this data indicated a decline in the age-adjusted pneumonia prevalence among preschool children, ranging from 23.8 % to 31.3 %, a notable decrease from the figures reported in 2019 [5]. While comprehensive data on the prevalence and determinants of pneumonia in preschool children across China are yet to be published by CCHH, our preliminary findings in Urumqi show a prevalence rate of approximately 29.5 % [6]. Intriguingly, these findings suggest a potential correlation between indoor environmental factors and the incidence of pneumonia in this age group [6]. To delve deeper into this association, we leveraged data from the recent cross-sectional survey. We meticulously gathered information from 1522 preschool children diagnosed with pneumonia in the past year and matched them with children who had not contracted the disease, considering variables such as gender, age, and ethnicity. This approach enabled us to rigorously explore the relationship between indoor environmental factors and pneumonia prevalence in preschool children.

2. Subjects and methods

Subject. In December 2019, we conducted a study involving 1522 preschool children. These children were diagnosed with pneumonia within the 12 months preceding December 2019, effectively covering the period from December 2018 to December 2019. Selected from Xinshi, Shayibake, Tianshan, Toutunhe, Shuimogou, and Midong districts of Urumqi, the study aimed to capture a comprehensive snapshot of pneumonia cases within this timeframe. A control group was concurrently assembled, comprising children who had never contracted pneumonia. The controls were recruited from the same kindergartens and classrooms as the case group children and were matched on a 1:1 ratio based on gender, age, and ethnicity. This matching ensures a contemporaneous comparison group that reflects the population at risk during the same period. No additional geographic matching was performed. The study received ethical approval from the Ethics Committee of Fudan University (Approval Nos.: IRB00002408 & FWA00002399). Written informed consent was obtained from the parents or guardians of all participants.

Questionnaire. Our research employed a questionnaire-based survey for both case and control groups. The questionnaire, adapted from the one used in the CCHH study [3] and modified to suit Urumqi's context, encompassed various domains: (1) Demographic details such as gender, ethnicity, and age; (2) Feeding practices, including exclusive child status and breastfeeding duration; (3) Incidence and history of pneumonia in children; (4) Characteristics of the living environment, including type of housing, decoration, furniture, and materials used for floors and walls; (5) Lifestyle habits, covering indoor pet and plant keeping, smoking habits, and the use of air conditioning and air filtration systems. Prior to the survey, we obtained approval from the Urumqi Education Bureau and conducted the survey among parents at selected kindergartens during parent-teacher meetings. Trained surveyors provided detailed explanations of the questionnaire to ensure comprehensive and accurate responses.

Determination of pneumonia and associated predictors in preschool children. Outcomes were determined based on: (1) Parental reports of children diagnosed with pneumonia by a physician at least once in the past year. Pneumonia was defined for this study according to the World Health Organization (WHO) clinical criteria, which include symptoms such as cough or difficulty breathing, with rapid breathing (respiratory rate >50 breaths/min for children aged 2–12 months, and >40 breaths/min for children aged 1–5 years), or chest indrawing, with or without fever. Additionally, physician diagnosis based on chest X-ray findings showing lung consolidation or infiltrates was considered [7]; (2) Classification of ethnicities, with a focus on minority groups in Xinjiang, such as Uyghur, Kazakh, and Hui, apart from the Han majority; (3) Exposure to indoor passive smoking, defined as the presence of indoor smoking by family members or others [8]; (4) Evidence of dampness in living spaces, indicated by visible mold, moisture, or water damage [4].

Data analysis. Data were compiled using Epidata 3.1 and analyzed using R software (version 4.3.0). The chi-square test was applied for univariate analysis. Multivariable conditional logistic regression was utilized to explore factors associated with pneumonia incidence in preschool children, reporting odds ratio (OR) and 95 % confidence interval (CI). Differences with $P < 0.05$ were considered statistically significant.

