OPEN ACCESS J PREV MED HYG 2026; 67: E132-E150

INFECTIOUS DISEASE

A five-season regional analysis of influenza-related indicators in Piedmont, Italy: insights from comparison with national trends

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Keywords

Influenza-like illness • Influenza vaccination • Excess mortality • Surveillance

Summary

Introduction. *Influenza remains a major public health concern, while vaccination coverage has persistently remained below national targets. This study aimed to describe influenza-related indicators in Piedmont over five influenza seasons and to compare regional findings with national data to inform current prevention strategies.*
Methods. *A descriptive analysis of the 2019/2020-2023/2024 influenza seasons was conducted using publicly available data from Piedmont and Italy. Weekly and cumulative Influenza-Like Illness (ILI) incidence were assessed overall and by age group. Virological surveillance data were used to describe circulating influenza strains, excess mortality among adults aged ≥65 years was estimated by comparing observed and expected weekly average daily deaths, and influenza vaccination coverage was analysed overall and by age group.*
Results. *Overall cumulative ILI incidence increased during the study period, despite a marked reduction in 2020/2021. Piedmont generally showed higher ILI incidence than Italy. Although children remained the most affected group, the gap between paediatric and adult/older age groups progressively narrowed, with a growing absolute burden among adults and older adults. Virological surveillance showed substantial variability across seasons, with influenza A predominating in most years. Excess mortality was highest in 2019/2020 and 2020/2021 and was generally more pronounced in Piedmont than nationally. Vaccination coverage improved compared with the pre-pandemic period but remained below national targets across key population groups.*
Conclusion. *Influenza-related burden in Piedmont remained considerable over the study period. These findings support the need for stronger vaccination strategies and integrated epidemiological, virological, and mortality surveillance to guide timely and context-specific public health action.*

Introduction

Influenza represents a priority for public health: globally, the influenza-related hospitalization rate is 40.5 (95% CI=24.3-67.4) per 100,000 inhabitants, with higher hospitalization rates among children up to 4 years old and adults over 65 years [1]. Although most estimates of the global burden of influenza disease focus on respiratory complications, the possible consequences of influenza include worsening of underlying chronic conditions, increased susceptibility to secondary infections, cardiovascular events, and functional decline [2].
Specifically, in Italy, the influenza attack rate is estimated to range between 13% and 31%, depending on the circulating virus strain during the season, and only about 18-29% of infections are detected by the surveillance system. While people aged over 65 do not represent the group most frequently contracting influenza [3], this age group reports the highest rates of complications and deaths [4]. Italian estimates indicate that the majority of influenza-related deaths (65%-96%) occur in individuals aged 65 or older; moreover, the excess mortality rate in the elderly is more than six times higher compared to the general population [4].
Vaccination is one of the key strategies to reduce the impact of influenza. Although real-world effectiveness varies depending on the virus type and the age of the infected individuals, vaccines have proven effective in reducing the risk of hospitalization [5]. Vaccines have also proven effective, for example, in reducing cardiovascular complications in the older adults, thus representing a crucial ally in decreasing the disease burden associated with influenza [6]. In Italy, the National Vaccination Prevention Plan (PNPV) 2023-2025 [7] defines a minimum vaccination coverage target of 75% among people over 65 years old, with an optimal goal set at 95%. However, in Italy, influenza vaccination coverage among adults aged 65 years or older has never reached the recommended 75% target and has consistently remained at approximately 50%. Piedmont is among the regions that have persistently reported coverage levels below the national average [8].
Given the substantial burden of influenza and the persistently low vaccination coverage in Piedmont, this study aimed to describe the regional epidemiology of influenza and its associated health burden in the Piedmont population. In addition, by comparing regional

 https://doi.org/10.82082/2421-4248/jpmh2026.67.2.3909

findings with national data across five influenza seasons, the study sought to provide a broader perspective on current prevention strategies.

Methods

This report considers an observation period that includes five influenza seasons, from 2019/2020 to 2023/2024, in Piedmont. All analyzed data were obtained from publicly available online sources. Data management, statistical analyses, and graph production were conducted using Excel and Stata. Details on the data sources, study procedures, and statistical analyses are provided in the following sections.

Epidemiological Surveillance

In Italy, epidemiological monitoring of influenza is carried out through RespiVirNet (previously InfluNet until the 2022-2023 season), a surveillance system coordinated by the Italian National Institute of Health (ISS) [9]. The system consists of two main components: epidemiological surveillance and virological surveillance. The former aims to measure and describe the trend of Influenza-Like Illness (ILI) cases, while the latter focuses on detecting circulating respiratory viruses, including influenza viruses [10]. ILI is defined as an acute syndrome characterized by general symptoms (fever, malaise) and respiratory symptoms (cough, sore throat, runny nose), which can be caused not only by influenza viruses but also by other respiratory pathogens [10]. Information collected within the RespiVirNet epidemiological surveillance context refers to ILI. The system relies on the collaboration of sentinel physicians, including general practitioners (GPs), family pediatricians (PLS), and regional representatives of Local Health Authorities (ASL). To ensure adequate coverage, starting from the 2020/2021 season, the system increased the number of sentinel physicians, doubling coverage from 2% to 4% of the population, as reaffirmed by the Operational Protocol for the 2024-2025 season [10]. RespiVirNet employs a "zero-reporting" method, whereby sentinel physicians are required to report also the absence of ILI cases during a given week. Surveillance normally extends from week 42 of each year to week 17 of the following year [10].
To describe the epidemiology of ILI in Piedmont from the 2019-2020 to the 2023-2024 season, epidemiological data were extracted from weekly reports published by RespiVirNet [11]. Extracted data included the total number of ILI cases each week, the corresponding total number of population under surveillance, and the weekly ILI incidences overall and stratified by age groups (0-4 years, 5-14 years, 15-64 years, and 65 years and over). Incidences are expressed as the number of ILI cases per 1,000 monitored individuals.
To highlight any differences or similarities in the progression of the influenza epidemic at the regional and national level, corresponding national data were extracted and compared with the Piedmont data. Additionally, to assess temporal variations in the epidemic trend, data from the previous five seasons (2014/2015 to 2018/2019), *i.e.* before the COVID-19 pandemic, were also extracted. This paper also presents the average values for the seasons from 2014/2015 to 2018/2019 and for the five-season observation period from 2019/2020 to 2023/2024.
To evaluate the overall cumulative incidence of ILI in different seasons, an estimate was calculated starting from weekly ILI incidences by age group and for the total population in Piedmont and Italy. Given the variability in the monitored population each week, the weekly incidence was first multiplied by the population as of January 1 of the reference year (*e.g.*, population on January 1, 2020, for the 2019/2020 season) to estimate the number of cases in Piedmont and Italy for that week. The cumulative incidence was then calculated by summing the estimated weekly cases and dividing by the population as of January 1 of the same year; this result was multiplied by 100 to obtain the cumulative incidence. For Piedmont, the estimated number of cases per influenza season is also reported, noting that estimates may be underestimated due to missing data in some weeks (Tab. S1). Considering that cumulative incidence in Piedmont was calculated over fewer weeks than the national cumulative incidence, the Italian cumulative incidence was recalculated by considering only the weeks for which Piedmont data were also available to ensure comparability of data.
Line charts were produced to visualize the trend of total ILI cases across seasons separately for Piedmont and Italy, including the average of the 2014/2015 to 2018/2019 seasons and those of the observation period. For each of the last five influenza seasons and for the average of the previous five years, a graph was created showing the weekly incidence trends of ILI for both Italy and Piedmont.
As a measure of intensity of ILI incidence in different seasons in Piedmont, maximum weekly incidences and the corresponding weeks of observation were reported for the total population and stratified by age group. To measure the epidemic period in each influenza season, weeks marking the start and end of the epidemic, the peak week, and the duration of the epidemic were identified for Piedmont and Italy. The epidemic period was defined based on a weekly incidence threshold according to Boccalini et al. [12]. Specifically, the start week was identified as the first week in which the weekly incidence was ≥2 cases of ILI per 1,000 monitored individuals, while the end week was the first week in which incidence fell below this threshold without rising above it again.

Virological Surveillance

As for Piedmont, virological surveillance reports [11] allowed extraction of the number of weeks during which samples were collected and sent and the number of weeks during which each influenza virus strain (unsubtyped influenza A, H1N1pdm09, H3N2, and B) was detected for each season of interest. Percentages of weeks in which each strain was observed were then calculated. Corresponding national data were extracted for comparison. Additionally, for Italy, data on the number of positive swabs were obtained from the FluNews/RespiNews-Italia archive [13], and for each influenza season, the total number of influenza-positive swabs, the percentage positivity among total samples, and the percentage distribution of each influenza strain out of the total positive swabs were calculated. Data were not available for the 2014/2015 and 2015/2016 seasons.

Excess Mortality

To evaluate the disease burden associated with influenza, we compared observed and expected average daily deaths per week in the population aged ≥65 years, following a methodology similar to that used in the weekly Flunews-Italia bulletin by ISS [14]. Because influenza-specific mortality data are not available in real time and death certificates may underestimate the contribution of influenza, all-cause mortality is commonly used in surveillance systems as an indirect proxy to capture excess mortality temporally associated with influenza circulation [14]. Therefore, our estimates should be interpreted as excess all-cause mortality occurring during periods of influenza activity, rather than as deaths directly attributable to influenza.

