Seasonality of RSV and Influenza-Like Illness (ILI) in the Post-COVID Era: A Narrative Literature Review of Global and U.S. Trends

ABSTRACT

Seasonality of RSV and Influenza-Like Illness (ILI) in the Post-COVID Era: A Narrative Literature Review of Global and U.S. Trends

By

Aisha Bushra

DATE

12-10-2025

Introduction

Before the COVID-19 pandemic, Respiratory Syncytial Virus (RSV) and Influenza-Like Illnesses (ILI) followed predictable winter peaks, guiding healthcare preparedness. However, the extensive non-pharmaceutical interventions (NPIs) implemented globally to curb SARS-CoV-2 profoundly altered the epidemiology and seasonality of these respiratory viruses.

Aims

This review examines the shifts in the timing, intensity, and demographic distribution of RSV and ILI from 2020 to 2024, comparing global and U.S. trends and exploring implications for surveillance and vaccination strategies.

Methods

A systematic literature review was conducted following PRISMA 2020 guidelines. PubMed, Scopus, Cochrane Library, and WHO Global Health Library were searched for peer-reviewed articles published in English between March 2020 and November 2024. Eligible studies described RSV or ILI epidemiology before and after COVID-19. Findings were synthesized narratively due to heterogeneity in study designs.

Results

NPIs led to a near disappearance of RSV and influenza during 2020–2021, followed by atypical, off-season resurgences as restrictions lifted. In the U.S., RSV activity reappeared unusually early in mid-2021, peaking in summer rather than winter, with similar patterns observed in Europe and Australia. The disruption produced an “immune debt,” marked by older age at hospitalization and higher post-pandemic infection intensity. While seasonality began reverting toward prepandemic norms by 2023, considerable variability persisted.

Discussion

COVID-19-related NPIs caused a historic reshaping of respiratory virus circulation, highlighting the fragility of viral seasonality. Continuous, year-round surveillance and flexible immunization strategies such as maternal RSV vaccination and monoclonal antibody prophylaxis are essential to adapt to evolving epidemic patterns. Further research should explore viral interactions, immunity gaps, and the long-term reestablishment of stable respiratory seasonality.

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Author’s Statement Page

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1. Introduction

Respiratory Syncytial Virus (RSV) and Influenza-Like Illnesses (ILI) have long followed well-defined seasonal patterns, typically peaking in the winter months in temperate climates. These patterns have historically allowed healthcare systems to predict surges in hospitalizations, guide vaccine campaigns, and manage public health preparedness (Perofsky et al., 2022). However, the emergence of the COVID-19 pandemic in early 2020 triggered unprecedented global public health measures, including mask mandates, social distancing, school closures, and lockdowns. These non-pharmaceutical interventions (NPIs), though implemented to curb SARS-CoV-2 transmission, also dramatically impacted the circulation dynamics of other respiratory viruses (Baker et al., 2020). Background on RSV, ILI, and their historical seasonal patterns.

Respiratory Syncytial Virus (RSV) is globally recognized as the primary cause of lower respiratory tract infection (LRTI) in infants and young children, making it the main reason for infant hospitalization in the United States(Hvers et al., 2022). Historically, RSV follows a distinct seasonal pattern(Liu et al., 2021)(Abushahin et al., 2024). In temperate regions (Northern Hemisphere), epidemics typically occur during the fall and winter seasons, usually commencing in October, peaking in December or January, and ending by March or April(Tempia et al., 2021)(Be’er et al., 2022). In the United States, pre-pandemic RSV seasons (2017–2020) nationally began in October, peaked in December, and ended in April(Cong et al., 2024). In tropical countries, RSV tends to circulate year-round, peaking during the rainy season. Acute respiratory infections (ARIs), which include those associated with influenza (ILI), represent a significant global public health burden in terms of morbidity and mortality(Chen et al., 2025) (Cong et al., 2024).

