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Epidemiological surveillance and incidence of respiratory viruses in Chile: Before and after COVID-19

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Abstract

Objective: During the COVID-19 pandemic, various measures, such as lockdowns and travel restrictions, were implemented to curb the spread of SARS-CoV-2, significantly impacting case numbers. These interventions also influenced the incidence of other respiratory viruses, including respiratory syncytial virus (RSV) and influenza A (InfA).

Materials and methods: This study examines the effect of SARS-CoV-2 on the circulation of major respiratory viruses by analyzing epidemiological data from Chile between 2015 and 2023.

Results: Data analysis revealed that during the pandemic, RSV, InfA, adenoviruses (ADV), and human metapneumovirus (HMPV) reached historically low levels. However, the relaxation of restrictions in 2021 led to a surge in respiratory virus infections, with RSV cases approaching pre-pandemic levels by 2022. Notably, in 2022 and 2023, infections caused by these viruses exceeded pre-pandemic numbers.

Conclusions: These findings align with epidemiological predictions regarding shifts in infection patterns due to preventive measures. Understanding these trends, particularly during lockdowns, is crucial for planning future outbreak response strategies. The insights gained from this analysis have recently informed proactive measures for Chile's upcoming winter season, helping mitigate an anticipated rise in respiratory emergencies, especially among children in regions with high humidity and low temperatures.

Keywords: SARS-CoV-2; Respiratory viruses; Epidemiological surveillance

Vigilancia epidemiológica e incidencia de virus respiratorios en Chile: antes y después del COVID-19

Resumen

Objetivo: Durante la pandemia de COVID-19, se implementaron diversas medidas, como confinamientos y restricciones de viaje, para frenar la propagación del SARS-CoV-2, lo que tuvo un impacto significativo en el número de casos. Estas intervenciones también influyeron en la incidencia de otros virus respiratorios, como el virus respiratorio sincitial (RSV) y la influenza A (InfA).

Materiales y métodos: Este estudio examina el efecto del SARS-CoV-2 en la circulación de los principales virus respiratorios mediante el análisis de datos epidemiológicos de Chile entre 2015 y 2023.

Resultados: El análisis de datos reveló que, durante la pandemia, los niveles de RSV, InfA, adenovirus (ADV) y metapneumovirus humano (HMPV) alcanzaron mínimos históricos. Sin embargo, la relajación de las restricciones en 2021 provocó un aumento en las infecciones por virus respiratorios, con casos de RSV acercándose a los niveles previos a la pandemia en 2022. Notablemente, en 2022 y 2023, las infecciones causadas por estos virus superaron los números pre-pandemia.

Conclusiones: Estos hallazgos coinciden con las predicciones epidemiológicas sobre los cambios en los patrones de infección debido a las medidas preventivas. Comprender estas tendencias, especialmente durante los confinamientos, es crucial para planificar estrategias de respuesta ante futuros brotes. Los conocimientos obtenidos a partir de este análisis han permitido recientemente la implementación de medidas proactivas para la próxima temporada invernal en Chile, ayudando a mitigar un aumento esperado en las emergencias respiratorias, especialmente en niños de regiones con alta humedad y bajas temperaturas.

Palabras clave: SARS-CoV-2; Virus respiratorios; Vigilancia epidemiológica

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Introduction

Respiratory tract infections represent a challenge to public health, particularly among children, the elderly, and people presenting with comorbidities. The World Health Organization (WHO) estimates that more than 2 million people succumb each year to acute respiratory infections, predominantly pneumonia, with approximately 70% of these deaths occurring in Africa and Asia[1]. The principal viral respiratory infections (VRI) are caused by influenza virus (InfA), respiratory syncytial virus (RSV), parainfluenza (PI), adenovirus (ADV), human metapneumovirus (HMPV), human coronaviruses (HCoVs), and rhinovirus (RV)[2]. InfA and RSV infections often lead to pneumonia, especially in children under 5 years of age in developing countries. The acquisition and spread of VRIs vary among different populations[3]. These variations may be derived from cultural and socioeconomic factors, geographic or climatic differences, or disparities in access to healthcare systems. Understanding the local epidemiology of VRIs and identifying risk factors are critical for implementing preventive programs[4]. VRIs are largely favored by cold weather seasons, as reported in different regions[5]. However, the role of low temperature is likely to be modulated by humidity and UV radiation, as investigated by Li et al.[6].

