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ORIGINAL RESEARCH

Trends and Dynamics of Respiratory Viruses in Hospitalized Children of Fuzhou: Insights Into the Impact of COVID-19 Pandemic Control Measures

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Purpose: This study aimed to investigate the prevalence of common respiratory viruses among children with acute respiratory infections in Fuzhou from 2017 to 2023, considering the varying Corona Virus Disease 2019 (COVID-19) epidemic control measures in place.

Patients and Methods: This study retrospectively analyzed the detection of respiratory viruses in children diagnosed with acute respiratory infections at a tertiary hospital in Fuzhou during the study period. The analysis covers three distinct phases: Phase I (2017–2019), Phase II (2020–2022), and Phase III (2023). The subjects of this study included adenovirus (ADV), influenza A virus (Flu A), influenza B virus (Flu B), parainfluenza virus types 1, 2, and 3 (PIV-1, PIV-2, PIV-3), and respiratory syncytial virus (RSV).

Results: A total of 24,838 throat swab samples were collected, resulting in an overall positive detection rate of 17.87% (4439/24,838). The positive detection rates of respiratory viruses among hospitalized children in Phases I, II, and III were 18.51%, 18.27%, and 15.90%, respectively, demonstrating a statistically significant decreasing trend over the years ($P < 0.001$). Among the detected viruses, RSV, PIV-3, and Flu A were the most prevalent. RSV infections was most common in children under six years of age. Seasonal trends for Flu A, PIV-3, and RSV varied throughout the outbreak; specifically, the detection rate of Flu A increased during March and April in 2023, while RSV detection rebounded sharply from April to June. The incidence of mixed respiratory virus infections was 0.40% (100/24,838), the most common being PIV-3 and RSV.

Conclusion: Using COVID-19 safety rules has helped stop the spread of some viruses in kids. But these rules have not made much difference in how often RSV and PIV-3 viruses show up.

Keywords: children, coronavirus disease 2019, prevent and control measures, respiratory virus

Introduction

Respiratory viruses pose a persistent and significant threat to global health, leading to a spectrum of illnesses ranging from mild colds to severe conditions such as pneumonia and acute respiratory distress syndrome. They are particularly impactful in causing acute respiratory infections in children and represent the leading cause of pneumonia in infants and young children.[1] Prior to the emergence of the COVID-19 pandemic, research on respiratory viruses primarily focused on their epidemiology, pathogenesis, and control measures.[2] Influenza and respiratory syncytial virus (RSV) were central to these investigations, which primarily focus on vaccine development, improvements in existing vaccines, and the enhancement of antiviral therapies.[3–5]

Since late 2019, the emergence of COVID-19 has led to a global pandemic, affecting societies in unprecedented ways. This pandemic has underscored the critical need for rapid diagnostics, effective public health interventions, and the

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expedited development of vaccines.[6,7] From January 2020 to December 2022, China implemented a range of non-pharmaceutical intervention (NPI) measures, including lockdowns, social distancing, mask-wearing, and case isolation.[8] These NPIs successfully halted the spread of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) and other respiratory pathogens, causing a notable drop in related infections.[9–12] Lockdowns and social distancing measures have also altered the seasonal patterns of certain respiratory viruses, such as influenza and RSV, leading to decreased virus activity in certain areas.[13,14] After closely monitoring the epidemic, China lifted its strict prevention and control measures on January 8, 2023. However, the relaxation of these restrictions raises worries about the possible resurgence of these viruses.[15,16] It is crucial to comprehend the transmission of respiratory viruses across various seasons, geographic regions, and age demographics. Such knowledge will enhance our ability to diagnose and treat patients promptly.

Existing studies have predominantly focused on comparing changes in viral epidemiology during the pandemic, particularly emphasizing the effects of stringent public health measures such as lockdowns, social distancing, and mask mandates.[17–19] However, few studies have conducted a comprehensive analysis of the epidemiological trends of common respiratory viruses across different phases: prior to the implementation of COVID-19 mitigation strategies, during the pandemic, and following the relaxation of control measures. Therefore, this study aims to report and discuss the changes in the epidemiological characteristics of common respiratory viruses among children of various age groups during and after the COVID-19 pandemic in a provincial hospital in the Fuzhou area from January 2017 to December 2023. By providing a detailed analysis of these trends, we hope to offer valuable insights that will support the development of more effective protective strategies in the future.

Materials and Methods

Study Design

This retrospective study was conducted at a tertiary maternity and child health hospital in Fuzhou, China, over a seven-year period from January 1, 2017, to December 31, 2023. This hospital boasts high-level medical services and concentrated medical resources, exerting significant influence in pediatric care within the region. It also has a broad patient base, making it representative in the diagnosis and treatment of pediatric patients in the area. During the study period, a total of 24,838 pediatric patients with respiratory tract infections were admitted.