1.1. Overview of the COVID-19 pandemic's impact on respiratory virus transmission:

The outbreak of COVID-19 in late 2019 prompted governments worldwide to implement extensive NPIs (Niu et al., 2025) (Bherwani et al., 2021). These measures included mandatory face coverings, social distancing, travel restrictions, school closures, shelter-in-place orders, and stringent lockdowns. These policies resulted in a dramatic disruption of the typical seasonal circulation patterns of most common respiratory viruses. The most evident effect during the initial pandemic year (2020–2021) was the substantial suppression and near disappearance of enveloped viruses such as RSV and influenza in many regions globally. This disruption had the unexpected positive consequence of a significant decrease in ARI-related pediatric hospital admissions and emergency department visits during the lockdown period (Ayouni et al., 2021; Gilca et al., 2024).

The COVID-19 pandemic provided a unique opportunity to gain insight into the dynamics of various other infectious diseases. The massive disturbances to viral circulation require a new perspective on the epidemiology and clinical burden of respiratory infections (Hamid et al., 2023). Understanding the post-pandemic evolution of respiratory viruses is essential for anticipating future epidemic cycles. Furthermore, precise quantification of RSV burden is critical for informing policy evaluations of emerging RSV prevention strategies, such as long-acting monoclonal antibodies (e.g., nirsevimab) (Fischli et al., 2024)and maternal RSV immunization. Ongoing monitoring is vital to inform targeted disease prevention and control strategies.

1.2. Scope and Objectives of the Review:

This review aims to describe the evolving landscape of RSV and ILI seasonality and disease burden from 2020 to 2024, focusing specifically on:

1. Analyzing the changes in seasonality (onset, peak, and duration) of RSV and influenza compared to pre-pandemic norms.

2. Examining the fluctuations in patient age distribution and clinical severity.

3. Synthesizing the varying regional responses and epidemiological changes across geographic areas.

4. Discussing implications for public health policy, particularly concerning vaccine timing and surveillance strategies.

The purpose of this review is to explore how these pandemic control measures disrupted the typical seasonality of RSV and ILI, what patterns have emerged in the years following the pandemic's peak, and the implications for health systems worldwide. This review draws upon global and U.S.-based literature, highlighting not only the virological trends but also the sociodemographic and climatic factors influencing viral transmission in a post-pandemic world. Through this exploration, the thesis aims to contribute to the understanding of emerging respiratory seasonality and its relevance for public health planning, especially for vulnerable pediatric populations.

2. Methods

2.1. Study Design:

This study is a systematic review conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The review aimed to evaluate published evidence on the epidemiologic trends and seasonal variations of Respiratory Syncytial Virus (RSV) and Influenza-Like Illness (ILI) before and after the COVID-19 pandemic.

2.2. Search Strategy:

I conducted a comprehensive electronic search in PubMed to identify relevant peer-reviewed articles, published in English between March 2020 and November 2024. The search strategy combined Medical Subject Headings (MeSH) and free-text keywords to capture studies examining the epidemiology, seasonality, and geographic patterns of RSV and ILI across different population groups.

The PubMed search returned 7,245 records using the following query:

("Respiratory Syncytial Virus Infections"[mh] OR "Respiratory Syncytial Virus, Human"[mh] OR "Respiratory Syncytial Viruses"[mh] OR "Respiratory Syncytial Virus"[tiab] OR "Influenza-like"[tiab] OR "ILI"[tiab])
AND ("pre-covid"[tiab] OR "post-covid"[tiab] OR (("Seasons"[mh] OR "seasonalit*"[tiab]) AND (trend*[tiab])))
AND ("Pediatrics"[mh] OR "Aged"[mh] OR "Frail Elderly"[mh] OR "Immunocompromised Host"[mh] OR pediatric[tiab] OR child*[tiab] OR elderly[tiab] OR "older adults"[tiab] OR frail[tiab] OR immunocompromised[tiab])
AND ("Geography"[mh] OR "Geographic Locations"[mh] OR "Epidemiology"[mh] OR "Climate"[mh] OR "Climatic Processes"[mh] OR "Socioeconomic Disparities in Health"[mh] OR "Socioeconomic Factors"[mh] OR "Health Status Disparities"[mh] OR "Social Class"[mh] OR "Financial Stress"[mh] OR "Residential Segregation"[mh] OR geograph*[tiab] OR epidemiol*[tiab] OR climat*[tiab] OR socioeconomic[tiab] OR social[tiab] OR disparit*[tiab] OR segregat*[tiab] OR societ*[tiab] OR status*[tiab])

Searches were conducted for studies published in two periods: before June 1, 2020 (pre-COVID-19) and on/after June 1, 2020 (post-COVID-19). To ensure comprehensiveness, the search was restricted to article types categorized as “Review” or “Systematic Review.”
Additional searches were performed in Scopus, Cochrane Library, and WHO Global Health Library, and reference lists of key studies and surveillance reports from CDC, ECDC, and WHO were screened manually to identify additional relevant literature.