3. Results

3.1. Participant demographics

In the initial phase of our study, a total of 1725 preschool children were identified for the case group. However, due to the application of inclusion and exclusion criteria, incomplete information, and refusal to participate, the number was narrowed down to 1522 children who were finally included in the case group. Similarly, for the control group, 1700 children were initially matched as potential participants. Following the same criteria for exclusion and based on the availability of complete information and willingness to participate, 1522 healthy children were successfully matched as controls. Consequently, the study ultimately included 3044 preschool children from Urumqi, evenly divided into case and control groups, each consisting of 779 boys (51.2 %) and 743 girls (48.8 %). In terms of ethnicity, the participants were predominantly of Han ethnicity, comprising 1342 (88.2 %) children across both groups. The remaining 180 (11.8 %) participants belonged to other ethnic groups. The age range in the case group was from 2.00 to 7.49 years, and in the control group from 2.00 to 7.66 years. Both groups had 296 children aged 2–4 years (19.4 %), 517 children aged 4–5 years (34.0 %), and 709 children aged 5–7 years (46.6 %).

3.2. Pneumonia incidence comparison by characteristics (Table 1)

The analysis revealed significant differences between the case and control groups in several aspects: birth mode, only child status, gestational period, duration of breastfeeding, and antibiotic treatment during the first year of life (all $P < 0.05$).

3.3. Univariate analysis of pneumonia incidence and indoor environmental factors (Table 2)

Key indoor environmental factors associated with pneumonia in children included Mother smoking, passive smoking during mother's pregnancy, passive smoking in residence (child aged 0–1 years), use of air purifiers in child's residence, use of fresh air filters in child's residences, type of house (child's residence), flooring materials in child's residence, wall surface materials in child's residence, dampness in dwelling (during first year of mother's pregnancy) (all $P < 0.05$).

3.4. Multivariate conditional logistic regression analysis (Table 3)

In the multivariate analysis, with pneumonia incidence as the dependent variable (0 = no; 1 = yes), nine variables emerged as significantly associated with pneumonia incidence. These included cesarean birth (OR = 1.27; 95%CI = 1.08–1.48), being an only child (OR = 1.32; 95%CI = 1.13–1.55), antibiotic treatment in the first year of life (OR = 2.51; 95%CI = 1.98–3.19), passive smoking during the mother's pregnancy (OR = 1.62; 95%CI = 1.24–2.13), residing in multi-family apartments (OR = 1.64; 95%CI = 1.28–2.10) and other types of housing (OR = 1.47; 95%CI = 1.09–1.99), composite flooring (OR = 1.31; 95%CI = 1.01–1.72) and ceramic/stone/cement flooring (OR = 1.31; 95%CI = 1.06–1.61), and Dampness in dwelling (during first year of mother's pregnancy) (OR = 1.30; 95%CI = 1.04–1.63) as risk factors. The use of fresh air filtration systems in the child's residence emerged as a protective factor (OR = 0.66; 95%CI = 0.50–0.86).

Table 1
Demographics and characteristics of the AR and controls groups ($n = 3044$).

Factors	Control group (%)	Pneumonia group (%)	χ^2	*P* value
Type of birth delivery			13.70	< 0.01
Normal childbirth	777 (51.1)	675 (44.3)		
Cesarean delivery	745 (48.9)	847 (55.7)		
Only child			19.72	< 0.01
Yes	668 (43.9)	548 (36.0)		
No	854 (56.1)	974 (64.0)		
Premature labour			9.64	< 0.01
Yes	1419 (93.2)	1458 (95.8)		
No	103 (6.8)	64 (4.2)		
Birth weight			2.80	0.25
Low birth weight	164 (10.8)	145 (9.5)		
Normal birth weight	1197 (78.6)	1234 (81.1)		
Macrosomia	161 (10.6)	143 (9.4)		
Duration of breastfeeding			7.40	< 0.01
< 6 months	511 (33.6)	583 (38.3)		
≥6 months	1011 (66.4)	939 (61.7)		
Antibiotic treatment during the first year of life			76.02	< 0.01
Yes	135 (8.9)	304 (20.0)		
No	1387 (91.1)	1218 (80.0)		

Table 2
Univariate analysis of pneumonia and indoor environmental factors in preschool children between pneumonia and control groups ($n = 3044$).

