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**Yingcong Chen**
Hangzhou Children's Hospital
**Jie Wang**
Hangzhou Children's Hospital
**Xudong Xu**
Hangzhou Children's Hospital
**Jun Zhou**
Hangzhou Children's Hospital
**Meina Yue**
Hangzhou Children's Hospital
**Gongbo Zeng**
Hangzhou Children's Hospital
**Xinfeng Zhao**
zhaoxinfeng8516@163.com

Hangzhou Children's Hospital

**Research Article**

**Keywords:** Parainfluenza Virus, Child, Epidemiology, Retrospective studies, Post-pandemic period

**Posted Date:** November 25th, 2026

**DOI:** https://doi.org/10.21203/rs.3.rs-11290031/v1

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**Additional Declarations:** No competing interests reported.

# Epidemiological Analysis of Parainfluenza Virus Infections in Pediatric Inpatients of Hangzhou from 2022 to 2025

Yingcong Chen[1], JieWang[1], Xudong Xu[1], Jun Zhou[1] Meina Yue[1], Gongbo Zeng[1], Xinfeng Zhao*[1]

1 Hangzhou Children's Hospital, Department of Clinical Laboratory, Hangzhou, Zhejiang Prov. China.

Corresponding author: Xinfeng Zhao
Email: zhaoxinfeng8516@163.com

## Abstract

**Background:** The COVID-19 pandemic profoundly disrupted the circulation patterns of common respiratory viruses. This study aimed to characterize the post-pandemic epidemiological dynamics of human parainfluenza virus (PIV) among hospitalized children in Hangzhou, China, from 2022 to 2025.

**Methods:** Respiratory specimens were collected from pediatric inpatients and screened for PIV types 1 and 3 (PIV1 and PIV3) via real-time fluorescent quantitative PCR. Temporal, seasonal, age, and gender distributions were comprehensively analyzed.

**Results:** Among 43777 samples, the overall PIV positivity rate was 5.68%, with PIV3 (3.87%) dominating over PIV1 (1.82%). Notably, the positivity rate peaked at 10.91% during the late-pandemic year (2022) and subsequently stabilized between 5%-6% in 2023-2025. A clear seasonal alternation pattern was observed: PIV3 predominated in late spring and summer, while PIV1 resurged in autumn and winter. Children aged 0-3 years bore the highest infection burden, with positivity declining significantly with age, and no sex-based differences were detected. Importantly, our data reveal a gradual restoration of the typical PIV epidemic rhythm - characterized by alternating subtype predominance - following the relaxation of non-pharmaceutical interventions.

**Conclusion:** The COVID-19 pandemic transiently suppressed PIV circulation and disrupted its natural seasonality, but the epidemic pattern is now reverting to its historical baseline in Hangzhou. These findings provide critical baseline data for refining surveillance strategies, facilitating early clinical identification, and informing targeted prevention and control measures for pediatric PIV infections in the post-pandemic era.

**Key words:** Parainfluenza Virus; Child; Epidemiology; Retrospective studies; Post-pandemic period

## INTRODUCTION

Human parainfluenza virus (PIV), an enveloped single-stranded RNA virus belonging to the *Paramyxoviridae* family, ranks among the most prominent viral pathogens responsible for acute respiratory tract infections in infants and young children worldwide[1-3]. Four serotypes have been identified, namely PIV1, PIV2, PIV3 and PIV4[2]. Of these, PIV1 and PIV3 circulate most extensively in pediatric populations and correlate closely with the most severe clinical outcomes[2,3]. Primarily transmitted via respiratory droplets and intimate personal contact, PIV features high population susceptibility, frequent clustered cases and pronounced seasonal epidemicity[4-6]. Children under five constitute the most vulnerable subgroup for PIV exposure; epidemiological investigations have documented that 75%-80% of individuals within this age bracket experience at least one PIV infection in early life, with this population also bearing the major burden of hospital admission and mortality linked to pediatric lower respiratory tract diseases[1,7]. PIV infection manifests as a broad spectrum of respiratory disorders, ranging from upper respiratory tract symptoms and acute bronchitis to bronchiolitis and pneumonia[8]. Beyond elevating pediatric hospitalization rates and overall medical burden, it predisposes infants and immunologically vulnerable children to severe clinical complications and protracted disease courses, with occasional occurrences of community and nosocomial outbreaks[9,10].