Daily mortality data for Piedmont and Italy were extracted from ISTAT (Italian National Institute of Statistics) databases [15], considering the weeks of influenza seasons from 2014/2015 to 2023/2024, as defined by Piedmont ILI surveillance. Weekly total deaths and average daily deaths per week were calculated for each season.

Weekly total deaths were calculated, and the corresponding mean daily deaths were then estimated for each week of every influenza season. For each year of interest (from the 2019/2020 to the 2023/2024 influenza season), the expected mortality was estimated as the weekly mean daily mortality based on the historical series of the previous five years, weighted by the resident population as of 1 January of the reference year, following an approach similar to that used in the FluNews-Italia bulletin [16]. For each influenza season, the resident population as of 1 January of the calendar year in which the season ended was used (*e.g.*, 1 January 2020 for the 2019/2020 season), according to ISTAT data [17], to account for the progressive increase in the older population in recent years.

Observed and expected values of average daily deaths for Piedmont were graphically represented alongside ILI incidence in the ≥65 years age group. The association between observed mortality and ILI incidence was assessed using Spearman's rank correlation test. For each week, the percentage difference (delta) between observed and expected deaths was calculated. Weeks with the maximum and minimum deltas were identified to highlight periods of excess mortality. National mortality data were processed using the same methodology to allow regional-to-national comparisons.

Vaccination Coverage

Influenza vaccination coverage data for Piedmont and Italy are available on the website of the Ministry of Health [18]. Considering our five-year observation period, data on vaccination coverage were extracted, stratified by the following age groups: 6-23 months, 2-4 years, 5-8 years, 9-14 years, 15-17 years, 18-44 years, 45-64 years, and 65 years and over. For the previous five years, coverage data were only available for the 65+ category and total population.

Additional vaccination coverage estimates were obtained from the PASSI [19] and PASSI d'Argento [20] surveillance systems, which survey adults 18–64 years and those aged 65 and over, respectively. These systems monitor influenza vaccination uptake in the 12 months preceding the interview and provide stratifications by chronic condition status.

Results

Epidemiological surveillance

Cumulative incidence of Influenza-Like Illness (ILI)

Table I summarizes the total estimated cases of ILI in Piedmont during the reference period (from the 2019/2020 season to the 2023/2024 season) as well as in the preceding five-year period. Overall, the number of estimated cases increased during our observation period. However, there was a decrease in estimated cases among children and adolescents (0-14 years) and an increase among adults (15-64 years) and the older adults (≥65 years), with an inversion in the relative burden between younger and older age groups.

Considering the estimated cases in the Piedmont population, in the pre-pandemic seasons from 2014/2015 to 2018/2019, an average of 13.8% of the population was affected by ILI (range 11.4-15.6%). Although the average from the 2019/2020 to 2023/2024 season was 16%, the range of values is more variable: from 4.5% in the 2020/2021 season to 25.3% in the 2022/2023 season, followed by 21.6% in the 2023/2024 season, as shown in Table S2. Regarding age groups, in all seasons in the pre-pandemic seasons, the 0-4 (average: 55.2%) and 5-14 (23.8%) age groups had higher cumulative ILI incidences than adults (13%) and older adults (6%), which had the lowest cumulative incidence. In the most recent five-year period, although the younger age groups continue to have a higher cumulative incidence of ILI, the differences between age groups have narrowed.

For comparison, Supplementary Table S3 shows the cumulative incidence of ILI in Italy, calculated on the basis of estimated cases, considering both all available weeks and only those weeks for which data were also available for Piedmont. In Italy, in the pre-pandemic seasons from 2014/2015 to 2018/2019, it was estimated that an average of 11% of the population was affected by ILI, with an incidence lower than the Piedmont's data. Overall, even in the five-year period from the 2019/2020 season to the 2023/2024 season, a lower incidence was reported in Italy than in Piedmont. Similarly to Piedmont,

Tab. I. Estimated ILI cases by age group in Piedmont, influenza seasons 2014/2015 to 2023/2024.

Estimated ILI cases in Piedmont					
Season	**0-4 years**	**5-14 years**	**15-64 years**	**≥65 years**	**Total Population**
2014-2015	87,339	98,574	369,856	63,873	602,363
2015-2016	77,559	97,021	258,957	45,974	501,117
2016-2017	94,543	78,420	353,785	74,186	598,607
2017-2018	107,591	94,420	413,309	80,400	677,412
2018-2019	101,061	87,382	376,186	63,395	629,417
Average 2014/2015-2018/2019	**93,618**	**91,163**	**354,419**	**65,565**	**601,783**
2019-2020	51,258	62,038	292,612	55,932	523,123
2020-2021	9,464	9,035	152,076	33,458	190,791
2021-2022	66,303	81,491	441,847	78,313	710,513
2022-2023	67,346	112,525	685,735	172,072	1073,636
2023-2024	47,374	68,813	648,840	153,590	918,351
Average 2019/2020-2023/2024	**48,349**	**66,781**	**444,222**	**98,673**	**683,283**

Italy also showed a much lower cumulative incidence of ILI for the 2020/2021 season than in all other seasons. Furthermore, Italy also experienced a significant increase in ILI incidence during the 2022/2023 and 2023/2024 seasons compared with previous seasons (Fig. 1).

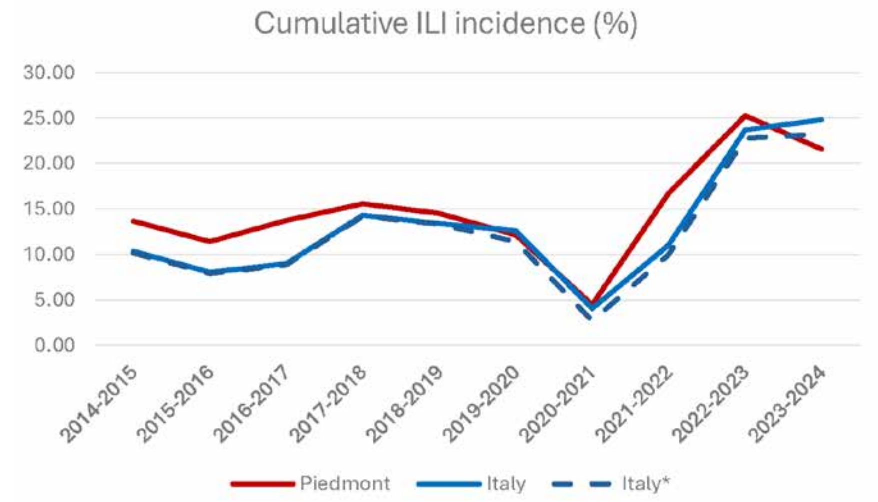
Considering the distribution by age group, in Italy during the pre-pandemic period, although the younger categories had higher cumulative incidences, the difference between age groups was less pronounced than in Piedmont. In the last five years, incidence has increased on average across all age groups, particularly in the 0-4 age group. Compared with Piedmont, in Italy the cumulative incidence of ILI is higher in the 0-4 age group, whereas it is slightly lower in the 15-64 and ≥65 age groups (Tab. S2 and S3).

In Piedmont, the highest weekly incidence was recorded in the 2022/2023 season, with a peak in week 50 (21.3 cases per 1,000 patients). Overall, the 2022/2023 season showed weekly incidence values consistently above the average observed from the 2014/2015 to the 2018/2019 seasons, with the exception of a few weeks (weeks 3-6). Higher peak values were also observed in the 2023/2024 season (16.4 cases per 1,000 patients). By contrast, the 2020/2021 season showed consistently lower values than all other seasons, with a peak of 3.3 cases per 1,000 patients in week 49 (Fig. 2; Tab. S4).

Table S4 reports the maximum weekly incidences for each season and the corresponding week, stratified by age group. The peak values for each age group reflect the pattern observed for cumulative incidences. Although the peaks across the different categories are highly variable, in three years the peak in the 0-4 age group preceded that in the ≥65 age group.

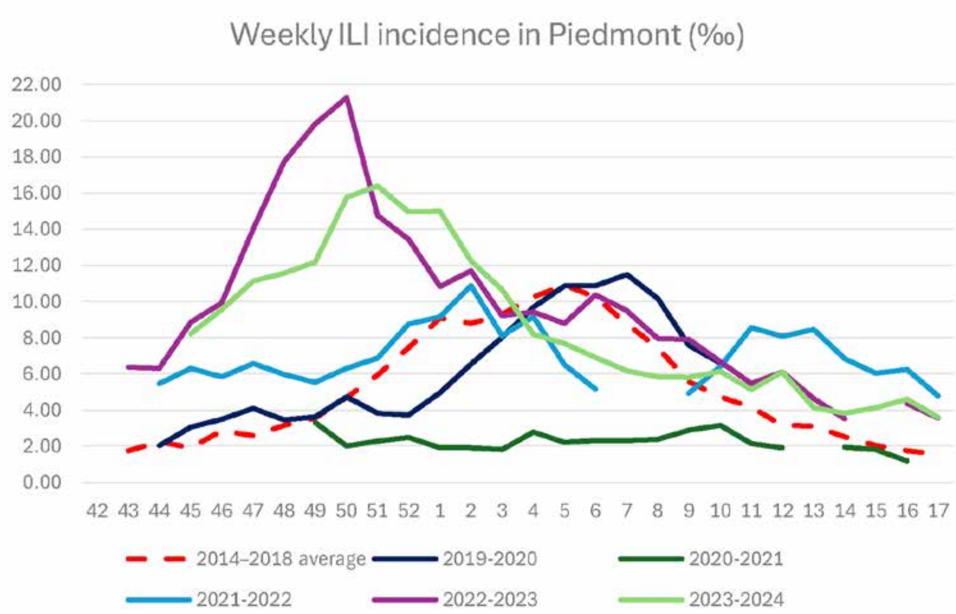
In general, over the last three years of our observation

Fig. 1. Total cumulative incidence of ILI (%) for the seasons from 2014/2015 to 2023/2024 in Italy and Piedmont (Italy*: estimate including only weeks also available for Piedmont).