For the purpose of analysis, the collected cases were categorized into three distinct groups, corresponding to the different phases of epidemic control measures implemented during this period:

- Phase I: Pre-control phase (before the implementation of prevent and control measures) from January 1, 2017, to December 31, 2019.
- Phase II: Control phase (While carrying out disease prevention and control actions) from January 1, 2020, to December 31, 2022.
- Phase III: Post-control phase (after the control measures were canceled) from January 1, 2023, to December 31, 2023.

Inclusion Criteria

(1) hospitalized children aged below 14 years; (2) presence of acute infection manifestations (at least one), including fever, chills, and abnormal white blood cells; (3) manifestation of respiratory clinical symptoms (at least one), including cough, sputum production, rales, wheezing, shortness of breath, sore throat, nasal congestion, rhinorrhea, chest pain, nasal and pharyngeal congestion, and abnormal auscultatory breath sounds, etc., with the basis of imaging diagnosis such as X-ray: referring to the diagnostic criteria in “Zhu Futang’s Practical Pediatrics” 8th edition (People’s Medical Publishing House).

Exclusion Criteria

(1) Children with non-infectious diseases, including allergic diseases and tumors. (2) Cases involving congenital respiratory dysplasia or impaired immune systems. (3) Individuals with incomplete medical records.

Specimen Collection and Detection

Samples were collected by trained medical staff using flocked swabs [18]. Each swab was gently rotated in the patient's nasopharynx to ensure an adequate sample is obtained, and then placed into a sterile viral transport medium. Immediately after collection, samples were stored at 4°C to maintain viral integrity. They were transported to the laboratory within 24 hours of collection for further processing and analysis.

We collected throat swabs from participants and ensured that trained personnel handled them appropriately. Once the samples reached the lab, we utilized a specialized tool known as the Respiratory Virus Antigen Detection Kit (Genesis) to identify the presence of various viruses, including RSV, ADV, Flu A, Flu B, PIV-1, PIV-2 and PIV-3. Here are the specific steps: (1) Vortex the sample vigorously for 15 seconds. (If the specimen has a significant mucous layer, centrifuge for 10 minutes at 2000 rpm, discard the mucous layer, and add 700 μL of PBS); (2) Mix the sample thoroughly to resuspend the cell layer, creating a slightly misty suspension. Add 20 μL of the sample suspension to each well of an 8-well glass slide and allow it to air dry completely; (3) Place the slides in ice-cold acetone for 10 minutes to fix the cells. Remove the slides from the fixative and air dry; (4) Add a drop of the seven-plex respiratory virus fluorescent reagent to each well on the slide; (5) Place the slides in a moist chamber and incubate at 35–37°C for 45 minutes; (6) Wash the stained slides with 1× PBS wash solution, immersing the slides and moving them up and down four times; (7) Discard the wash solution and replace it with fresh 1× PBS wash solution, repeating the washing step; (8) Rinse the stained slides with distilled water, fully submerging them and moving up and down four times; (9) Air dry the slides, add a sealing solution, and cover with a cover slip; (10) Examine the stained and sealed sample slides under a fluorescence microscope.

To validate the precision of our testing, we incorporated control samples into our experiments—one group with confirmed viral presence (positive controls) and another without any viral material (negative controls). This approach allowed us to identify potential errors or contamination in our testing process.

Samples are initially fixed onto glass slides using acetone. Subsequently, fluorescein isothiocyanate (FITC), which is directly conjugated with virus-specific monoclonal antibodies, is applied to the slides, resulting in the formation of antigen-antibody complexes. Cells exhibiting green fluorescence on their surface are classified as positive when observed under a fluorescence microscope, whereas cells that appear red are considered negative. The specimen is deemed positive if the number of green fluorescent cells exceeds two within the field of view under the microscope at a 200x magnification.

Statistical Analysis

All statistical analyses were performed in SPSS Statistics version 27.0. Descriptive statistics are reported as number (percentage) for categorical data. Utilizing percentages for comparison offers a more precise and objective depiction of specific trends. The Chi-square or Fisher's exact test was used to compare discrete variables. Fisher's exact test was preferred when one or more expected values were equal or less than five. Binary logistic regression was used to analyze relevant data. All p-values < 0.05 were considered statistically significant. A priori sample size calculations were not performed due to the retrospective nature of this analysis, and all eligible cases were included.

Results

Overall Respiratory Virus Detection Rate Among Hospitalized Children

A total of 24,838 cases were analyzed for respiratory virus detection from 2017 to 2023, including 396 in 2017, 2037 in 2018, 5010 in 2019, 3803 in 2020, 4170 in 2021, 4490 in 2022 and 4932 in 2023. Among the specimens, 4439 tested positive, resulting in an overall detection rate of 17.87% (4439/24,838). The positive rates of viruses detected in 2022 were the lowest among all positive rates recorded in this study. In positive cases, a total of 2282 (11.36%) cases were male and 1617 (6.51%) were female. Notably, samples tested from children under three years old represented the largest proportion of positive samples, accounting for 87.56% (3387/4439).