2.2.a. Inclusion Criteria

Studies were included if they met the following criteria:

1. Reported on RSV or ILI epidemiology or seasonality.
2. Examined pre- and post-COVID-19 trends.
3. Focused on pediatric, elderly, frail, or immuno-compromised populations.
4. Provided data related to geography, climate, or socioeconomic factors.

5. Were review or systematic review articles published in English.

2.2.b. Exclusion criteria:

- Studies focus exclusively on SARS-CoV-2 without reference to RSV or ILI.
- Animal or in vitro studies.
- Modeling or vaccine-development papers without seasonal analysis.
- Editorials, commentaries, or letters without original data.

2.2.c. Study Screening and Selection

All retrieved articles were imported into Zotero for duplicate removal. Title and abstract screening were performed independently, followed by full-text review to confirm eligibility. A PRISMA flow diagram summarizes the number of records identified, screened, excluded, and included in the final synthesis.

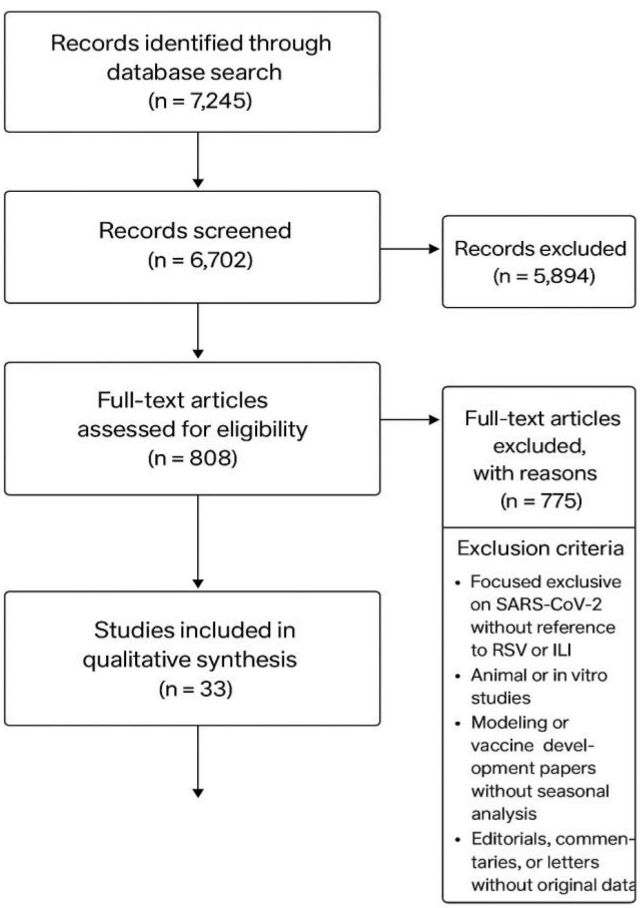

Fig.1. PRISMA flow diagram for data collection and screening

Data Extraction:

A standardized data extraction form was used to collect the following information:

- Study author(s), year, and country.
- Population characteristics (children, elderly, immunocompromised).
- Study period and design.
- Viral focus (RSV, ILI, influenza).
- Pre- and post-COVID comparisons.
- Geographic and climatic variables.
- Key findings related to seasonality and epidemiologic shifts.

2.3. Data Synthesis:

Due to heterogeneity in methodologies and reporting formats, a narrative synthesis was undertaken. The findings were organized into key thematic categories:

1. RSV and ILI seasonal shifts before and after COVID-19.
2. Population-specific patterns (pediatrics, elderly, immunocompromised).
3. Geographic and climatic influences.
4. Socioeconomic and public health implications.