Global pathogen surveillance has unveiled marked disparities in age stratification,

seasonal periodicity, annual fluctuation and serotype distribution of pediatric PIV infections[11,12]. A nationwide multicenter investigation involving 14 hospitals across 11 provinces of China observed significantly higher PIV positivity among children aged 1-3 years relative to other age subgroups, with PIV3 identified as the prevailing serotype driving pediatric respiratory illnesses and severe cases[13]. Related meta-analyses further illustrated that PIV3 predominantly infects infants and peaks in summer circulation, while PIV1 tends to affect preschool children and prevails during autumn and winter, with the two major serotypes displaying an alternating epidemic pattern[14-16]. Modulated by climatic conditions, population migration, herd immune status and public health intervention measures, PIV exhibits dynamic shifts in epidemic magnitude, dominant serotype circulation and seasonal peaks, presenting prominent temporal and spatial heterogeneity[17-19]. The traditional epidemic rhythm of PIV was profoundly disrupted amid the COVID-19 pandemic[20]. While post-pandemic surveillance has witnessed a gradual recovery of PIV activity, its overall epidemic level has yet to restore to pre-pandemic baselines[14].

Large-sample, long-term continuous epidemiological surveillance targeting PIV infection among hospitalized children in China remains inadequate, lacking systematic characterization of its epidemiological profiles stratified by age, gender, season and viral serotype. Following the COVID-19 pandemic, substantial restructuring has taken place in the transmission patterns of common respiratory pathogens[20,21]. Characterization of post-pandemic epidemiological trends, dominant serotype shifts, as well as age and seasonal distribution of PIV among hospitalized children, carries important public health implications. These findings help identify high-risk populations and forecast epidemic trends, supporting early clinical diagnosis, precise prevention and control, vaccine development, and evidence-based public health decision-making.

# METHODS

## Patients and samples

This retrospective study recruited pediatric patients undergoing human parainfluenza virus (PIV) detection at Hangzhou Children's Hospital from March 2022 to December 2025. Eligible participants satisfied the following inclusion requirements: aged 0-18 years, inpatients, clinically presenting with respiratory symptoms. All enrolled subjects were classified into four age groups for epidemiological analysis: 0-12 months, 1-3 years, 4-6 years, and 7-18 years.

**Detection of PIV**

Clinical data including age, gender, PIV testing time and results of hospitalized patients were obtained from the hospital laboratory information system. PIV1 and PIV3 were detected using the Respiratory Virus Nucleic Acid 6-plex Detection Kit (PCR Fluorescent Probe Method) manufactured by Beijing Zhuowei Huisheng Biotechnology Co., Ltd. (Cat. No.CT8046-48T). This kit was applied to perform nucleic acid extraction, amplification, and identification of parainfluenza virus type 1 and type 3 from the patients' throat samples.

**Statistical analysis**

Statistical analysis was carried out using IBM SPSS Statistics 24.0 Continuous data were described as mean ± standard deviation. Enumeration data were presented as case numbers and percentages, and inter-group differences in categorical variables were compared using the Chi-square test. All statistical tests were two-tailed, and a *p*-value $<0.05$ was considered statistically significant.

**Definition of season**

Seasonal classification in this study was defined in accordance with the Chinese Meteorological Industry Standard (QX/T152-2012). Combined with the climatic and temperature characteristics of Zhejiang Province, the whole year was divided into four seasons: March to May was defined as spring, June to August as summer, September to November as autumn, and December to February of the following year as winter[21].