Among the detected viruses, RSV exhibited the highest detection rate at 11.45% (2845/24,838), followed by PIV-3 at 1.96% (488/24,838), Flu A at 1.55% (385/24,838), ADV at 1.31% (326/24,838), and PIV-1 at 0.76% (189/24,838). Additionally, Flu B was detected at a rate of 0.44% (109/24,838), and PIV-2 at 0.39% (97/24,838) (Table 1). The annual

Table 1 Respiratory Virus Detection Rate Among Hospitalized Children

	2017 n=396	2018 n=2037	2019 n=5010	2020 n=3803	2021 n=4170	2022 n=4490	2023 n=4932	*Total n=24838*
Positive cases, n(%)	94(23.74)	358(17.57)	926(18.48)	758(19.93)	889(21.32)	630(14.03)	784(15.90)	4439(17.87)
Characteristics								
Sex, n(%)								
Male	61(15.40)	224(11.00)	603(12.04)	484(12.73)	570(13.67)	400(8.91)	480(9.73)	2822(11.36)
Female	33(8.33)	134(6.58)	323(6.45)	274(7.20)	319(7.65)	230(5.12)	304(6.16)	1617(6.51)
Age (year), n(%)								
<1	63(15.91)	244(11.98)	495(9.88)	406(10.68)	521(12.49)	237(5.28)	292(5.92)	2258(9.09)
1–3	21(5.30)	84(4.12)	330(6.59)	305(8.02)	308(7.39)	265(5.90)	316(6.41)	1629(6.56)
4–6	9(2.27)	24(1.18)	80(1.60)	39(1.03)	40(0.96)	81(1.80)	124(2.51)	397(1.60)
7–9	1(0.25)	5(0.25)	16(0.32)	7(0.18)	14(0.34)	29(0.65)	38(0.77)	110(0.44)
>9	0	1(0.05)	5(0.10)	1(0.03)	6(0.14)	18(0.40)	14(0.28)	45(0.18)
Positive rate of viruses, n(%)								
ADV	3(0.76)	28(1.37)	136(2.71)	29(0.76)	32(0.77)	64(1.43)	34(0.69)	326(1.31)
Flu A	8(2.02)	14(0.69)	74(1.48)	24(0.63)	1(0.02)	112(2.49)	152(3.08)	385(1.55)
Flu B	4(1.01)	4(0.20)	23(0.46)	14(0.37)	27(0.65)	32(0.71)	5(0.10)	109(0.44)
PIV-1	3(0.76)	1(0.05)	41(0.82)	50(1.31)	33(0.79)	19(0.42)	42(0.85)	189(0.76)
PIV-2	2(0.51)	4(0.20)	39(0.78)	6(0.16)	8(0.19)	33(0.73)	5(0.10)	97(0.39)
PIV-3	10(2.53)	16(0.79)	100(2.00)	63(1.66)	79(1.89)	134(2.98)	86(1.74)	488(1.96)
RSV	64(16.16)	291(14.29)	513(10.24)	572(15.04)	709(17.00)	236(5.26)	460(9.33)	2845(11.45)

Abbreviations: ADV, adenovirus virus; Flu A, influenza A virus; Flu B, influenza B virus; PIV-1, parainfluenza virus types 1; PIV-2, parainfluenza virus types 2; PIV-3, parainfluenza virus types 3; RSV, respiratory syncytial virus.

detection rates for each virus were calculated and presented in Figure 1 and Table 1. Throughout the study period, RSV consistently accounted for the largest proportion of all positive specimens, ranging from 5.26% to 17.00%. The annual detection rate for ADV ranged from 0.69% to 2.71%, with the highest rate observed in 2019. For Flu A, the annual detection rate varied from 0.02% to 3.08%, demonstrating an upward trend in the past two years, culminating in a significant peak in 2023. Detection rates for the other four respiratory viruses, remained more consistent detection rates.