Quantitative data (e.g., onset, peak, and duration of seasonal peaks) were summarized descriptively where available.

Ethical Considerations:

As this review utilized published and publicly accessible data, no institutional review board approval was required. All sources were properly cited to maintain research integrity.

3. Results

3.1. Global Epidemiological Patterns of Respiratory Viruses in the Post-Pandemic Era:

Acute respiratory infections (ARIs), which encompass both upper respiratory infections (URIs) and lower respiratory infections (LRIs), remain a significant public health concern globally, posing a substantial burden on morbidity and mortality(Niu et al., 2025). ARI pathogens include various viruses and bacteria. Historically, certain viruses like Respiratory Syncytial Virus (RSV) have followed predictable winter seasonal patterns in temperate climates(Fischli et al., 2024)(Hamid et al., 2023).

The defining epidemiological trend of the early 2020s was the massive disruption of these predictable patterns due to the global implementation of non-pharmaceutical interventions (NPIs) aimed at combating SARS-CoV-2 (Guitart et al., 2022). NPIs, such as facial masking, enhanced hand hygiene, social distancing, international travel controls, and school closures, not only mitigated COVID-19 transmission but also reduced the incidence of other respiratory pathogens (Chow et al., 2022)(Abushahin et al., 2024).

Global Patterns: Disruption, Shifting Seasonality, and Resurgence

3.1.a. Baseline Global Burden of Respiratory Infections

Acute respiratory infections are highly consequential globally. For example, seasonal influenza-related ARIs cause an estimated 250,000–500,000 deaths worldwide annually(Paget et al., 2019).

A systematic review of the Global Burden of Disease (GBD) data indicates that, over the long term (1990 to 2021), the global age-standardized incidence rates (ASIR) of both URIs and LRIs have decreased. Furthermore, the global age-standardized mortality rate (ASMR) of LRIs dropped significantly, moving from the 4th to the 7th place in the global mortality causes ranking during this period. Respiratory Syncytial Virus (RSV) is acknowledged as the primary cause of Lower Respiratory Tract Infection (LRTIs) among infants and young children globally. Worldwide, RSV is estimated to cause 3. million hospitalizations each year among children younger than 5 years of age, with the majority occurring in infants.

3.1.b. Impact of Non-Pharmaceutical Interventions (NPIs)

The near-simultaneous global implementation of NPIs (such as facility closures, social distancing, mask use, and enhanced hand hygiene) intended to mitigate SARS-CoV-2 transmission resulted in a massive disruption of the predictable winter epidemics typically observed in temperate climates. These NPIs not only mitigated COVID-19 transmission but also significantly reduced the incidence of other respiratory pathogens.

Broad Suppression: The worldwide implementation of NPIs had a measurable effect on the circulation of common respiratory viruses (ORVs), dramatically altering their usual seasonality. For instance, influenza (IFV) activity was historically low in the United States during October

2020–May 2021(Be'er et al., 2022). In China, dramatic reductions in positive rates were seen for most pathogens during the intense lockdown phases (Phase I and II in early 2020). IFV activity remained consistently suppressed across all periods in China, regardless of age or region.

Viral Exceptions: Unlike most enveloped viruses like IFV and RSV, non-enveloped viruses, notably Rhinovirus (HRV), demonstrated remarkable persistence through NPIs(Kitanovski et al., 2021). This persistence is potentially due to factors such as prolonged shedding, high genetic diversity, and persistence on environmental surfaces. In fact, Rhinovirus was reported as the dominant virus during the COVID-19 and post-COVID-19 seasons in Qatar, contrasting with the RSV dominance seen pre-pandemic(Abushahin et al., 2024).

Bacterial Impact: The protective measures extended to bacterial infections. Implementation of basic NPIs, such as facial masking and enhanced hand hygiene, led to a significant reduction (40–67%) in the incidence rates of Invasive Pneumococcal Disease (IPD) across all age groups in Taiwan in 2020(Janapatla et al., 2021) (Danino et al., 2022).

3.2. Post-Pandemic Seasonality Shifts and Resurgence

Following the relaxation or discontinuation of NPIs, most viruses returned to or exceeded historical levels. This created a large, immunologically naïve population, contributing to unusual epidemic patterns(Abushahin et al., 2024).The predictable RSV winter seasons were widely disrupted.

