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SEASONAL DISTRIBUTION PATTERNS OF INFLUENZA AND ACUTE RESPIRATORY VIRAL INFECTIONS EPIDEMIOLOGY, MECHANISMS, AND PREVENTION STRATEGIES

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Abstract
Influenza and acute respiratory viral infections (ARVIs) represent among the most significant recurring public health challenges worldwide, imposing substantial morbidity, mortality, and socioeconomic burden on populations across all income settings. Worldwide, annual seasonal influenza affects up to 1 billion people and causes 3-5 million severe cases and up to 650,000 deaths related to respiratory causes. The seasonal nature of these infections - driven by a convergence of environmental, virological, and behavioral factors - follows predictable yet complex patterns that vary by hemisphere, climate zone, pathogen type, and host population. This article provides a comprehensive, evidence-based review of the seasonal epidemiology of influenza and ARVI, examining the environmental and immunological mechanisms underlying seasonal peaks, the comparative epidemiology of major respiratory viruses, patterns in high-risk populations, and current evidence on vaccination and antiviral prophylaxis as control measures. Understanding these patterns is foundational to designing effective surveillance systems and preventive strategies.

Keywords: Influenza, acute respiratory viral infection, seasonality, epidemiology, transmission, humidity, vaccination, antiviral therapy, surveillance, prevention.

Introduction

The seasonal cyclicity of respiratory viral diseases has been recognized for centuries. Annual epidemics of the common cold and influenza disease hit the human population like clockwork in the winter season in temperate regions, and epidemics caused by viruses such as SARS-CoV and SARS-CoV-2 similarly occur during winter months. Despite this predictability, the mechanisms underlying seasonal respiratory infection peaks remain a subject of active investigation, and the practical question of how to most effectively harness this knowledge for public health prevention continues to evolve.

Influenza is a global public health threat, with seasonal and pandemic influenza resulting in substantial impact on health, the economy, and society. The World Health Organization (WHO) has estimated that every year, 290,000 to 650,000 deaths are associated with respiratory diseases from seasonal influenza. These figures represent only direct mortality; the full burden encompassing hospitalizations, lost productivity, health system strain, and secondary bacterial complications is substantially larger.

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Acute respiratory viral infections - a broader category encompassing rhinovirus, respiratory syncytial virus (RSV), adenovirus, coronavirus, human metapneumovirus, and parainfluenza viruses alongside influenza - are collectively the most frequent infectious diseases globally. Influenza A and B, and many unrelated viruses including rhinovirus, RSV, adenovirus, metapneumovirus, and coronavirus share the same seasonality, since these viral acute respiratory tract infections (vARIs) are much more common in winter than summer. This convergence of seasonality across viruses of widely differing biological structure implies the existence of shared transmission mechanisms responsive to common environmental drivers. In the context of Central Asia and Uzbekistan specifically, acute respiratory infections constitute a leading cause of morbidity. Acute respiratory infections (ARIs) are a significant cause of morbidity and mortality worldwide, and this is particularly evident in regions such as Uzbekistan within Central Asia. Forecasting and responding to seasonal surges remains a priority for health authorities across the region.

Methodology

Until recently, the WHO estimated the annual mortality burden of influenza to be 250,000 to 500,000 all-cause deaths globally; however, a 2017 study indicated a substantially higher mortality burden, at 290,000-650,000 influenza-associated deaths from respiratory causes alone, and a 2019 study estimated 99,000-200,000 deaths from lower respiratory tract infections directly caused by influenza. Regions such as Southeast Asia and Africa bear the heaviest burden, exhibiting mortality rates ranging from 3.5 to 9.2 per 100,000 individuals, whereas the United States reports a comparatively lower average mortality rate of 1.4 per 100,000 individuals. This geographic disparity reflects differences in healthcare access, underlying population health, vaccination coverage, and surveillance capacity rather than intrinsically different viral behavior.

The COVID-19 pandemic disrupted seasonal influenza patterns globally. The year 2020 witnessed a global decrease in influenza circulation due to widespread lockdowns and travel restrictions. However, a resurgence was observed in late 2021, notably with out-of-season activity in the Southern Hemisphere. This disruption of established seasonal patterns created an immunological debt - a period of reduced population-level immunity to respiratory pathogens - that contributed to unusually intense post-pandemic seasons.

