Literature review on the disease burden due to respiratory infections in Switzerland and public health mitigation measures

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1. Abstract

Respiratory infections remain an important cause of illness, death, and healthcare use in Switzerland. We conducted a scoping review to map the burden of influenza, respiratory syncytial virus (RSV), and SARS-CoV-2, with additional targeted searches for seven other respiratory pathogens. Of the 2,523 articles screened, 58 met the inclusion criteria; 13 additional articles were later identified, and grey literature was also incorporated from national surveillance and the Global Burden of Disease study. Seven indicators were examined: outpatient visits, reported cases, hospitalisations, intensive care admissions, mortality, seroprevalence, and disability-adjusted life years (DALYs). Influenza and RSV accounted for the largest seasonal burden, particularly in infants and older adults. SARS-CoV-2 showed similar to higher in-hospital mortality than influenza in the endemic phase. In addition to RSV, SARS-CoV-2, and influenza, *Streptococcus pneumoniae*, *Mycoplasma pneumoniae*, and rhinoviruses also contributed substantially to the burden of respiratory infections, though data remains limited. Strengthening and extending surveillance systems, including serosurveys and outpatient monitoring, will be essential to obtain more complete and timely data on respiratory infections. Economic estimates indicate that influenza generates CHF 42-73 million in annual healthcare costs and more than CHF 100 million in productivity losses, with RSV and pneumococcal pneumonia also generating high costs. Economic impact estimates for SARS-CoV-2 were not available for the post-pandemic period. Vaccines and some targeted non-pharmaceutical measures (e.g., ventilation or masking) are effective ways to reduce the disease burden and will remain important during the post-pandemic period. Gaps remain in Swiss-specific data, especially for seroprevalence estimates.

2. Introduction

Respiratory infections are a leading cause of morbidity and mortality worldwide, with substantial seasonal and interannual variability influenced by pathogen circulation, host susceptibility, and public health responses. In Switzerland, as in other high-income settings, diseases such as influenza, respiratory syncytial virus (RSV), and SARS-CoV-2 continue to pose significant public health challenges beyond the acute phase of the COVID-19 pandemic. A clear understanding of the epidemiological burden of these pathogens across outpatient care, hospitalisations, intensive care use, seroprevalence, mortality, and quality-adjusted life years (QALYs) or disability-adjusted life years (DALYs) is essential for guiding effective interventions, allocating health resources, and designing appropriate surveillance systems.

This report presents the findings of a scoping review of the burden of respiratory pathogens in Switzerland. The review focused on influenza, RSV, and SARS-CoV-2, using systematic PubMed searches tailored to each pathogen and burden indicator, complemented by simplified searches for seven additional pathogens (*Streptococcus pneumoniae, Bordetella pertussis, Mycoplasma pneumoniae, Chlamydia pneumoniae, Haemophilus influenzae* type b, rhinoviruses, and human metapneumovirus). Where Swiss data were lacking, evidence from neighbouring or comparable high-income countries was included, alongside national grey

literature sources such as sentinel surveillance networks and official reports. Two complementary narrative reviews were also conducted: one on the economic impact of respiratory infections, and another on the effectiveness of public health interventions. These analyses map available evidence, highlight gaps, and provide information for respiratory pathogen control in Switzerland.

3. Methods

3.1. Scoping review on the burden of respiratory pathogens in Switzerland

3.1.1. Selection of pathogens

Respiratory pathogens can be defined in several ways, whether referring to the transmission mode or the main focus of infection. For this review, we are using the term "respiratory pathogens" for pathogens mainly infecting the respiratory tract. Respiratory pathogens include viruses and bacteria. The main focus has been put on respiratory viruses such as influenza, RSV, and SARS-CoV-2, considered the most frequent circulating respiratory pathogens. Additional searches targeted common causes of lower-respiratory tract infections or influenza-like illnesses. Pathogens considered outside the scope of the review, in the sense that they did not prompt a specific search strategy, were: pathogens causing specific upper respiratory tract infections such as Group A hemolytic Streptococcus (GABHS), mycobacteria, fungi or parasites, and upper respiratory tract clinical syndromes such as pharyngitis, otitis media or sinusitis.

3.1.2. Search strategy

To assess the epidemiological burden of influenza, RSV, and SARS-CoV-2 in Switzerland, we have selected seven public health indicators:

- Reported cases / incidence rate
- Outpatient consultations
- Hospitalisations
- ICU admissions
- Mortality
- Seroprevalence
- DALYs/QALYs

For each pathogen and indicator, we have created a specific literature search equation in Pubmed, resulting in 21 targeted queries (7 indicators × 3 pathogens). In addition, a simpler, more general equation was constructed for each pathogen to capture 'epidemiological burden' studies. The searches were set up to include studies specifically focused on Switzerland, as well as broader studies, systematic reviews and meta-analyses that include neighbouring countries (France, Italy, Austria and Germany), Europe or high-income countries. We restricted the search to articles published from 2010. In addition, articles relying solely on the years 2020-2022 were discarded as we aim to focus on the usual burden

of respiratory viruses outside of the COVID-19 pandemic period. For SARS-CoV-2, we only considered data from 2022.

We also considered seven other respiratory pathogens using the same simple burden equation, with appropriate search terms: *Bordetella pertussis, Chlamydia pneumoniae, Streptococcus pneumoniae, Haemophilus influenzae type b, Mycoplasma pneumoniae*, Rhinovirus, and Human metapneumovirus.

All search equations were validated by a librarian (see Appendix 7.1). The search took place on 29 May 2025.

3.1.3. Article selection and screening

All the identified items have been imported in Covidence® (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org). Using this tool, duplicates were identified and excluded. After deduplication, all remaining records underwent title and abstract screening to identify potentially relevant articles, followed by a full-text review of the selected studies, which was conducted independently by two reviewers. Divergences were resolved through discussion. The screening phase started on 30 May 2025. The main reasons for exclusion were if the data did not cover the appropriate period, if the population included was too narrow or specific, or if none of the targeted indicators were mentioned. When no information existed for Switzerland for a particular combination of pathogen and indicator, we extended the search to neighbouring countries. Global systematic reviews and meta-analyses were included if the data were at least separated into high-, middle-, and low-income countries.

The eligibility phase based on full-text review involved a detailed assessment of whether each article met the inclusion criteria, specifically whether it provided information on at least one of the seven public health indicators (outpatient consultations, reported cases, hospitalisations, ICU admissions, seroprevalence, mortality, or DALYs/QALYs) for influenza, RSV, SARS-CoV-2, or one of the seven additional respiratory pathogens. Articles also needed to align with the relevant timeframe and geographical scope, focusing on Switzerland or, when necessary, including data from neighbouring countries or comparable high-income settings. Studies that presented data in aggregated European formats were included only if they stratified results in a way that allowed relevance for Switzerland to be reasonably inferred.

3.1.4. Grey literature search

In addition to peer-reviewed publications, we conducted a comprehensive search of grey literature from 2010 to 2024 (including pandemic years) to capture relevant epidemiological data on the pathogens of interest in Switzerland. This included systematic consultation of surveillance data and annual reports from the national platforms: mandatory laboratory notification data from the Swiss Federal Office of Public Health (FOPH), routine surveillance

data from the Sentinella primary-care network, the CH-SUR hospital sentinel programme, the National Reference Centre for Influenza (NRCI) and the hospital medical statistics (*MedStats*) from the Federal Statistical Office (FSO).

We paid special attention to estimates of yearly deaths and DALYs linked to respiratory infections from the Global Burden of Disease (GBD) for Switzerland available until 2021, which were extracted from the online tool (https://vizhub.healthdata.org/gbd-results/). GBD estimates can be considered both peer-reviewed and grey literature, since the published articles provide only part of the outputs, while country-specific estimates (e.g. for Switzerland) are accessible online. The yearly estimates of deaths and DALYs also use a different grouping of pathogens (Influenza, *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Mycoplasma pneumoniae*, Respiratory syncytial virus, and Other viral etiologies of lower respiratory infection). For these reasons, we present GBD outputs in a dedicated section.

3.1.5. Data extraction

Following the screening phase, data extraction was carried out systematically for the included articles using a standardized template in Covidence®, in order to ensure consistency and comparability across studies. For each article, general information such as the study ID, title, authors, journal, and full citation was recorded. The geographical scope of the article was categorized to distinguish between Swiss-specific data and those from comparable settings (e.g., Western Europe, high-income countries), with particular attention paid to whether Swiss data were explicitly reported.

Metadata were extracted regarding the time period of data collection, study population size and characteristics (e.g., age group, specific population group), and the healthcare setting (e.g., community, hospital, long-term care home). The studied pathogen(s) were identified for each study, with differentiation between the three primary pathogens of interest (influenza, RSV, SARS-CoV-2) and the seven additional pathogens under consideration. The study design and case definition methodology were extracted, including whether diagnoses were laboratory-confirmed, clinically diagnosed, syndromic, modelled, or based on electronic health records (e.g., ICD-10 codes). Where applicable, the anatomical site of infection (upper vs. lower respiratory tract) was also documented.

In terms of epidemiological outcomes, data on each of the seven main indicators was recorded. Studies reporting on economic impacts or post-COVID syndrome were also flagged. Quantitative data were extracted and organized into structured tables for comparison, stratified by pathogen, outcome, and year. Particular attention was paid to extracting incidence rates, hospitalisation and ICU admission rates, mortality counts and case fatality ratios, seroprevalence estimates, and DALY/QALY values.

3.2. Narrative review on the economic impact of respiratory pathogens in Switzerland

This narrative review explored the economic impact of respiratory pathogens in Switzerland, focusing on influenza, RSV, and SARS-CoV-2. We searched the PubMed database using pathogen-specific terms combined with keywords related to economic outcomes such as costs, burden, or cost-effectiveness. The non-systematic search was limited to studies published from 2010 onwards and focused on non-pandemic years. We included studies reporting economic data relevant to Switzerland, and where Swiss data were lacking or incomplete, we considered studies from comparable high-income countries. Titles, abstracts, and full texts were screened to identify relevant evidence, including direct and indirect costs, healthcare utilization, productivity losses, or economic evaluations of interventions.

3.3. Narrative review on the effectiveness of public health interventions in reducing disease burden

This second narrative review examined the effectiveness of public health mitigation strategies against respiratory infections in Switzerland, again with a focus on influenza, RSV, and SARS-CoV-2. We searched PubMed using combinations of pathogen-specific terms and keywords related to interventions such as vaccination, non-pharmaceutical measures (e.g. mask use, social distancing, school closures), or other preventive strategies. The search was restricted to studies published from 2010 onwards. We included studies that assessed the impact of interventions on transmission, morbidity, or mortality, prioritising those with relevance to the Swiss context or to comparable high-income countries.

4. Results

4.1. Scoping review on the burden of respiratory pathogens in Switzerland

4.1.1. General

The final search took place on 29 May 2025 and resulted in the identification of a total of 2,523 items, of which 536 were identified as duplicates and excluded, resulting in 1,987 items for the screening phase (Figure 1). Of 1,987 items, 1,846 were excluded based on their title and abstract. 141 articles were assessed for eligibility using full-text review. During this phase, 88 articles were excluded, resulting in a final count of 53 included articles. Reasons for exclusion included not fitting inclusion criteria in terms of outcomes (47), population (20), time period (17), setting (1), study design (1) or outdated data (2). In addition to the results of the systematic search, 18 additional articles meeting the eligibility criteria were identified subsequently (e.g., through reference lists and expert knowledge) and were included. These include 13 newly identified studies and 5 studies that were previously screened and incorrectly discarded. Of the 71 selected articles, 28 (39%) included Swiss-specific data, while the remainder provided relevant data from settings such as Italy, France, the UK, the USA, or multiple countries at the same time. The majority of studies (n=32, 45%) used data

collected exclusively before 2020. Populations studied were diverse: while over half (51%) focused on the general population, others included high-risk groups, hospitalised patients, individuals living in care homes, pregnant women, and children under five. In addition, 29 (41%) were restricted to adult and older adult populations, 18 (25%) to populations under 18 years of age, while the remainder encompassed both age groups.

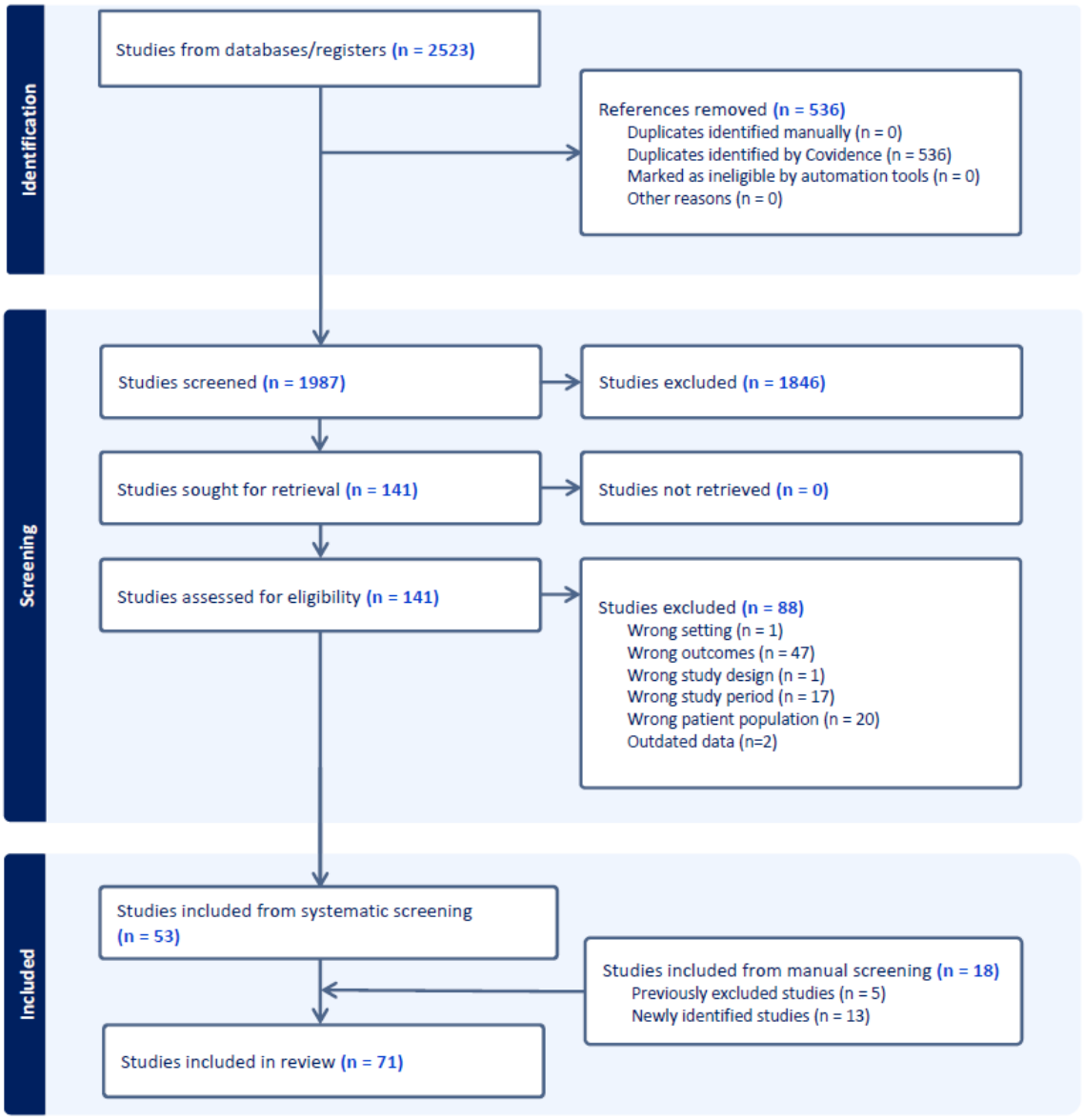

Figure 1. PRISMA flow diagram for the scoping review on the burden of respiratory pathogens in Switzerland.