◦ In the United States, the typical winter RSV epidemic was absent during the 2020–2021 season. The 2021–2022 season began unusually early in May and peaked in July, lasting longer (33 weeks) than pre-pandemic seasons (median 27 weeks). By the 2022–2023 season, the onset (June) and peak (November) suggested a shift back towards pre-pandemic seasonality, though still earlier than historical norms(Hamid et al., 2023).

◦ In the Southern Hemisphere (e.g., Australia) and parts of the Northern Hemisphere (e.g., Spain, France), an interseasonal or off-season resurgence was observed. For instance, in Spain, the outbreak occurred late, starting in summer 2021(Foley et al., 2021).

◦ In Switzerland, surveillance showed two consecutive major RSV epidemics during the 2022–2023 and 2023–2024 seasons, a pattern previously unrecorded(Fischli et al., 2024).

Resurgence of Other Viruses in China: In China, positive rates for RSV, Human Parainfluenza Virus (HPIV), Human Coronavirus (HCoV), and Human Bocavirus (HBoV) rose significantly above historical levels during Phase III (September 2020–January 2021), coinciding with the large-scale lifting of NPIs and school re-openings(Guo et al., 2024; Liu et al., 2021; Niu et al., 2025).

3.3. Shifts and Clinical Vulnerability

The shift in viral circulation dynamics led to important changes in the affected populations.

Age Shift**:** A post-lockdown trend toward older age at hospitalization for respiratory viruses, often attributed to the "immune debt" hypothesis (lack of first year-of-life exposure), was observed globally (Agha & Avner, 2021). In Switzerland, this age shift was particularly evident in the third post-lockdown season (2023–2024), where only 61% of hospitalized patients were below 12 months of age, significantly lower than the pre-pandemic median of 73%(Fischli et al., 2024).

High-Risk Groups (China): Across 1990–2021 in China, the burden of URIs and LRIs was relatively higher in neonates and the elderly. The disease burden of URIs was primarily concentrated in children under 4 years of age, while the burden of incidence for LRIs was predominantly concentrated in the elderly population aged over 80 years. Both URIs and LRIs were significantly influenced by age, period, and birth cohort effects(Liu et al., 2021).

RSV Vulnerability (US): Infants below 3 months of age, as well as those with prematurity (<32 weeks or 32–36 weeks), airway anomalies, congenital heart disease, and neuromuscular disorders, were independently associated with ICU admission due to RSV (Fischli et al., 2024). The high hospitalization rates for RSV typically occur during the first months of life and decline with increasing age in infancy and early childhood.

Integration and comparison of global vs. U.S. trends

Table 1: The data highlight substantial heterogeneity in how different regions experienced the viral disruption and recovery, particularly concerning RSV and influenza.

Region/Area	Pathogens	Key Epidemiological Trends (2020–2024)	Source
United States (US)	RSV, IFV, HRV	IFV activity was historically low (2020–2021). RSV shifted seasonality: absent winter 2020–2021; resurgence began unusually early in April 2021; 2021–2022 season peaked in July. Resurgence began earliest in the Southeast (Florida) consistently. Estimates suggest approx. 80,000 RSV infant hospitalizations annually.	(*Mask Usage, Social Distancing, Racial, and Gender Correlates of COVID-19 Vaccine Intentions among Adults in the US | PLOS One*, n.d., p. 19)(Hamid et al., 2023)
Canada (Quebec)	RSV, IFV, ORVs	IFV and RSV completely absent in hospitalized children in 2020–2021. RSV resurgence started in August 2021 (16 weeks earlier than pre-pandemic peak). IFV peak shifted dramatically (17 weeks later in 2021–2022; 4 weeks earlier in 2022–2023).	(Gilca et al., 2024)