# Results

## Overall

A total of 43777 respiratory samples from hospitalized children were collected from March 2022 (since the launch of this testing project) to December 2025, including 2465 samples in 2022, 12410 in 2023, 17207 in 2024, and 11695 in 2025. The minimum age of patients was 9 days and the maximum age was 17 years. In summary, 2488 samples tested positive for PIV, with an overall positivity rate of 5.68%. Of these, 1693 were PIV3-positive (3.87%) and 795 were PIV1-positive (1.82%), yielding a PIV3/PIV1 ratio of 2.13:1 (**Table 1**). The overall PIV positivity rate was 5.63% in males (3.93% for PIV3 and 1.70% for PIV1) and 5.74% in females (3.79% for PIV3 and 1.95% for PIV1). The male/female ratio of 1.20:1 was consistent with the gender structure in the general pediatric population and similar respiratory virus epidemiological surveys, indicating minimal selection bias and satisfactory sample representativeness[22].

**Table 1** PIV detection in pediatric patients, 2022-2025.

| Variable | 2022 | 2023 | 2024 | 2025 | Total |
|---|---|---|---|---|---|
| Number of positive specimens/PIV3/PIV1/Total (rate of positive specimens/PIV3/PIV1, %) | 269/130/139/2465 (10.91/5.27/5.64) | 670/528/142/12410 (5.40/4.25/1.14) | 852/650/202/17207 (4.95/3.78/1.17) | 697/385/312/11695 (5.96/3.29/2.67) | 2488/1693/795/43777 (5.68/3.87/1.82) |
| Gender | | | | | |
| Male | 140/71/69/1333 (10.50/5.33/5.18) | 368/286/82/6732 (5.47/4.25/1.22) | 457/362/95/9351 (4.89/3.87/1.02) | 380/220/160/6461 (5.88/3.41/2.48) | 1345/939/406/23877 (5.63/3.93/1.70) |
| Female | 129/59/70/1132 (11.40/5.12/6.18) | 302/242/60/5678 (5.32/4.26/1.06) | 395/388/107/7856 (5.03/3.67/1.36) | 317/165/152/5234 (6.06/3.15/2.90) | 1143/754/389/19900 (5.74/3.79/1.95) |
| Age group | | | | | |
| 0-12 months | 80/50/30/639 (12.52/7.82/4.69) | 317/285/32/2888 (10.98/9.87/1.11) | 354/309/45/4077 (8.68/7.58/1.10) | 238/165/73/3524 (6.75/4.68/2.07) | 989/809/180/11128 (8.89/7.27/1.62) |
| 1 to 3 years | 110/60/50/847 | 233/180/53/3001 | 258/183/75/3597 | 259/150/109/3024 | 860/473/387/10496 |

| | | | | | |
|---|---|---|---|---|---|
| | (12.99/7.08/5.90) | (7.76/6.00/1.77) | (7.17/5.09/2.09) | (8.56/4.96/3.60) | (8.19/4.51/3.69) |
| 4-6 years | 60/12/48/615 (9.76/1.95/7.80) | 87/42/45/3360 (2.59/1.25/1.34) | 156/89/67/4909 (3.18/1.81/1.36) | 155/47/108/2791 (5.55/1.68/3.87) | 458/190/268/11675 (3.92/1.63/2.30) |
| 7-18 years | 19/8/11/364 (5.22/2.20/3.02) | 33/21/12/3161 (1.04/0.66/0.38) | 84/96/15/4624 (1.82/1.49/0.32) | 45/23/22/2356 (1.91/0.98/0.93) | 180/121/59/10505 (1.71/1.15/0.56) |
| $X^2$ | 32.47/62.71/41.10 | 489.35/598.30/54.11 | 472.16/469.27/81.44 | 211.83/141.55/112.08 | 967.52/789.41/412.37 |
| *p* Value | <0.001/<0.001/<0.001 | <0.001/<0.001/<0.001 | <0.001/<0.001/<0.001 | <0.001/<0.001/<0.001 | <0.001/<0.001/<0.001 |

*p*-values were determined by Chi-square test or Fisher's exact test.
Cochran-Armitage test for trend (year and age): $p<0.001$.