Airborne disease transmission has historically impacted humanity, ranging from acute infections to high-chronicity tuberculosis[7,8]. These diseases propagate through small particles suspended in the air that harbor pathogenic bacteria or viruses. These particles can transmit diseases from one individual to another, affecting both the upper and lower respiratory tracts[9]. The rapid spread of diseases via airborne transmission, along with their capability to impact vast populations, is illustrated in Figure 1.

Influenza, an acute viral illness, predominantly affects the respiratory system and swiftly propagates through the air, thereby instigating epidemics and pandemics with serious public health consequences. It is primarily transmitted via direct contact and through small respiratory droplets when an infected individual coughs or sneezes[10]. Additionally, Tuberculosis, a bacterial infection, primarily targets the lungs and disseminates via the same mechanism as influenza[11].

The emergence of the COVID-19 pandemic caused by the SARS-CoV-2, underscored the crucial role of airborne disease transmission. This virus disperses mainly through small respiratory droplets laden with viral particles produced when infected individuals talk, cough, or breathe[12,13]. These aerosols, with a size less than 5 µm, can linger in the air for up to three hours and travel 7 to 8 m, thereby allowing inhalation in long-range locations, even in the absence of infected individuals[14,15,16].

Unlike direct transmission via close contact or contaminated surfaces, airborne transmission via aerosols can occur without awareness of the possibility of infection. One factor that contributes to infection is time: the longer an individual is exposed to an environment laden with pathogens, the higher the likelihood of infection. This risk is intrinsically linked to population density[17]. Additionally, temperature and humidity can exacerbate the spread of airborne respiratory diseases[18]. In this regard, vaccines play a crucial role in preventing the spread of infectious diseases[19]. Since their systematic use, numerous diseases have been eradicated or controlled by vaccination[19]. Preventive actions such as practicing respiratory hygiene (i.e., covering the mouth and nose when coughing or sneezing), frequent handwashing, physical distancing, and proper ventilation of spaces contribute to reducing the spread of infection[20]. The combination of these preventive strategies was instrumental in preventing major disasters in

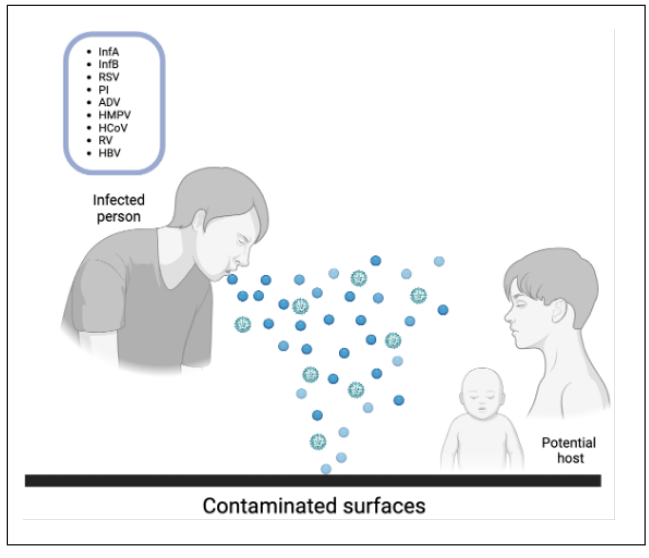

Figure 1. Respiratory Viruses and Airborne and Person-to-Person Transmission Systems. Respiratory viruses have the capacity to spread within the population through airborne and person-to-person transmission systems. This is attributed to the fact that viral particles can remain latent both in the air and on surfaces, remaining highly transmissible