Weekly incidence of Influenza-Like Illness (ILI).

Fig. 2. Weekly ILI incidence for the seasons from 2019/2020 to 2023/2024 and for the average of the seasons from 2014/2015 to 2018/2019 in Piedmont. Week 53 has not been included as it only occurred in 2020-2021.



period, the duration of the epidemic period has increased, with peaks occurring earlier compared to pre-pandemic seasons (Fig. 2; Tab. S5).

As in Piedmont, Italy also reported substantially higher maximum weekly incidences in the 2022/2023 and 2023/2024 seasons compared with other seasons, although the incidence in Italy was higher than in Piedmont for the 2023/2024 season. Similarly, the 2020/2021 season recorded significantly lower weekly incidences than all other seasons (Fig. S1). In Italy, the peak incidence has generally occurred earlier (with the exception of the 2021/2022 season), and the duration of the epidemic period, in terms of the number of weeks, has increased in the 2021/2022 season and subsequent seasons (Tab. S6).

Figure 3 graphically compares the weekly incidence of ILI in Italy and Piedmont during the reference seasons. Overall, ILI incidence was consistently higher in Piedmont than in Italy, with the exception of the 2019/2020 and 2023/2024 seasons.

Virological surveillance

Data from Piedmont indicate that, over our five-year reference period, the detection of different influenza strains was highly variable (Tab. S7). In the 2019/2020 and 2022/2023 seasons, both strain A and strain B were identified in most of the weeks in which samples were sent. In contrast, strain B was completely absent in 2021/2022 and present in only a few weeks in 2023/2024. It should be noted that in the 2020/2021 season, none of the analyzed samples tested positive for influenza.

Comparing this with the Italian situation (Tab. S8) over the last five years, the weekly pattern of strain presence was similar to that observed in Piedmont, except in the 2023/2024 season, when strain B was detected in almost all surveillance weeks at the national level. Even considering the entire country, no samples tested positive for influenza in the 2020/2021 season.

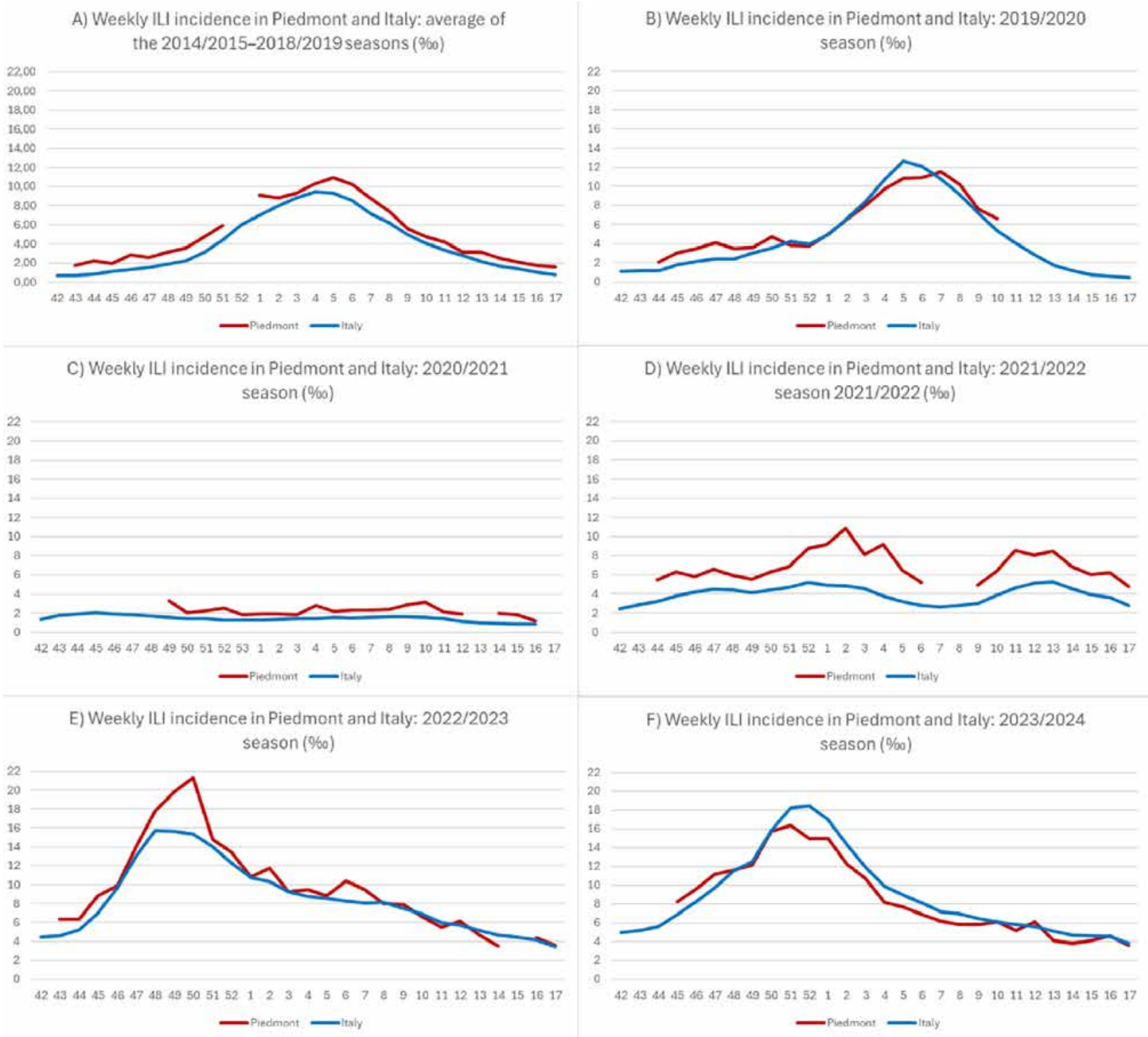
Although these data were not analyzed for Piedmont, some Italian data are presented in Table S9 and Figure 4 to better characterize the seasons of interest. Table S9 shows an overall lower percentage of influenza-positive samples compared with pre-pandemic seasons. Figure 4 illustrates the distribution of influenza-positive samples between strains A and B, showing a clear predominance of strain A in all seasons except 2017/2018.

Excess mortality

Marked excess mortality was observed in Piedmont during the 2019/2020 and 2020/2021 seasons, whereas mortality in subsequent seasons remained broadly in line with, or below, the expected values derived from the previous five years (Fig. S2-S6). In 2019/2020, excess mortality emerged from week 10 onwards and peaked in weeks 13 (+122%), 14 (+112%), and 15 (+102%). In 2020/2021, mortality also remained consistently above expected levels, with peaks in weeks 48 (+113%), 47 (+112%), and 46 (+106%). By contrast, excess mortality was modest in 2021/2022, with maximum weekly increases of 9%, and remained limited in 2022/2023 and 2023/2024, with peaks of 12% and 8%, respectively. Overall, excess mortality in Piedmont was highest in 2019/2020, remained elevated in 2020/2021, and progressively declined in subsequent seasons, a decline partially influenced by the increase in the expected number of deaths.

National trends broadly mirrored those observed in Piedmont, with marked excess mortality in 2019/2020 (peaking at +84% in week 13) and 2020/2021 (peaking at +54% in week 48). In later seasons, national excess

Fig. 3. Comparison of weekly ILI incidence in Italy and Piedmont. A) Average of the 2014/2015–2018/2019 seasons; B) 2019/2020 season; C) 2020/2021 season; D) 2021/2022 season; E) 2022/2023 season; F) 2023/2024 season.



mortality was substantially attenuated, with peak weekly increases ranging from 7% to 11%. Across seasons, excess mortality in Piedmont was generally more pronounced than the national average.

No significant correlation between observed deaths and ILI incidence was found in 2019/2020 (Spearman's rho=0.281, p=0.216) or 2020/2021 (rho=0.317, p = 0.171). In contrast, significant positive correlations were observed in 2021/2022 (rho=0.646, p=0.001), 2022/2023 (rho = 0.805, p<0.001), and 2023/2024 (rho = 0.947, p<0.001).

Vaccination coverage

Piedmont showed a slight improvement. In the older adults (aged 65+), coverage was consistently below 50% in the 2018/2019 season and earlier seasons, whereas since the 2019/2020 season it has remained slightly above 50%, with the highest coverage observed in the 2020/2021 season (65.3%). Similarly, coverage has improved in the total population: while it peaked at 15.3% before 2019/2020, it has been higher since that season, reaching 21.9% in 2020/2021. However, compared to Italy, over the last five years Piedmont has shown average coverage approximately 3 percentage points lower in the elderly population and about 1 percentage point lower in the total population. Considering the five seasons prior to our reference period, these differences with Italy have decreased for the elderly population but increased for the total population (Fig. 5; Fig. 6; Tab. S10).