Study settings spanned primary care, hospitals, care homes, and administrative registries, with many combining data from multiple sources. Community and hospital settings together featured in over one-third of studies, while purely hospital-based studies accounted for about 28%. A variety of methodologies were employed, including observational studies, retrospective analyses, modelling approaches, and systematic reviews. Studies covered diverse groups and settings. Including both Swiss and European data increases relevance for public health in Switzerland.

4.1.2. Global burden of disease estimates

Based on the GBD data for Switzerland, lower respiratory infections caused by influenza, RSV, *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Mycoplasma pneumoniae*, and other viral agents represent a consistent health burden, especially among the youngest (<1 year) and the oldest (75+ years) age groups. Influenza-related mortality in people aged ≥75 years ranged from around 200 deaths annually in 2010 to peaks around 330 deaths in 2018–2019, before declining sharply in 2020–2021, coinciding with the COVID-19 pandemic and associated mitigation measures. RSV and *S. pneumoniae* were also notable contributors: in all-age estimates for 2019, RSV accounted for 28 deaths, while *S. pneumoniae* was associated with over 218 deaths, with the majority concentrated in older adults. For infants, pathogen-specific deaths were rare in absolute numbers (typically <1 per year for RSV, Hib, and influenza), but DALY losses highlight the disproportionate impact of these infections in early life.

In terms of overall burden, DALY estimates demonstrate the dominance of *S. pneumoniae* and influenza as drivers of morbidity and mortality in Switzerland (Figure 2). In 2019, *S. pneumoniae* accounted for roughly 2,700 DALYs, influenza for over 4,300 DALYs, while RSV contributed about 450 DALYs and *Mycoplasma* around 380 DALYs. Taken together, other viral causes of LRI were also associated with substantial disability, contributing over 1,300 DALYs in the same year. Bacterial pathogens caused proportionally more DALYs than viral ones, due to deaths in older adults and illness in infants. A marked drop in both deaths and DALYs is observed only for influenza and RSV in 2020–2021, reflecting the indirect effects of pandemic-related interventions.

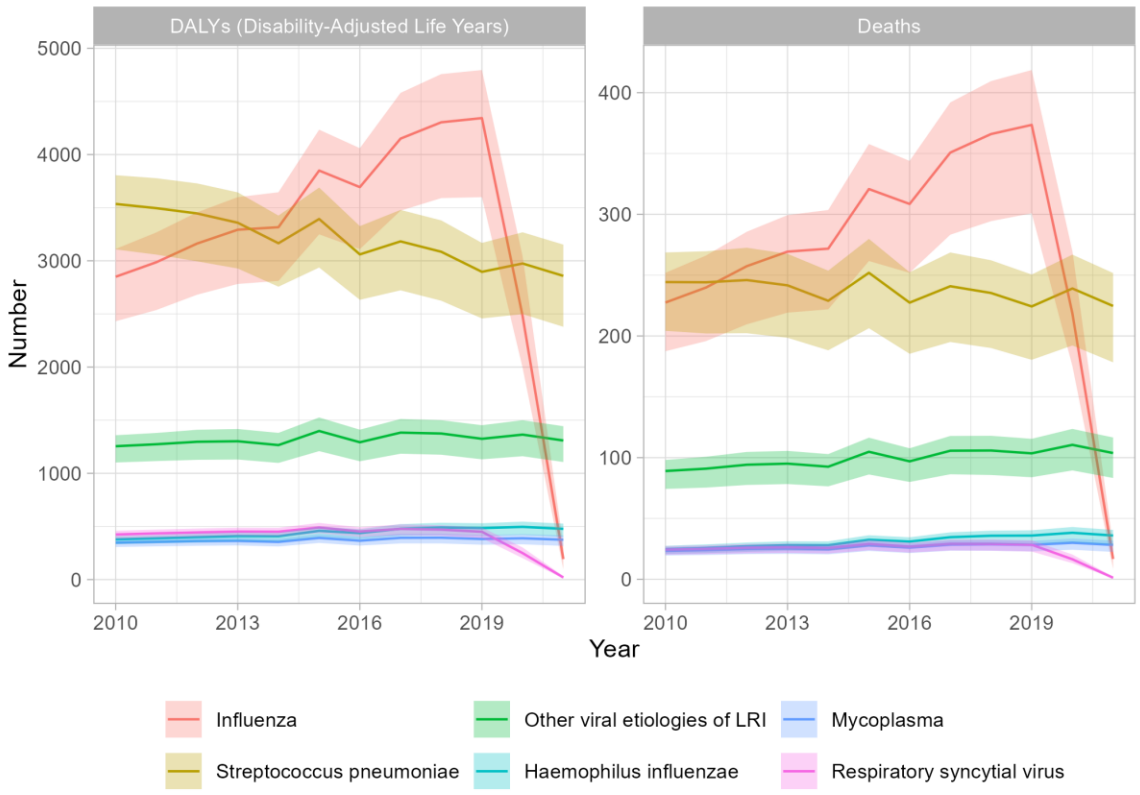

Figure 2: Estimated absolute number of disability-adjusted life years (DALYs) and deaths caused by lower respiratory infections in Switzerland, 2010 to 2021 (GBD, 2024).

4.1.3. Seasonal influenza

A total of 23 articles were identified that provide insights into the burden of seasonal influenza in Switzerland and comparable high-income settings. Almost half of these studies (11/23) included data specific to Switzerland, while the rest originated from other comparable countries. Most studies analysed data spanning from the 1990s to 2023, reflecting both seasonal and long-term trends in influenza burden. Study populations varied, with a strong focus on adults and the elderly, though some also included children, adolescents, and specific groups like pregnant women or high-risk individuals. Over half of the studies (12/23) targeted the general population, while others focused on hospitalised patients or emergency department attendees. Data sources were diverse, with many studies using laboratory-confirmed diagnoses, often combined with syndromic surveillance of influenza-like illness (ILI), administrative records, or modelled estimates. Study designs included prospective cohorts, retrospective analyses, systematic reviews, and complex modelling studies, including global burden estimates. Nearly all studies addressed both upper and lower respiratory tract infections, and several reported multiple outcomes such as cases, hospitalisations, ICU admissions, and case-fatality.

The 11 studies including Swiss data provide a fragmented but informative picture of the burden of influenza across several public health indicators. The study by (Ammann et al., 2023) was the most comprehensive, offering a global assessment of the burden of seasonal influenza in the Swiss adult population across three influenza seasons (2016/2017 to 2018/2019). For reported cases and outpatient consultations, the authors estimated an average of 203,090 general practitioner (GP) visits for ILI per season, corresponding to an extrapolated 330,000 total ILI cases (including non-consultants) and about 110,000 influenza infections per season among adults. In terms of hospitalisations, the study reports an average of 4,944 influenza-attributable hospitalisations annually, with a majority (93%) admitted through the emergency department. ICU admissions occurred in approximately 5% of hospitalised cases, averaging 225 patients per season. Mortality was estimated using excess death modelling, yielding an average of 1,355 influenza-attributable deaths per season, with the burden especially concentrated in the elderly population (65+ years). The estimated total health impact translated to an average of 9,103 QALYs lost per season, of which 88% are attributed to premature mortality and the remainder to quality-of-life loss during illness episodes. Another study highlighted that the probability of an influenza infection being ascertained (i.e. symptomatic, leading to a GP consultation and virologically confirmed) declined with age, with ascertainability estimated around 5% in children and adolescents but dropping to about 3% in adults aged 30 years and older, including those 65+ (Brugger & Althaus, 2020).

Three studies – one conducted in the emergency department (ED) of the Lausanne University Hospital (2014-15) and two using surveillance data on hospitalised patients – provided evidence about hospital burden of influenza in Switzerland (Beysard et al., 2018). Between 17% and 24% of patients hospitalised for acute respiratory illness or identified through hospital surveillance systems tested positive for influenza. In the ED study during the 2014–2015 season, 2.2% of all ED admissions tested positive, with a positivity rate of 33.4% among those tested. Among influenza-positive patients seen in the ED, over half (55.9%) required hospitalisation, occupying 28% of ED beds with respiratory isolation. The proportion of hospitalised influenza patients requiring ICU care ranged from 5% to 10% across the three studies. Influenza-positive patients had longer stays, reflecting the additional burden of isolation requirements, with median hospital and ICU stays of 7 and 4 days, respectively. Mortality among ED-hospitalised influenza cases was low (2/123) but reached 6–7% in the other two studies when following patients up to 30 days post-admission. Finally, a regional study reported that nosocomial infections accounted for 16.7% of all laboratory-confirmed influenza cases (Qalla-Widmer et al., 2021).

To date, no seroprevalence studies of seasonal influenza have been conducted in Switzerland. However, indirect information can be drawn from a modeling study which used data from the Swiss Sentinel Surveillance Network (Sentinella) to estimate influenza transmission dynamics between 2003 and 2015 (Brugger & Althaus, 2020). By applying a Bayesian compartmental model, the authors inferred age-specific susceptibility to influenza, which ranged from 29% to 98% depending on age group and season, generally decreasing with age.

While these estimates are not based on serological surveys, they provide indirect insights into population-level susceptibility patterns that would otherwise be obtained through seroprevalence studies. The decline of susceptibility over time is consistent with other modelling results based on influenza A (H3N2) serological data, which suggest that "antigenic seniority" (where earlier exposures dominate immune responses) and rapidly waning cross-reactivity shape individuals' neutralisation titres, while infection frequency declines from childhood but remains stable after age 30 (Kucharski et al., 2015).

In the wider context of high-income countries, the burden of seasonal influenza prior to the COVID-19 pandemic was substantial (Ciofi Degli Atti et al., 2023; GBD, 2024). Influenza accounted for an estimated 14.1% of adult lower respiratory infection hospitalisations overall, with more than 5 million cases annually. During the COVID-19 pandemic (2020–2021), non-pharmaceutical interventions led to sharp declines in influenza activity: reported cases dropped by 60% and mortality by 72%. Other recent evidence from European countries also shows that community-acquired pneumonia, frequently caused by influenza and other respiratory viruses, leads to high rates of outpatient consultations, hospitalisations, ICU admissions, and short-term mortality, particularly in older adults (Tsoumani et al., 2023).

Grey literature

Routine surveillance data from the Sentinella primary-care network, the CH-SUR hospital sentinel, the National Reference Centre for Influenza (NRCI) and the hospital medical statistics (*MedStats*) from the Federal Statistical Office (FSO) fill several gaps left by the studies summarized above.

The Sentinella networks shows that medical visits for ILI vary across seasons. Consultation rates peaked at 3,950 per 100,000 inhabitants during the 2014/15 season and dropped to 2,112 per 100,000 in 2020/21 during COVID-19 non-pharmaceutical interventions, and stabilized around 2,400 per 100,000 in 2022/23 and 2023/24. This corresponds to approximately 200,000-330,000 visits per season, consistent with the estimate of 203,090 by (Ammann et al., 2023). Fewer than 1% of these outpatient cases are referred to hospital in an average season (range: 0.4%-1% between 2010/11 and 2024/25).

Swab positivity for influenza in nasopharyngeal samples collected by Sentinella physicians and tested at the NRCI was high before the pandemic, ranging from 33% to 58%. During the 2020/21 season, coinciding with strict public-health measures, it dropped sharply to 0.08%. Circulation then rebounded, with positivity reaching 23% in 2022/23 and 17% in 2023/24.

The CH-SUR sentinel system (covering 20 acute-care hospitals) recorded 969 influenza admissions in 2021/22, 3,565 in 2022/23 and 1,653 in 2023/24. Among these inpatients, ICU admission rates increased from 7% (2021/22) to 11% (2022/23) and 12% (2023/24). In-hospital case-fatality ratio (CFR) also rose from 2.6% to 4.2% over the same periods. These figures are consistent with recent multicentre cohort studies (Chorazka et al., 2021;

Portmann et al., 2023), which reported ICU admission rate of 5%-10% and case fatality around 4%.

Under Switzerland's mandatory laboratory reporting system, all positive influenza tests must be declared. Notification data illustrate the impact of testing behaviour, with 13,412 cases in 2018/19 and 11,999 in 2019/20, dropping sharply to 41 in 2020/21, consistent with the decline observed by NRCI. A strong rebound followed, with 24,024 cases in 2022/23 and a new peak of 27,872 in 2024/25, likely reflecting increased community testing. All the mentioned surveillance indicators are summarized in Tables 1 and 2.

Table 1: surveillance indicators for seasonal influenza in Switzerland (Sentinella, NRCI, CH-SUR, mandatory laboratory notification).