## Temporal and Seasonal Epidemiological Characteristics of PIV Infection

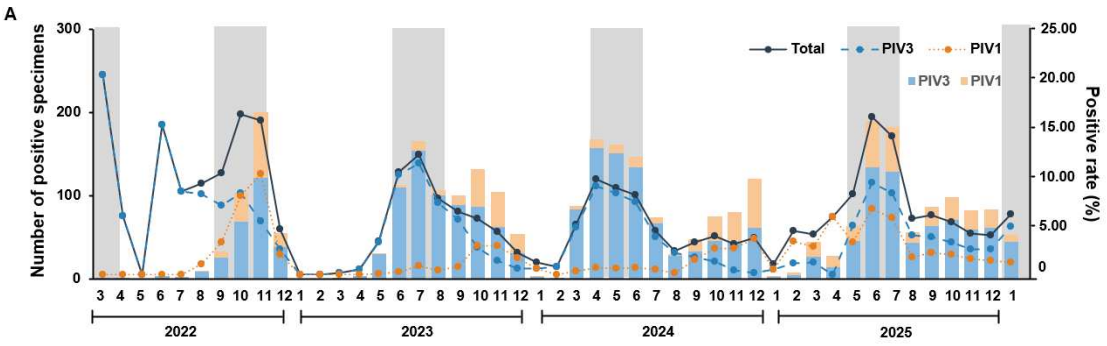
Restricted by the isolation and public health control policies during the COVID-19 pandemic in 2022, the number of hospitalized children decreased substantially, with only 2465 specimens recruited in that year. The notably elevated PIV positive rate of 10.91% in 2022 was closely associated with the small annual sample size. From 2023 to 2025, annual specimen volume returned to the normal baseline, accompanied by a decline in PIV positivity, followed by a slight rebound in 2025. Overall, the annual PIV positive rate exhibited significant temporal fluctuations ($\chi^2=146.49$, $p<0.001$).

**Table 2** Seasonal distribution of PIV infection.

| Year | Season | Number of specimens tested | Number of positive specimens/PIV3/PIV1 | Rate of positive specimens (%) |
|---|---|---|---|---|
| 2022 | Spring | 30 | 2/2/0 | 6.67/6.67/0 |
| | Summer | 143 | 14/13/1 | 9.79/9.09/0.70 |
| | Autumn | 1458 | 215/94/121 | 14.75/6.45/8.30 |
| | Winter | 901 | 38/21/17 | 4.22/2.33/1.89 |
| 2023 | Spring | 2297 | 34/33/1 | 1.48/1.44/0.04 |
| | Summer | 3664 | 364/344/20 | 9.93/9.39/0.55 |
| | Autumn | 4419 | 238/140/98 | 5.39/3.17/2.22 |
| | Winter | 1704 | 34/10/24 | 2.00/0.59/1.41 |
| 2024 | Spring | 5036 | 391/365/26 | 7.76/7.25/0.52 |
| | Summer | 4386 | 228/206/22 | 5.20/4.70/0.50 |
| | Autumn | 3594 | 121/39/82 | 3.37/1.09/2.28 |

| | | | | |
|---|---|---|---|---|
| | Winter | 1943 | 67/4/63 | 3.45/0.21/3.24 |
| 2025 | Spring | 1449 | 85/35/50 | 5.87/2.42/3.45 |
| | Summer | 2541 | 306/184/122 | 12.04/7.24/4.80 |
| | Autumn | 3834 | 193/120/73 | 5.03/3.13/1.90 |
| | Winter | 2266 | 105/74/31 | 4.63/3.27/1.37 |

PIV infection presented pronounced seasonal heterogeneity ($\chi^2$=386.24, $p$<0.001). The limited sample size and aberrant epidemic pattern observed in 2022 were largely attributable to stringent COVID-19 prevention and control measures. Following the gradual recovery of respiratory virus circulation, PIV activity formed a stable epidemic pattern: the peak occurred in summer, prevalence was moderate in spring, circulation declined in autumn, and the lowest activity was recorded in winter, which conformed to the natural epidemiological rhythm of respiratory viruses in subtropical Zhejiang (**Table 2**). As the predominant serotype, PIV3 maintained a consistent summer predominance consistent with its classic epidemiological traits ($\chi^2$=524.69, $p$<0.001). Despite the disruptive impact of the COVID-19 pandemic, PIV3 consistently reached its highest detection level in summer from 2023 to 2025 and dominated the annual PIV epidemic peaks, with moderate positivity in spring and relatively low circulation throughout autumn and winter.