From the 2019/2020 season, more detailed data on vaccination coverage are available for age groups under 65. For the pediatric population (up to 8 years of age), differences between Piedmont and Italy are more pronounced than those observed for the elderly and the total population. In Piedmont, the highest coverage rates are reported in the 2023/2024 season for children aged

Fig. 4. Distribution of influenza A and B viruses in Italy from the 2016/2017 to 2023/2024 seasons.

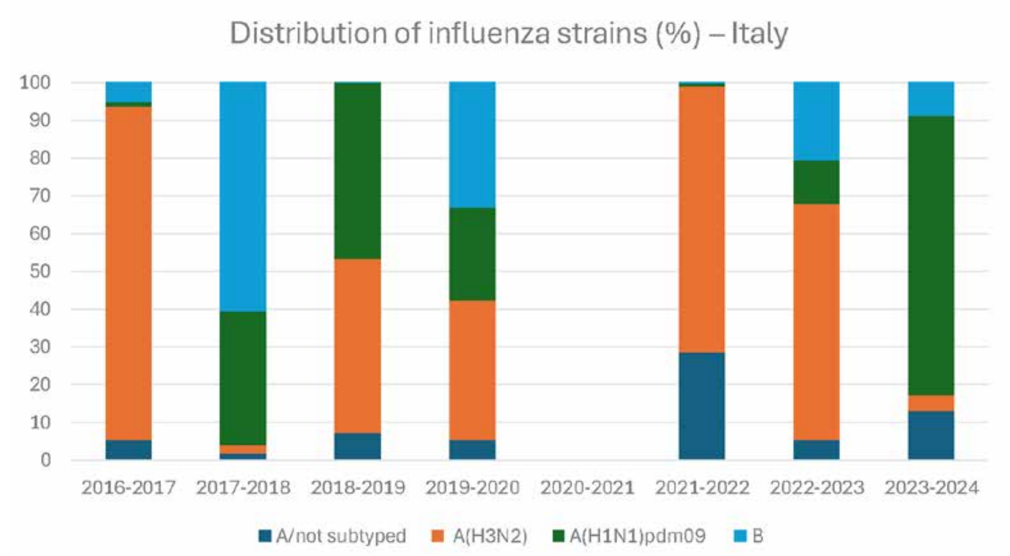
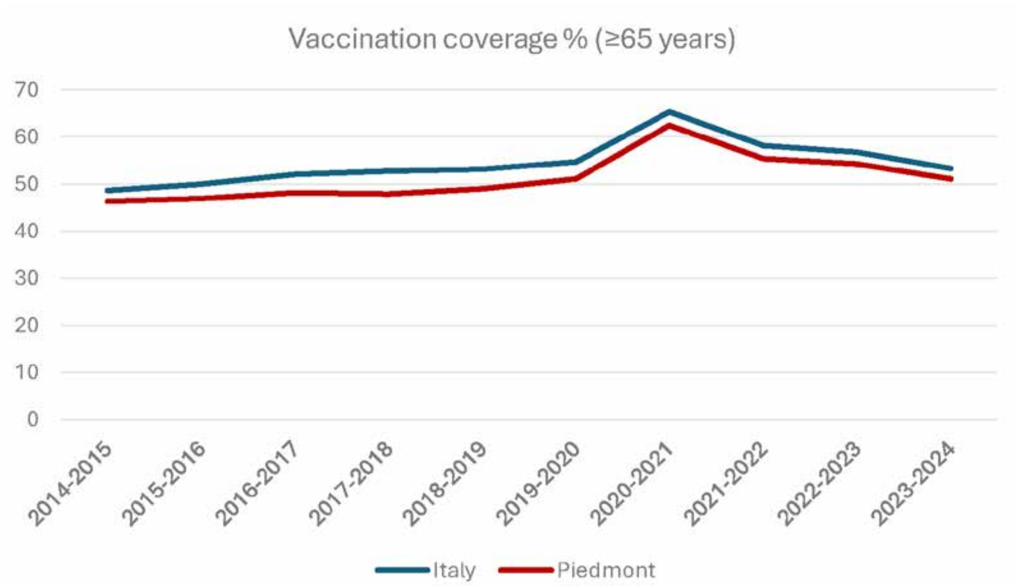


Fig. 5. Influenza vaccination coverage in the 65+ age group in Piedmont and Italy.



6-23 months (5.3%) and 2-4 years (9.5%), whereas for children aged 5-8 years, the highest coverage is observed in the 2022/2023 season (8.2%).

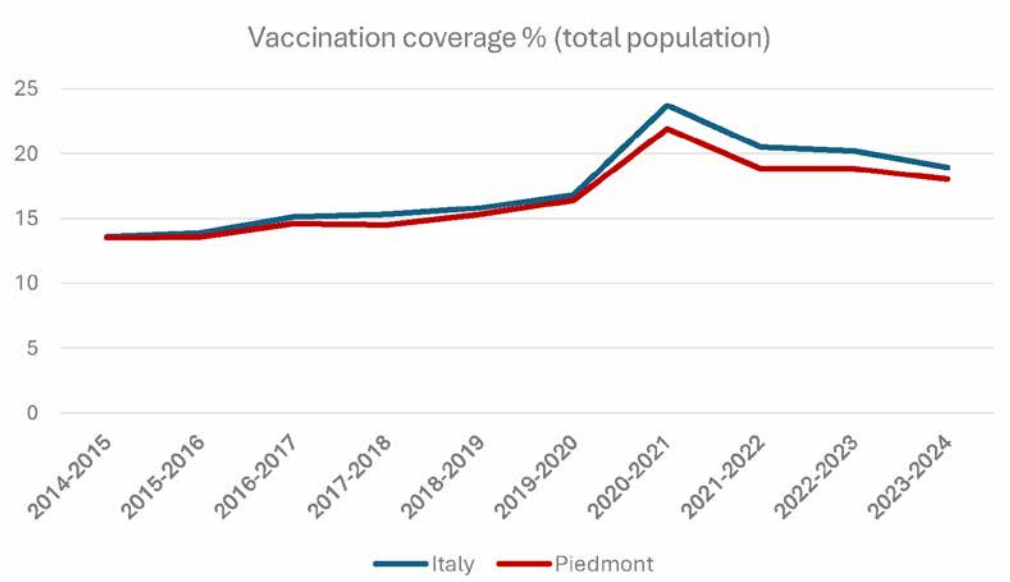
For the pre-adolescent/adolescent population (up to 17 years), differences between Piedmont and Italy are smaller, with the largest difference observed in children aged 9-14 years (-2.5 percentage points). In Piedmont, the highest coverage in the 2020/2021 season is among children aged 9–14 years (2.4%) and 15-17 years (1.7%).

In the adult population (up to 64 years of age), differences between Piedmont and Italy remain low, although a larger difference is observed in the 45-64 age group (-2.6 percentage points). In Piedmont, the highest coverage in the 2020/2021 season is among adults aged 18-44 years (3.9%) and 45-64 years (13.5%) (Tab. II).

Last, the PASSI and PASSI d'Argento surveillance systems provide an opportunity to evaluate influenza vaccination coverage in the adult population, both with and without chronic diseases. Considering the population aged 18-64 years (Tab. S11) and the population aged 65 years and over (Tab. S12), data from Piedmont from 2016-2019 to 2022/2023 generally show improvement, although the Region consistently reports lower coverage than Italy (the only exception being adults aged ≥65 years with at least one chronic disease in 2016-2019).

Regarding the most recent data (2022-2023), individuals with chronic diseases show higher coverage than those without chronic conditions in both age groups, with a larger difference observed in the 18-64 age group. Coverage among people aged 18-64 with chronic conditions remains very low (20.5%). In the 65+ age group, coverage improves, although still below the recommended target, with 59% vaccinated overall (64% when considering only those with at least one chronic disease).

Fig. 6. Influenza vaccination coverage in the total population in Piedmont and Italy.



Tab. II. Influenza vaccination coverage in Piedmont and Italy by age group (% of population).

Influenza vaccination: vaccination coverage %														
	6-23 months		2-4 years		5-8 years		9-14 years		15-17 years		18-44 years		45-64 years	
Season	**It.**	**Pi.**	**It.**	**Pi.**	**It.**	**Pi.**	**It.**	**Pi.**	**It.**	**Pi.**	**It.**	**Pi.**	**It.**	**Pi.**
2019-2020	2.8	0.8	4.2	1.5	3.1	1.2	1.9	1	1.9	1	3.1	2.5	9.6	8
2020-2021	9.2	2	19	3.8	13.1	3.4	6	2.4	4.5	1.7	5.9	3.9	16.8	13.5
2021-2022	7	3	17.4	6.5	12.2	4	4.4	1.9	2.5	1	4.2	2.6	13.7	10.1
2022-2023	7.2	3.1	9.2	3.6	22.6	8.2	4.9	1.8	2.1	1	4.1	2.7	13.3	10.5
2023-2024	9.8	5.3	16.7	9.5	11.7	5.8	4.6	2.1	1.9	1.1	3.7	2.9	11.8	9.9
Average	**7.2**	**2.8**	**13.3**	**5.0**	**12.5**	**4.5**	**4.4**	**1.8**	**2.6**	**1.2**	**4.2**	**2.9**	**13.0**	**10.4**

It. Italy; Pi. Piedmont

Discussion

This study examined influenza-related indicators in Piedmont over five influenza seasons, in a regional context characterized by persistently low vaccination coverage. By comparing regional findings with national data, it also sought to place the Piedmont experience within a broader public health perspective and to inform reflections on current prevention strategies.