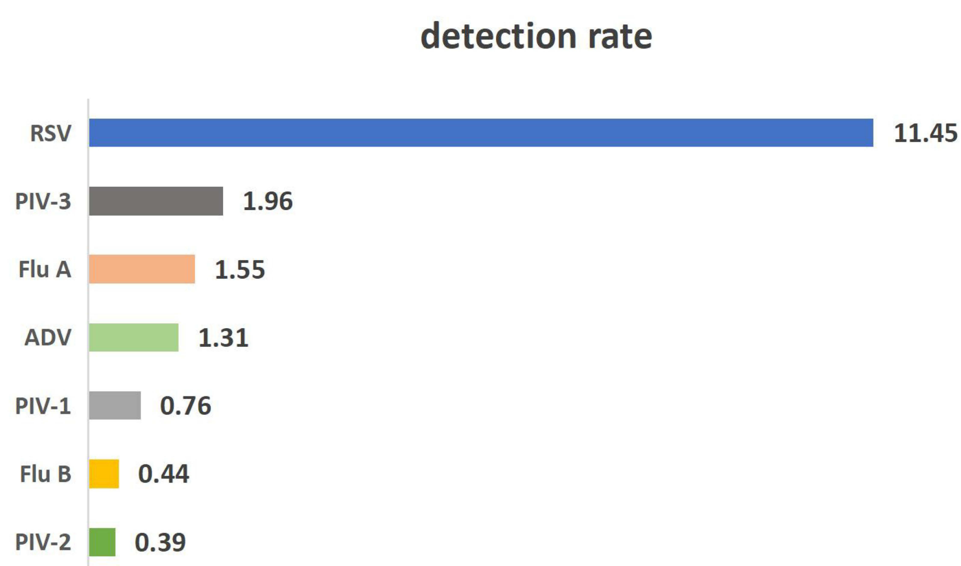

Figure 1 Overall respiratory virus detection rate among hospitalized children (%).

Abbreviations: ADV, adenovirus virus; Flu A, influenza A virus; Flu B, influenza B virus; PIV-1, parainfluenza virus types 1; PIV-2, parainfluenza virus types 2; PIV-3, parainfluenza virus types 3; RSV, respiratory syncytial virus.

Comparison of Detection Rates of Respiratory Viruses Across Three Phases

Among children hospitalized for ARIs, the detection rates of respiratory viruses across different phases were as follows: 18.51% (1378/7443) in Phase I (2017–2019), 18.27% (2277/12463) in Phase II (2020–2022), and 15.90% (784/4932) in Phase III (2023). The detection rate in the third phase showed a significant decrease compared to the previous periods (P < 0.01). In Phase I, the predominant viruses detected were RSV, ADV, and PIV-3. In the subsequent phases, the main pathogens shifted to RSV, Flu A, and PIV-3, as illustrated in Table 2 and Figure 2. Notably, the detection rates of all viruses, except for PIV-3, varied significantly across the different phases (P < 0.01). Trend analysis revealed a gradual decline in the incidence of ADV and PIV-2 from Phase I to Phase III, whereas the detection rate of PIV-1 showed a slight upward trend. Flu B and RSV exhibited an increase in Phase II followed by a significant decrease in Phase III. Flu A demonstrated a decline in Phase II, succeeded by a notable increase (3.08%) in Phase III.

Comparison of Detection Rates Among Patients of Different Genders and Ages

Among the 4439 positive samples, 2282 samples were obtained from male children and 1617 samples from female children, resulting in a detection rate ratio of 1.41:1 by gender. RSV was the most frequently detected pathogen in both male and female patients, followed by PIV-3 and Flu A. No significant differences were observed in the detection rates of all seven respiratory viruses assessed by gender (Table 3).

We categorized the positive cases into five age groups. Among these, children under one year old exhibited the highest detection rate, comprising 50.86% (2258/4439) of the positive samples. This was followed by children aged 1–3 years, who accounted for 36.70% (1629/4439). The group of children over 9 years old represented the smallest proportion, with only 1.01% (45/4439) of the total cases. The positive detection rate demonstrates a gradual decline with increasing age. In the infant group and the 1–3 years age group, RSV was the predominant pathogen, responsible for 77.59% and 58.56% of positive cases, respectively. PIV-3 was the second most frequently detected pathogen. In the 4–6 years age group, the pathogens with the highest detection rates were RSV (28.97%), Flu A (26.70%), and ADV (25.94%). In the 7–9 years and over 9 years age groups, Flu A had the highest positivity rates at 36.36% and 33.33%, respectively, while the prevalence of RSV was lower, at 11.82% and 24.44% (Table 3).

Monthly Distribution of Respiratory Viruses

During the period before COVID-19 pandemic and control phase (2017–2022), in addition to Flu A, the other six viruses exhibited seasonal patterns, with most detection peaks occurring from October each year to February of the following year. In Phase III (2023), after the lifting of control measures, some viruses, such as Flu B, PIV-1, and PIV-2, maintained their peak detection times. However, the seasonal patterns of other viruses changed; for instance, RSV, PIV-3, and ADV demonstrated different trends. The detection peaks for RSV and PIV-3 occurred in the summer months (May and June), with a smaller peak noted in the autumn (September and October). Conversely, ADV showed no significant seasonal variation. Additionally, Flu A experienced an epidemic in the spring of 2023, with a detection rate notably higher than those in previous years. Specifically, the detection rate reached 16.39% (78/476) in April. Subsequently, during the summer and autumn months, the detection rate declined significantly (Figure 3).