the pre-immunization phase of the COVID-19 pandemic. The use of vaccines has marked an inflection point in combating and defeating SARS-CoV-2 associated morbidity. In addition, surveillance of VRI, unlike SARS-CoV-2, indicated lower levels. This observation led to a worldwide warning for VRI, which showed a dramatically increased incidence as confinement due to COVID-19 eased[21]. The background presented in this work suggests that the lockdown measures and mobility restrictions implemented during the COVID-19 pandemic in Chile led to a significant decrease in the incidence of other respiratory viruses, such as RSV and influenza A. Therefore, we hypothesize that confinement, over other factors, is the main trigger for the rapid increase in infections by VRI, surpassing even pre-pandemic incidence levels. This study analyzed the surveillance data of VRI in Chile. Data included the incidences of RSV, InfA, ADV, HMPV, and SARS-CoV-2 by epidemiological weeks from 2015 to 2023. The data demonstrate a record increase of VRI during 2022-2023, after VRI different from SARS-CoV-2 reported record low levels during–2020-2021. Considering the characteristics and implications of each of these respiratory viruses representing the population, it is of utmost importance to evaluate the incidence of respiratory diseases in each region worldwide. The analyzed data allowed us to establish a behavioral pattern for each virus and, based on this, propose epidemiological surveillance measures that could anticipate outbreaks and critical weeks of infection for each of the studied viruses.

Materials and Methods

Data were extracted from the weekly reports of the Chilean Public Health Institute (ISP), accessible through [https://www.ispch.cl/virusrespiratorios/]. The analysis covers data from 2015 to 2023. The data presented in this analysis were extracted from 53 annual reports published since 2011. Since mid-2017, data from previous years have been reported in the last two epidemiological weeks since 2015. Therefore, in our analysis, we included data from 2015 onward.

The publicly available data are somewhat limited, as indicated in the summary of all reports, where most cases originated from children under 5 years of age at the time of hospitalization. For example, the report for week 43 of 2022 specifies that 27.8% of the cases studied corresponded to the group between 5 and 14 years of age, potentially representing the majority group. Additionally, the reports only recorded the overall positivity of all cases studied. However, since 2019, more detailed data have been provided, featuring positivity disaggregated by virus (reported as a 4-week rolling average) and information on the age groups of positive cases by epidemiological week. The age ranges of the positive cases reported were under 1 year, 1–4. These additional data have enriched our understanding of epidemiology in recent years. It is pertinent to note that 2019 was the most challenging year in terms of circulating virus incidence since 2011 prior to the pandemic. Therefore, it seems more adequate to compare information that is slightly less detailed but more comprehensive, considering the data from 2015 onward.

The methodology considers the context provided in the executive summaries of the ISP reports regarding their surveillance objectives. ISP surveillance primarily aims to identify the circulation of influenza and other respiratory viruses, focusing on characterizing the spread of antigenic variants in the case of influenza. As indicated in the reports, a significant portion of the collected samples came from pediatric patients, particularly those under five years of age, who underwent respiratory virus testing upon hospitalization. The predominance of data from young patients is a critical aspect of our analysis, influencing our understanding of viral etiologies and their severity across different patient types.

Various statistical and epidemiological techniques were employed to improve the validity and reproducibility of this study. Data were analyzed using specialized software for epidemiological analysis, and annual and seasonal comparisons were performed to identify trends and patterns in the incidence of respiratory viruses. Additionally, subgroup analyses by age and virus type were conducted to determine the variability in the incidence and severity of respiratory infections in different patient cohorts. This methodological approach not only provides a broad and detailed view of the epidemiology of respiratory viruses in Chile before and after the COVID-19 pandemic, but also allows the identification of potential risk factors and priority areas for public health interventions.

Results

Incidence and Prevalence of Respiratory Viruses in Chile

The incidence of respiratory viruses in Chile has remained a major public health challenge owing to their rapid spread and the severity of associated diseases. The COVID-19 pandemic (March 2020–September 2021) has significantly impacted public health, with SARS-CoV-2 being the predominant virus. Following the implementation of both local and global vaccination campaigns, the SARS-CoV-2 incidence began to decrease (Figure 2), which was closely tied to the mitigation measures enforced by health authorities[22]. These measures, including strict confinement and travel restrictions, were associated with a significant reduction in the circulation of other respiratory viruses, such as influenza and RSV, which reached their lowest levels in 2020 and 2021, with fewer than 1000 cases recorded in 2020 (Figure 2 and Table 1).