Season*	**10/11**	**11/12**	**12/13**	**13/14**	**14/15**	**15/16**	**16/17**	**17/18**	**18/19**	**19/20**	**20/21**	**21/22**	**22/23**	**23/24**	**24/25**
Laboratory-confirmed cases / 100 000	-	-	-	19	70	44	112	176	160	135	1	135	274	210	314
Absolute (n)	-	-	-	-	-	-	-	-	13,412	11,999	41	11,962	24,024	18,617	27,872
ILI out-patient consultations / 100 000	2,950	1,820	3,315	1,332	3,393	2,931	2,759	3,950	2,466	2,671	2,112	2,407	2,400	2,259	-
Absolute (n x 1000)	230	144	265	107	276	251	226	330	209	228	182	210	210	200	-
% hospitalised among Sentinella-reported cases	0.4%	0.4%	0.6%	0.8%	0.8%	1%	0,6%	1%	1%	0,7%	-	1%	0,7%	-	-
% positive NRCI swabs**	46%	35%	57 %	33%	52%	48%	49%	58%	40%	43%	0.08%	12%	23%	17.2%	-
CH-SUR hospitalisations(absolute)	-	-	-	-	-	-	-	-	-	-	-	969	3,565	1,653	-
ICU admissions (% of CH-SUR)	-	-	-	-	-	-	-	-	-	-	-	7%	11%	12.0%	-
Case-fatality ratio (CH-SUR)	-	-	-	-	-	-	-	-	-	-	-	2.6%	2.3%	4.2%	-

*Standard influenza season: week 20 of year n to week 16 of year n + 1. From the 2020/21 season onward, the observation window is extended to week 20 of the following year

**Starting with the 2022/23 season, the panel covers all acute respiratory infections (ARI), not just ILI.

The MedStat database from the FSO, reporting number of hospitalisations per calendar year, provides additional insight into the impact of influenza on inpatient services (Table 2). From 2010 to 2023, annual admissions rose from 308 cases in 2010 to a pre-pandemic peak of 6,679 in 2018, then fell sharply to 114 cases in 2021 before recovering to 4,550 cases in 2023. In 2023, MedStat reported that 2.8% of influenza hospitalisations required ICU care and 1.6% resulted in in-hospital death, both lower than CH-SUR estimates, likely because MedStat includes many short-stay or low-acuity cases. Also, CH-SUR may have tested more systematically, whereas Medstata probably also includes clinical diagnoses. Confirmed hospital deaths were lower than GBD estimates but followed a similar trend.

Table 2: Annual hospitalisations, ICU admissions and mortality for influenza in Switzerland (FSO hospital medical statistics, calendar-year data*).

Year	2010		2011		2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		2022		2023	
Hospitalised cases	308		639		551		1,100		828		2,943		2,479		4,805		6,679		5,697		3,206		114		3,556		4,550	
% admitted to ICU																									2.8%			
% deaths in hospital																									1.6%			
Deaths	3		14		32		73		50		144		89		284		221		282		137		5		129		225	
Mortality rate M / F per 100 000	0.0	0.0	0.1	0.1	0.2	0.2	0.5	0.5	0.5	0.3	1.3	1.4	0.7	0.5	1.8	1.3	2.1	1.7	1.7	1.4	0.9	0.7	0.0	0.0	0.7	0.6	1.2	1.1

*Data correspond to ICD-coded hospital discharges from all Swiss hospitals.

4.1.4. Respiratory syncytial virus (RSV)

Among 27 articles providing information about RSV, 9 included Swiss-specific data and most others drew from multi-country analyses or studies conducted in countries such as the USA, UK, France, Italy, and Australia. The studies primarily focused on the general population, including children and elderly groups, with substantial representation of data from hospital and community settings. Key outcomes measured included reported cases (74%), hospitalisations (81%), ICU admissions (26%), and mortality (67%), though none of the studies included DALYs or QALYs. The evidence spans data from the mid-1990s to early 2024 and is drawn from diverse designs, including systematic reviews with meta-analyses, retrospective cohorts, and global burden modelling studies. Overall, the data provide a broad and multi-source picture of RSV burden, especially among young children and older adults, in Switzerland and similar contexts.

The number of cases and consultations due to RSV remains difficult to assess. Each year, 2,000 to 3,000 infants under one year of age are hospitalised for RSV infections in Switzerland, which also leads to an unmeasured but high volume of consultations in pediatric practices and emergency departments (Brahier et al., 2025).

Stucki et al. (2024) provides the most comprehensive analysis to date of the inpatient burden of RSV in Switzerland using national hospital data from 2003 to 2021 (Stucki et al., 2024). It documents 39,863 RSV-related hospitalisations over the period, with around 70% occurring in infants under one year old. Hospitalisation rates peaked at 26.7 per 1,000 infants in 2018/19, and up to 18% of admitted infants aged 0–30 days required ICU care, often with ventilation. RSV accounted for up to 11% of all infant hospitalisations in some years. The case-fatality was low, with no deaths recorded in infants and 95% of the 70 deaths occurring in adults aged 60 and older. The level of knowledge about the burden of RSV in Switzerland has further improved thanks to the establishment of the RSV EpiCH national surveillance initiative launched in early 2021, which compiles laboratory-confirmed RSV cases in children across 20 hospitals (von Hammerstein et al., 2021). An atypical interseasonal surge was

detected in spring 2021, with 337 hospitalisations in May and 425 in June (above normal levels for those months). These cases were primarily among infants <12 months (54%), followed by children aged 1–2 years (24%). This was confirmed in another study on RSV-related children hospitalisations in 2018–2024 (Fischli et al., 2024). RSV hospitalisation incidence for infants <12 months averaged 1.6% of the birth cohort, peaking in the third week of life, and 11.4% of all hospitalised children required ICU admission, with 15% of these needing mechanical ventilation. Mortality was rare, with just two deaths (0.1%), both occurring during the 2023-2024 season. 81% of hospitalised children were previously healthy, though prematurity and chronic conditions strongly predicted ICU admission. The study also modeled the potential vaccine impact of nirsevimab, projecting up to 69% reduction in RSV hospitalisations under optimal coverage and efficacy scenarios. Globally, preterm infants, particularly those born very early, make up about 25% of RSV-related hospitalisations in children under 1 year, illustrating their substantial contribution to the overall burden (Wang et al., 2024).

Among adults, mortality is notably elevated in hospitalised people aged 60 and over, with in-hospital case-fatality ratio of around 7% and long-term survival at one year lower than for influenza (Brahier et al., 2025). A systematic review found that the mortality risk in this age group was comparable to that of influenza (Maggi et al., 2022). No data are provided on DALYs or QALYs, but the included articles underscore the significant direct and indirect impacts on patients and healthcare systems, while also detailing recent preventive advances, including the introduction and reimbursement of monoclonal antibodies and maternal and adult vaccination strategies.

In the wider context of high-income countries, adults with asthma or COPD represent a key vulnerable group, being overrepresented in RSV cases at 18% and 28%, respectively (Penders et al., 2025). The proportion of hospitalisation was significantly elevated in these groups, reaching up to 370 per 100,000 for asthma and over 1,000 per 100,000 for COPD in those aged 65+. ICU admissions occurred in 18% of COPD patients, and up to 21% of those admitted required mechanical ventilation. Case-fatality ranged from 2.6% to 4.3% in adults with asthma and from 2.8% to 17.8% in those with COPD.

Grey literature

Grey literature data on RSV in Switzerland come primarily from virological surveillance (NRCI) and national hospital discharge statistics compiled by the Federal Statistical Office (FSO) and summarized in FOPH reports. While RSV is not subject to mandatory notification, these sources provide a partial but valuable picture of the disease burden, particularly among young children. According to FSO hospital statistics, annual RSV-related hospitalisations ranged from 2,230 to 5,203 cases between 2014 and 2023, peaking in 2022 (5,203 cases) before declining to 2,923 in 2023. These hospitalisations predominantly affect young children, with estimates indicating that 2.6% of infants were hospitalised for RSV-related infections during each winter semester from 2015 to 2019, and RSV accounted for up to 11% of all infant hospitalisations in some years.

Virological data from the NRCI confirm the seasonal circulation. The proportion of positive RSV tests among nasopharyngeal swabs collected through Sentinella ranged from 0.3% (only 2 positive samples) in 2020/21, likely reflecting pandemic-related suppression, to 9.7% (149 positives) in 2022/23. For 2023/24, the positivity rate was 5.1%, with 70 positive samples identified.

While RSV typically causes mild illness in most children, severe outcomes can occur. In 2022, at least five deaths in children under two years of age were reported (FSO mortality statistics). Mortality in adults—particularly those aged 60 and older—is considerably higher, with in-hospital case-fatality ratios estimated at around 7% based on linked datasets.

4.1.5. SARS-CoV-2

We were not able to identify publications directly measuring the burden of post-2022 "endemic" SARS-CoV-2 in Switzerland or in neighbouring countries. Still, a few studies provide an indirect picture of the situation. One of the defining features of the post-2022 period is the near-universal immunity against SARS-CoV-2 in the Swiss population. Seroprevalence surveys show that by mid-2022, the vast majority of people in Switzerland had acquired antibodies through vaccination, infection, or both. For example, a population-based study in Geneva after the Omicron BA.2 wave found 93.8% seroprevalence of anti-SARS-CoV-2 antibodies in the general population (Zaballa et al., 2022). Notably, 72.4% of people had infection-induced antibodies (as indicated by anti-nucleocapsid markers) by that point, reflecting the widespread reach of the virus. Older adults had the highest overall seroprevalence (>90%) due to near-complete vaccine coverage, though a smaller fraction of them had been naturally infected (only ~46% of ≥75-year-olds had infection-derived antibodies by mid-2022). Nationwide data from the Corona Immunitas program likewise showed that seroprevalence was very high in Switzerland in 2022, without major differences across cantons and age groups (Frei et al., 2023). By mid-2022, well over 90% of the population had evidence of immune exposure, and a majority had developed hybrid immunity (from both vaccination and infection) with broad neutralizing capacity. These findings underscore that entering 2023, Switzerland had a highly immunized population, a key factor in reducing disease severity and subsequent burden. Despite these high levels of immunity, another study comparing COVID-19 hospital mortality with that of influenza in 2022 in Switzerland found the in-hospital all-cause 30-day mortality was about 1.5-fold higher for COVID-19 than for influenza patients (Portmann et al., 2023). In contrast, healthcare-associated infections show similar mortality risk between COVID-19 (Omicron) and influenza patients, with comparable case-fatality (6.2% vs. 6.1%), 30-day in-hospital mortality, and ICU admission rates (2.4% vs. 2.6%) (Grant et al., 2024). This suggests that COVID-19 remains at least as lethal as influenza even in the post-pandemic era, especially for vulnerable patients.

There were also several publications on the long-term burden of persistent post-COVID-19 conditions (also known as « long COVID ») in Switzerland. A population-based cohort study examined 431 participants six to eight months after confirmed SARS-CoV-2 infection (Menges

et al., 2021). Among 431 participants, 26% had not fully recovered, 55% experienced fatigue, 25% reported dyspnea, and 26% showed symptoms of depression. While 40% had at least one COVID-19-related healthcare contact, including 36% with general practitioner visits and 10% of previously hospitalised individuals requiring rehospitalisation, QALYs were not quantified. These findings were confirmed in another similar study of 245 previously hospitalised COVID-19 patients, with 72% reported at least one persistent symptom, most commonly fatigue, respiratory issues, and cognitive impairments (Tacchini-Jacquier et al., 2024). A study based on serological data reported that 9.1% of seropositive children experienced such symptoms lasting over 12 weeks (Dumont et al., 2022). The study also identified chronic health conditions and lower socioeconomic status as key risk factors for post-COVID conditions in children. A longitudinal study of persons with persistent post-COVID-19 conditions in Switzerland provided robust evidence on impaired quality of life (Malesevic et al., 2023). Patients reported high frequencies of fatigue (81%), dyspnea (60%), and concentration difficulties (60%), with notable reductions in physical functioning compared to the pre-pandemic Swiss population, clearly showing that long COVID may impose a significant and measurable burden on daily life and well-being in Switzerland.

Grey literature

As with influenza, grey literature data on SARS-CoV-2 are drawn from national surveillance sources. During the 2023/24 season, the hospitalisation rate among Sentinella-reported cases was 0.3%, while virological testing by the NRCI indicated a 21.6% positivity rate among nasopharyngeal swabs (Table 3). CH-SUR data for the same season reported 4,081 hospitalisations, with 7.9% of patients requiring intensive care and an in-hospital case fatality ratio (CFR) of 6.9%. Aggregated CH-SUR data from January 2022 to early 2023 provide consistent figures, with a mean ICU admission rate of 8.5% and a CFR of 4.2%. These findings align Portmann et al., showing that COVID-19 remained more lethal than influenza even in the post-pandemic period. Finally, according to FSO mortality statistics, 5,188 deaths attributed to COVID-19 were recorded in 2022. This number declined to 1,357 deaths in 2023, with a mortality rate of 9.0 per 100,000 men and 4.9 per 100,000 women in 2023.

Table 3: Surveillance indicators for SARS-CoV-2 in Switzerland (Sentinella, NRCI, CH-SUR, mandatory laboratory notification).

Epidemiological year*	19/20	20/21	21/22	22/23	23/24
Laboratory-confirmed cases / 100 000 Absolute (n)	351	7,597	34,232	7,494	553 48,970
IRA out-patient consultations / 100 000 Absolute (n x 1000)					4,014 355
% hospitalised among Sentinella-reported cases					0.3%
% positive NRCI swabs					21.6%
CH-SUR hospitalisations (absolute)					4,081
ICU admissions (% of CH-SUR)					7.9%
Case-fatality ratio (CH-SUR)					6.9%

*Epidemiological season: week 26 of year n to week 25 of year n + 1, except for NRCI (weak 40 to 16)

4.1.6. Bordetella pertussis

We identified 4 articles about the burden of *Bordetella pertussis* infection, none of which were specific to Switzerland. In high-income countries, including Switzerland, the burden of *B. pertussis* is likely substantially underestimated due to diagnostic challenges, atypical symptom presentation in older individuals, and limitations in surveillance systems. Reported case rates from surveillance systems were generally low, but seroprevalence studies consistently indicated higher infection rates ranging between 4 to 12% among older adults in several European countries, pointing to substantial underrecognition (Kandeil et al., 2019). Hospitalisation data for adults were limited, but a notable disease burden was observed in infants. In those under 3 months, hospitalisation rates ranged from approximatively 100 to 1000 per 100,000 population across European countries, with lower rates observed among infants aged 3-5 months (Kandeil et al., 2020). ICU admissions were rarely reported, and mortality was generally low but not negligible: the case fatality rate was approximatively 0.8% among infants in European settings. However, mortality among hospitalised adults could reach 11.5% to 17.4% (Macina & Evans, 2021). No DALY or QALY estimates specific to pertussis were found. Overall, the evidence underscores a significant, yet hidden, burden of pertussis, particularly among older populations in high-income settings.