Table 2 Comparison of Detection Rates of Respiratory Viruses in Three Phases

	Total Positive Cases, n(%)	Detection of Virus-positive Speciment, n(%)						
		ADV	Flu A	Flu B	PIV-1	PIV-2	PIV-3	RSV
Phase I, n=7443	1378(18.51)	167(2.24)	96(1.29)	31(0.42)	45(0.60)	45(0.60)	126(1.69)	868(11.66)
Phase II, n=12463	2277(18.27)	125(1.00)	137(1.10)	73(0.59)	102(0.82)	47(0.38)	276(2.21)	1517(12.17)
Phase III, n=4932	784(15.90)	34(0.69)	152(3.08)	5(0.10)	42(0.85)	5(0.10)	86(1.74)	460(9.33)
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.017	<0.001

Abbreviations: ADV, adenovirus virus; Flu A, influenza A virus; Flu B, influenza B virus; PIV-1, parainfluenza virus types 1; PIV-2, parainfluenza virus types 2; PIV-3, parainfluenza virus types 3; RSV, respiratory syncytial virus.

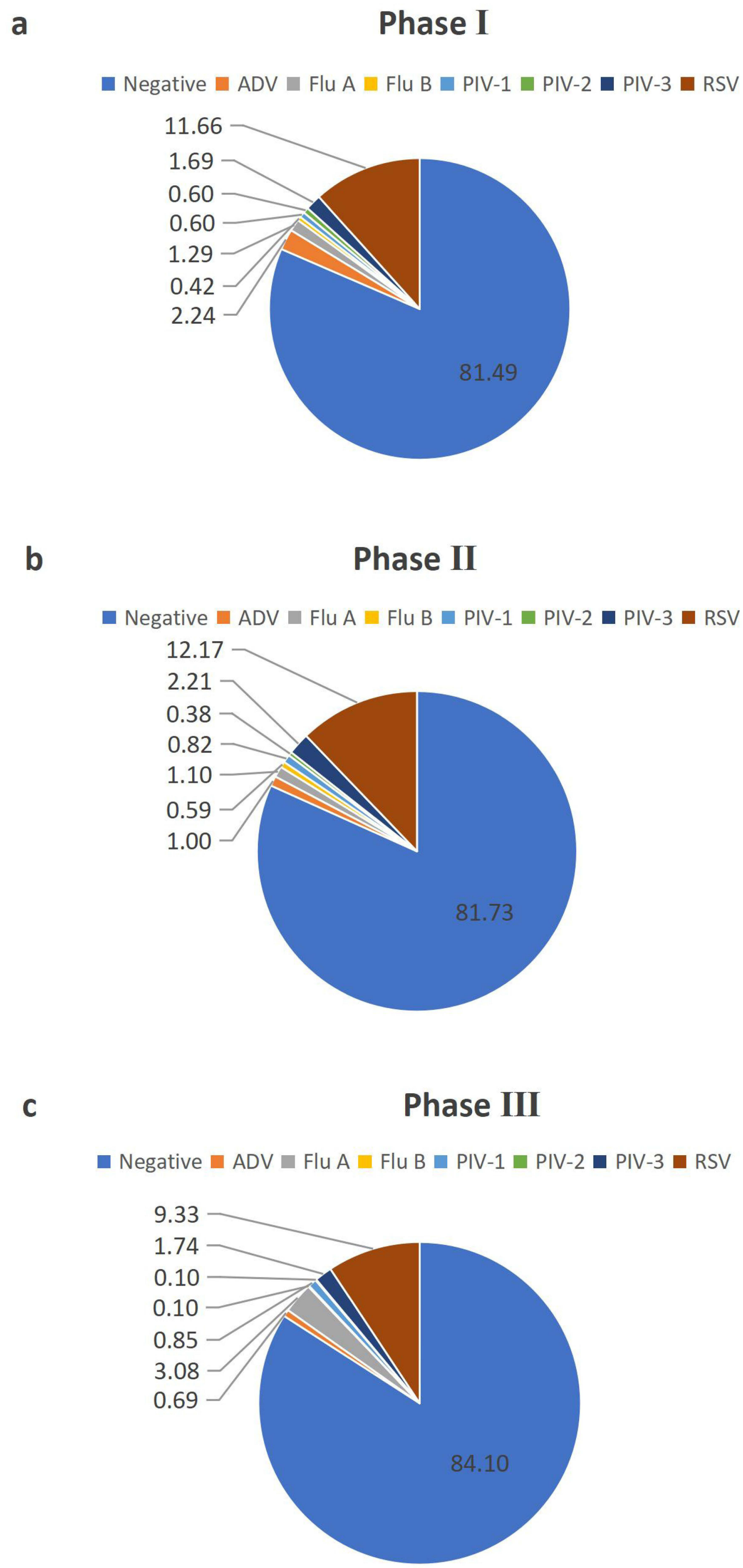

Figure 2 Comparison of detection rates of respiratory viruses in three phases (%). Phase I (**a**) Pre-control phase (before the implementation of prevent and control measures) from January 1, 2017, to December 31, 2019. Phase II (**b**) Control phase (during the implementation of prevent and control measures) from January 1, 2020, to December 31, 2022. Phase III (**c**) Post-control phase (after the control measures were lifted) from January 1, 2023, to December 31, 2023.