		SARS-CoV-2 was the main cause of adult ARI hospitalization in the first 2 years, but ORVs dominated pediatric cases.	
Europe (Spain, Switzerland, France)	RSV, IFV	Severe suppression of RSV during winter 2020–2021. Delayed, out-of-season RSV peak occurred in Summer 2021 (June/July) in Spain, under atypical temperature conditions (23°C). Switzerland experienced two consecutive major RSV epidemics (2022–2023 and 2023–2024), unprecedented historically. The 2023–2024 Swiss season saw a major age shift to older children (only 61% under 12 months).	(Meslé et al., 2023)(Fischli et al., 2024)
Asia (China, Taiwan)	IFV, RSV, HRV	IFV suppressed by 87.6% (largest drop among pathogens). Rhinovirus surged significantly (exceeding historical levels among children) during and after NPI relaxation and school reopening in 2020. RSV resurgence occurred later in 2020 in China's northern regions. Taiwan reported an unexpected RSV outbreak in September–December 2020.	(Niu et al., 2025) (Liu et al., 2021) (Guo et al., 2024)
Middle East (Qatar)	RSV, HRV	Total viral ALRTI hospitalizations reduced significantly during the pandemic. RSV infection rate dropped from 50.9% pre-COVID-19 to 10.4% during, then partially rebounded post-COVID-19 (29.1%). Rhinovirus dominated during the COVID-19 season (61%).	(Alaib et al., 2023)(Abushahin et al., 2024)
Oceania (Australia, New Zealand)	RSV, IFV	Both RSV and IFV experienced substantial reductions (e.g., 98% reduction in RSV and 99.4% in IFV ALRTIs in Australia for 2020 winter). An interseasonal RSV resurgence occurred in spring/summer 2020/2021 following easing of measures.	(Foley et al., 2021) (Garg et al., 2022)

The strict NPIs resulted in a reduction of exposure to common respiratory pathogens, leading to an accumulation of susceptible individuals and the hypothesis of “immune debt”(Agha & Avner, 2021). This deficit, particularly in young children who missed their first exposure, is cited as a likely factor driving the high-intensity, off-season RSV epidemics and the subsequent shift in age distribution. The observation of older children being hospitalized for RSV, as seen in the 2023–2024 season in Switzerland, supports the idea that the cohort of immunologically naïve individuals increased their age without having developed natural immunity (Fischli et al., 2024). This lack of exposure can also potentially lead to lower levels of maternal antibody transferred to newborns, possibly increasing the risk and severity of infection in infants.

Challenges in Forecasting and Preparedness:

Although nonpharmaceutical interventions (NPIs) helped prevent many infections and reduced related morbidity and mortality, they also led to an “immunity gap” a group of susceptible individuals who, having avoided exposure, lack pathogen-specific immunity for future protection. Pandemic-related disruptions to health-care services further contributed to this gap by reducing childhood vaccination rates for preventable diseases such as influenza, measles, and polio (Messacar et al., 2022). The combined impact of newly susceptible birth cohorts, waning immunity from reduced exposure to endemic viruses, and persistently low vaccination rates in some regions continues to widen this immunity gap, heightening the risk of future outbreaks of endemic infections (Reicherz et al., 2022).The COVID-19-related disruption continues to cause an unpredictable shape of annual winter epidemics.(Gentile et al., 2025; Hamid et al., 2023) This volatility makes accurate forecasting challenging, particularly regarding the timing and intensity of future seasons.

Because RSV immunization programs primarily target infants (e.g., nirsevimab for those <8 months), (Cong et al., 2024)the year-to-year fluctuation of cases among older children (up to 40% of hospitalizations in recent seasons) leads to substantial variability in estimated vaccine impact (approximately 15% variation predicted in simulation models)(Raina MacIntyre et al., 2024).

Hospital administrators must consider these uncertainties when anticipating the resources needed for pediatric intensive care unit (PICU) capacity and staffing for the winter months. Accurate burden estimates are complicated by the methodology used. Active surveillance studies yield RSV hospitalization rates roughly half those derived from administrative claims or modeling approaches in US infants. This divergence necessitates careful evaluation when defining true burden for policy formulation.

In addition to these epidemiologic shifts, global warming is altering the seasonal patterns of respiratory viruses, including RSV. Warmer autumns and milder winters can lengthen transmission windows, shift peak activity outside traditional winter months, and create more overlapping waves of viral circulation. These climate-driven changes further complicate predictions of RSV burden and add another layer of uncertainty for public health planning.