A modelling study estimated a 10-60% increase in population susceptibility for influenza, which might lead to a maximum of 1-5-fold rise in peak magnitude and 1-4-fold rise in epidemic size for the 2022-23 influenza season across locations, with a significantly higher fold rise in Singapore and Taiwan. In Europe, surveillance data confirmed these projections. During the 2022-2023 season, 81,800 specimens from sentinel primary care providers were tested for influenza virus and 19,538 (24%) tested positive in the EU/EEA. The following season saw a partial normalization: during the 2023-2024 season in the EU/EEA, 89,343 specimens from sentinel primary care providers were tested for influenza virus and 15,028 (17%) of the specimens tested positive. The number of influenza virus detections decreased by 23% compared with 2022-2023 but represented a 37% increase from the pre-pandemic season 2019-2020.

Influenza A viruses evolve through two primary mechanisms of antigenic variation: antigenic drift and antigenic shift. Antigenic drift involves gradual point mutations in hemagglutinin (HA) and neuraminidase (NA) genes, leading to minor antigenic changes and recurring seasonal outbreaks of

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varying intensity. In contrast, antigenic shift results from major genetic reassortment between animal and human strains, producing novel subtypes capable of triggering pandemics. Antigenic drift is the reason annual vaccine reformulation is required - previously acquired immunity from natural infection or vaccination provides partial but not complete protection against drifted strains, generating ongoing susceptibility even in previously exposed populations. This feature of influenza biology is central to understanding why seasonal peaks can vary dramatically in intensity from year to year.

The period from October 2022 to September 2023 was characterized by early and high activity of influenza A(H1N1)pdm09 virus, which was subsequently replaced by influenza B virus. The antigenic and genetic properties of strains were closely related to influenza vaccine viruses recommended by WHO experts for the current season. The effectiveness of influenza vaccines was confirmed at 75.0%. The 2023/2024 season witnessed a longer duration of the winter-spring epidemic weeks and a higher disease burden compared with previous high-epidemic years. The A(H3N2), A(H1N1)pdm09, and B/Victoria lineages alternated among the predominant circulating strains from the 2022/2023 season to the 2024/2025 season. Among non-influenza ARVI pathogens, the structure and proportion of other ARVI pathogens changed somewhat compared to the previous season: there was a tendency to increase the activity of human adenovirus (HAdV) and human metapneumovirus (HMPV); almost equivalent activity of RSV, rhinovirus, coronavirus, and bocavirus; and a decrease in parainfluenza virus (HPIV) activity.

Results

Seasonal respiratory viral infections do not affect all population segments equally. Children, elderly adults, pregnant women, and immunocompromised individuals consistently bear disproportionate burdens of severe disease. Groups most likely to suffer serious complications from influenza include people over the age of 65, children under the age of 5, pregnant women, and people with chronic medical conditions. In all influenza seasons, children report the highest incidence values of influenza-like illness and longer epidemic periods in contrast with the older population. This reflects children's central role as transmission amplifiers within communities - higher contact rates in school settings, prolonged viral shedding, and less pre-existing immunity from prior exposures combine to make children both the most frequently infected group and the primary drivers of community-level spread. In the EU/EEA surveillance data, the test positivity for influenza crossed the 10% threshold in week 49 of 2023, indicating the start of the influenza seasonal activity. The activity started later than the previous season. Timing of seasonal onset varies not only by year but also by age group: children typically drive early-season peaks through school-based transmission before infection cascades into older age groups.