Factors	Control group (%)	Pneumonia group (%)	χ^2	*P* value
Father smoking			2.94	0.09
Yes	563 (37.0)	609 (40.0)		
No	959 (63.0)	913 (60.0)		
Mother smoking			4.28	0.04
Yes	11 (0.7)	23 (1.5)		
No	1511 (99.3)	1499 (98.5)		
Passive smoking during mother's pregnancy			21.81	< 0.01
Yes	372 (24.4)	488 (32.1)		
No	1150 (75.6)	1034 (67.9)		
Passive smoking in residence (child aged 0–1 years)			7.40	< 0.01
Yes	479 (31.5)	550 (36.1)		
No	1043 (68.5)	972 (63.9)		
Flowering plants in home (child aged 0–1 years)			1.54	0.22
Yes	380 (25.0)	410 (26.9)		
No	1142 (75.0)	1112 (73.1)		
Hairy pets in home (child aged 0–1 years)			1.17	0.28
Yes	48 (3.2)	59 (3.9)		
No	1474 (96.8)	1463 (96.1)		
Use of air purifiers in child's residence			4.13	0.04
Yes	502 (33.0)	450 (29.6)		
No	1020 (67.0)	1072 (70.4)		
Use of air conditioning in child's residence			2.61	0.11
Yes	528 (34.7)	486 (31.9)		
No	994 (65.3)	1036 (68.1)		
Use of fresh air filters in child's residences			12.98	< 0.01
Yes	204 (13.4)	141 (9.3)		
No	1318 (86.6)	1381 (90.7)		
Type of house (child's residence)			18.11	< 0.01
Single-family homes, single-family houses, townhouses	213 (14.0)	143 (9.4)		
multi-family apartment housing	1077 (70.8)	1166 (76.6)		
Others	232 (15.2)	213 (14.0)		
Size of house (child's residence)			0.91	0.34
< $75m^2$	351 (24.6)	391 (26.1)		
$\geq 75m^2$	1076 (75.4)	1105 (73.9)		
Flooring materials in child's residence			18.49	< 0.01
Solid Wood Flooring	308 (20.2)	241 (15.8)		
Multi-layer solid wood flooring	76 (5.0)	81 (5.3)		
composite flooring	230 (15.1)	252 (16.6)		
Bamboo Flooring	25 (1.6)	22 (1.4)		
ceramic/stone/cement flooring	816 (53.6)	884 (58.1)		
PVC/plastic/plastic leather flooring	15 (1.0)	12 (0.8)		
Other	52 (3.4)	30 (2.0)		
Carpets or mats in child's residence			0.25	0.62
Yes	189 (12.4)	180 (11.8)		
No	1333 (87.6)	1342 (88.2)		
Wall surface materials in child's residence			23.76	< 0.01
Wallpaper	623 (40.9)	618 (40.6)		
Water-based paint/latex paint	520 (34.2)	594 (39.0)		
Oil-based paint	6 (0.4)	14 (0.9)		
Wooden board	13 (0.9)	7 (0.5)		
Lime/cement	44 (2.9)	24 (1.6)		
Stucco	255 (16.8)	218 (14.3)		
Seaweed mud	17 (1.1)	21 (1.4)		
Others	44 (2.9)	26 (1.7)		
Purchase of new furniture (1 year before mother's pregnancy)			0.56	0.45
Yes	376 (24.7)	394 (25.9)		
No	1146 (75.3)	1128 (74.1)		
Home renovation (1 year before mother's pregnancy)			0.11	0.74
Yes	262 (17.2)	269 (17.7)		
No	1260 (82.8)	1253 (82.3)		
Dampness in dwelling (during first year of mother's pregnancy)			8.58	< 0.01
Yes	193 (12.7)	250 (16.4)		
No	1329 (87.3)	1272 (83.6)		
Purchase of new furniture (during mother's pregnancy)			0.67	0.41
Yes	185 (12.2)	200 (13.1)		
No	1337 (8738)	1322 (86.9)		
Home renovation (during mother's pregnancy)			0.04	0.85
Yes	135 (8.9)	138 (9.1)		

(*continued on next page*)

Table 2 (*continued*)

Factors	Control group (%)	Pneumonia group (%)	χ^2	*P* value
No	1387 (91.1)	1384 (90.9)		
Dampness in dwelling (during mother's pregnancy)			0.12	0.73
Yes	163 (10.7)	169 (11.1)		
No	1359 (89.3)	1353 (88.9)		
Purchase of new furniture (when child aged 0–1 years)			1.45	0.23
Yes	182 (12.0)	161 (10.6)		
No	1340 (88.0)	1361 (89.4)		
Home renovation (when child aged 0–1 years)			0.22	0.64
Yes	126 (8.3)	119 (7.8)		
No	1396 (91.7)	1403 (92.2)		
Dampness in dwelling (when child aged 0–1 years)			1.90	0.17
Yes	144 (9.5)	167 (11.0)		
No	1378 (90.5)	1355 (89.0)		

Table 3
Multivariate logistic regression analysis of the onset of pneumonia in preschool children between pneumonia and control groups ($n = 3044$).