Abbreviations: ADV, adenovirus virus; Flu A, influenza A virus; Flu B, influenza B virus; PIV-1, parainfluenza virus types 1; PIV-2, parainfluenza virus types 2; PIV-3, parainfluenza virus types 3; RSV, respiratory syncytial virus.

Table 3 Comparison of Pathogen Infection by Gender and Age

Gender				Age (Year)					
	Male, n(%) n=2822	**Female, n(%) n=1617**	***P*-value**	**<1, n(%) n=2258**	**1–3, n(%) n=1629**	**4–6, n(%) n=397**	**7–9, n(%) n=110**	**>9, n(%) n=45**	***P*-value**
ADV	200(7.09)	126(7.79)	0.386	54(2.39)	142(8.72)	103(25.94)	21(19.09)	6(13.33)	<0.001
Flu A	252(8.93)	133(8.23)	0.422	75(3.32)	149(9.15)	106(26.70)	40(36.36)	15(33.33)	<0.001
Flu B	69(2.45)	40(2.47)	0.953	24(1.06)	40(2.46)	18(4.53)	21(19.09)	6(13.33)	<0.001
PIV-1	124(4.39)	65(4.02)	0.552	92(4.07)	74(4.54)	20(5.04)	2(1.82)	1(2.225)	<0.001
PIV-2	64(2.27)	33(2.04)	0.618	29(1.28)	46(2.82)	20(5.04)	2(1.82)	0(0)	<0.001
PIV-3	298(10.56)	190(11.75)	0.222	232(10.27)	224(13.75)	15(3.78)	11(10.00)	6(13.33)	<0.001
RSV	1815(64.32)	1030(63.70)	0.680	1752(77.59)	954(58.56)	115(28.97)	13(11.82)	11(24.44)	<0.001

Abbreviations: ADV, adenovirus virus; Flu A, influenza A virus; Flu B, influenza B virus; PIV-1, parainfluenza virus types 1; PIV-2, parainfluenza virus types 2; PIV-3, parainfluenza virus types 3; RSV, respiratory syncytial virus.

Mixed-Infection Pathogens

Our research checked when people got hit with two or more viruses at once. Out of 24,838 folks, 100 had these mixed infections, which is just 0.40%. The mixed infection numbers changed with each part of the study: Phase I saw 0.56% (42/7443), Phase II had 0.39% (48/12,463), and Phase III was the least with 0.20% (10/4932). The usual combo was PIV-3 with RSV, making up 38.78% of mixed infections (38/98). After that, Flu B with RSV and PIV-1 with RSV each took 10.20% (10/98). In Phases I and III, all mixed infections had just two viruses. But in Phase II, there were 2 cases with over two viruses (ADV, Flu B and RSV all at once, and PIV-1, PIV-2, and RSV all at once), while the other 46 cases had only two viruses.

Discussion

In response to the ongoing COVID-19 pandemic, the Chinese government deployed a comprehensive suite of stringent NPIs.[20] The implementation of these key measures has achieved a notable decrease in the number and percentage positive of prevalent respiratory viruses.[21] Despite this, existing studies primarily focus on comparing virus dynamics between the pre-pandemic and pandemic stages.[17–19] However, there is a notable lack of research on virus prevalence in children following the removal of COVID-19 control measures, and few studies have compared virus dynamics across all three stages. This study conducted a comparative investigation into the epidemiological characteristics of seven major respiratory viruses among children hospitalized at our institution from 2017 to 2023. The findings revealed a significant decrease in the detection rates of respiratory viruses following the lifting of control measures, in contrast to the higher detection rates observed before and during the implementation of these measures.

The Fuzhou city government's proactive measures since January 2020 had been pivotal in controlling the spread of COVID-19, ensuring that all individuals who test positive for SARS-CoV-2 were isolated and treated in designated medical facilities. As a result, the samples collected in this study were all SARS-CoV-2 negative samples. The research identified RSV, PIV-3, and Flu A as the most prevalent viruses, similar to earlier research. The results of the Chinese respiratory infectious disease surveillance data (2009–2019) showed that the main viruses causing pneumonia in childhood were RSV, human rhinovirus (hRV), PIV, influenza virus, and ADV.[22] A parallel study from Xuzhou reported a detection rate of 38.5% for respiratory viruses in hospitalized children with SARI between 2015 and 2021, with hRV, RSV, and hPIV-3 topping the list.[23] This study did not involve the detection of hRV, resulting in a significantly different overall detection rate compared to previous studies. While the implementation of COVID-19 control measures had markedly reduced the transmission of respiratory viruses among children, the persistently high detection rates of RSV and PIV-3 both before and during these measures indicated that their prevalence in the region was largely unaffected by the enacted policies. This phenomenon may be related to the increased use of alcohol-based disinfectants,[24] which exhibit limited efficacy against non-enveloped viruses such as PIV. While alcohol can effectively inactivate RSV, it is ubiquitous on surfaces around infected patients, and its application on a large scale is not feasible; thus, the disinfection effect remains limited. Notably, between 2020 and 2021, precipitation levels in the middle and lower reaches of the Yangtze