The decrease in the incidence of SARS-CoV-2 and other respiratory viruses during the strict lockdown period reflects how sanitary measures, such as mobility restrictions, played a decisive role in limiting viral transmission. However, when these restrictions began to ease in the second half of 2021, the circulation of respiratory viruses, including influenza and RSV, rose sharply, returning to the levels observed before the pandemic (Figures 2, 3, and Table 1). Notably, this increase occurred despite the continuing presence of SARS-CoV-2, which also showed an upward trend over time, underscoring the complex interplay between different viruses and the impact of non-pharmaceutical interventions (NPIs) on their transmission dynamics[23,24].

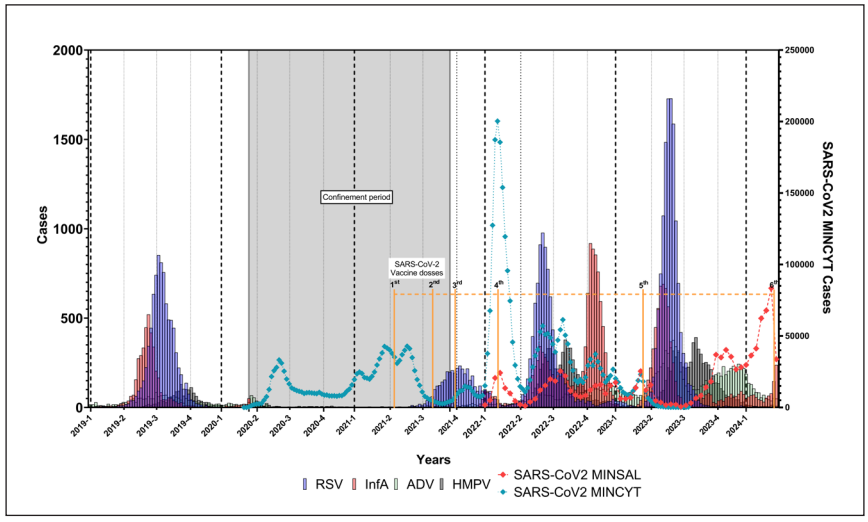

Figure 2. Graph representing the incidence of the most common respiratory viruses in Chile, from 2019 to 2024. It can be observed that the prevalence of respiratory viruses during the critical period of the COVID-19 pandemic decreases dramatically due to the dominance of SARS-CoV-2, coupled with the preventive measures implemented during this period.

Influenza: The incidence of influenza varies considerably in Chile. For instance, the 2019 influenza season saw an uptick around week 24 (Southern Hemisphere winter) with notable outbreaks across several regions. However, the most significant peak occurred in the spring of 2022 (week 43), reaching 918 reported cases, coinciding with the lifting of the mandatory mask-wearing directive in Chile (Figure 3A). This surge was most apparent in school-aged children, whose cases accounted for 50.8% of all reported influenza cases, suggesting a potential link between the lifting of mask mandates and the subsequent increase in cases. This observation highlights the potential long-term effects of relaxing preventive measures, particularly in settings with high transmission risk, such as schools[25,26].

Respiratory Syncytial Virus (RSV): RSV, which typically circulates more during the winter months (July–September in Chile), saw a marked reduction in 2020 and 2021 when mobility restrictions limited person-to-person transmission. However, after these restrictions were eased, the RSV incidence surged, mirroring the general trend of increased circulation of other respiratory viruses (Figures 3C and 2). This rise was particularly evident in 2022 and 2023, with the authorities reporting records of cases of RSV coinciding with the relaxation of health measures. This indicates that the interplay between SARS-CoV-2 restrictions and other respiratory viruses is an essential factor in modulating the seasonal behavior of RSV[27].

Adenovirus: Adenovirus circulation, which typically fluctuates within a narrow range, was significantly disrupted during the pandemic. From 2015 to 2021, the number of adenovirus cases in Chile rarely exceeded 100 per week. However, in 2022, a dramatic increase in cases was observed, peaking at nearly 140 cases in week 23 (Figure 3B). This escalation will continue until 2023, reaching 376 cases by week 23. This unusual pattern suggests that the pandemic and accompanying restrictions may have altered the typical seasonal dynamics of adenovirus transmission, leading to higher-than-usual levels of circulation in the post-pandemic period[28].