Factors	β	*S·E*	Waldχ^2	*P* value	*OR*	95%*CI*
Cesarean Delivery	0.24	0.08	8.80	< 0.01	1.27	1.08–1.48
Only Child	0.28	0.08	12.14	< 0.01	1.32	1.13–1.55
Premature Labour	−0.40	0.18	5.18	0.02	0.67	0.47–0.95
Duration of Breastfeeding ≥6 Months	−0.15	0.08	3.48	0.06	0.86	0.73–1.01
Antibiotic Treatment During the First Year of Life	0.92	0.12	57.18	< 0.01	2.51	1.98–3.19
Passive Smoking During Mother's Pregnancy	0.48	0.14	12.30	< 0.01	1.62	1.24–2.13
Mother Smoking	0.56	0.41	1.90	0.17	1.75	0.79–3.88
Passive Smoking in Residence (Child Aged 0–1 Years)	−0.18	0.13	1.76	0.18	0.84	0.65–1.09
Use of Air Purifiers in Child's Residence	−0.03	0.09	0.14	0.71	0.97	0.81–1.15
Use of Fresh Air Filters in Child's Residences	−0.42	0.14	9.26	< 0.01	0.66	0.50–0.86
Type of House (Child's Residence)						
Single-Family Homes, Single-Family Houses, Townhouses			15.61	< 0.01		
Multi-Family Apartment Housing	0.49	0.13	15.55	< 0.01	1.64	1.28–2.10
Others	0.39	0.15	6.23	0.01	1.47	1.09–1.99
Flooring Materials in Child's Residence						
Solid Wood Flooring			8.50	0.20		
Multi-layer Solid Wood Flooring	0.26	0.20	1.69	0.19	1.29	0.88–1.89
Composite Flooring	0.27	0.14	4.01	0.05	1.31	1.01–1.72
Bamboo Flooring	0.27	0.33	0.68	0.41	1.31	0.69–2.51
Ceramic/Stone/Cement Flooring	0.27	0.11	6.30	0.01	1.31	1.06–1.61
PVC/Plastic/Plastic Leather Flooring	0.24	0.43	0.31	0.58	1.27	0.55–2.95
Other	−0.13	0.27	0.23	0.63	0.88	0.52–1.49
Wall Surface Materials in Child's Residence						
Wallpaper			14.04	0.05		
Water-Based Paint/Latex Paint	0.13	0.09	2.10	0.15	1.14	0.96–1.36
Oil-Based Paint	0.91	0.52	3.02	0.08	2.48	0.89–6.92
Wooden Board	−0.27	0.51	0.28	0.60	0.77	0.28–2.06
Lime/Cement	−0.53	0.28	3.63	0.06	0.59	0.34–1.02
Stucco	−0.15	0.12	1.59	0.21	0.86	0.68–1.09
Seaweed Mud	0.38	0.36	1.15	0.29	1.47	0.73–2.97
Others	−0.22	0.29	0.59	0.45	0.80	0.45–1.42
Dampness in Dwelling (During First Year of Mother's Pregnancy)	0.26	0.12	5.16	0.02	1.30	1.04–1.63

4. Discussion

This study conducted a comprehensive analysis of preschool children's pneumonia cases in Urumqi, focusing on the association with indoor environmental factors. Pediatric pneumonia remains a significant public health challenge, especially in low- and middle-income countries, where it continues to be one of the leading causes of child mortality [9–11]. Our findings align with global research, highlighting the substantial impact of indoor environmental factors, such as passive smoking, housing types, flooring materials, and dampness, on the incidence of pneumonia in children [5]. A local study in Urumqi revealed that the prevalence of pneumonia in preschool children was associated with factors like home mold/dampness, windowpane condensation, and environmental tobacco smoke, along with chemicals emitted from interior surface materials [4]. This is consistent with our findings, which indicate a close relationship between the incidence of pneumonia in preschool children in Urumqi and various indoor environmental factors. Moreover, global studies have shown that the incidence of childhood pneumonia is associated with indoor air pollution, poor sanitation, lack of basic immunization, and lower family income [12].