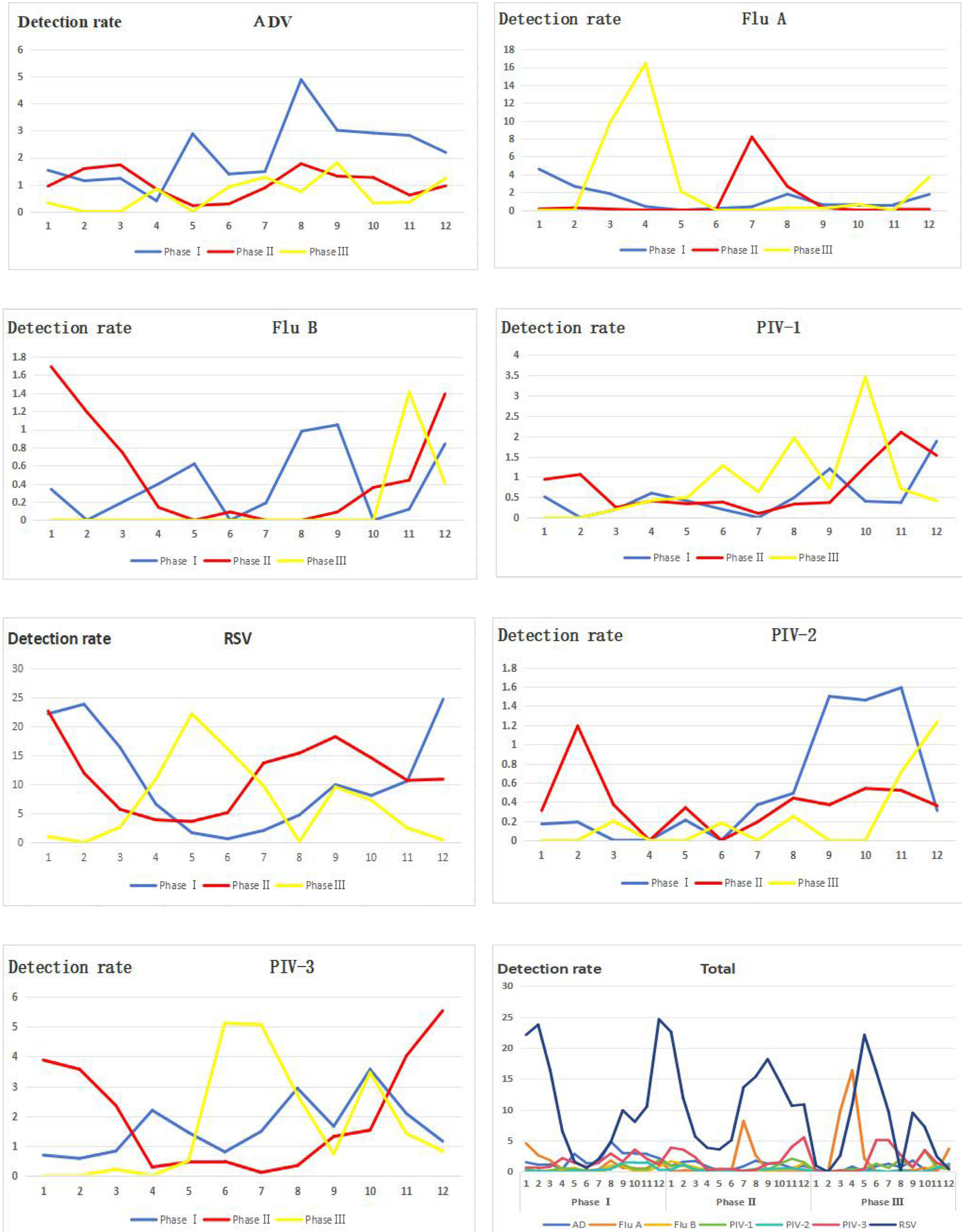

Figure 3 Monthly distribution of respiratory viruses (%).

Abbreviations: ADV, adenovirus virus; Flu A, influenza A virus; Flu B, influenza B virus; PIV-1, parainfluenza virus types 1; PIV-2, parainfluenza virus types 2; PIV-3, parainfluenza virus types 3; RSV, respiratory syncytial virus.

River in China increased compared to previous years.[25,26] This rise in air humidity may facilitate the survival and spread of RSV, potentially contributing to the observed increase in its detection rate.