Table 1. Total cases of respiratory viruses per year (2015 to 2024), as reported by Institute of Public Health, Government of Chile. RVS, respiratory syncytial virus; Inf A, influenza virus A; Inf B, influenza virus B; P Inf, parainfluenza virus; ADV, adenovirus; HMPV, human metapneumovirus. *Data collected by the Ministry of Science and Technology, Government of Chile. **Data from weeks 1-10 only.

year	RSV	Inf A	Inf B	P Inf	ADV	HMPV	SARS_COV2
2015	6783	1684	560	1534	792	915	0
2016	7160	2844	871	1497	1030	983	0
2017	7438	2787	822	1897	933	1386	0
2018	7555	3067	625	1876	1411	1463	0
2019	8614	3944	2592	2514	1820	1464	0
2020	74	189	63	332	517	180	494330*
2021	3523	76	0	1270	339	58	1010392*
2022	9274	11174	83	5236	3162	5559	5223
2023	13140	6764	2687	7825	8576	6455	6057
2024**	39	534	66	380	942	70	3886

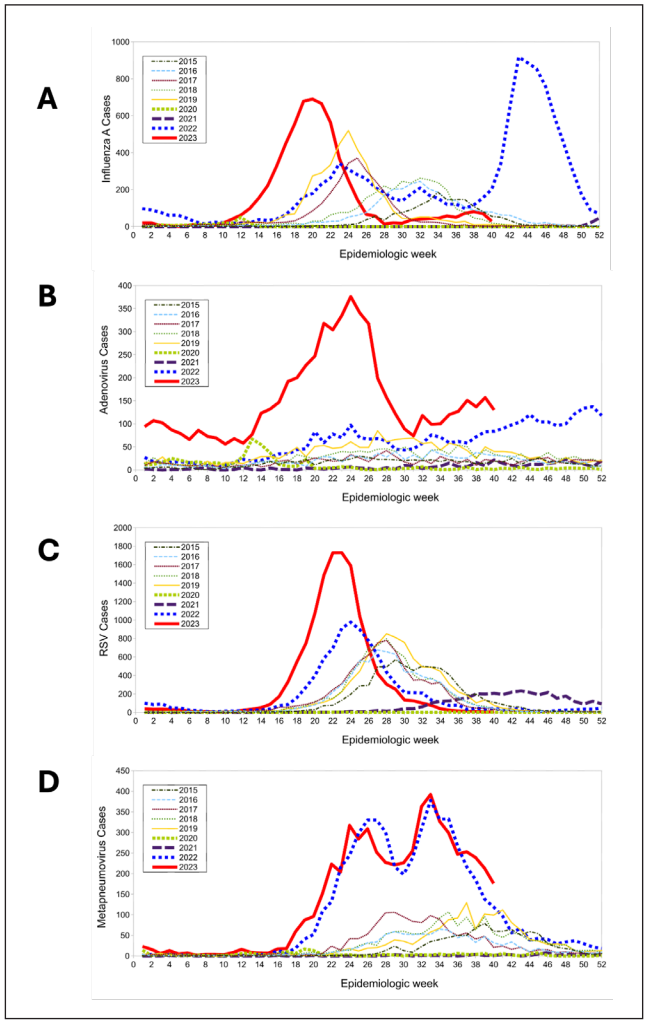

Figure 3. Cases of influenza A, adenovirus, RSV, and Metapneumovirus reported in Chile from 2015 to 2023, showing changes in virus incidence during the epidemiological weeks of each year, both in pandemic times and in the pre and post COVID-19 era.

Human Metapneumovirus (HMPV): Similar to adenovirus, HMPV exhibited low circulation before the pandemic but saw a sharp increase in 2022 and 2023, with peak incidences recorded in weeks 26 and 33 (Figure 3C). This surge, especially in 2023, was likely influenced by the relaxation of COVID-19-related restrictions, which previously limited the spread of this virus. The total number of HMPV cases for both years reached over 5559 and 6455 cases, respectively, with a notable increase in 2024 (Table 1).

These findings underline the complex relationship between public health measures and the spread of respiratory viruses. The strict sanitary measures initially implemented to control SARS-CoV-2 spread appear to have had a broader effect, limiting the circulation of other respiratory pathogens. However, as these measures were relaxed, the reemergence and increase in the circulation of multiple respiratory viruses, including influenza, RSV, adenovirus, and HMPV, suggest a rebound effect that highlights the need for ongoing surveillance and strategic interventions.