The cumulative incidence of ILI in Piedmont increased overall during the observation period. Compared with national data, Piedmont consistently reported higher incidence rates than the Italian average, a difference that may reflect demographic characteristics, differences in the implementation of preventive measures, and seasonal variability in influenza circulation. A marked reduction in incidence was observed during the 2020/2021 season, followed by a sharp increase in 2022/2023 and 2023/2024. This pattern is consistent with the findings of Bert et al. [21], who suggested that the exceptionally low influenza circulation observed in 2020/2021 was mainly driven by COVID-19 containment measures rather than by reduced surveillance or increased vaccination coverage. The absence of laboratory-confirmed influenza cases in sentinel samples during the same season further supports the impact of these measures on influenza transmission. Although younger age groups continued to show the highest incidence rates, the gap between age groups progressively narrowed over time, suggesting a redistribution of disease burden. In particular, adults and older adults recorded a greater absolute number of estimated cases than children aged <14 years, a pattern that may reflect post-pandemic changes in exposure and transmission dynamics. In addition, the earlier onset and longer duration of seasonal peaks observed in recent years suggest a shift in the epidemiological pattern of ILI. Peak incidence in children aged <4 years generally preceded that in older adults, supporting the hypothesis that the paediatric population plays a central role in influenza transmission [12]. Owing to their high incidence and earlier involvement in seasonal epidemics, children likely represent an important source of transmission to more vulnerable groups, including older adults and individuals with chronic conditions [22]. Although influenza is usually self-limiting in children, the high number of infections in this group contributes substantially to hospitalizations, school absenteeism, and healthcare utilization [23]. Conversely, while incidence rates in older adults remained lower than in children, the absolute number of cases was substantial and increasing, which is particularly relevant given their higher risk of severe complications, hospitalization, and death due to age-related vulnerability and comorbidities [24]. Together, these findings reinforce the need for effective prevention strategies, particularly for more vulnerable population groups.

Virological surveillance showed considerable variability in the circulation of influenza virus strains across seasons. The 2019/2020 and 2022/2023 seasons were characterized by the co-circulation of influenza A and B viruses, with both strains detected during most surveillance weeks. By contrast, influenza B was not detected in 2021/2022 and was only sporadically identified in 2023/2024, suggesting changes in strain circulation patterns. These findings are consistent with national and global data, which also indicate a predominance of influenza A in most seasons, with the notable exception of 2017/2018 [25, 26]. This pattern underscores the importance of continuous virological surveillance to inform vaccine composition and support prevention strategies. At the global level, the absence of detection of the B/Yamagata lineage since March 2020 has led the EMA to recommend removal of the B/Yamagata component from seasonal influenza vaccines, supporting the transition from quadrivalent to trivalent formulations from the 2025/2026 season onwards [27, 28]. In addition, national data showed a lower number of influenza-positive samples compared with pre-pandemic seasons. Taken together, these findings support the value of integrated surveillance systems, such as RespiVirNet, and suggest that broader prevention strategies targeting respiratory viruses beyond influenza alone may provide more effective long-term control.

Excess mortality in Piedmont was generally more pronounced than at the national level, suggesting regional disparities that warrant further investigation. Across the study period, excess mortality fluctuated markedly, peaking in 2019/2020 and progressively declining thereafter. This pattern may partly reflect the concurrent increase in expected mortality, which reduced the relative magnitude of observed deviations. Although excess mortality estimated in this way cannot be attributed to specific causes, COVID-19, influenza, and RSV likely represented major contributors, with their impact shaped by pathogen virulence, population immunity, and the age distribution of affected individuals [29]. In this regard, the return of winter mortality in Europe to pre-pandemic levels in 2023/2024, following several years of atypical patterns, provides an important broader context [29]. As noted by Nørgaard et al. [29], continuous mortality surveillance remains essential for monitoring epidemic trends and enabling timely public health responses. However, because excess mortality provides only a partial measure of disease burden, it should be interpreted alongside other indicators to achieve a more comprehensive assessment of overall impact.

Although influenza vaccination coverage in Piedmont improved over the five-year observation period compared with the pre-pandemic period, it remained well below national targets [7]. Among adults aged ≥65 years, coverage increased from below 50% before the 2018/2019 season to a peak of 65.3% in 2020/2021, but still remained approximately 3 percentage points lower than the national average. Coverage also increased in the general population, reaching 21.9% in 2020/2021, possibly reflecting greater public awareness during the COVID-19 pandemic. Nevertheless, vaccination uptake in Piedmont remained consistently lower than the national average across all age groups, with the largest gap observed among children aged <8 years, suggesting difficulties in fully implementing recent national vaccination policy updates. In recent years, recommendations from the Italian Ministry of Health on influenza prevention and control have progressively expanded eligibility for free and actively offered vaccination. Since 2019/2020, newly included groups have comprised pregnant women, individuals at increased risk, long-term care facility residents, blood donors, and caregivers [30]. In 2020/2021, postpartum women and adults aged 60-64 years were also included [31], while in 2022/2023 eligibility was further extended to children aged 6 months to 6 years [32]. The National Vaccination Prevention Plan 2023-2025 [PNPV] further reinforces the importance of reaching both traditional and newly identified target groups, highlighting the need for regional strategies to align more closely with national recommendations [7]. A further area of concern is the persistently low vaccination coverage among individuals with chronic conditions. Although coverage in these groups was higher than among people without comorbidities, it remained below both the national average for individuals with chronic diseases and the recommended target for high-risk populations [7]. Overall, while the increase in vaccination coverage observed in Piedmont is encouraging, additional efforts are still needed to meet public health objectives.

The lower influenza vaccination coverage observed in Piedmont compared with the Italian average is likely to reflect a combination of supply-side and demand-side factors. On the supply side, Italian evidence suggests that GP workload may impair influenza vaccination uptake among older adults, possibly by reducing opportunities for counselling, active recommendation, and timely vaccine delivery [33]. On the demand side, the OBVIOUS project showed that influenza vaccine uptake is strongly influenced by awareness of being in a priority group, social influence, and recommendations from GPs [34]. In addition, recent national evidence indicates that vaccine hesitancy remains highly prevalent in Italy and is shaped by multiple social, cultural, informational, and trust-related factors [35]. A higher prevalence of vaccine hesitancy was described in Northern Italy rather than in Southern Italy [35], a finding that is consistent with a possible demand-side contribution to lower uptake in Piedmont. This suggests that the lower coverage observed in Piedmont should not be interpreted solely as a marker of structural disadvantage, particularly because broader territorial inequalities in Italy have historically been more pronounced in Southern and peripheral areas [36]. Rather, suboptimal coverage may reflect a complex interplay between primary-care organization, active invitation practices, risk perception, trust, and local patterns of vaccine confidence that should be further investigated.

Although centred on Piedmont, this study highlights issues that are likely to be relevant in other regional and national contexts. The observed post-pandemic reshaping of ILI patterns, the growing contribution of adult and older populations to overall burden, and the persistent gap between vaccination recommendations and vaccine uptake suggest that influenza prevention should be supported by both adaptable immunisation strategies and integrated surveillance systems. Targeted strategies are essential to reduce the burden of seasonal influenza and improve vaccination coverage. Although social distancing measures have proven effective, their sustainability during influenza seasons is likely to be limited, as noted by Fricke et al. [37]. Evidence from previous studies indicates that vaccine uptake can be improved through interventions such as written reminders, home visits, personalised phone calls, and educational initiatives, as reported in the meta-analysis by Thomas and Lorenzetti [38]. Strategies that reduce access barriers, including free vaccination and delivery in non-traditional settings such as hospital outpatient clinics, nursing homes, pharmacies, and mobile units, have also shown value in increasing coverage among at-risk populations [39]. Likewise, incentives for healthcare professionals and personalised approaches, including individual counselling and targeted public health campaigns, may help strengthen uptake, especially among older adults and high-risk groups [40]. Further research is nevertheless required to adapt and validate these interventions within the local context and to assess their long-term sustainability and effectiveness.

This study had several limitations that should be acknowledged. First, the analysis was constrained by incomplete data availability, particularly at the regional level in Piedmont, which limited its comprehensiveness. Moreover, no additional indicators of disease burden were accessible, which could have provided a more holistic understanding of influenza impact. Most data analysed derive from the ILI surveillance system rather than laboratory-confirmed influenza cases. While ILI is a useful proxy for estimating influenza trends, its accuracy may be affected by the co-circulation of other respiratory viruses. Lastly, because influenza-specific mortality data were not available, we used excess all-cause mortality as an indirect proxy for influenza-associated mortality; however, this measure is not specific to influenza and may have been substantially confounded by SARS-CoV-2 circulation during the COVID-19 pandemic.

Conclusion

This study provides a comprehensive overview of influenza-related indicators in Piedmont across five influenza seasons. Overall, Piedmont showed a higher ILI incidence than the Italian average, together with a progressive narrowing of the gap between paediatric and adult/older age groups, suggesting a redistribution of disease burden towards older populations. Virological findings further support the need for an integrated approach to the surveillance and prevention of respiratory infections beyond influenza alone, while the excess mortality results highlight the importance of combining multiple indicators to better capture seasonal burden. Although vaccination coverage improved compared with the pre-pandemic period, it remained below national targets across key population groups. Beyond the regional setting, these findings suggest that post-pandemic influenza prevention requires adaptable vaccination strategies, closer alignment between national recommendations and local implementation, and integrated surveillance systems capable of monitoring changing epidemiological patterns and informing timely public health action.