Annual influenza vaccination remains the most effective single intervention for reducing seasonal influenza burden. During the 2022-2023 influenza season, vaccine effectiveness was estimated at around 50%, offering higher protection against influenza A (H3N2) and H1N1 strains but somewhat lower protection against influenza B. Despite imperfect strain matching, vaccination remained effective in preventing severe disease and hospitalization. In the United States, the practical impact of vaccination is quantifiable: during the 2022-23 influenza season, vaccination was estimated to have prevented 5.9 million illnesses, 2.9 million medical visits, 64,000 hospitalizations, and 3,600 deaths associated with influenza. Yet coverage remains suboptimal: in the 2023-24 influenza season, an

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estimated 49% of adults and 54% of children were vaccinated against influenza, falling below the Healthy People 2030 target of 70% coverage for all age groups. Specific vaccine formulations are recommended for different age groups. Individuals aged 65 years and over were primarily offered the adjuvanted quadrivalent inactivated influenza vaccine (aQIV). The quadrivalent cell-based influenza vaccine (QIVc) was recommended for adults aged 18-64 years in clinical risk groups, including pregnant women, carers, and frontline healthcare workers. For children aged 2 years to under 18 years, the live attenuated influenza vaccine (LAIV) was used, except where contraindicated. In Uzbekistan, WHO has supported annual vaccination campaigns targeting high-risk groups. In collaboration with WHO and the Sanitary and Epidemiological Wellbeing Agency (SEWA), the Ministry of Health of Uzbekistan conducted workshops and training sessions for medical staff in immunization centres, sharing detailed information about influenza vaccine types and at-risk groups recommended by WHO for vaccination.

For cases where vaccination fails or is unavailable, antiviral agents provide a secondary line of defense. Neuraminidase inhibitors have generally been about 70-90% effective in preventing influenza caused by susceptible strains of influenza A or B viruses. Antiviral chemoprophylaxis with oral oseltamivir or inhaled zanamivir is recommended by the CDC for control of institutional influenza outbreaks. Post-exposure prophylaxis should be considered within 48 hours of exposure for persons at increased risk of complications who have not received an annual influenza vaccine for the current season.

Early initiation of antiviral therapy is critical for clinical benefit. Evidence from a multicenter US study of adults hospitalized with laboratory-confirmed influenza during the 2022-23 season demonstrated that patients receiving oseltamivir on the day of hospital admission experienced significantly better pulmonary outcomes than those in whom treatment was delayed, after adjustment for baseline severity, age, sex, and vaccination status. To address the dual burden of influenza in the post-COVID era, the implementation of influenza vaccination programs and the promotion of vaccination for both children and adults are essential preventive measures. Non-pharmacological interventions - hand hygiene, respiratory etiquette, ventilation of indoor spaces, and targeted isolation of symptomatic individuals - retain important complementary roles, particularly in settings where vaccination coverage is low.

Discussion

The seasonal pattern of influenza and ARVI is among the most reproducible phenomena in infectious disease epidemiology. The convergence of environmental drivers - low absolute humidity, cold temperatures, and increased indoor crowding - creates conditions highly favorable to respiratory viral transmission in temperate winters, while the corresponding reversal of these conditions in summer suppresses epidemic spread. The post-COVID era has complicated this picture by creating immunological debt and disrupting established seasonal baselines, producing unexpectedly intense post-pandemic seasons in 2022-23 and necessitating recalibration of surveillance thresholds.

The multi-pathogen complexity of the ARVI category adds a layer of difficulty to both surveillance and prevention. While influenza dominates winter respiratory illness narratives, RSV, rhinovirus, adenovirus, and coronaviruses each contribute substantially to overall seasonal ARVI burden, each with its own environmental sensitivities and epidemiological dynamics. Integrated respiratory virus

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surveillance - as implemented by ECDC's ERVISS platform - represents the appropriate response to this complexity.

Vaccination coverage remains the central modifiable determinant of seasonal influenza outcomes. The gap between achievable protection and current uptake - with only 49-54% of target populations vaccinated in high-income countries and considerably less in Central Asian settings - represents a preventable burden that robust health communication, healthcare worker vaccination, and removal of access barriers can meaningfully reduce.

Influenza and acute respiratory viral infections follow predictable seasonal patterns driven by environmental conditions, host immune states, and behavioral factors that concentrate transmission in winter months in temperate climates. Annual global mortality from influenza alone exceeds 290,000-650,000 deaths, with an additional enormous burden of non-fatal morbidity. The post-pandemic resurgence of influenza and co-circulating respiratory viruses underscores the necessity of sustained surveillance, annual vaccine reformulation and uptake, and evidence-based antiviral deployment for high-risk populations. Strengthening these systems - particularly in Central Asian regions where surveillance infrastructure is still developing - constitutes a clear public health priority.

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