Grey literature

Bordetella pertussis has been subject to mandatory notification in Switzerland since 1991, based on clinical symptoms. Between 2010 and 2023, reported cases ranged from 9 to 96 annually, with a notable decline in 2020–2022, likely due to pandemic-related factors. Data from the Sentinella network, extrapolated to the general population, estimated 5,900 cases in 2010, peaking at 13,200 in 2013 (164 per 100,000 population), before declining to 40–50

per 100,000 in 2018–2019. Hospital data indicate that between 2012 and 2017, there was an average of 40 hospitalisations per year in infants, compared with just 10 per year between 2018 and 2022. Recent surveillance suggests a resurgence: in the first semester of 2024, pertussis notifications had already reached the annual totals for 2018 and 2019.

4.1.7. Chlamydia pneumoniae

Data on the burden of *Chlamydia pneumoniae* remained scarce, even when extending the scope to other high-income countries. It is estimated that *C. pneumoniae* accounts for approximatively 10% of all community acquired pneumonia cases and 5-10% of adult pneumonia-related hospitalisations in Europe, making it one of the top three atypical causes of pneumonia, alongside with *Mycoplasma pneumoniae* and *Legionella pneumophila* (Dumke et al., 2015; Premachandra & Jayaweera, 2022). *C. pneumoniae* typically affects younger populations, as illustrated by a recent outbreak in Lausanne, where 20 out of 28 PCR-confirmed cases occurred in children (Tagini et al., 2024). Severe pneumonia requiring ICU care is rarely due to *C. pneumoniae*, with a detection in less than 2% of severe pneumonia cases (S. Wang et al., 2023). However, the few seroprevalence studies indicate that widespread exposure, surpassing 30% in adults across Europe (De Meyst et al., 2024). Deaths directly attributable to *C. pneumoniae* infection are uncommon.

Grey literature

According to hospital discharge data from 2014 to 2023, respiratory infections caused by *C. pneumoniae* remained relatively rare in Switzerland, with annual hospitalisations ranging from 6 to 40 cases (including only pneumonia-specific ICD-10 codes).

4.1.8. Streptococcus pneumoniae

Streptococcus pneumoniae is generally considered as the most common cause of community-acquired pneumonia (CAP) in Europe, including Switzerland. In Switzerland, its contribution to CAP cases had been estimated at 7% among children under five (Rudan et al., 2013) and at 15% among adults (Garin et al., 2022). Other data point to 9.2% of community-acquired pneumonia due to *S. pneumoniae* (Ieven et al., 2018) , and even less in admitted children (Vasconcelos et al., 2023). Among adults, several factors influence severity of CAPs, such as antimicrobial resistance or underlying comorbidities, increasing risk of ICU admission and length of stay, while lethality due CAP varies according to age and comorbidities, reaching up to 45% in hospitalised older patients. These findings are consistent with the Global Burden of Disease 2024 estimates, which, although not specific to Switzerland, confirm that *Streptococcus pneumoniae* remains a leading cause of lower respiratory tract infections globally and a major contributor to pneumonia-related mortality, particularly among older adults (GBD, 2024). However, the GBD and reviewed studies did not provide estimates for outpatient consultations, ICU admissions, seroprevalence, DALY or QALY for Switzerland.

Grey literature

Invasive pneumococcal disease, including pneumonia, is part of the mandatory notification system (Table 4). This allows to monitor the evolution of serotypes included in the vaccines recommended in Switzerland (Albrich et al., 2025). However, identification of *S. pneumoniae* in clinical samples poses several challenges, resulting in notification data clearly underestimating the actual burden. Hospital discharge data from the FSO can allow for an indirect estimate of the burden of pneumococcal pneumonia as a respiratory infection. In 2022, among 94,350 admissions for respiratory disease as main diagnostic group, there were 31.6% pneumonia, corresponding to almost 30'000 cases in one year (FSO, 2024). If we consider that up to 20% of community-acquired pneumonia are due to *S. pneumoniae*, this would translate to up to 6,000 annual cases admitted, ten times the number of notified cases.

Table 4: Annual notifications for pneumonia among invasive pneumococcal diseases in Switzerland (mandatory notifications cited in Albrich et al).

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N per 100,000	7.8	7.9	6.5	7.6	6.5	7.7	7.9	6.7	3.6	3.2	5.6
Absolute no. oof cases	629	642	533	637	544	657	671	578	311	276	496
(%) among all notifed	(75.3)	(74.7)	(70.4)	(73.5)	(71.7)	(73.1)	(76.6)	(74.8)	(69.1)	(71.7)	(72.5)

4.1.9. Haemophilus influenzae type b

The evidence regarding the burden of *Haemophilus influenzae type b* (Hib) relied on the same three multi-country reviews as *S. pneumoniae*. Following the massive roll-out of Hib vaccination in the 1990s, we observe low Hib morbidity in Switzerland. Hib was detected in 1% of the CAP cases (56 out of 5,431) among children under five (Rudan et al., 2013), and in 2% among adults (Garin et al., 2022). Slightly higher morbidity (7% of the CAP cases) was reported globally in Europe, making it the second CAP-causative bacteria, behind *S. pneumoniae* (Tsoumani et al., 2023). We observed moderate severity (22 out of the 56 cases were hospitalised) and no deaths among children under five. In line with these findings, the GBD 2024 study emphasized that while Hib was historically the second-leading cause of childhood pneumonia, its incidence has decreased substantially with the implementation of vaccination (GBD, 2024). Hib now accounts for a small share of lower respiratory infection mortality and DALYs in high-income countries. No specific data were provided for outpatient consultations, ICU admissions, seroprevalence, or QALYs.

Grey literature

Hospital discharge data from 2014 to 2023 indicate that annual non-invasive respiratory infections attributed to Hib ranged from 357 to 610 cases. This estimate includes only respiratory diagnoses such as bronchitis, unspecified infections, and pneumonia.

4.1.10. *Mycoplasma pneumoniae*

We identified a recent publication about *Mycoplasma pneumoniae* in Switzerland, which presents this pathogen as a reemerging cause of CAP globally (Sauteur et al., 2024). In Switzerland, the resurgence has affected both children and young adults since late 2023 after a drop in incidence during the COVID-19 pandemic (Bouras et al., 2024). Other factors include the lack of a vaccine and antibiotic (macrolide) resistance. Reported case rates and outpatient consultations surged in late 2023, with laboratory PCR positivity rates reaching up to 49% in one Geneva hospital (Hôpital de la Tour à Meyrin) and 14.4% at HUG, especially in pediatric patients. Although many cases are mild and self-limiting, hospitalisation occurs in up to 14% of notified cases (probably an overestimation due to selection bias), and severe illness requiring ICU admission, as illustrated in case report about a 59-year-old woman, can occur even in previously healthy individuals (Bouras et al., 2024). Seroprevalence data are lacking, but past estimates suggest underdiagnosis is common due to nonspecific symptoms and limited testing (Kumar, 2018). Mortality is rare, though severe pulmonary and extrapulmonary complications can arise. While no DALY or QALY estimates are provided, the burden includes quality-of-life impairment in complicated cases. Swiss resistance to macrolides remains low (2–9%), supporting their continued use as first-line treatment, although resistance monitoring is advised.

These Swiss findings align with broader European data. A large German laboratory study covering 2015–2024 confirmed the cyclical re-emergence of *M. pneumoniae*, with epidemic peaks in 2015/16, 2018, and late 2023, and virtually no cases detected during the pandemic years (Waldeck et al., 2025). The majority of cases occurred in children ≤18 years and in the outpatient setting (>95% post-pandemic), confirming the predominance of mild clinical courses, though adult hospitalisations and severe CAP were also observed. Co-infections with respiratory viruses such as influenza, rhinovirus, and RSV were frequent, occurring in around 20% of cases.

Before this resurgence, *M. pneumoniae* was characterized as a relevant but rare cause of community-acquired pneumonia in Europe. It is included among atypical pathogens, causing between 3% and 12% of all community-acquired pneumonia (Dumke et al., 2015; Tsoumani et al., 2023).

Grey literature

Hospitalisations related to respiratory infections due to *M. pneumoniae* (including pneumonia, acute bronchitis, and unspecified infections) ranged from 17 to 661 cases per year between 2014 and 2023, with a sharp increase observed in 2023.

4.1.11. Rhinovirus

We found no Swiss-specific study on human rhinovirus (HRV). A recent review has highlighted that HRV has a substantial but often under-recognized burden in adults globally

(Morelli et al., 2025). Reported cases and outpatient consultations are frequent, as HRV is a leading cause of ILI and lower respiratory infections. Hospitalisations are common, with HRV frequently identified in adults admitted for community-acquired pneumonia and acute respiratory infections, often exceeding the prevalence of influenza. ICU admissions are notable, especially in severe cases of CAP, with HRV being the most or second most co-detected virus in ICU patients across multiple cohorts. Seroprevalence data are limited, but the high rate of reinfection and detection in asymptomatic individuals suggests widespread and repeated exposure. Co-infections are not uncommon and may contribute to increased disease severity (Golke et al., 2021). Mortality associated with HRV is significant and can match or exceed that of influenza in hospitalised older patients, particularly those with comorbidities or immunosuppression. No data were provided on QALYs, indicating a gap in the burden quantification literature for HRV. Among children, evidence is scarcer. A pediatric German study found that HRV was also a common cause of hospitalisation for children, with co-infections increasing risk of severe outcomes. It also linked HRV species with specific clinical presentation, such as bronchiolitis or asthma (Neugebauer et al., 2022).

Grey literature

Non-invasive respiratory infections due to rhinoviruses, including bronchitis, were recorded in hospital discharge data, with annual case numbers ranging from 139 to 373 between 2014 and 2023. Virological surveillance by the NRCI further shows positivity rates for rhinovirus/enterovirus across five recent seasons, ranging from 13.1% in 2019/20 to 35% in 2020/21, reflecting frequent circulation in outpatient settings. Annual number of hospitalisations and positive nasopharyngeal swabs regarding the selected respiratory pathogens are summarized in Tables 5-6.

Table 5: Annual number of hospitalisations due to selected respiratory pathogens in Switzerland 2010-2023

(FSO, hospital discharge data, 2010–2023)
Includes non-invasive respiratory infections (pneumonia, bronchitis, unspecified infections).

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
B. Pertussis	62	67	96	85	79	60	88	100	67	50	21	9	24	33
S. Pneumoniae	-	-	-	-	1173	1188	1286	1659	1028	1731	1200	985	1574	2026
Chlamydia pneumoniae	-	-	-	-	22	23	22	21	18	9	12	14	6	40
Mycoplasma pneumoniae	-	-	-	-	298	302	295	220	370	473	230	17	19	661
Haemophilus influenzae type b	-	-	-	-	357	451	452	434	484	430	210	156	434	610
Rhinovirus	-	-	-	-	139	201	259	218	226	180	179	324	373	309

Table 6: Percentage and number of positive nasopharyngeal swabs for selected respiratory viruses in outpatient surveillance (NRCI, 2019/20-2023/24)

Season	19/20		20/21		21/22		22/23		23/24	
RSV (%, n)	6.3%	55	0.3%	2	6.8%	136	9.7%	149	5.12%	70
Rhinovirus/Enterovirus (%, n)	13.1%	114	35%	202	21.7%	433	21.7%	303	19.99%	273
SARS-CoV-2 (%, n)	2%	17	36.2%	209	34.5%	687	21%	322	31.19%	426
Influenza (%, n)	55.8%	485	0.2%	1	14.1%	282	30.8%	273	25.77%	352
HMPV (%, n)	6.1%	53	0.3%	2	4.5%	90	4.1%	63	4.47%	61

4.1.12. Human metapneumovirus

Human metapneumovirus (hMPV) circulates seasonally (typically winter to spring) and contributes to a measurable share of respiratory infections in the community. The only study identified in Switzerland found that the intensity of hMPV outbreaks can vary widely between seasons, below 1% of tested respiratory specimens in symptomatic children during some winters but up to 11–14% in peak years (Heininger et al., 2009). Similar patterns have been seen elsewhere in Europe, with prevalence of hMPV infection in outpatient respiratory illness ranging from only a few percent to over 10% in epidemic years (Lüsebrink et al., 2010; Pratt et al., 2022). Compared with RSV, hMPV affects a broader age range, with infections peaking later in the season (Pierangeli et al., 2023). In high-income countries, the burden of hMPV in children under 5 years was moderate compared to lower-income settings, with an incidence of 22.6 cases of acute infection per 1,000 children under 5 per year, about 3 hospitalisations per 1,000 infants under 1 per year, and a low case fatality ratio upon hospitalisation around 0.5% (X. Wang, Li, Deloria-Knoll, et al., 2021). About 4% of acute lower respiratory tract infections in children and adolescents could be attributed to hMPV (X. Wang, Li, Mei, et al., 2021). Data on adults remain limited. Among hospitalised patients with laboratory-confirmed hMPV infections, ICU admission rates range from 6.5% to 29% (Jongbloed et al., 2021; Kapandji et al., 2023; Loubet et al., 2021; Philippot et al., 2024). The case fatality ratio varies between 2% and 18% (Jongbloed et al., 2021; Kapandji et al., 2023; Loubet et al., 2021; Philippot et al., 2024), but as with other respiratory pathogens, it depends strongly on individual characteristics. The case fatality ratio can reach up to 30% in immunocompromised individuals during outbreaks, and deaths have been reported during outbreaks in long-term care facilities (Bhattacharya et al., 2025). Overall, the articles underscore hMPV as an underrecognized yet serious respiratory pathogen, particularly affecting the very young, elderly, and immunocompromised.

4.2. Narrative review on the economic impact of respiratory pathogens in Switzerland

Respiratory infections impose significant costs on healthcare systems and on society. In the following sections, we summarize peer-reviewed and official studies (post-2010) on the economic burden of major respiratory pathogens, separating direct costs and indirect costs.