Our study identified cesarean birth as a risk factor for pediatric pneumonia. Research by Montoya-Williams et al. [13] suggests that cesarean delivery may impact the infant's microbiome, potentially explaining the association between cesarean birth and adverse child health outcomes, such as asthma and obesity. This could be related to differences in the gut microbiome of cesarean-born infants, which are more likely to contain skin flora or potentially pathogenic microbes. Furthermore, our study found that being an only child may pose a higher risk of pediatric pneumonia, potentially due to factors related to the home environment, social interaction, and microbial exposure. Research by Verani et al. [14] indicates that household crowding is a significant risk factor for pneumonia in well-nourished children, underscoring the role of the home environment and social interaction in the risk of pediatric pneumonia. Additionally, the lack of social interaction may be a contributing factor to the increased risk of pneumonia in only children, as suggested by research from Abebaw et al. [15], which found that children from larger families had a lower risk of pneumonia, possibly due to more social interaction and microbial exposure.

Our study also found that early antibiotic treatment (0–1 years old) is associated with the incidence of pediatric pneumonia. Research by Ni et al. [16] indicates that early antibiotic exposure may disrupt the balance of the gut microbiome, increasing the risk of asthma and allergic rhinitis in children. This could be related to the impact of the gut microbiome on the development of the immune system, thereby affecting children's resistance to respiratory infections. However, research by Bubser et al. [17] found that early antibiotic treatment did not increase the risk of carrying potential pathogens in preterm infants. Yet, research by Chen et al. [18] points out that early antibiotic exposure is associated with an increased risk of bronchopulmonary dysplasia in very low birth weight infants. These findings emphasize the importance of a conservative approach to antibiotic use in early childhood, especially when developing preventive measures for respiratory diseases in children.

Our study further revealed that passive smoking during the mother's pregnancy is a significant risk factor for pediatric pneumonia. This is consistent with our survey results from seven cities in the CCHH study, which indicated that environmental tobacco smoke (ETS) is a significant risk factor for pediatric pneumonia [5]. A literature review by Vanhanova [19–22] highlights that passive smoking during pregnancy is associated with various pathological consequences for children's future health, including an increased incidence of respiratory diseases. Additionally, our study found that living in multi-family apartment housing and other types of housing is associated with the incidence of pediatric pneumonia. Research by Mekle et al. [23] in India also found similar results, indicating that low socioeconomic status and poor housing conditions are significant risk factors for community-acquired pneumonia (CAP) in children. Moreover, our study identified composite flooring and ceramic/stone/cement flooring as risk factors for pediatric pneumonia. This may be due to these materials' propensity to accumulate dust and microbes, thereby increasing the risk of respiratory infections. Flooring materials can affect indoor air quality and, consequently, children's respiratory health. Particularly in poorly ventilated residences, flooring materials can become breeding grounds for bacteria and viruses, increasing children's exposure to respiratory pathogens. Our study also found that dampness in the home during the year before the mother's pregnancy is a risk factor for pediatric pneumonia. Research by Lu et al. [24] in preschool children in Changsha also found a significant association between exposure to mold/dampness and children's pneumonia. Additionally, research by Zheng et al. [25] in Nanjing found that household dampness, poor ventilation, cooking with coal or natural gas (compared to electricity), new furniture, and "modern" flooring and wall covering materials are significantly associated with pediatric pneumonia. However, there is a lack of reports on the association between indoor dampness during the year before pregnancy and pediatric pneumonia. Our study also discovered that the use of fresh air filtration systems in children's residences is a protective factor against pediatric pneumonia. This may be related to the improvement of indoor air quality and the reduction of pathogens in the air by fresh air filtration systems. Research by Wahdan et al. [26] in children's operating rooms in Egypt found that the use of electronic air purification devices significantly reduced the risk of surgical site infections, indicating the effectiveness of air purification technology in controlling airborne pathogens. Research by Rodrigues et al. [27] points out that indoor air pollution is one of the main factors leading to children's allergies, asthma, immune reactions, and respiratory infections, and the application of fresh air filtration systems shows potential effectiveness in reducing respiratory diseases in children, possibly due to the improvement of indoor air quality by fresh air filtration systems.