Limitations in the existing literature and gaps in data

Several limitations constrain a full understanding of these post-pandemic dynamics in the literature. Many available studies are retrospective, single-center designs, which may limit the generalizability of findings across wider geographic regions. Changes in institutional testing strategies (e.g., widespread use of PCR and multiplex PCR since the pandemic began) likely increased the detection of viruses, especially in older children, potentially contributing to the observed age shift and obscuring baseline burden comparisons. The GBD dataset, used in some analyses, fails to capture specific pathogen information related to diseases, restricting the capacity to customize interventions for individual pathogens. Detailed analyses of disease burden differences at the provincial level, such as within China, is lacking due to uneven development across regions. The mechanism behind the resurgence of timing and severity of discrepancies remains unclear. Further research is required to understand the long-term interactions (interference or co-circulation) between SARS-CoV-2 and other respiratory viruses and their impact on severity.

4. Discussion

The onset of the COVID-19 pandemic and the subsequent implementation of NPIs led to a significant reduction or virtual elimination of seasonal respiratory viruses, especially enveloped viruses like IFV and RSV, resulting in historically low activity during 2020–2021. The key post-pandemic pattern was the resurgence of viruses (RSV, HPIV, HRV), often manifesting as delayed or out-of-season epidemic**s** (e.g., summer RSV peaks in 2021 in the US, Spain, and Australia). This period was marked by an unpredictable epidemic shape. The emergence of an immunologically naïve population led to a shift in RSV hospitalizations toward older children in many high-income countries, supporting the theory of accrued “immune debt”. Rhinovirus, a non-enveloped virus, demonstrated exceptional persistence and often became the dominant circulating pathogen during periods of strict NPIs. By the 2022–2023 season, seasonality began showing signs of reverting toward pre-pandemic norms, though volatility persisted.

4.1. Implications for public health policy and practice

The drastic epidemiological changes emphasize the need for robust, flexible public health strategies. Continuous, year-round surveillance using systematic multiplex testing for multiple respiratory pathogens is essential to monitor unpredictable seasonal shifts and co-circulation patterns. Policymakers must consider changing seasonality when guiding the timing of immunization and prophylaxis products. The high effectiveness demonstrated by new preventive agents like nirsevimab (90% against RSV hospitalization in infants) supports the recommendation that all infants should be protected by either maternal vaccination or nirsevimab during their first RSV season. Hospital systems must prepare for significant volatility in pediatric case volumes and age distributions, prioritizing resource allocation based on established risk factors for severe disease (e.g., prematurity, congenital heart disease) in vulnerable infants.

Future efforts should focus on closing critical gaps in knowledge and preparedness into the risk factors for high-risk populations is required to develop more targeted prevention strategies. Continuous surveillance and serological surveys are needed to better understand the long-term impact of the pandemic and the recovery time required for the seasonality of normal winter viruses (RSV and IFV) to resume globally. Future research should identify which NPIs are most effective against specific viral pathogens and determine when these interventions should be applied to optimize prevention while maintaining social acceptability. Further investigation is needed into the complex interplay between SARS-CoV-2 and other respiratory viruses, including potential viral interference mechanisms, to fully understand the dynamics governing co-circulation and virulence in the post-pandemic era. Research focusing on province-specific disease burden differences (e.g., across China) will aid in formulating tailored prevention measures and resource allocation.