Basically, while the direct costs are directly attributed to the specific condition and mainly refer to medical costs (e.g. doctor visits, medications, hospitalisations), the indirect costs represent the value of resources lost due to illness (e.g. productivity losses due to absenteeism, presenteeism i.e. coming to work but not functioning at full capacity due to illness, and caregiving). We separate findings from Switzerland versus other high-income countries. We exclude the unusual impact of the COVID-19 pandemic, focusing instead on typical years, but retained some estimates generated during the pandemic that could still be relevant in the post-pandemic period (e.g., cost per hospitalisation or absenteeism duration). All numbers were converted to CHF (exchange rate of CHF 0.94 per euro, CHF 0.80 per US$ and CHF 1.08 per GBP on 25/08/2025).

4.2.1. Seasonal influenza

Seasonal influenza leads to a substantial annual burden in Switzerland. A recent study of the 2016–2019 seasons found direct medical expenditures ranging from about CHF 42 million to CHF 73 million per season (Ammann et al., 2023). On average, about 80% of these costs came from hospitalisations (mostly in older patients). Another study conducted in a 75-bed rehabilitation center reported total (direct and indirect) costs of CHF 114,000 for managing an influenza outbreak from an institution point of view (Sendi et al., 2020). During this event, 25 employees (15%) were absent for 89 days during the outbreak month, leading to a productivity loss of CHF 87,000. Thus, this study indicates that productivity losses are larger than direct costs in Switzerland for seasonal flu. More broadly, research analyzing 2016 and 2017 data from the Swiss Sentinel Surveillance Network found that influenza and influenza-like illnesses resulted in 101,287 cases of work inability in 2016 and 86,373 cases in 2017 (Tomonaga et al., 2021). The total number of workdays lost was estimated at 324,118 in 2016 and 278,121 in 2017, higher for men than for women. The estimated costs of lost productivity were substantial, calculated at CHF 115 million in 2016 and CHF 103 million in 2017.

Systematic reviews of workplace productivity reveal consistent patterns across high-income countries. In adults aged 18 to 64 years, up to 88% of the economic burden of influenza was attributable to indirect costs, and up to 75% of overall direct costs were attributable to hospitalisations (de Courville et al., 2022). In Europe, overall direct costs ranged from CHF 53 in Italy per self-reported influenza case to CHF 85 in Germany per medically attended case, and cost per hospitalisation ranged from CHF 1,911 in Germany to CHF 6,414 in Belgium (de Courville et al., 2022). Only two studies reported overall indirect costs, both concluding that indirect costs largely exceeded direct costs, accounting for 83% and 99% of the total costs. A comprehensive review found that 20-75% of employees miss work due to influenza and influenza-like illness, with mean absences usually between 2 and 3 days and 60-80% report working while symptomatic, indicating significant costs due to presenteeism (Blanchet Zumofen et al., 2023). A detailed workplace analysis conducted in Hong Kong found that employee-reported productivity losses averaged 10.7 equivalent days of perfect health lost per person per year, translating to CHF 670 in losses annually (Lee et al., 2008).

Evidence for older adults (≥65 years) is more limited. Most studies reporting on economic burden were from the US, few examined indirect costs, and methodologies varied depending on whether productivity losses considered hospitalisations, extended care, mortality, or non-medically attended illness (Langer et al., 2023). Consequently, it is difficult to conclude on the overall economic burden of influenza in older adults, highlighting a need for further research in this age group.

4.2.2. RSV

A national analysis of Swiss hospital registry data between 2003 and 2021 revealed substantial direct costs associated with RSV, with mean inpatient costs of CHF 7,559 per hospitalisation, with around two-thirds of hospitalisations occurring in infants. For infants, the mean cost was slightly lower at CHF 7,350 (Stucki et al., 2024). The economic burden varied significantly based on severity of care required. Infants requiring intensive care unit admission incurred dramatically higher costs at CHF 26,212 compared to CHF 5,631 for those without ICU admission. Total yearly medical costs for RSV hospitalisations in Switzerland ranged between CHF 16.7 million in 2020 and CHF 31.5 million in 2019. Limited data exist on indirect costs for RSV in Switzerland, though the high proportion of infant cases suggests substantial caregiver burden and parental work absenteeism, consistent with patterns observed in other European countries.

Direct costs for RSV vary significantly across European countries and age groups. The UK has conducted comprehensive assessments of RSV's economic burden. A major study covering children under five years estimated that RSV results in approximately CHF 87 million annually in healthcare costs and productivity losses (Fusco et al., 2022). This translates to a mean total cost of CHF 105 per child under five attending primary care with RSV. Costs were divided into 80% for direct healthcare costs, 17% for productivity losses, and 2% for out-of-pocket costs incurred by parents and caregivers. Spanish data for adults aged ≥60 years show RSV infections result in significantly higher direct costs compared to other acute respiratory infections, particularly in patients aged 70-80 years (Peláez et al., 2025). European studies have reported on the indirect impact of the disease but not always by providing cost estimates. A family burden study in multiple countries (France, Germany, Italy and Sweden) documented significant work productivity losses and caregiver burden for the entire family, extending beyond the acute infection phase (Trautmannsberger et al., 2024). European comparisons found that from a societal perspective, including parental work absence, average costs per RSV episode varied from CHF 427 in the UK to CHF 934 in Belgium (Sankatsing et al., 2025), indicating that indirect costs from parental work loss are significant, though comparatively smaller than medical costs for infant RSV.

Systematic reviews examining RSV costs across Europe provide additional context. In Germany, a review of 23 papers on health care resource use found that outpatient RSV-LRTI cases in children ≤3 years averaged CHF 153 per case, while hospitalised cases averaged CHF 2,604 (direct + indirect costs), extrapolating to CHF 16.45 million for outpatient and CHF 61.9 million for inpatient care nationally (Poshtiban et al., 2024). A prospective cohort study in

Belgium, the UK, and the Netherlands estimated mean total costs per RSV episode in community-dwelling older adults (≥60 years) at CHF 28.9, with CHF 24.8 direct and CHF 4.1 indirect (Mao et al., 2022). Overall, most systematic reviews, particularly from the US, highlight frequent under-ascertainment of RSV in adults and the difficulty of obtaining reliable estimates for both direct and indirect costs, as methodologies vary and most studies report only direct hospital costs (Grace et al., 2023).

4.2.3. SARS-CoV-2

We found no estimate of the economic cost of SARS-CoV-2 in Switzerland in the post-pandemic period. Direct costs per hospitalisation in Switzerland have decreased from about CHF 27,000 in the early stage of the pandemic to CHF 22,000 at the end of 2020 (OFSP, 2021). We did not find any update for this figure, but it is likely that direct costs for COVID-19 hospitalisations in the post-pandemic era will come closer to that of influenza, with lower severity due to population immunity, shorter hospital stays and lower ICU utilization (Cohen et al., 2022). Studies examining primary care consultation costs reveal significant economic burden in outpatient settings. Long COVID patients have particularly high healthcare usage, leading to an increase of 43% in primary care consultation costs compared to patients without long COVID symptoms (Tufts et al., 2023).

During the pandemic, SARS-CoV-2 infections generated substantial productivity loss through work absenteeism. In Germany, it was measured that an outpatient case led to a median 10 days absenteeism and a hospital case to a median 15 days absenteeism (Yang et al., 2024). In the Netherlands, long COVID patients showed higher individual productivity losses by a factor 2, emphasizing chronic disease burden (Monteiro Sanchez et al., 2024). In a French context, about a third of long COVID patients had not returned to work when referred to specialized clinics (Yang et al., 2025). In the US, among workers suffering from long COVID, substantial productivity losses through presenteeism and absenteeism were observed (Martin et al., 2023). German estimates suggest CHF 3.2 billion in production losses with nearly 0.4% of employees withdrawn from labor market (Gandjour, 2023).

4.2.4. Community-acquired pneumonia

Streptococcus pneumoniae is a leading bacterial cause of CAP and other invasive diseases. Direct costs for pneumococcal pneumonia are very high, especially when hospitalisation is required. In Switzerland, a prospective cost study at a Geneva hospital (2008–2010) found the average cost per pediatric pneumonia case was CHF 11,258 (Keitel et al., 2014). Crucially, this average masks a huge difference by severity: hospitalised children with pneumonia incurred about CHF 23,900 per episode (including ICU), whereas outpatient cases (milder pneumonias treated at home) costed only around CHF 1,000. Direct costs for CAP are substantial across Europe. A German study reports mean direct medical costs of CHF 7,600 per hospitalisation linked to *S. pneumoniae* and CHF 1,370 per CAP episode (Deb et al., 2022). Even higher figures have been published for England, with CHF 4,233 per CAP episode (Campling et al., 2022). One systematic review of community-acquired pneumonia in

European countries identified seven studies with direct cost data, reporting inpatient costs ranging from CHF 7,991 to CHF 17,489 per case, and outpatient costs from CHF 104 to CHF 925 (Tsoumani et al., 2023). These differences could be partly caused by differences in methods.

In all of these studies, pediatric costs remain significant despite pneumococcal vaccination programs. Economic data specifically for atypical pathogens (*Mycoplasma pneumoniae*, *Chlamydia pneumoniae*) are limited. These infections are often managed in outpatient settings, resulting in much lower direct costs per case compared to pneumococcal pneumonia. For instance, the outpatient pneumonia cost in Switzerland (CHF 1,000 per episode) can be considered a proxy for an uncomplicated *M. pneumoniae* or *C. pneumonia* case (covering consultation, antibiotics, and follow-up) (Keitel et al., 2014).

Indirect costs of pneumococcal disease come from work absenteeism during illness and long-term disability in severe cases. Working-age adults with pneumonia often need 1–2 weeks off work to recover. If the patient is a young child or an older person, indirect costs are lower, but without considering the productivity loss of caregivers due to their absenteeism from work, that also could be substantial (Ho et al., 2015). Costs are likely lower for atypical pathogens for *S. pneumoniae* due to less frequent hospitalisation requirements, but specific cost estimates are scarce.

4.2.5. Bordetella pertussis

Data are lacking for the economic impact of pertussis in Switzerland. In the United States, direct treatment cost per pertussis case was estimated at about CHF 2,550 for infants (who often need hospitalisation), versus only CHF 270 for adolescents/adults in outpatient settings (Caro et al., 2005). In a German context, a more recent study estimated hospitalization costs of CHF 2,700 per child and CHF 3,300 per adult (Krammer et al., 2024).

Indirect costs have been estimated far higher. Pertussis illnesses can last for weeks, causing parents to miss work to care for sick infants or patients themselves to be out of work or school for extended periods. An analysis in England (2009–2018) of pertussis in adults over 50 estimated the annual economic burden at CHF 258 million, the majority of which were indirect costs (CHF 172 million lost productivity) and the remainder medical costs (CHF 72 million) (Versteeg et al., 2023). This highlights that in an aging workforce, productivity losses (e.g. time off due to coughing illness or caregiving) make up to about 70% of total pertussis costs.

4.2.6. Other viral respiratory infections (Hib, rhinovirus, human metapneumovirus)

In the absence of Swiss studies, German pediatric data provides the most comprehensive recent European cost analysis for multiple respiratory viruses. Non-ICU inpatient costs were similar across non-influenza respiratory viruses at approximately CHF 2,000 to 2,500, while

ICU costs were about CHF 6,000, far lower than the cost of ICU admission with influenza or RSV (Alchikh et al., 2024). This is consistent with the fact that these pathogens generally cause less severe disease than influenza or RSV. In addition, most infections are managed in outpatient settings, keeping direct medical costs relatively low per case. However, because these infections are so ubiquitous, the aggregate economic impact is huge.

4.2.7. Summary

Studies on the economic costs of respiratory pathogens show that indirect costs dominate in working-age adults, while direct costs are more important in children and older adults. In adults 18–64, influenza generates the highest indirect costs through productivity losses, making this age group the most costly overall. In contrast, RSV and CAP drive substantial direct costs in older adults, mainly from hospitalizations, with influenza and CAP contributing most to their overall burden. Children face a more moderate economic impact, though RSV accounts for the largest share of their direct costs.

4.3. Narrative review on the effectiveness of public health interventions in reducing disease burden

This section summarizes evidence on how pharmaceutical and non-pharmaceutical prevention interventions can mitigate the impact of these respiratory viruses, with an emphasis on Switzerland and similar high-income countries. Instead of conducting a systematic review, we based this section on the most influential and relevant publications in the field. Given the extensive body of research generated during the COVID-19 pandemic, we also incorporate studies conducted during the pandemic, with the hypothesis that many of their findings are applicable and relevant to non-pandemic periods.

4.3.1. Pharmaceutical interventions

Influenza vaccines

Three main types of seasonal influenza vaccines are currently used: inactivated influenza vaccines (IIV), live-attenuated influenza vaccines (LAIV), and recombinant influenza vaccines (RIV) (Gupta & Mohan, 2023). The most common in high-income countries are IIV containing three or four virus strains, with high-dose or adjuvanted formulations for older adults (WHO, 2025a). Because influenza viruses continually evolve, the vaccine composition is updated each year. The WHO Global Influenza Surveillance and Response System (GISRS) coordinates the biannual selection of vaccine strains through a sophisticated global surveillance network (WHO, 2025b). Experts analyze worldwide circulating viruses and recommend which influenza A (H1N1 and H3N2 subtypes) and B lineage strains to include. Strain selection occurs twice yearly, in February for the northern hemisphere and in September for southern hemisphere vaccines to allow sufficient time for vaccine production.

Influenza vaccine efficacy varies by season and population, but overall the vaccines provide moderate protection. In healthy adults, a pooled analysis of clinical trials found 59% efficacy

against lab-confirmed influenza (Osterholm et al., 2012) and observational studies in practice show about a 40–60% reduced risk of medically attended influenza illness in seasons when circulating strains are well-matched to the vaccine (CDC, 2025a). Vaccine effectiveness is typically higher against influenza A(H1N1)pdm09 and B viruses and lower against A(H3N2) (Belongia et al., 2016). In poorly matched seasons the efficacy can be very low, for instance estimated to 19% during the 2014–2015 season (Zimmerman et al., 2016). Vaccination also reduces the severity of breakthrough infections. A recent study found that among adults hospitalised with flu, vaccinated patients had a 26% lower risk of ICU admission and a 31% lower risk of death from flu compared with those who were unvaccinated (Ferdinands et al., 2021). Vaccination is associated with lower rates of cardiac events among people with heart disease (Udell et al., 2013), and with lower hospitalisation rates for people with chronic lung disease (Bekkat-Berkani et al., 2017) and diabetes (Colquhoun et al., 1997). This is most likely a combined effect of vaccine on reducing infection and hospitalization upon infection.