In conclusion, this study provides important insights into the significant impact of indoor environmental factors, such as passive smoking, housing types, flooring materials, and indoor dampness, on the risk of pediatric pneumonia. These factors' identification and management are crucial for developing effective public health strategies. This study emphasizes the importance of preventive measures, particularly in terms of residential design and indoor air quality improvement, for the prevention of pediatric pneumonia. However, this study still has some limitations. Firstly, the study was conducted only in Urumqi, which may not fully represent the situation in other regions or countries. Regional-specific environmental factors and lifestyles may affect the general applicability of the study results. Secondly, due to the case-control study design used in this study, it is difficult to determine causality. The data used in the study were mainly based on questionnaire surveys, and the data reported by parents may be subject to recall bias, and the study results may be affected by uncontrolled confounding factors. Additionally, individuals who declined to participate or were excluded for various reasons might have presented different characteristics or exposures compared to those included, which could influence the study's conclusions. Another limitation of our study is the lack of data on socio-economic status. Economic factors may underlie many of the associations observed in this study. For instance, families with higher incomes may be more likely to afford air purifiers and maintain lifestyles that are protective against infectious diseases. The absence of socio-economic data means we could not account for these potential confounding factors. Future studies should include socio-economic data to better understand its influence on the risk of pediatric pneumonia. Finally, it is important to acknowledge the timing of the study, which was conducted from December 2019. The evolving nature of environmental factors, healthcare practices, and public health policies, especially in the context of recent global health events, may have influenced the prevalence and risk factors associated with pediatric pneumonia since the completion of this study. This temporal gap may limit the applicability of our findings to the current context, underscoring the need for ongoing research to validate and update the study's conclusions in light of new evidence and changing conditions. Future research should consider conducting studies in a broader geographical range to increase the general applicability of the study results and more comprehensively consider the impact factors of pediatric pneumonia from multiple aspects, such as indoor environment, socioeconomic factors, outdoor factors, and the environment of the kindergartens where the children are located. Secondly, by implementing long-term cohort studies, to better understand the long-term impact of indoor environmental factors on children's respiratory health. This will help to reveal potential causal relationships and long-term health consequences and provide a scientific basis for developing effective prevention and intervention measures.

5. Conclusion

This study conducted an in-depth analysis of pediatric pneumonia cases among preschool children in Urumqi, revealing that indoor environmental factors, including passive smoking, types of housing, flooring materials, and indoor dampness, significantly increase the risk of pneumonia in children. Additionally, the use of fresh air filtration systems was found to be an effective protective factor against pediatric pneumonia. These findings highlight the importance of improving indoor environments in the prevention of pediatric pneumonia. Public health strategies should take these indoor environmental factors into account to reduce the incidence of pneumonia in children.

Ethics approval and consent to participate

The study was conducted strictly in accordance with the Declaration of Helsinki and approved by the research ethics committee of Fudan University (protocol no. IRB00002408 & FWA00002399), all parents and class teachers of the children under investigation have signed written informed consent.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available because the data belong to School of Nursing & Health Management, Shanghai University of Medicine & Health Sciences. Data will be made available on request.

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CRediT authorship contribution statement

Chong Zhao: Writing – original draft, Methodology, Investigation. **Li Wang:** Methodology, Investigation, Formal analysis. **Xiaohui Xi:** Methodology, Investigation, Funding acquisition. **Enhong Dong:** Investigation. **Xiaolan Wang:** Investigation. **Yingxia Wang:** Investigation. **Jian Yao:** Investigation. **Jinyang Wang:** Investigation, Funding acquisition. **Xiaojuan Nie:** Investigation. **Jianhua Zhang:** Investigation. **Haonan Shi:** Investigation. **Ye Yang:** Methodology, Investigation, Formal analysis. **Peng Zhang:** Software, Methodology, Investigation. **Tingting Wang:** Writing – review & editing, Methodology, Investigation, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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