Funding

Financial support for this study was provided by CSL Seqirus. The sponsor had no role in study design; in the collection, analysis, or interpretation of data; in the writing of the manuscript; or in the decision to submit the manuscript for publication.

Ethical approval

Not applicable.

Conflict of interest statement

The Authors declare that there is no conflict of interest.

Authors' contributions

RS: Conceptualization; GLM: Methodology; GLM, FG, DC, SM: Formal analysis; GLM, FG, DC, SM: Data curation; GLM, FG, DC, SM: Writing-Original Draft; GLM, RS: Writing-Review & Editing; GLM, FG, DC, SM: Visualization; RS: Supervision; GLM, RS: Project Administration; RS: Funding acquisition.

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Received on March 26, 2026. Accepted on May 13, 2026.

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How to cite this article: Lo Moro G, Consoli D, Mazzeo S, Golzio F, Siliquini R. A five-season regional analysis of influenza-related indicators in Piedmont, Italy: insights from comparison with national trends. J Prev Med Hyg 2026;67:E132-E150. https://doi.org/10.82082/2421-4248/jpmh2026.67.2.3909

Supplementary material

Tab. S1. Missing data on weekly Influenza-like Illness (ILI) incidence.

Piedmont	MISSING
season	**week**
2014-2015	43
	44
	45
2015-2016	42
	43
	17
2016-2017	42
	43
2017-2018	42
	43
2018-2019	42
2019-2020	42
	43
	11
	12
	13
	15
	16
2020-2021	42
	43
	44
	45
	46
	47
	48
	13
	17
2021-2022	7
	8
	42
	43
2022-2023	42
	15
2023-2024	42
	43
	44
Italy	**MISSING**
season	**week**
2015-2016	17
2020-2021	17

Tab. S2. Cumulative ILI incidence (%) for the seasons 2014/2015 to 2023/2024, by age group in Piedmont.

Estimated cumulative incidence of ILI in Piedmont (%)					
Season	**0-4 years**	**5-14 years**	**15-64 years**	**≥65 years**	**Total Population**
2014-2015	47.9	25.5	13.4	5.9	13.7
2015-2016	43.9	25.2	9.5	4.2	11.4
2016-2017	55.3	20.5	13.0	6.8	13.7
2017-2018	65.3	24.8	15.3	7.3	15.6
2018-2019	63.9	23.2	14.0	5.7	14.5
Average 2014/2015-2018/2019	**55.2**	**23.8**	**13.0**	**6.0**	**13.8**
2019-2020	33.6	16.6	11.0	5.0	12.1
2020-2021	6.4	2.4	5.7	3.0	4.5
2021-2022	46.3	22.3	16.8	7.0	16.7
2022-2023	48.5	31.4	26.1	15.3	25.3
2023-2024	34.9	19.6	24.6	13.6	21.6
Average 2019/2020-2023/2024	**33.9**	**18.5**	**16.8**	**8.8**	**16.0**

Tab. S3. Cumulative ILI incidence (%) for the seasons 2014/2015 to 2023/2024, by age group in Italy.

Estimated cumulative incidence of ILI in Italy (%) *(estimates including only the weeks for which data were also available for Piedmont)*					
Season	**0-4 years**	**5-14 years**	**15-64 years**	**≥65 years**	**Total Population**
2014-2015	24.6 (24.1)	16.8 (16.6)	9.6 (9.4)	4.5 (4.4)	10.3 (10.1)
2015-2016	22.1 (21.9)	16 (15.9)	6.9 (6.8)	2.8 (2.8)	8 (7.9)
2016-2017	22 (21.7)	12.7 (12.5)	8.4 (8.3)	4.9 (4.8)	9 (8.8)
2017-2018	37.7 (37.2)	20.7 (20.5)	13.2 (13)	7.4 (7.3)	14.3 (14.1)
2018-2019	36.6 (36.4)	19.3 (19.3)	12.6 (12.5)	6.1 (6.1)	13.4 (13.3)
Average 2014/2015-2018/2019	**28.6 (28.3)**	**17.1 (17)**	**10.1 (10)**	**5.1 (5.1)**	**11 (10.9)**
2019-2020	31.8 (30.2)	19.9 (19.1)	11.8 (10.4)	5.5 (4.7)	12.6 (11.4)
2020-2021	7.5 (5.8)	3.5 (2.6)	4.3 (2.8)	2.8 (1.8)	4 (2.7)
2021-2022	32.4 (28.6)	13.5 (12.2)	10.6 (9.6)	5.6 (5)	11 (10)
2022-2023	69.7 (67.2)	34.3 (33.2)	21.8 (20.9)	12.1 (11.6)	23.7 (22.8)
2023-2024	61.8 (58.8)	26.8 (25.5)	24.8 (23.1)	14.8 (13.7)	24.8 (23.2)
Average 2019/2020-2023/2024	**40.7 *(38.1)***	**19.6 *(18.5)***	**14.7 *(13.4)***	**8.1 *(7.4)***	***15.2 (14)***

Tab. S4. Maximum weekly incidence of ILI in Piedmont for the 2014/2015 to 2023/2024 seasons. The week of each peak is indicated in parentheses.

Maximum weekly incidence of ILI (‰) in Piedmont (week)					
Season	**0-4 years**	**5-14 years**	**15-64 years**	**≥65 years**	**Total Population**
2014-2015	51.8 (6)	31.3 (6)	15.1 (6)	5.9 (7)	14.9 (5)
2015-2016	38.3 (weeks 5 and 6)	29.9 (8)	8.1 (7)	3.1 (11)	10 (7)
2016-2017	54.3 (3)	21.4 (51)	13.6 (1)	8.7 (1)	13.1 (1)
2017-2018	65.2 (4)	29.9 (52)	19.5 (1)	12.7 (1)	18.1 (1)
2018-2019	54.5 (7)	26.4 (6)	13.3 (6)	6.5 (6)	14.5 (6)
Average 2014/2015-2018/2019	**52.8**	**27.8**	**13.9**	**7.4**	**14.1**
2019-2020	38.4 (7)	20.9 (8)	9.2 (5)	4.6 (5)	11.5 (7)
2020-2021	7.3 (4)	2.2 (5)	5.3 (49)	2.5 (9)	3.3 (49)
2021-2022	32.7 (47)	18.2 (12)	12.9 (2)	6.2 (1)	10.9 (2)
2022-2023	47.8 (50)	34.6 (49)	20.9 (50)	12 (50)	21.3 (50)
2023-2024	41.7 (51)	22 (51)	17.4 (50)	11.5 (1)	16.4 (51)
Average 2019/2020-2023/2024	**33.6**	**19.6**	**13.1**	**7.3**	**12.7**

Tab. S5. Weeks of onset, peak, and end, and duration of the epidemic period for the 2014/2015 to 2023/2024 seasons in Piedmont.

Season	Beginning	Peak	End	Duration (weeks)
2014-2015	46	5	15	22
2015-2016	50	7	15	19
2016-2017	44	1	13	22
2017-2018	46	1	16	23
2018-2019	45	6	15	23
Average 2014/2015-2018/2019	**46**	**-**	**15**	**22**
2019-2020	44	7	10	19
2020-2021	49	49	11	16
2021-2022	44	2	17	26
2022-2023	43	50	17	27
2023-2024	45	51	17	25
Average 2019/2020-2023/2024	**45**	**-**	**14**	**23**

Tab. S6. Weeks of onset, peak, and end, and duration of the epidemic period for the 2014/2015 to 2023/2024 seasons in Italy.

Season	Beginning	Peak	End	Duration (weeks)
2014-2015	51	4	13	15
2015-2016	52	8	14	16
2016-2017	48	52	9	14
2017-2018	48	2	12	17
2018-2019	47	5	13	19
Average 2014/2015-2018/2019	**49**	**-**	**12**	**16**
2019-2020	46	5	12	19
2020-2021	45	45	45	1
2021-2022	42	13	17	28
2022-2023	42	48	17	28
2023-2024	42	52	17	28
Average 2019/2020-2023/2024	**43**	**-**	**10**	**21**

Tab. S7. Number of weeks per season in which each influenza strain was detected - Piedmont.

Season	Number of weeks with samples submitted	Number of weeks in which each strain was detected (% of weeks with samples sent)			
		A/not subtyped	A(H3N2)	A(H1N1)pdm09	B
2016-2017	22	2 (9.1)	10 (45.5)	4 (18.2)	3 (13.6)
2017-2018	18	3 (16.7)	0 (0)	15 (83.3)	8 (44.4)
2018-2019	21	15 (71.4)	10 (47.6)	15 (71.4)	0 (0)
2019-2020	15	10 (66.7)	4 (26.7)	5 (33.3)	9 (60)
2020-2021	22	0 (0)	0 (0)	0 (0)	0 (0)
2021-2022	24	9 (37.5)	13 (54.2)	0 (0)	0 (0)
2022-2023	22	16 (72.7)	10 (45.5)	12 (54.5)	15 (68.2)
2023-2024	21	12 (57.1)	4 (19)	11 (52.4)	3 (14.3)

Tab. S8. Number of weeks per season in which each influenza strain was detected - Italy.