Discussion

During the COVID-19 pandemic, Chile implemented restrictive measures, including lockdowns and mobility restrictions, which significantly influenced the spread of the respiratory viruses. Geographical and temporal analyses have revealed distinct patterns shaped by these measures and local characteristics.

In the early phase of the pandemic (March–June 2020), strict restrictions were imposed in densely populated areas, particularly in the Metropolitan Region of Santiago (33°15′22″ S–33°38′15″ S), where most COVID-19 cases were concentrated. During this period, the incidence of other respiratory viruses such as influenza and RSV declined markedly nationwide, indicating that lockdowns and social distancing effectively limited their circulation, especially in urban settings. Similar declines in respiratory virus activity have been observed globally due to COVID-19 control measures[29,30].

From July 2020 onwards, as restrictions eased, especially in less affected southern regions like Los Lagos (40°15′18″S - 44°00′15″S), a slight resurgence in respiratory virus cases was noted, though still below historical averages. The continued use of masks and reduced mobility likely contributed to this moderation[31]. However, by 2021, with further relaxation of restrictions, respiratory virus infections had surged nationwide, particularly in urban areas such as Santiago.

By 2022, infections with viruses such as RSV not only returned to pre-pandemic levels but also exceeded them in regions such as Los Ríos (39°16′36′ ′S–40°40′10 ′′ S) and La Araucanía, which typically experience higher infection rates during the winter months (May through August). This rebound underscores the significant impact of relaxing public health measures on respiratory virus transmission[32,33].

These findings highlight the necessity for continuous monitoring and adaptive policies to manage respiratory virus transmission in both the pandemic and post-pandemic contexts. They also illustrate how incidental factors, such as confinement, modulate the transmission and prevalence of respiratory viruses, often superseding seasonal and geographical factors.

Global preventive measures against SARS-CoV-2, along with shifts in population behavior during the pandemic, have led to a marked decline in the circulation of respiratory viruses. However, this scenario was reversed as preventive measures were relaxed[34]. The resurgence of respiratory viruses, including increased hospitalizations, highlights the complexities of viral dynamics during this period[35].

One significant factor was the "viral niche," in which SARS-CoV-2 dominated during the pandemic's peak[36]. For example, rhinovirus has been shown to negatively affects the circulation of influenza A[37]. Broader studies have reported

negative interactions between influenza and non-influenza viruses and positive interactions between non-influenza viruses[38]. The apparent early lack of co-infections, particularly between SARS-CoV-2 and other respiratory viruses, may have been influenced by SARS-CoV-2's high circulation and the effects of confinement[39].

While vaccination campaigns reduced SARS-CoV-2 prevalence, data suggest that the virus's circulation persisted, challenging the notion that SARS-CoV-2 alone influences the dynamics of other respiratory viruses. This underscores the need for comprehensive studies exploring the interactions between SARS-CoV-2 and other respiratory viruses.

From 2020 to 2022, variations in the SARS-CoV-2 incidence across countries reflected the influence of health measures and vaccination campaigns (Figure 4A). For example, strict measures, such as lockdowns and social distancing, combined with extensive COVID-19 vaccination efforts, reduced influenza transmission in the Americas, including Chile, Argentina, Brazil, Mexico, and the United States (Figures 4B and 4C) [40,41]. These measures indirectly lowered influenza cases by reinforcing public health practices and raising awareness of respiratory disease prevention[42].

The phenomenon of "viral interference" further explains the reduced number of influenza cases during the COVID-19 peak. This interaction, where one virus inhibits another's replication, contributes to the atypical seasonality of influenza during this time[43,44]. However, by 2022, the number of influenza cases had dramatically increased, surpassing the pre-pandemic levels (Figure 7C). This resurgence is likely linked to relaxed control measures, resumption of normal activities, and diminished population immunity due to reduced exposure in previous years[45].

Understanding these infectious dynamics is critical for developing future public health strategies. The interplay between SARS-CoV-2 measures, vaccination campaigns, and other respiratory viruses underscores the complexity of the global epidemiological dynamics. The sharp decline in influenza during the pandemic, followed by its unprecedented resurgence, highlights the importance of robust epidemiological surveillance and adaptive health policies[46,47].