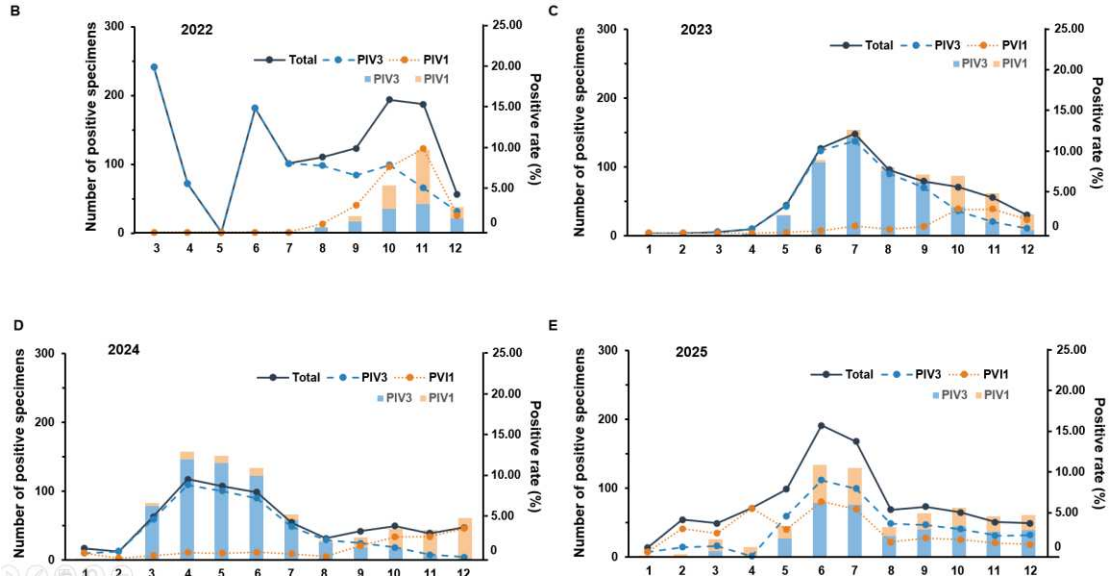



**Figure 1** Number and positive rate of PIV among pediatric patients, 2022-2025. **(A)** Overview of Annual PIV1/PIV3 Positive Counts and Positivity Rates. **(B)-(E)** Monthly variations in PIV positive cases and positive rates from 2022 to 2025. PIV3/PIV1: parainfluenza virus type 3/type1; The gray background columns indicate the months with a high total PIV positivity rate in that year.

By contrast, PIV1 typically peaked in autumn and winter, showing an obvious seasonal alternating pattern with PIV3 ($\chi^2$=297.83, $p$<0.001). PIV1 activity remained low in spring and summer, began to rise in autumn, and sustained a high level through winter, which was in line with global seasonal epidemiological profiles. The high positive rate in the autumn of 2022 and the subsequent annual data further validated its inherent autumn-winter epidemic predominance (**Figure 1**).

## Age-related Epidemiological Characteristics of PIV Infection

PIV-positive cases were predominantly concentrated in children aged 0-3 years, accounting for over 70% of all infections throughout the study period. Infants aged 0-12 months exhibited the highest susceptibility, particularly in 2023 and 2024, and the proportional burden of infection declined gradually with increasing age. Children aged 4-6 years maintained a moderate positive rate, while those aged 7-18 years presented the lowest infection proportion, demonstrating a typical age distribution pattern for pediatric respiratory viruses (**Figure 2**).