Season	Number of weeks with samples submitted	Number of weeks in which each strain was detected (% of weeks with samples sent)			
		A/not subtyped	A(H3N2)	A(H1N1)pdm09	B
2016-2017	24	14 (58.3)	21 (87.5)	14 (58.3)	19 (79.2)
2017-2018	23	19 (82.6)	19 (82.6)	22 (95.7)	21 (91.3)
2018-2019	23	18 (78.3)	23 (100)	23 (100)	5 (21.7)
2019-2020	24	14 (58.3)	19 (79.2)	19 (79.2)	17 (70.8)
2020-2021	24	0 (0)	0 (0)	0 (0)	0 (0)
2021-2022	24	15 (62.5)	23 (95.8)	12 (50)	5 (20.8)
2022-2023	24	23 (95.8)	22 (91.7)	24 (100)	24 (100)
2023-2024	24	21 (87.5)	24 (100)	23 (95.8)	23 (95.8)

Tab. S9. Number of samples collected, influenza-positive samples, and positivity rate (%) – Italy.

Season	Total samples collected	Total influenza positive samples	Influenza positivity (%)
2016-2017	12,034	3,518	29.23
2017-2018	16,135	5,494	34.05
2018-2019	20,009	6,368	31.83
2019-2020	16,146	3,760	23.29
Average 2014/2015-2018/2019	**16,081**	**4,785**	**29.60**
2020-2021	6,818	0	0.00
2021-2022	13,063	1,899	14.54
2022-2023	28,977	6,325	21.83
2023-2024	59,662	7,985	13.38
Average 2019/2020-2023/2024	**27,130**	**4,052**	**12.44**

Tab. S10. Influenza vaccination coverage in Piedmont and Italy, and differences in percentage points (pp) for the total population and the 65+ age group.

	Influenza vaccination: vaccination coverage per 100 inhabitants					
	≥65 years			**Total population**		
Season	**Italy**	**Piedmont**	**p.p.**	**Italy**	**Piedmont**	**p.p.**
2014-2015	48.6	46.3	-2.3	13.6	13.5	-0.1
2015-2016	49.9	46.9	-3	13.9	13.6	-0.3
2016-2017	52	48.2	-3.8	15.1	14.6	-0.5
2017-2018	52.7	47.9	-4.8	15.3	14.5	-0.8
2018-2019	53.1	49	-4.1	15.8	15.3	-0.5
Average 2014/2015-2018/2019	**51.26**	**47.66**	**-3.6**	**14.74**	**14.3**	**-0.4**
2019-2020	54.6	51	-3.6	16.8	16.4	-0.4
2020-2021	65.3	62.4	-2.9	23.7	21.9	-1.8
2021-2022	58.1	55.4	-2.7	20.5	18.8	-1.7
2022-2023	56.7	54.2	-2.5	20.2	18.8	-1.4
2023-2024	53.3	51	-2.3	18.9	18	-0.9
Average 2019/2020-2023/2024	**57.6**	**54.8**	**-2.8**	**20.02**	**18.78**	**-1.2**

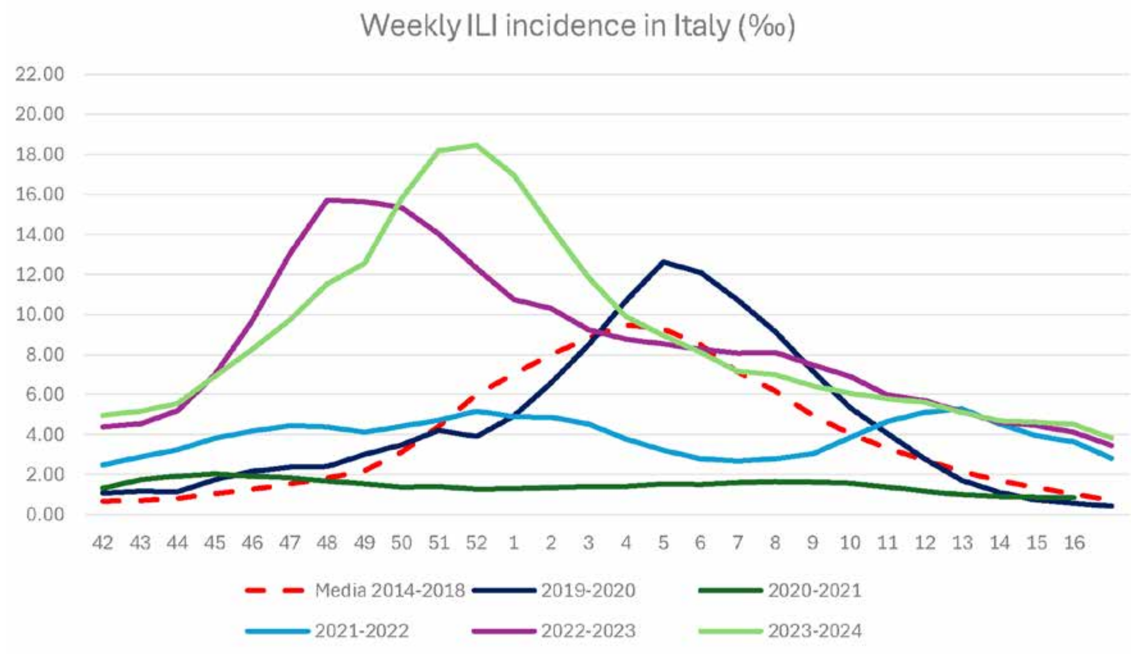
Tab. S11. Influenza vaccination coverage in Piedmont and Italy according to PASSI surveillance: adults aged 18–64 years with and without chronic diseases (%).

	Influenza vaccination coverage: Passi surveillance					
	18-64 years		**18-64 years: with at least 1 chronic disease**		**18-64 years: without chronic disease**	
Season	**Italy**	**Piedmont**	**Italy**	**Piedmont**	**Italy**	**Piedmont**
2016-2019	7.8	7	20.7	19.1	5.4	4.6
2020-2021	13.5	10.5	27.6	17.6	10.7	8.9
2021-2022	13.9	11.3	28.7	18.8	10.9	9.6
2022-2023	12.8	10.5	27.6	20.5	10	8.4

Table S12. Influenza vaccination coverage in Piedmont and Italy according to PASSI d'Argento surveillance: adults aged ≥65 years with and without chronic diseases (%).

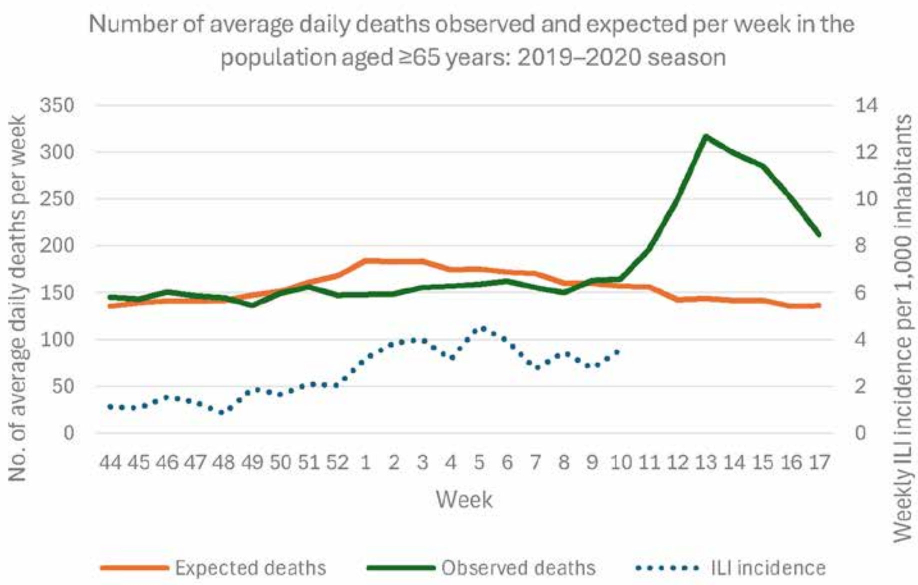
	Influenza vaccination coverage: Passi d'Argento surveillance					
	≥65 years		**≥65 years: with at least 1 chronic disease**		**≥65 years: without chronic disease**	
Season	**Italy**	**Piedmont**	**Italy**	**Piedmont**	**Italy**	**Piedmont**
2016-2019	56.4	53.4	62.9	64.3	46.3	42.7
2020-2021	68	-	72.7	-	61	-
2021-2022	68.2	-	72.8	-	61.8	-
2022-2023	65.3	59	71	63.6	57.4	53.6

Fig. S1. Weekly ILI incidence in Italy for the 2019/2020 to 2023/2024 seasons and for the average of the 2014/2015 to 2018/2019 seasons..