The findings of this study highlight the global public health challenges posed by respiratory infections. The high morbidity and mortality associated with these infections, particularly in vulnerable populations such as children and the elderly, necessitates a deeper understanding of their epidemiology to inform preventive strategies[48].

Airborne transmission is a critical consideration in public health measures. Environmental factors, particle size, and exposure duration significantly influenced respiratory pathogen transmission, underscoring the importance of hygiene practices in enclosed spaces[49,50,51]. Vaccination remains the cornerstone of respiratory infection prevention. Timely immunization against viruses, such as influenza and SARS-CoV-2, has proven effective in reducing the disease burden[52].

Our study identified respiratory viruses and bacterial pathobionts as key drivers of heightened nasal innate immunity in children[53]. These findings highlight the need to investigate how seasonal respiratory viruses and bacterial pathobionts influence SARS-CoV-2 pathogenesis and broader pediatric immune responses, including responses to mucosal vaccines[54]. The data show that respiratory pathogens modulate host immune responses, exacerbate inflammation, and contribute to severe respiratory diseases[55,56]. Coinfections, particularly viral bacteria, are associated with more severe clinical symptoms, underscoring the need for continuous surveillance and effective control strategies to mitigate their impact on child health[57].

During the pandemic, vaccination campaigns played a pivotal role in curbing SARS-CoV-2 infection. Chile's extensive COVID-19 vaccination program includes vaccines such as CoronaVac (Sinovac), Pfizer-BioNTech, AstraZeneca-Oxford, CanSino, and Moderna, targeting diverse populations [(Vaccines.

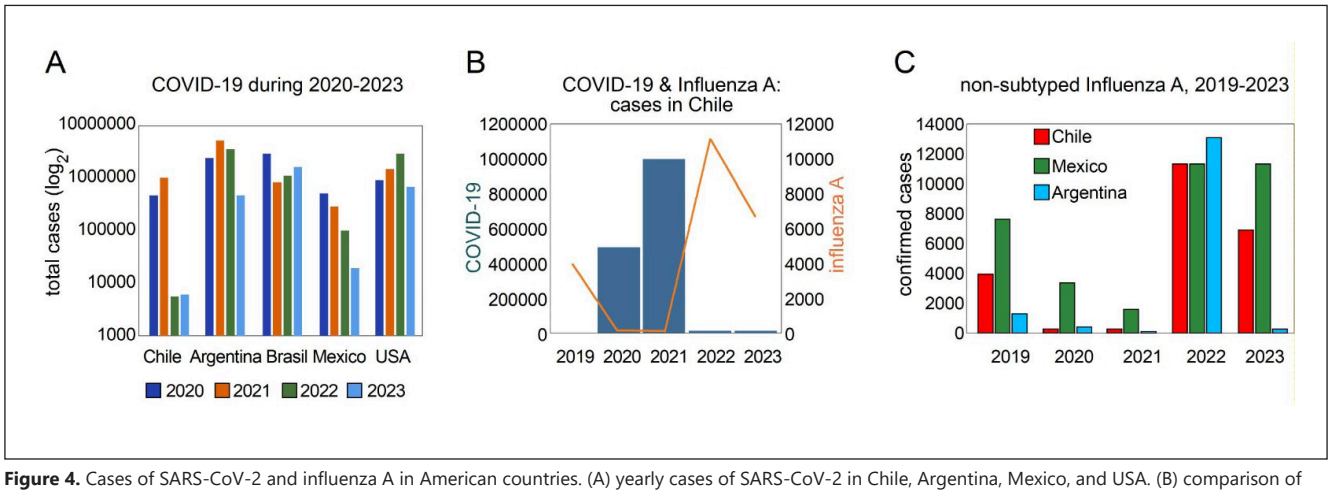

Figure 4. Cases of SARS-CoV-2 and influenza A in American countries. (A) yearly cases of SARS-CoV-2 in Chile, Argentina, Mexico, and USA. (B) comparison of yearly cases of COVID-19 and Influenza A in Chile from 2019-2023. (C) influenza A cases in Chile, Mexico and Argentina from 2019 to 2023.

gov), (WHO), (CDC)]. Understanding the individual immune responses to these vaccines and their effects on respiratory virus incidence remains a critical area for further research[58,59,60].