Despite its benefits, influenza vaccine coverage in Europe remains suboptimal. In 2022 only about 48% of people aged ≥65 in the EU received a flu vaccine, far below the 75% target coverage recommended for at-risk groups (Eurostat, 2024). Even at current uptake levels, vaccination has a substantial public health impact: modeling studies estimate that seasonal influenza immunization in Europe averts on the order of 1.6 to 2.1 million infections, 45,000 to 65,000 hospitalisations, and 25,000 to 37,000 deaths annually (Preaud et al., 2014). The exact numbers vary by year depending on the vaccine antigenic match, with greater benefits in well-matched seasons. Recent modelling across eight European countries shows that outcomes depend strongly on both vaccine type and target group (Sandmann et al., 2022). Switching older adults to improved vaccines (adjuvanted or high-dose) reduced infections by about 262 per 100,000, while quadrivalent vaccines yielded smaller gains. Universal paediatric vaccination achieved comparable indirect benefits for the elderly, highlighting the potential of new vaccine formulations and expanded target groups to enhance the impact of seasonal influenza vaccination (ECDC, 2024).

RSV vaccines and monoclonal antibodies

Recent years have seen the introduction of effective pharmacological interventions against RSV, including vaccines and monoclonal antibodies. Two RSV vaccines (Arexvy™ and Abrysvo™) have been approved for older adults, and a maternal RSV vaccine (RSVpreF™) was approved to protect infants via transplacental antibodies (Du et al., 2025). Alongside vaccines, monoclonal antibody (mAb) prophylaxis has progressed: the long-used palivizumab (a short-acting mAb requiring monthly doses) is now largely replaced by nirsevimab (a single-dose long-acting mAb) for infants' first RSV season (Graham, 2023).

Clinical trials have demonstrated high efficacy for these interventions. In older adults, RSV vaccines prevented approximately 80–90% of RSV-associated lower respiratory tract disease (Papi et al., 2023; Walsh et al., 2023). These vaccines also reduced severe outcomes (e.g. pneumonia and ICU admissions) in the elderly. Maternal immunization was 82% efficient against severe RSV infection in infants below 3 months (Kampmann et al., 2023). Similarly, a

single dose of nirsevimab in early infancy has been shown to prevent 70 to 80% of RSV-associated hospital admissions (Drysdale et al., 2023; Griffin et al., 2020; Hammitt et al., 2022), an improvement compared to palivizumab's more limited efficacy of about 50%. These findings underscore that both active vaccination and passive immunization can dramatically lessen RSV disease across age groups.

Despite these advances, RSV vaccine coverage in Europe is still nascent. As of 2024, RSV vaccination for seniors was recommended by only a few countries but not Switzerland (Anastassopoulou et al., 2024), and broad infant immunization programs (maternal vaccine or nirsevimab at birth) are just starting (e.g., PIPELINE-RSV which involves Switzerland). However, epidemiological models indicate that even moderate uptake could significantly reduce RSV burden. For example, vaccinating about one-third of older adults might cut RSV-related hospitalisations in that group by on the order of 8–10%, and widespread infant immunization could reduce infant RSV hospitalisations by ~40% (Krauer et al., 2024). Looking ahead, research is focused on next-generation vaccines and broader protection. Notably, the first mRNA-based RSV vaccine was approved in 2024 for older adults (Mullard, 2024). In summary, the current pharmacological tools (vaccines for seniors and pregnant women, plus infant antibodies) have shown remarkable efficacy in preventing RSV infection, hospitalisation, and death, and continued innovation in vaccine technology is expected to further improve RSV control in the future.

SARS-CoV-2 vaccines

Several types of COVID-19 vaccines have been developed and deployed globally. The main platforms include mRNA vaccines (e.g., Pfizer-BioNTech's BNT162b2 and Moderna's mRNA-1273) and viral vector vaccines (e.g., Oxford-AstraZeneca's ChAdOx1-S). High-income countries have primarily relied on mRNA vaccines due to their high efficacy and early availability, with updated mRNA boosters (targeting recent Omicron variants) now in widespread use (Mayo Clinic, 2025). In pivotal clinical trials, the first COVID-19 vaccines demonstrated remarkably high efficacy. For example, a two-dose regimen of an mRNA vaccine (Pfizer-BioNTech) conferred about 95% protection against symptomatic COVID-19 in adults (Polack et al., 2020). Such trials, mostly conducted before the emergence of later variants, indicated near-complete protection against severe outcomes in the short term. These findings set the stage for mass vaccination campaigns across high-income countries, which by mid-2023 have led to over 70% of the global population receiving at least one dose (Ao et al., 2023). Together with post-infection immunity, this explains the very high levels of seroprevalence found in European population in the early post-pandemic period (see section 3.3).

Real-world studies since 2020 have consistently shown that while vaccine-induced immunity offers incomplete protection against infection (especially with the more evasive variants) it still provides robust protection against severe disease and death. Vaccine effectiveness against infection has waned over time, particularly in the Omicron era. Under Omicron, vaccine effectiveness against any SARS-CoV-2 infection can range from 0–62% after a

primary series, improving to about 34–66% shortly after a booster, but still remaining relatively low and short-lived (Külper-Schiek et al., 2022). Against severe COVID-19, protection remained robust for at least up to 6 months (Külper-Schiek et al., 2022). A recent multi-country analysis found COVID-19 vaccines prevented over half of COVID-related hospitalisations and deaths even during 2022–2023, underscoring that the greatest benefits of vaccination are in averting severe cases (Katz et al., 2024). Although vaccine effectiveness has declined against highly mutated variants, health agencies note that keeping up-to-date with boosters significantly restores protection in high-risk groups, which is why ongoing booster campaigns (including annual boosters for vulnerable populations, analogous to seasonal influenza) are recommended (WHO, 2024).

Future directions

Future directions in vaccine technology aim to further improve this efficacy and consistency. Researchers are actively developing "universal" mRNA influenza vaccines that target conserved viral proteins to induce broad and long-lasting immunity across diverse strains (Arevalo et al., 2022). Similar ideas are being pursued for SARS-CoV-2, with variant-proof "pan-coronavirus" vaccines or nasal/mucosal vaccines (Cankat et al., 2024). Research into combination vaccines targeting multiple pathogens simultaneously is gaining momentum (Rubin, 2024). These innovations hold promise for higher and more durable vaccine effectiveness, which could enhance control and better mitigate the impact of respiratory viruses. A particular challenge for respiratory vaccines is the rapid waning of mucosal immunity, which limits protection against infection even when systemic protection against severe disease persists. Intranasal or mucosal vaccine strategies are therefore being explored to induce stronger and longer-lasting local immune responses at the site of viral entry (Lavelle & Ward, 2022). Several candidates are in clinical trials, showing some potential, but achieving consistent and robust protection against infection remains a challenge (Tian et al., 2025; Tscherne & Krammer, 2025).

4.3.2. Non-Pharmaceutical Interventions (NPIs)

NPIs before 2020

Before COVID-19, high-income countries relied on a range of NPIs to combat influenza and other respiratory viruses. Pandemic preparedness plans emphasized individual measures (e.g. voluntary isolation when ill, coughing etiquette, hand hygiene) and environmental measures (e.g. routine surface cleaning) as everyday interventions (Qualls, 2017). More disruptive NPIs like school closures, cancelling mass gatherings, quarantine of exposed contacts, and workplace distancing or closures were considered for severe influenza pandemics. For example, a pre-COVID systematic review found that isolating sick persons, tracing and quarantining contacts, and pre-emptive school closures may have moderate impact on slowing influenza spread (Fong et al., 2020). While NPIs were recognized as the only immediately available measures early in a pandemic before vaccines or antivirals became accessible, in practice aggressive measures like school shutdowns or city-wide

lockdowns were rarely used, and were generally reserved in plans for a truly severe pandemic scenario (WHO, 2019).

NPIs during the COVID-19 pandemic

The COVID-19 pandemic saw an unprecedented global scale-up of NPIs, including several innovations in high-income countries. Governments implemented enforced stay-at-home orders, nationwide mask mandates, bans on large gatherings, and extensive travel restrictions (far beyond what was ever implemented for influenza). Digital contact tracing apps and mass temperature screenings were introduced as novel tools to identify exposures (Kucharski et al., 2020; Salathé et al., 2020). Remote work and online schooling became widespread, reducing contact rates in workplaces and education settings. Many of these NPIs were deployed in combination, achieving larger collective impact on transmission than any single measure. For instance, Hong Kong, New Zealand, and South Korea used multi-layered NPI packages (from strict travel quarantine to mask-wearing and crowd limits) to successfully contain early COVID-19 waves (Walport, 2023) . The effect was also seen on other respiratory viruses in 2020. Global influenza activity dropped to historic lows, with a 90% reduction in influenza incidence during 2020–21 under NPIs (Kim et al., 2023). This highlighted that NPIs can effectively reduce respiratory virus spread, even at the cost of economic hardship, educational losses, and "pandemic fatigue", emphasizing that such measures must be restricted to situations of emergency.

The comparative effectiveness of various NPIs has been studied in depth during and after the COVID-19 pandemic. Early modeling studies in Europe suggested that strict lockdowns were highly effective: Flaxman et al. (2020) estimated that complete lockdowns reduced COVID-19 transmission by 81%, larger than any other single intervention (Flaxman et al., 2020). In the first pandemic wave, closing schools, banning mass gatherings, and shutting high-risk businesses were consistently among the top NPIs for curbing virus spread. For example, Brauner et al. (2021) found that limiting gatherings to <10 people, closing schools/universities, and closing restaurants/bars each reduced COVID-19 transmission by 30 to 40%, often outperforming strict lockdowns in terms of marginal impact (Brauner et al., 2021). Similarly, a comprehensive analysis of 130 countries identified school closures and internal movement restrictions (travel limits/lockdowns) as having the most robust association with reduced transmission (Liu et al., 2021). By contrast, policies like public transit closures, travel bans, or mask mandates were harder to isolate (Liu et al., 2021). Targeted testing and contact tracing were critical in many countries to control clusters: a UK modeling study showed that combined isolation of cases with robust contact tracing could cut transmission by 60% (Kucharski et al., 2020). However, contact tracing alone was often insufficient once case numbers were high and outpaced tracing capacity. In all these evaluations, it should be noted that major methodological challenges limited the comparability and policy relevance of estimates of NPI effectiveness (Lison et al., 2023). Notably, the timing and context of NPIs was key: restrictions were most effective when applied proactively before infection peaks, and their apparent effect often diminished once

vaccines, immunity, and more transmissible variants changed the landscape (Walport, 2023). In that sense, NPI effectiveness is dependent on timely implementation, and thus on the performance of forecasting tools.

NPIs in the post-pandemic period

With COVID-19 now transitioning to an endemic stage, public health is focusing on which NPIs are sustainable and effective for long-term respiratory virus control. Targeted and less disruptive NPIs are favored for routine use, including improved indoor ventilation and air filtration, coughing etiquette and hand hygiene promotion, and face masks in high-risk settings. Enhancing ventilation is now considered essential for healthy indoor environments, as it can significantly lower viral particle concentrations and thus infection risk (CDC, 2025b). Many high-income countries are updating building standards and investing in ventilation upgrades (and even ultraviolet disinfection in some facilities) to mitigate not just COVID-19 but influenza and other aerosol-transmitted viruses. Mask use has become more common, as voluntary masking is encouraged for vulnerable groups and during seasonal peaks, especially in crowded indoor spaces. Voluntary testing and isolation when symptomatic or quarantining after a close contact with a case (supported in both cases by generalized sick leave or work from home policies in companies). The pandemic has also highlighted the importance of healthcare -associated infections, in hospitals but also more widely in nursing homes and primary care settings. Thus, targeted prevention and control measures in healthcare settings and nursing homes remain essential and should be further supported in order to become standard each winter.

Looking ahead, a key future direction is to refine NPI implementation to be smarter and more targeted, avoiding the social and economic disruptions that characterized the initial pandemic response. This includes using real-time surveillance and forecasting to trigger NPIs only when and where needed, thereby minimizing unnecessary restrictions. In that regard, developing robust data pipelines that integrate multiple data sources (including the mandatory notification system but also sentinel networks, outpatient and hospital electronic health records, targeted pooled testing, wastewater monitoring, and repeated serological surveys) with epidemiological forecasts remains a key challenge. Steps in this direction have been taken with the development of the FOPH *Infectious Diseases Dashboard*. Insights from behavioral science are also crucial for improving public adherence to recommendations, with a transparent communication of risks and community engagement to sustain voluntary compliance with measures like masking or vaccination (ECDC, 2025). Evidence indicates that public willingness to adopt preventive measures has declined since the COVID-19 pandemic, as seen in decreased influenza vaccination rates in several countries (Turjeman et al., 2025). The pandemic's lessons will thus shape a more resilient approach, where NPIs are deployed in a graduated, evidence-based manner to protect public health.

5. Conclusion

This review examined the burden, costs, and interventions for respiratory infections in Switzerland. To achieve this, we conducted a scoping review of the epidemiological burden of respiratory pathogens, a narrative review of their economic impact, and a narrative review of the effectiveness of public health interventions.

The scoping review highlighted the substantial burden of influenza and RSV in Switzerland, particularly among infants and the elderly, while also documenting the continued health impact of SARS-CoV-2 in the post-pandemic period. Other respiratory pathogens such as *Streptococcus pneumoniae* and *Mycoplasma pneumoniae* remain under-recognized but contribute significantly to morbidity and healthcare utilization. Across all pathogens, hospitalisations, ICU admissions, and mortality remain concentrated in vulnerable groups, while outpatient consultations represent the largest share of cases. Yet, data gaps persist: data on seroprevalence, DALYs/QALYs, and comprehensive outpatient surveillance remain limited or absent for several pathogens.