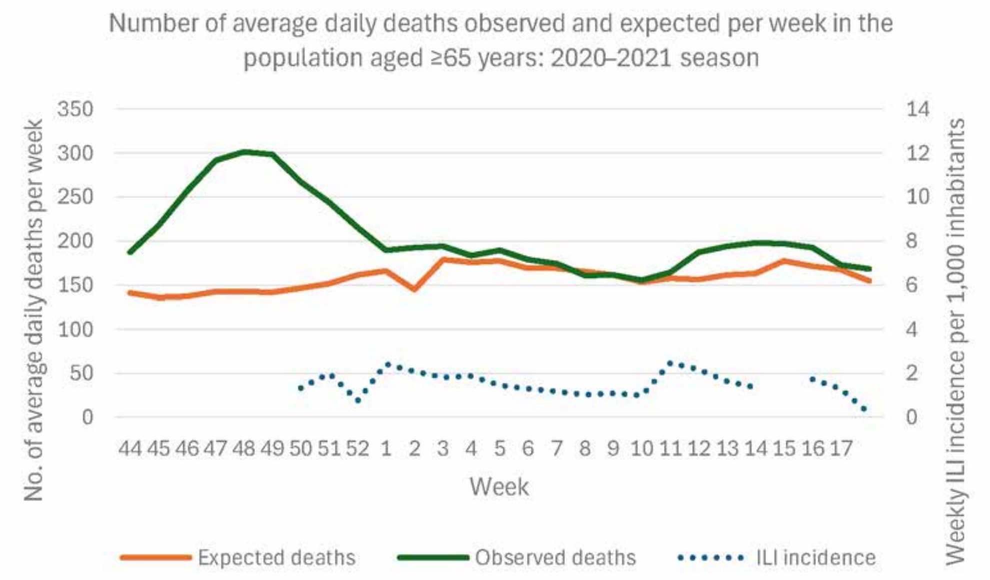
Week 53 was excluded, as it occurred only in the 2020/2021 season within our five-year reference period.

Fig. S2. Average daily number of observed and expected deaths per week in the population aged 65 and over in Piedmont during the 2019/2020 season.



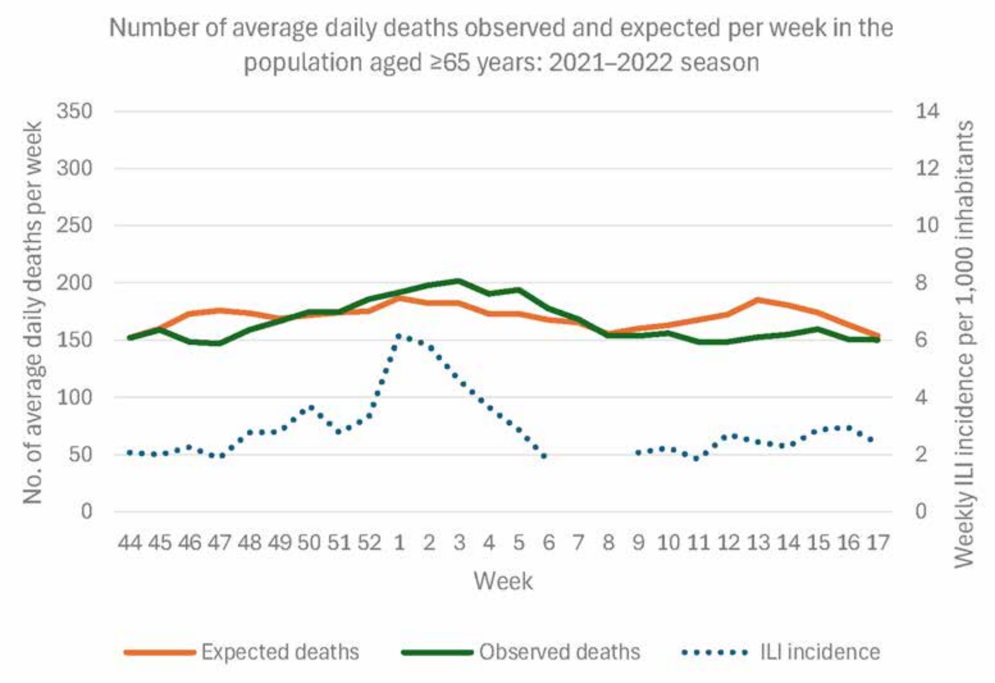
Expected deaths were estimated based on the 2014/2015–2018/2019 seasons. The incidence of ILI in the 65+ age group during the 2019/2020 season is also shown.

Fig. S3. Average daily number of observed and expected deaths per week in the population aged 65 and over in Piedmont during the 2020/2021 season.



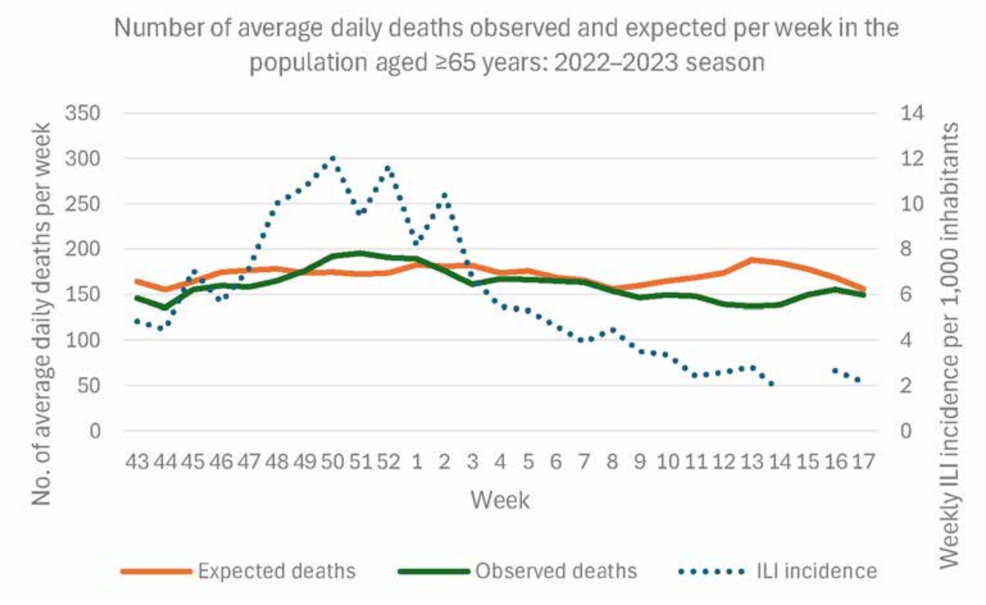
Expected deaths were estimated based on the 2015/2016–2019/2020 seasons. The incidence of ILI in the 65+ age group during the 2020/2021 season is also shown

Fig. S4. Average daily number of observed and expected deaths per week in the population aged 65 and over in Piedmont during the 2021/2022 season.



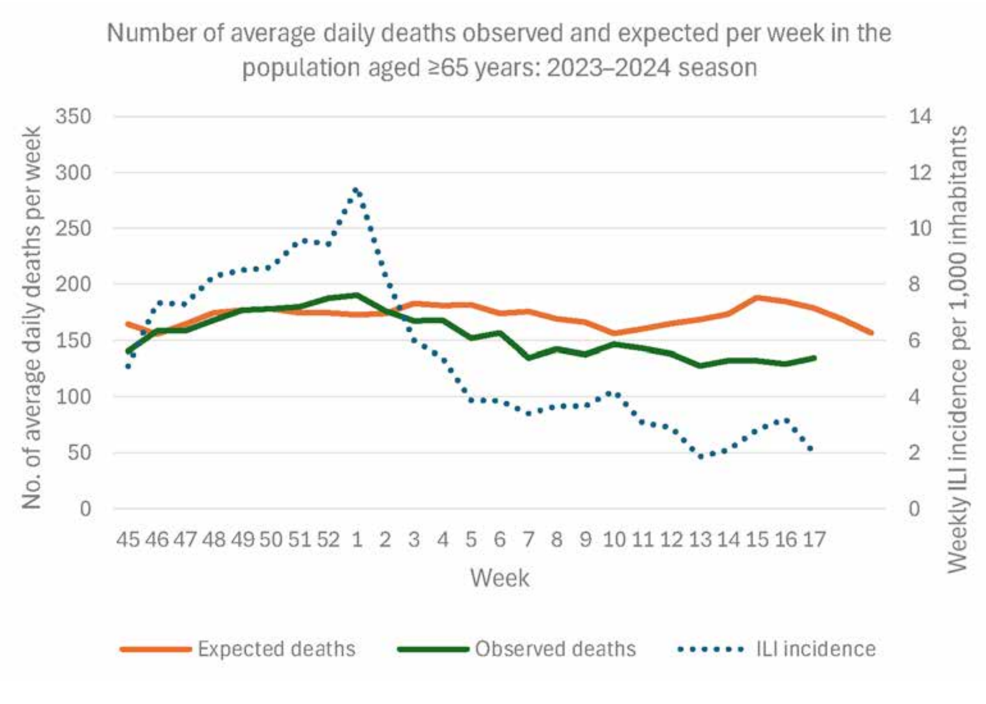
Expected deaths were estimated based on the 2016/2017–2020/2021 seasons. The incidence of ILI in the 65+ age group during the 2021/2022 season is also shown.

Fig. S5. Average daily number of observed and expected deaths per week in the population aged 65 and over in Piedmont during the 2022/2023 season.



Expected deaths were estimated based on the 2017/2018–2021/2022 seasons. The incidence of ILI in the 65+ age group during the 2022/2023 season is also shown.

Fig. S6. Average daily number of observed and expected deaths per week in the population aged 65 and over in Piedmont during the 2023/2024 season.



Expected deaths were estimated based on the 2018/2019–2022/2023 seasons. The incidence of ILI in the 65+ age group during the 2023/2024 season is also shown.