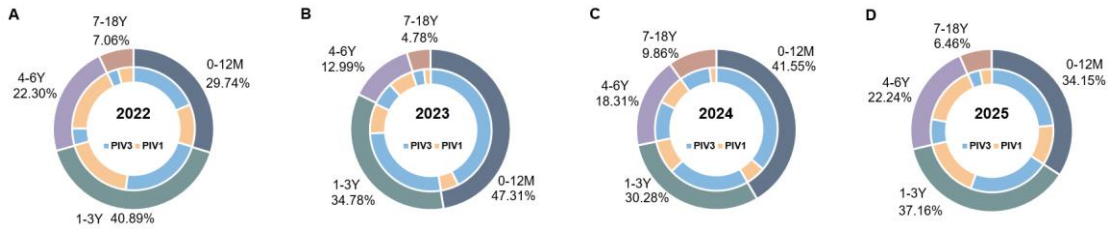



**Figure 2 (A)-(D)** PIV positive rates in children across different age groups during 2022-2025. **Outer ring:** overall PIV positive rates in four age groups (1-12 months, 1-3 years, 4-6 years, and 7-18 years); **inner ring:** proportional distributions of PIV3 and PIV1 within the corresponding outer ring sectors.

PIV3 infection showed a strong predilection for younger age groups, with infants aged 0-12 months as the most susceptible population. The PIV3 positive rate was markedly higher in children aged 0-12 months than in any other age subgroup, followed by the 1-3 years group. Older children aged 4-18 years had relatively low PIV3 positivity, which aligns with the established epidemiological features of PIV3 (**Figure 3**).

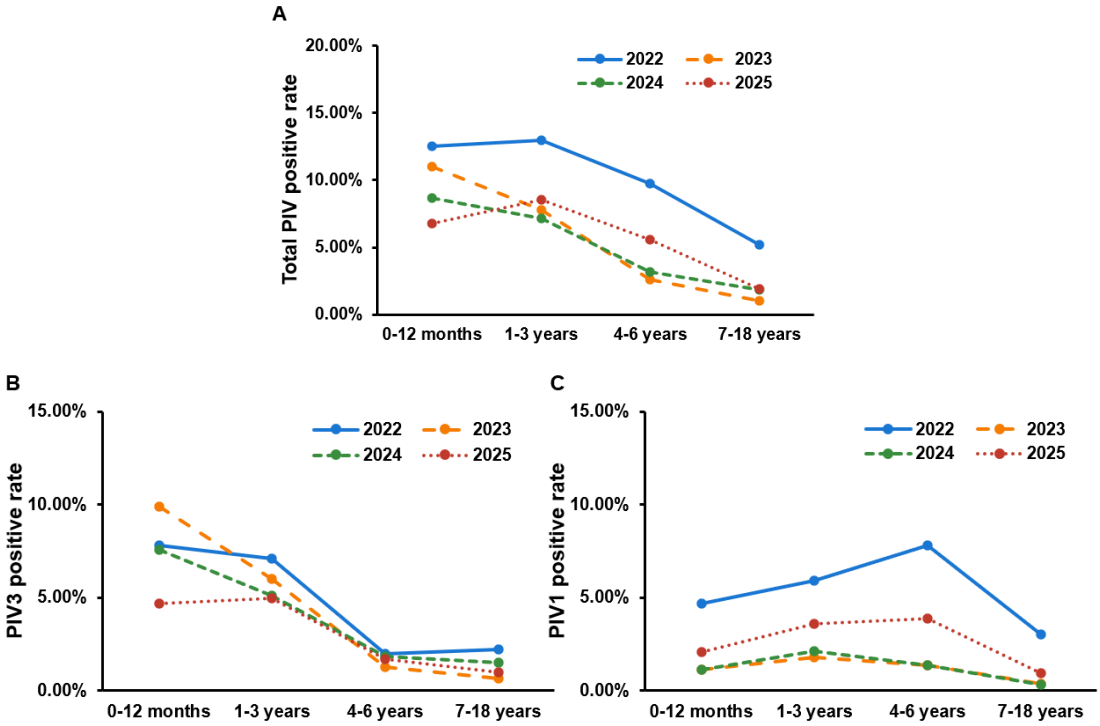



**Figure 3** Changes in PIV positive rates among children of different age groups, 2022-2025. Temporal trends in positive rates of total PIV**(A)**, PIV3 **(B)** and PIV1 **(C)** across pediatric age groups.