The narrative review on the economic burden showed that respiratory pathogens generate high costs in Switzerland, both through direct healthcare expenditures and indirect productivity losses. Seasonal influenza is the best documented, with annual healthcare expenditures of CHF 42–73 million, driven largely by hospitalisations, and productivity losses exceeding medical costs (CHF 103–115 million annually in a conservative estimate), reflecting substantial work absenteeism. RSV also generates high direct costs, with average hospitalisation costs of CHF 7,500 per case and ICU admissions exceeding CHF 26,000, amounting to CHF 16–32 million per year, while indirect costs from caregiver absenteeism are significant but less well quantified. For SARS-CoV-2, data on Swiss cost are limited, with international data indicating major productivity losses linked to absenteeism and long COVID. Community-acquired pneumonias, particularly those due to *Streptococcus pneumoniae*, entail very high direct costs, with Swiss estimates reaching CHF 23,900 for severe paediatric hospitalisations, and German and English studies reporting CHF 7,600 and CHF 4,233 per episode, respectively. Indirect costs include 1–2 weeks of work absence for adults and caregiver burden for children and elderly patients. For *Bordetella pertussis*, no Swiss data are available, but European studies suggest that productivity losses can constitute up to 70% of total costs, outweighing relatively modest treatment expenses. Finally, other viral infections such as Hib, rhinovirus, and human metapneumovirus generally have lower per-case costs (CHF 2,000–2,500 per hospitalisation, CHF 6,000 for ICU) but impose a large aggregate burden given their high attack rate.

The review of public health interventions demonstrated that both pharmaceutical and non-pharmaceutical measures play a crucial role in mitigating this burden. Vaccination against influenza, RSV, and SARS-CoV-2 has proven effective in reducing severe disease and mortality, though coverage remains suboptimal in many target groups. Recent advances, including RSV monoclonal antibodies and next-generation vaccine technologies (e.g. universal influenza and pan-coronavirus vaccines, mucosal and combination vaccines), open

new opportunities for more durable and broader protection. Non-pharmaceutical interventions remain relevant in the post-pandemic era, particularly ventilation, targeted mask use, prevention and control of healthcare-associated infections, and voluntary isolation and quarantine. These measures require stronger collaboration with public and private companies and, where appropriate, regulatory frameworks at both the cantonal and national level to ensure consistent implementation and long-term sustainability. Awareness campaigns may also have a role to play: it is still too uncommon for employees to stay at home or switch to remote work when symptomatic, which limits the ability to protect coworkers and interrupt transmission chains. Importantly, the effectiveness of NPIs depends on timely and evidence-based deployment, which requires robust surveillance and forecasting systems.

This work also highlights limitations in the available information. Swiss-specific data remain scarce for several pathogens and indicators, especially seroprevalence, forcing reliance on studies from neighboring countries or aggregated European datasets. Considerable uncertainty persists around the true incidence of outpatient infections, the contribution of pathogens like rhinoviruses and hMPV, and the long-term health and economic consequences of infections such as long COVID. DALY and QALY estimates are largely absent, complicating burden quantification and cost-effectiveness analyses.

Strengthening surveillance of respiratory infections is therefore a critical priority for Switzerland. Existing infrastructures such as the national sentinel physician networks *Sentinella* and wastewater monitoring already provide valuable insights into pathogen circulation, yet their scope and integration remain limited compared to other countries. These systems should be further extended, both geographically and in terms of the range of pathogens monitored. Complementary approaches hold a lot of promise: targeted pooled testing can increase efficiency in outbreak detection (Riou et al., 2024). Repeated population-based serological surveys (i.e., *serosurveillance*) have become more accessible thanks to recent technological developments, and could be used to understand gaps in population-level exposure, susceptibility, and immunity to infectious diseases and improve our capacity to anticipate on threats (Carcelen et al., 2024). Continued efforts towards linkage between hospital and outpatient datasets will allow a more comprehensive picture of disease burden across the continuum of care. Equally important is continuing the development of real-time data pipelines that can feed into robust forecasting models, enabling earlier warnings and more precisely targeted public health responses. This need is underscored by a rapidly changing landscape of preventive tools, with new vaccines and long-acting monoclonal antibodies for RSV, next-generation influenza vaccines, and early-stage candidates for other respiratory pathogens entering clinical use or development. Fostering stronger collaboration across Switzerland's rich network of academic researchers will also be key to accelerating both innovation and education, ensuring preparedness, and reinforcing outbreak response capacity (e.g. on the example of *Insight Net* in the US*)*. Together, these advances underline that sustained investment in surveillance and prevention is not only medically necessary but

also economically sound, as it supports more efficient allocation of healthcare resources and mitigates both direct treatment costs and broader societal impacts.

In conclusion, respiratory infections will continue to impose a considerable burden on Swiss public health with or without a pandemic. By strengthening surveillance, optimizing vaccination, and maintaining targeted NPIs, Switzerland can not only reduce disease and death but also achieve long-term cost-effectiveness through avoided healthcare costs and productivity losses. Respiratory pathogens remain a major health concern in Switzerland and require continued attention in surveillance and prevention.

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7. Annexes

7.1. Search Equations

1. Outpatient consultation

(("Influenza, Human"[Mesh] OR "human influenza"[tiab] OR "influenza in humans"[tiab] OR "human flu"[tiab] OR "grippe"[tiab]) AND ("Switzerland"[Mesh] OR Switzerland[tiab] OR Swiss[tiab] OR Suisse[tiab]) AND ("ambulatory care"[Mesh] OR "outpatient consultation"[tiab] OR "outpatient care"[tiab] OR "primary care"[tiab] OR "doctor visit"[tiab] OR "consultation"[tiab] OR "consultation rate"[tiab] OR "visit rate"[tiab] OR "healthcare utilization"[tiab] OR "medical visits"[tiab])) NOT (Comment[pt] OR Editorial[pt] OR Letter[pt

2. Reported cases

(("Influenza, Human"[Mesh] OR "human influenza"[tiab] OR "influenza in humans"[tiab] OR "human flu"[tiab] OR "grippe"[tiab]) AND ("Switzerland"[Mesh] OR Switzerland[tiab] OR Swiss[tiab] OR Suisse[tiab]) AND ("Morbidity"[Mesh] OR "Incidence"[Mesh] OR "Disease Notification"[Mesh] OR "Sentinel Surveillance"[Mesh] OR "Sentinel Surveillance"[tiab] OR "case count"[tiab] OR "number of cases"[tiab] OR "reported cases"[tiab] OR "attack rate"[tiab] OR "case notification"[tiab] OR "notification rate"[tiab] OR "disease notification"[tiab] OR "incidence rate"[tiab] OR "incidence"[tiab] OR "surveillance data"[tiab])) NOT (Comment[pt] OR Editorial[pt] OR Letter[pt])

3. Hospitalisation

(("Influenza, Human"[Mesh] OR "human influenza"[tiab] OR "influenza in humans"[tiab] OR "human flu"[tiab] OR "grippe"[tiab]) AND ("Switzerland"[Mesh] OR Switzerland[tiab] OR Swiss[tiab] OR Suisse[tiab]) AND ("Hospitalization"[Mesh] OR "Patient Admission"[Mesh] OR "hospitalization"[tiab] OR "patient admission"[tiab] OR "hospital admissions"[tiab] OR "admission to hospital"[tiab] OR "hospital stay"[tiab] OR "hospitalised"[tiab] OR "hospitalized"[tiab] OR "hospitalization rate"[tiab] OR "admission rate"[tiab] OR "rate of hospitalization"[tiab] OR "number of hospitalizations"[tiab] OR "number of admissions"[tiab] OR "hospital admission rate"[tiab] OR "incidence of hospitalization"[tiab])) NOT (Comment[pt] OR Editorial[pt] OR Letter[pt])

4. DALY/QALY

(("Influenza, Human"[Mesh] OR "human influenza"[tiab] OR "influenza in humans"[tiab] OR "human flu"[tiab] OR "grippe"[tiab]) AND ("Disability-Adjusted Life Years"[Mesh] OR "Quality-Adjusted Life Years"[Mesh] OR "quality-adjusted life year"[tiab] OR "quality-adjusted life years"[tiab] OR QALY[tiab] OR QALYs[tiab] QUALY[tiab] OR QUALYs[tiab] OR "disability-adjusted life year"[tiab] OR "disability-adjusted life years"[tiab] OR DALY[tiab] OR DALYs[tiab] OR "years lived with disability"[tiab] OR "quality of life"[tiab])) NOT (Comment[pt] OR Editorial[pt] OR Letter[pt])

5. Seroprevalence

(("Influenza, Human"[Mesh] OR "human influenza"[tiab] OR "influenza in humans"[tiab] OR "human flu"[tiab] OR "grippe"[tiab]) AND ("Switzerland"[Mesh] OR Switzerland[tiab] OR Swiss[tiab] OR Suisse[tiab]) AND ("Serology"[Mesh] OR "Serologic Tests"[Mesh] OR serology[tiab] OR "serological test"[tiab] OR "serologic test"[tiab] OR serodiagnosis[tiab] OR seroprevalence[tiab])) NOT (Comment[pt] OR Editorial[pt] OR Letter[pt])

6. Mortality

(("Influenza, Human"[Mesh] OR "human influenza"[tiab] OR "influenza in humans"[tiab] OR "human flu"[tiab] OR "grippe"[tiab]) AND ("Switzerland"[Mesh] OR Switzerland[tiab] OR Swiss[tiab] OR Suisse[tiab]) AND ("Mortality"[Mesh] OR mortality[tiab] OR "mortality rate"[tiab] OR "death rate"[tiab] OR death[tiab] OR fatality[tiab] OR lethality[tiab]"number of deaths"[tiab] OR "case fatality rate"[tiab] OR "crude mortality rate"[tiab])) NOT (Comment[pt] OR Editorial[pt] OR Letter[pt])

7. ICU admission

("Influenza, Human"[Mesh] OR "human influenza"[tiab] OR "influenza in humans"[tiab] OR "human flu"[tiab] OR "grippe"[tiab]) AND ("Switzerland"[Mesh] OR Switzerland[tiab] OR Swiss[tiab] OR Suisse[tiab]) AND "Intensive Care Units"[Mesh] OR "Critical Care"[Mesh] OR "intensive care"[tiab] OR "critical care"[tiab] OR ICU[tiab] OR "ICU admission"[tiab] OR "admitted to ICU"[tiab] OR"ICU hospitalization"[tiab] OR "intensive care hospitalization"[tiab] OR "critical care admission"[tiab] OR "critical care hospitalization"[tiab] OR "ICU admission rate"[tiab])

8. General epidemiological burden

("Global Burden of Disease"[Mesh] OR "burden of disease"[tiab] OR "disease burden"[tiab]OR "health burden"[tiab] OR "healthcare burden"[tiab] OR "health impact"[tiab] OR "public health burden"[tiab] OR "Global Burden of Disease"[tiab] OR "GBD study"[tiab] OR "Global Burden Study"[tiab] OR "burden"[tiab] OR "burden of illness"[tiab] OR "illness burden"[tiab] OR "Cost of Illness"[Mesh] OR "Cost of Illness"[tiab] OR "impact of disease"[tiab] OR "disease cost"[tiab] OR "economic evaluation"[tiab] OR "epidemiological impact"[tiab] OR "epidemiological burden"[tiab]) AND ("Influenza, Human"[Mesh] OR "human influenza"[tiab] OR "influenza in humans"[tiab] OR "human flu"[tiab] OR "grippe"[tiab]) AND ("Switzerland"[Mesh] OR Switzerland[tiab] OR Swiss[tiab] OR Suisse[tiab])

We use the same equation for RSV and SARS-Cov-2, we only change the term related to the pathogen as follows:

RSV: ("Respiratory Syncytial Virus, Human"[Mesh] OR "Respiratory Syncytial Virus Infections"[Mesh] OR "Bronchiolitis, Viral"[Mesh] OR "Human respiratory syncytial virus" OR "HRSV Human respiratory syncytial virus" OR HRSV OR "human RSV" OR "human RSVs" OR

"RSV, human" OR "Respiratory Syncytial Virus Infection" OR "Syncytial Virus" OR "RSV Infection" OR "Infection, RSV" OR "RSV Infections" OR "Bronchiolitides, Viral" OR "Viral Bronchiolitides" OR "Viral Bronchiolitis")

SARS-CoV-2: (("SARS-CoV-2"[Mesh] OR "COVID-19"[Mesh]) OR "Covid-19" OR "Coronavirus" OR "Covid" OR "Coronavirus disease" OR "Corona virus" OR "2019-nCoV" OR "Coronavirus Disease 2019 Virus" OR "Severe Acute Respiratory Syndrome Coronavirus 2" OR "SARS Coronavirus 2 Infection" OR "COVID19" OR "2019 novel coronavirus")

For the others pathogens, we only use the "general epidemiological burden" equation with the pathogen as follows:

Rhinovirus:

("Rhinovirus"[Mesh] OR "rhinovirus"[tiab] OR "rhinoviruses"[tiab] OR "human rhinovirus"[tiab] OR "HRV"[tiab])

Human Metapneumvirus:

"Metapneumovirus"[Mesh] OR "HMPV"[tiab] OR "Metapneumovirus"[tiab] OR "Human Metapneumovirus"[tiab] OR "hMPV infection"[tiab] OR "human metapneumovirus infection"[tiab]

H. influenzae type b

("H. influenzae type b"[tiab] OR "H. influenzae b"[tiab] OR "Haemophilus influenzae type b"[Mesh] OR "Haemophilus influenzae type b"[tiab] OR Hib[tiab])

Streptococcus pneumoniae:

("Pneumonia, Pneumococcal"[Mesh] OR "pneumococcal pneumonia"[tiab] OR "pneumonia due to Streptococcus pneumoniae"[tiab] OR "pneumonia caused by Streptococcus pneumoniae"[tiab] OR "Streptococcus pneumoniae pneumonia"[tiab] OR "S. pneumoniae pneumonia"[tiab] OR "pneumonia pneumococcal"[tiab] OR "Streptococcus pneumoniae"[tiab] OR "S. pneumoniae"[tiab] OR "pneumonia pneumococcal"[tiab])

Chlamydophila pneumoniae:

("Chlamydophila pneumoniae"[Mesh] OR "Chlamydia pneumoniae"[tiab] OR "Chlamydophila pneumoniae"[tiab] OR "C. pneumoniae"[tiab] OR"C pneumoniae"[tiab] OR "chlamydial pneumonia"[tiab] OR "chlamydial infection"[tiab] OR "chlamydia infection"[tiab] OR Chlamydia[tiab]) AND ("pneumonia"[tiab] OR "respiratory infection"[tiab] OR "respiratory tract infection"[tiab])