In conclusion, robust genomic surveillance of respiratory viruses and bacterial pathobionts is essential, particularly in pediatric populations. This surveillance informs public health policies and vaccination strategies to reduce the burden of respiratory diseases[61]. Preventive actions should include early detection systems, such as monitoring air and wastewater, to anticipate major infectious waves during critical periods[62].

Sentinel surveillance systems are invaluable in tracking disease trends and facilitating early outbreak detection. In Chile, sentinel systems have primarily monitored acute respiratory infections but face limitations, such as underestimation of total cases and overestimation of severe cases. Integrating genomic surveillance with "nowcasting" models could enhance outbreak detection and public health response[63].

Strengthening the connection between research on viral respiratory infections and epidemiological data is crucial. Collaboration between scientific and public health organizations enables the development of prophylactic surveillance models, prevents the collapse of healthcare systems, and improves patient outcomes. By adopting advanced practices from countries with effective systems, such as the United States, the United Kingdom, and Australia, Chile can enhance its surveillance capacity and public health strategies[64,65,66].

This study offers valuable insights into the impact of the COVID-19 pandemic on the epidemiological dynamics of respiratory viruses in Chile, highlighting key shifts in virus transmission, seasonality, and interaction. A significant strength of this work lies in its comprehensive analysis, which integrates epidemiological data from multiple respiratory viruses across a broad timeframe. Furthermore, this study contextualizes local findings within global trends, providing a robust framework for understanding the interplay between SARS-CoV-2 and other respiratory pathogens. However, this study has some limitations. First, the study relied on secondary data sources, which may have introduced biases related to underreporting or inconsistencies in data collection methods. Additionally, the absence of detailed genomic analyses limits the ability to explore the genetic factors that influence virus transmissibility and interactions. Future research incorporating real-time genomic surveillance and broader environmental and social determinants of health is essential to build on these findings and further elucidate the complex dynamics of respiratory viruses[67,68].

In conclusion, the COVID-19 pandemic has transformed the transmission dynamics of respiratory viruses, highlighting the impact of public health measures on viral epidemiology. In Chile, unusual patterns have been observed, such as a shift in influenza peaks to late 2022, coinciding with the relaxation of health restrictions. Additionally, the concurrent circulation of RSV, influenza, and SARS-CoV-2 during the winter of 2022 reflected an unprecedented "tripledemic." These events underscore the need for a better understanding of the interactions among respiratory viruses, including viral interference, genetic diversity, and population immunity.

The re-emergence of viruses such as RSV and influenza, surpassing pre-pandemic levels, underscores the importance of robust epidemiological surveillance, adaptive vaccination strategies, and preventive control measures. Strengthening the integration between scientific research and public policy is essential to anticipate and mitigate future waves of respiratory diseases and to optimize surveillance systems through approaches like "nowcasting" and genomic models. These findings provide a crucial foundation for designing effective strategies to address the current challenges and future public health threats.

Ethical considerations

Protection of Persons. This study adhered to ethical principles ensuring the protection of all individuals involved. Data collection and analysis were conducted using anonymized epidemiological records, preventing any direct or indirect identification of individuals. All procedures complied with national and international ethical guidelines for epidemiological research.

Protection of Vulnerable Populations. Given the significant impact of respiratory viruses on vulnerable populations, particularly children and individuals with pre-existing conditions, this study prioritized ethical considerations related to their protection. The findings contribute to public health strategies aimed at mitigating risks for these groups, ensuring evidence-based decision-making to safeguard their well-being.

Confidentiality. Strict confidentiality measures were implemented throughout the study. Only aggregated epidemiological data were analyzed, ensuring that no personal or sensitive information was disclosed. The study complied with data protection regulations, maintaining the integrity and security of all collected information.

Privacy. Privacy considerations were central to this research. The use of publicly available and de-identified epidemiological data ensured that individual privacy was not compromised. The study adhered to ethical and legal standards, preventing any potential breaches of personal information.

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Conflict of interests. The authors declare that this research was conducted in the absence of any commercial or financial relationships or any potential conflict of interest.

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