In contrast, PIV1 infection exhibited a broader age distribution and constituted a larger proportion among preschool children. The PIV1 positive rates in the 1-3 and 4-6 years age groups were notably higher than those of PIV3. Although infants aged 0-12 months

still accounted for a considerable proportion of PIV1 cases, their susceptibility to PIV1 was lower than that to PIV3, highlighting distinct inter-subtype differences in age distribution patterns.

**Dynamic Variation and Alternation of PIV Subtypes**

The constituent ratios of PIV1 and PIV3 varied significantly from 2022 to 2025 ($\chi^2$=145.92, $p$<0.001), showing a clear annual alternating trend. In 2022, the two subtypes maintained a nearly balanced composition, with PIV1 at 51.77% and PIV3 at 48.33%. This unique distribution was likely associated with rigorous COVID-19 prevention and control measures; during this period, most hospitalized children had typical and non-mild clinical symptoms, which disrupted the natural epidemic pattern of PIV subtypes. From 2023 to 2024, PIV3 dominated the epidemic and accounted for more than 76% of all PIV-positive cases. The proportion of PIV1 rebounded notably to 44.76% in 2025. These dynamic annual shifts in subtype composition suggest that the epidemic activity of PIV1 has gradually recovered, forming a regular alternating circulation with PIV3 once again.

## Discussion

Under normal epidemiological settings, human parainfluenza virus infections exhibit typical seasonal and age distribution: PIV3 is the predominant subtype with a consistent summer-autumn peak and primarily affects infants under 1 year of age, whereas PIV1 circulates predominantly in autumn and winter and infects a wider age range of preschool children[23]. The two subtypes generally show stable alternating circulation patterns without significant annual fluctuation. This study aimed to investigate and characterize the epidemiological features of PIV infection among children in Hangzhou, the capital of Zhejiang Province, China, during and after the COVID-19 pandemic. In early 2020, the global COVID-19 pandemic emerged, and China implemented a series of strict public health interventions, including isolation of confirmed/suspected cases, contact tracing, restrictions on population gathering and mobility, and universal

masking, which effectively controlled virus transmission. Prevention and control measures were significantly relaxed between mid-November and early December 2022, and a full reopening was officially implemented on January 8, 2023. Accordingly, this study defined 2022 as the late pandemic period and 2023-2025 as the post-pandemic period. Our data showed that both the number of tested specimens and positive PIV cases decreased markedly in 2022, whereas the overall positive rate increased. The elevated positive rate might be attributed to restricted hospital visits, where only children with severe symptoms sought medical care under strict pandemic control. Meanwhile, restrictions on social gathering and mobility, as well as widespread masking, greatly reduced the transmission of respiratory pathogens such as PIV and RSV, leading to a decline in tested specimens[24]. Taken together, these findings indicate that non-pharmaceutical interventions during the COVID-19 pandemic exerted a substantial impact on the natural epidemic pattern of PIV.

Multiple studies from different countries and regions have reported abnormal epidemiological changes of parainfluenza virus (PIV) after the COVID-19 pandemic. After the relaxation of non-pharmaceutical interventions, PIV showed disrupted seasonality, with delayed or shifted peaks, altered annual subtype dominance, and expanded age distribution compared with pre-pandemic patterns[25-27]. In China, similar abnormalities were widely observed in Beijing, Hainan, and southern China, including an obvious shift in seasonal peaks, an imbalanced alternation between PIV3 and PIV1, and a wider susceptible age range, especially in preschool and school-age children[11,15,22,28]. These findings are consistent with our results from Hangzhou, indicating that the COVID-19 pandemic has profoundly reshaped the natural epidemiological characteristics of PIV at a national and even global scale.