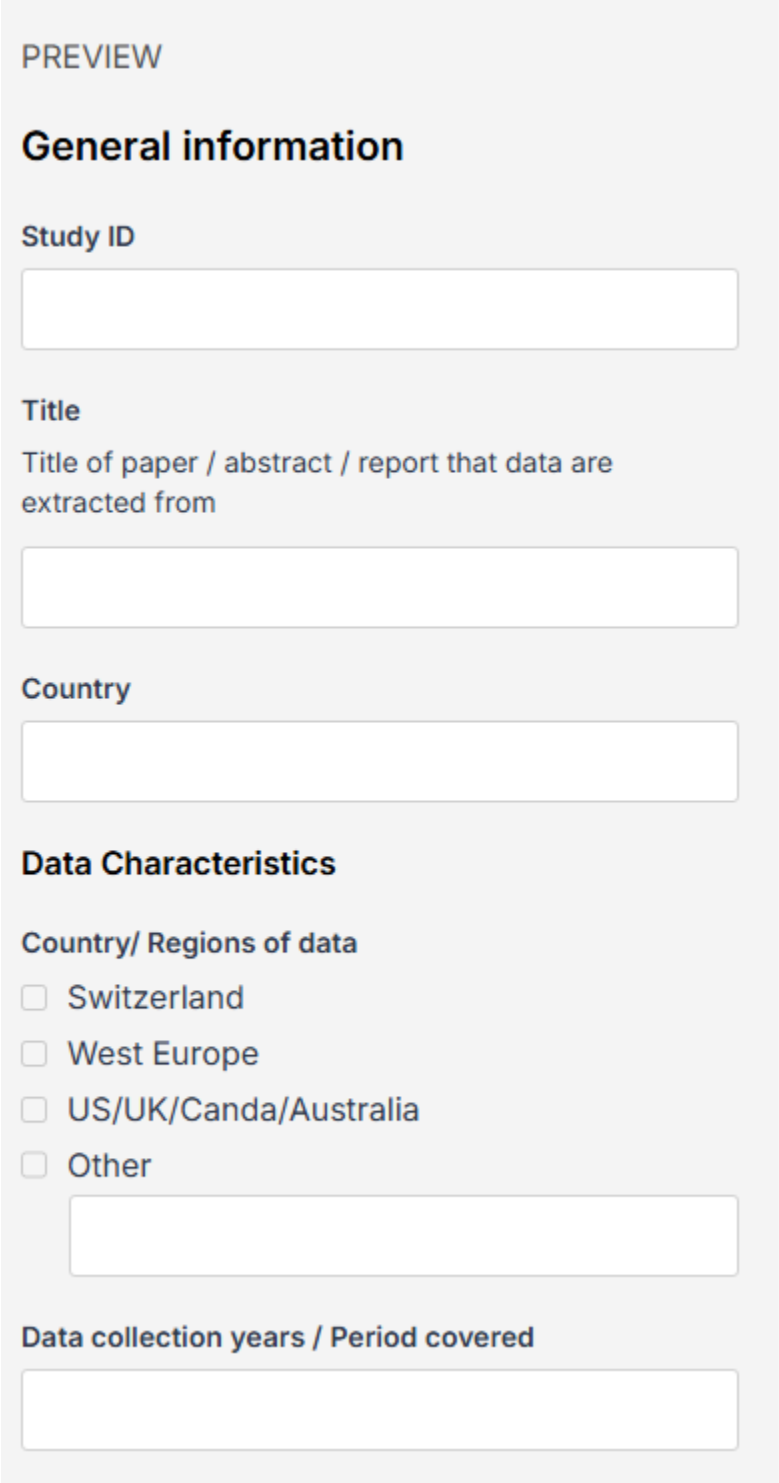
Bordetella pertussis:

("Bordetella pertussis"[Mesh] OR "B. pertussis"[tiab] OR "B pertussis"[tiab] OR "Whooping Cough"[Mesh] OR "Bordetella Infections"[Mesh] OR pertussis[tiab] OR "whooping cough"[tiab] OR coqueluche[tiab])

Mycoplasma pneumoniae:

("Mycoplasma pneumoniae"[Mesh] OR "Pneumonia, Mycoplasma"[Mesh] OR "Mycoplasma pneumoniae infection"[tiab] OR "pneumonie à mycoplasme"[tiab] OR "Mycoplasma pneumoniae"[tiab] OR "Mycoplasma respiratory infection"[tiab] OR “Mycoplasma pneumonia"[tiab] OR "M. pneumoniae"[tiab] OR "M pneumoniae"[tiab])

7.2. Data extraction template in Covidence



Population Description

Age

- [ ] Infant (0-1)
- [ ] Children (1-12)
- [ ] Adolescent (13-17)
- [ ] Adult (18-64)
- [ ] Elderly (>64)
- [ ] Other

Population Group

- [ ] General population
- [ ] High-risk groups (chronic conditions, immunocomprimised...)
- [ ] Institutionalized populations (e.g. nursing homes)
- [ ] Hospitalized patients
- [ ] Pregnant women
- [ ] Other

Table preview

	Influenza	RSV	SARS-CoV-2
Incidence			
Mortality			
Hospitalisation			
Consultation			
ICU Admission			
DALY/QALY			
Serology			

key findings

Data source

Pathogenes

- [ ] Influenza
- [ ] SARS-CoV-2
- [ ] Respiratory syncitial virus
- [ ] Streptococcus pneumoniae
- [ ] Chlamydia pneumoniae
- [ ] Mycoplasma Pneumoniae
- [ ] Human metapneumovirus.
- [ ] Haemophilus influenzae type b
- [ ] Rhinovirus
- [ ] Bordetella Pertussis

Study design

Data type

Epidemiological Burden

Outcomes measured

- [ ] Reported cases
- [ ] Mortality
- [ ] Seroprevalence
- [ ] Outpatient consultations
- [ ] Hospitalisations
- [ ] ICU admissions
- [ ] DALY/QALY
- [ ] Economical indicators

7.3. Included studies

Table S1. Included studies with data location (Swiss or not), setting, study design and studied pathogens. Abbreviations. RSV: Respiratory syncital virus, S. pneumonia: Streptococcus pneumoniae, C. pneumoniae: Chlamydia pneumoniae, M. pneumonia: Mycoplasma pneumoniae, Hib: Haemophilus influenzae type b, hMPV: Human metapneumovirus, B. pertussis: Bordetella pertussis.

Reference	Swiss Data	Setting	Study Design	Pathogen
Ammann 2023	yes	Community/Primary care; Hospital; Registry / Administrative	Retrospective analysis of multiple real-world datasets (Sentinel surveillance, hospital discharge registry, mortality registry, health-survey inputs)	Influenza
Beysard 2018	yes	Other: Hospital ED (49 beds, 29 isolation rooms)	retrospective monocentric cohort	Influenza
Bhattacharya 2025	nan	Community/Primary care; Hospital; Long-term care facility	Systematic review (PRISMA-conform) and narrative synthesis of incidence, hospitalisation, mortality, costs.	hMPV.
Bouras 2024	yes	Community/Primary care; Hospital	Narrative review + descriptive analysis of routine PCR positivity	M. pneumoniae
Brahier 2025	yes	Community/Primary care; Hospital	Narrative review, expert update	RSV
Brugger 2020	Yes	Hospital (mainly using data from Sentinella network)	Mathematical modelling study using surveillance data	Influenza
Chorazka 2021	yes	Hospital	Retrospective two-season hospital cohort	Influenza; RSV
Ciofi degli Atti 2023	No	Hospital	Retrospective observational study	Influenza; RSV; rhinovirus; hMPV
Cong 2023	no	Community/Primary care; Hospital	Systematic review + meta-analysis of modelled estimates	RSV
De Meyst 2024	No	Community	Cross-sectional analysis in two cohorts	C. pneumoniae
Domnich 2024	no	Community/Primary care; Hospital	systematic review + random effect meta-analysis	RSV
Duan 2023	no	Community/Primary care; Hospital	systematic review + random-effects meta-analysis of observational studies	RSV
Dumke 2015	No	Hospital	Prospective cross-sectional observational study	C. pneumoniae; M. pneumonia
Dumont 2022	yes	Community/Primary care	Population-based prospective cohort (baseline cross-sectional serological survey with adjusted prevalence comparison)	SARS-CoV-2
Fischli 2024	yes	Hospital	Retrospective, population-based hospital cohort	RSV

Frei 2023	Yes	Community	Repeated cross-sectional seroprevalence study	SARS-CoV-2
Fröhlich 2022	yes	Hospital	retrospective multi-centre cohort study	Influenza
Garin 2014	Yes	Hospital	Randomized controlled trial	S./M./C. pneumonia; Hib
GBD 2024	yes	Community/Primary care; Hospital; Registry / Administrative	Systematic analysis using GBD model	Influenza; RSV; S. pneumoniae; C. pneumoniae; M. pneumoniae; Hib
Giacchetta 2022	no	Community/Primary care; Hospital; Registry / Administrative; Long-term care facility	Systematic literature review (narrative synthesis)	Influenza
Golke 2021	No	Hospital	Retrospective observational study	Rhinovirus
Grant 2024	Yes	Hospital	Retrospective cohort study	SARS-CoV-2; Influenza
Heininger 2009	Yes	Hospital; Community (outpatients)	Prospective cohort study	hMPV; RSV
Johnson 2021	no	Hospital; Registry / Administrative	Modelling study: Bayesian mixed-effects meta-regression (MR-BRT) to estimate the proportion of ALRI admissions attributable to influenza or RSV, then applied to national ALRI admission envelopes ("BIRD" method).	Influenza; RSV
Jongbloed 2021	No	Hospital	Retrospective cohort study	hPMV
Kandeil 2019	no	Community/Primary care	Systematic literature review and narrative synthesis	B. pertussis
Kandeil 2020	no	Hospital; Registry / Administrative	systematic review	B. Pertussis
Kapanji 2023	No	Hospital	Retrospective monocentric cohort study + systematic review and meta-analysis	hPMV
Kucharski 2015	No	Community	Mathematical modelling study using serological data	Influenza
Lafond 2021	no	Hospital	Systematic review and meta-analysis of observational surveillance datasets	Influenza
Langer 2023	no	Community/Primary care; Hospital; Long-term care facility	systematic litterature review	Influenza
Li 2022	nan	Community/Primary care; Hospital; Other: post-mortem surveillance	Systematic review and generalised linear mixed-effects mode meta-analysis with risk-factor based modelling for some country-level incidence.	RSV
Li 2023	no	Hospital	systematic review + multilevel random-effects meta-analysis	RSV
Loubet	No	Hospital	Retrospective multicenter cohort study	hPMV

Lüsebrink 2009	No	Community	Cross-sectional seroprevalence study	hMPV
Macina 2021	no	Community/Primary care; Hospital	systematic review	B. pertussis
Maggi 2022	No	Community/Primary care; Hospital	Systematic review + meta-analysis	RSV
Maleki 2023	no	Community/Primary care; Hospital	systematic review	Influenza
Malesevic 2023	nan	nan	Observational cohort / cross-sectional HRQoL survey	SARS-CoV-2
Menges 2021	nan	nan	prospective cohort study	SARS-CoV-2
Mertz 2019	nan	nan	Systematic review + individual participant data (IPD) meta-analysis	Influenza
Meyer Sauteur 2024	No	Other – global surveillance network	Prospective surveillance study	M. pneumonia
Morelli 2025	no	Community/Primary care; Hospital; Long-term care facility	Narrative review of 120 + primary studies	Rhinovirus
Navarro-Torné 2021	no	Community	Systematic literature review + meta-analysis	S. pneumonia
Neugebauer 2022	No	Hospital	Observational cohort study	Rhinovirus
Paget 2023	no	Community/Primary care; Hospital; Registry / Administrative	Systematic literature review + multi-level meta-analysis	Influenza
Penders 2025	yes	Community/Primary care; Hospital; Registry / Administrative	systematic review and meta-analysis	RSV
Philippot 2024	yes	Hospital	Prospective observational multicenter study	hMPV
Portmann 2023	yes	Hospital	National multicentre cohort (prospective registry, retrospective analysis)	Influenza; SARS-CoV-2
Pratt 2022	no	Community/Primary care; Hospital	Systematic review + meta-analysis	Influenza; RSV; hMPV; Rhinovirus; Other: Parainfluenza, Adenovirus, Bocavirus, non-SARS coronaviruses, Enterovirus (22 viruses total)
Qalla-Widmer 2021	yes	Hospital	Prospective multicentre observational study	Influenza
Pierangeli 2022	No	Community/Primary care; Hospital	Prospective multicentre observational study	RSV; HMPV
Premachandra 2022	No	Other: mixed populations	Systematic review	C. pneumonia
Rudan 2013	yes	Community/Primary care	Global burden model fed by systematic reviews + risk-factor model	Influenza; RSV; S. pneumoniae; Hib
Rybak 2024	no	Community/Primary care	Prospective test-negative cohort	RSV

Savic 2023	no	Community/Primary care; Hospital	systematic literature review and meta-analysis	RSV
Shi 2017	no	Community/Primary care; Hospital	systematic review + risk-factor & mortality modelling	RSV
Shi 2020	no	Community/Primary care; Hospital	Systematic review + random-effects meta-analysis + 2015 population modelling	RSV
Shi 2022	no	Community/Primary care; Hospital	systematic review and meta-analysis	RSV
Stucki 2024	yes	Hospital; Registry / Administrative	Retrospective cohort using national administrative data	RSV
Tacchini-Jacquier 2024	yes	Community/Primary care; Hospital; Other: "Hospital" (index stay) plus Community follow-up (4-month questionnaire)	Cross-sectional patient-reported survey (PREMs)	SARS-CoV-2; Other: persistant post-covid conditions
Tagini 2024	Yes	Hospital	Case series	C. pneumonia
Tsoumani 2023	yes	Community/Primary care; Hospital	systematic literature review	S. pneumoniae; C. pneumoniae; M. pneumoniae; Hib; Other: virus
von Hammerstein 2021	yes	Hospital	Retrospective descriptive analysis of prospectively collected sentinel-surveillance data	RSV
Wang 2020	no	Community/Primary care; Hospital	systematic review and modelling study (mixes regression model)	Influenza
Wang 2021	no	Community/Primary care; Hospital	systematic literature review and meta-analysis	hMPV.
Wang 2021	no	Hospital	systematic review + meta-analysis + population modelled estimates	Influenza; RSV; hMPV.
Wang 2023	no	Community/Primary care; Hospital	systematic literature review and meta-analysis	C. pneumoniae; M. pneumoniae;
Wang 2024	no	Community/Primary care; Hospital	systematic review + meta-analysis	RSV
Yeung 2017	no	Other: Community incidence (WHO clinical definition)/ deaths modelled	nan	B. pertussis
Zaballa 2022	Yes	Community	Cross-sectional seroprevalence study	SARS-CoV-2