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6. Appendices

Table: 2. Prisma Style Data Extraction Table

PRISMA-Style Data Extraction Table

Author, Year	Country	Study Design	Population	Study Period	Virus Focus	Pre/Pos	Key Findings
Abushahin et al., 2024	Qatar	Retrospective hospital data	Children	2017–2022	RSV, respiratory viru	Yes	Pandemic restrictions reduced viral hospitalizations; increase after relaxation
Agha & Avner, 2021	USA	Surveillance	Children	2020–2021	RSV	Yes	Delayed, off-season RSV surge after NPIs relaxed
Alaib et al., 2023	Saudi Ara	Retrospective analysis	Children	2017–2022	RSV, influenza, othe	Yes	Shifted seasonality and fluctuating virus prevalence post COVID
Ayouni et al., 2021	Global	Systematic review	General	2020	NPIs	No (NPI	NPIs effectively reduced viral transmission
Baker et al., 2020	Global	Modeling study	General	2020	RSV, influenza	Yes (mo	NPIs may alter long-term transmission dynamics
Be'er et al., 2022	Israel	Retrospective study	Children	2020	Pediatric respirator	Yes	Major seasonal disruptions during the first pandemic year
Bherwani et al., 2021	Multiple c	Environmental analysis	General	2020	PM2.5-related respi	No	Improved air quality reduced respiratory impacts
Chen et al., 2025	Global	Surveillance	General	2022–2023	Influenza	Yes	Altered influenza epidemic patterns post-NPI lifting
Chow et al., 2022	Global	Review	General	2020–2022	RSV, flu, others	Yes	Community virus activity significantly reduced, rebounded post-NPI
Cong et al., 2024	Global	Systematic analysis	Children	2020–2023	RSV	Yes	Global RSV hospitalizations declined then surged
Danino et al., 2022	Israel	Prospective cohort	Children	2020–2021	Pneumococcus, RSV	Yes	Decline in pneumococcal disease correlated with viral suppression
Fischli et al., 2024	Switzerla	Surveillance	Children	2020–2023	RSV	Yes	Post-pandemic RSV fluctuations may impact immunization timing
Foley et al., 2021	Australia	Surveillance	Children	2020	RSV	Yes	Interseasonal resurgence after easing restrictions
Garg et al., 2022	USA	Review	Children	2020–2021	RSV	Yes	COVID altered RSV epidemiology and timing
Gentile et al., 2025	Argentina	Comparative epidemiology	General	2018–2019 vs	Influenza	Yes	Post-pandemic influenza seasonality was altered
Gilca et al., 2024	Canada	Hospital surveillance	General	2020–2023	Respiratory viruses	Yes	Changing viral landscape contributing to hospitalizations
Guitart et al., 2022	Spain	Retrospective cohort	Children	2019–2021	Bronchiolitis	Yes	Bronchiolitis patterns shifted markedly during COVID
Guo et al., 2024	China	Systematic analysis	Children	2017–2023	RSV	Yes	Changing RSV transmission zones and seasonality
Hamid et al., 2023	USA	National surveillance	General	2017–2023	RSV	Yes	RSV seasonality altered, earlier and more intense
Havers et al., 2022	USA	Hospital surveillance	Adults	2018–2022	RSV	Yes	Adult RSV hospitalizations changed during COVID
Janapatla et al., 2021	Taiwan	Surveillance	Children	2018–2021	IPD, RSV	Yes	Reduced invasive pneumococcal disease linked to NPI-viral reductions
Kitanovski et al., 2021	Germany	Surveillance	General	2020	Rhinovirus	Yes	Rhinovirus used as NPI effectiveness indicator
Liu et al., 2021	China	Retrospective analysis	Children	2019–2021	Respiratory viruses	Yes	Sharp decline in viral LRTIs during NPIs
Mask Usage Study (PLo	USA	Survey	Adults	2020	COVID behaviors	No	Behavior determinants for NPI compliance
Meslé et al., 2023	Europe	Surveillance	Children	2020–2022	RSV	Yes	Inter-seasonal RSV waves across Europe
Messacar et al., 2022	USA	Commentary	Children	2022	Pediatric viruses	Yes	Expected unpredictable viral surges post-disruption
Niu et al., 2025	China	Burden analysis	General	1990–2021	Respiratory infectio	Yes (tren	Long-term burden changes with COVID impact
Paget et al., 2019	Global	Mortality modeling	General	1990–2015	Influenza	No	Baseline flu mortality estimates pre-COVID
Perofsky et al., 2022	South Afri	Health utilization study	General	2020–2021	Respiratory infectio	Yes	Reduced healthcare utilization during COVID
Rimoin et al., 2024	Global	Review	General	2020–2023	Emerging infections	No	Emphasizes early detection for vaccines
Reicherz et al., 2022	Canada	Cohort analysis	General	2020–2021	RSV	Yes	Waning immunity due to low exposure during COVID
Tempia et al., 2021	South Afri	Surveillance	General	2020	Flu, RSV	Yes	Major declines in flu/RSV detection during NPIs