Although slight numerical differences in positive rates were observed between male and female children for total PIV, PIV3, and PIV1 in each year, these fluctuations were small, inconsistent in direction, and not statistically significant. No consistent or significant gender predilection was identified for PIV infection or either subtype during the entire study period.

Infants and young children are more susceptible to PIV infection, which can be

explained by immature immune function, incomplete airway mucosal barrier development, and lack of specific protective antibodies[29]. Compared with older children, infants have relatively lower levels of maternally derived antibodies, weaker cellular and humoral immunity, narrower and more collapsible airways, and poorer ciliary clearance function, all of which facilitate viral invasion, replication, and spread. In addition, genetic differences in innate immune receptors (such as TLRs and RIG-I-like receptors) and cytokine response patterns may lead to stronger inflammatory reactions and higher viral loads in younger children after PIV infection[30]. These biological characteristics determine that infants aged 0-3 years are the high-risk group for PIV infection. Clinically, this means that enhanced pathogen detection, early identification, and timely supportive treatment should be prioritized in this age group to reduce the risk of progression to severe lower respiratory tract infection.

In conclusion, this study delineates the epidemiological changes of PIV and its major subtypes (PIV3 and PIV1) among hospitalized children in Hangzhou during the late COVID-19 pandemic and post-pandemic periods. Our findings confirm that strict public health interventions temporarily suppressed PIV circulation and distorted its epidemiological pattern, while the post-pandemic era witnessed a gradual recovery toward classic seasonal and age distribution characterized by summer predominance of PIV3 and autumn–winter predominance of PIV1, with obvious alternating circulation between the two subtypes. PIV infection showed no gender predilection but exhibited significant age dependence, with infants and young children bearing the highest disease burden due to immature immune development and anatomical vulnerability. Our findings highlight the sustained impact of the COVID-19 pandemic on the epidemiology of respiratory viruses and offer key data to support targeted surveillance, timely recognition, and optimized prevention and control measures for pediatric parainfluenza virus infection in the post-pandemic period.

## CONCLUSIONS

This study demonstrated the epidemiological characteristics of human parainfluenza virus (PIV) infection among hospitalized children in Hangzhou during 2022-2025. The

overall positive rate was 5.68%, with PIV3 as the predominant subtype. PIV infection showed marked seasonality: PIV3 peaked in summer and PIV1 in autumn-winter. Children aged 0-3 years accounted for the majority of infections, with no significant gender difference. The COVID-19 pandemic disrupted epidemic patterns, followed by gradual recovery of typical seasonal and subtype alternation. These findings provide key data for targeted surveillance, clinical identification, and prevention and control of pediatric PIV infection in post-pandemic era.

## ETHICS STATEMENT

This study was reviewed and approved by the Ethics Committee of Hangzhou Children's Hospital (approval number: IRB-2026-016(IIT)). The study was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments. Given the retrospective nature of the study and the use of de-identified data, the requirement for informed consent was waived by the Ethics Committee. All collected data excluded the patient's private information.

## AUTHOR CONTRIBUTIONS

Yingcong Chen: conceptualization, methodology, data curation, formal analysis, project administration, writing-original draft and writing-review&editing. Jie Wang: methodology, formal analysis, project administration, and writing-review&editing. Xudong Xu: data curation, methodology, writing-original draft. Jun Zhou: data curation, methodology. Meina Yue: data curation, writing-review&editing. Gongbo Zeng: data curation, writing-review&editing. Xinfeng Zhao: conceptualization, funding acquisition, methodology, project administration, writing-original draft and writing-review&editing.

## CONFLICT OF INTEREST

The authors of this study declared that they have no conflict of interest.

## DATA AVAILABITY

All data generated or analysed during this study are included in this article.

**FUNDING**

This work was supported by Hangzhou biomedical and health industry development support science and technology special project [grant number: 2024WJC052].

**ACKNOWLEDGEMENTS**

The authors gratefully acknowledge the Department of Clinical Laboratory, Hangzhou Children's Hospital, for supplying clinical samples and technical support.

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