Our study has observed a notable rise in samples collected from infants under one year old, likely due to pandemic-related restrictions that have limited outdoor activities for older children, thereby reducing their exposure to various pathogens. During the period of stringent control measures, there was a significant decrease in the detection rates of common viruses like ADV and influenza among school-age children. This reduction has led to a relatively higher detection rate among the youngest children. Additionally, the limited availability of masks tailored for infants has further increased their susceptibility to respiratory viruses. Our research confirms that RSV is the leading pathogen in children under three years old, representing 87.5% of all RSV-positive cases.[27,28] Infants' immature immune systems, coupled with behaviors that increase exposure-such as frequent hand-to-mouth contact, and the absence of an effective vaccine, are likely contributing factors.[29–31] Children positive for RSV are more likely to be hospitalized, require intensive care, and receive oxygen compared to those positive for other viruses.[32] Therefore, it's crucial to enhance preventive measures for vulnerable children, improve early disease detection, and accelerate vaccine development to decrease the impact of RSV. Consistent with earlier research, hRV and influenza virus are more prevalent among school-age children and adolescents, possibly due to increased exposure in school environments.[33] Thus, reinforcing public health measures for children over 3 years old, particularly during school activities, is essential for disease prevention.

Interestingly, the manner in which we control the spread of disease influences the seasonal patterns of certain viruses. Typically, flu season in the Northern Hemisphere begins in the fall, around October or November, and peaks from December to April. However, during the period from 2020 to 2021, when control measures were implemented, the detection rate of the influenza virus declined significantly, deviating from the usual seasonal pattern. For instance, in the summer of 2022, a notable number of influenza cases, primarily of the H3N2 type, were reported in the Fuzhou area. This anomaly may be attributed to abrupt weather changes and the occurrence of epidemics associated with school gatherings. Following the relaxation of control measures, a new influenza outbreak emerged in Fuzhou from March to April 2023, predominantly involving H1N1 cases, with a smaller number of H3N2 cases. These observations align with findings from previous studies, suggesting that influenza viruses may resume their epidemic cycles once control measures are modified.[33,34]

PIV-3 is typically prevalent during the summer.[35] However, In this research, the usual pattern of PIV-3 changed after we started the control measures. Its busiest time moved from spring and summer (March to September) to autumn and winter. Once we stopped those control measures, PIV-3 came back in the summer. The potential reason for this observation is that the selection of this study consisted exclusively of hospitalized patients, who typically represent cases with higher risks or more pronounced symptoms. Future research should integrate data from both hospitalized patients and community samples, as this approach may provide a more comprehensive understanding of the virus's prevalence. RSV is the leading cause of severe acute respiratory illness (SARI) in hospitalized children during the autumn and winter.[36] Following the COVID-19 outbreak in 2020, the detection rate of RSV in Europe dropped significantly, remaining low even in the 2021 report.[37] Nevertheless, the study found that RSV was still common in fall and winter, which matches what another recent study in China found.25 After control measures stopped in January 2023, RSV cases picked up quickly in spring 2023. This might be because of the rainy season in Fuzhou, which made people gather more in closed spaces, helping RSV spread around.

Our study has several limitations. Due to time constraints, data were collected for only one year following the lifting of COVID-19 control measures, resulting in a relatively small sample size that may not adequately represent viral epidemic trends. Additionally, patients with severe illnesses may be at an increased risk of infection due to prolonged hospitalization and medical procedures. The prevention and control measures implemented during the COVID-19 pandemic may have had limited efficacy in preventing respiratory infections in severe cases. In this study, we did not perform a subgroup analysis focusing on severe cases. Another limitation is that this study only examined seven common respiratory viruses. Other prevalent viruses, such as human rhinovirus, human bocavirus, and human metapneumovirus, were not included due to the limitations of hospital testing programs. Further analysis of these viruses will be conducted in future experiments.

Conclusion

Putting in place COVID-19 prevention steps has mostly cut down how much respiratory viruses spread among kids. But these steps have not made a big difference for RSV and PIV-3. Also, changes in the weather can affect how common these viruses are, showing we need to keep watching and take special actions, especially for RSV and Flu A, to help reduce the number of respiratory infections in children.

Data Sharing Statement

The data can be obtained upon reasonable from the corresponding author.

Ethics Statement

This study was performed in line with the principles of the Declaration of Helsinki and was approved by the Ethical Committee of Fujian Maternity and Child Health Hospital College of Clinical Medicine for Obstetrics & Gynecology and Pediatrics, Fujian Medical University (the ethics approval number: 2024KY164). As this retrospective analysis used routinely collected data informed consent was waived. This study strictly adheres to the principles of patient confidentiality. All personal information and medical data of the patients have been anonymized to ensure that no individual identities can be identified. The collection, storage, and analysis of all data during the research process comply with the relevant ethical and privacy protection standards.

Consent for Publication

All authors consent for publication.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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