Public Health Interventions, Epidemic Growth, and Regional Variation of the 1918 Influenza Pandemic Outbreak in a Swiss Canton and Its Greater Regions

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Public health interventions implemented during the coronavirus disease 2019 (COVID-19) pandemic are based on experience gained from past pandemics. The 1918 influenza pandemic is the most extensively researched historical influenza outbreak. All 9335 reports available in the State Archives on 121 152 cases of influenza-like illness from the canton of Bern from 473 of 497 municipalities (95.2%) were collected; the cases were registered between 30 June 1918 and 30 June 1919. The overall incidence rates of newly registered cases per week for the 9 greater regions of Bern for both the first and second waves of the pandemic were calculated. Relative incidence rate ratios (RIRRs) were calculated to estimate the change in the slope of incidence curves associated with public health interventions. During the first wave, school closures (RIRR, 0.16 [95% CI, 0.15 to 0.17]) and restrictions of mass gatherings (RIRR, 0.57 [CI, 0.54 to 0.61]) were associated with a deceleration of epidemic growth. During the second wave, in autumn 1918, cantonal authorities initially reacted hesitantly and delegated the responsibility to enact interventions to municipal authorities, which was associated with a lack of containment of the second wave. A premature relaxation of restrictions on mass gatherings was associated with a resurgence of the epidemic (RIRR, 1.18 [CI, 1.12 to 1.25]). Strikingly similar patterns were found in the management of the COVID-19 outbreak in Switzerland, with a considerably higher amplitude and prolonged duration of the second wave and much higher associated rates of hospitalization and mortality.

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The emergence of new viral epidemics is a major challenge for public health, as shown by the coronavirus disease 2019 (COVID-19) pandemic. In most Western countries, none of the global pandemics caused by respiratory viruses after 1920 have reached the severity of the 1889 and 1918 influenza pandemic outbreaks (1). Health policymakers may benefit from examining historical events to increase risk awareness and inform decision making during the COVID-19 pandemic (2–8).

The 1918 influenza pandemic ("Spanish flu") is the most extensively researched historical influenza outbreak and caused an estimated 20 million to 100 million deaths worldwide (9,10). Interest in the pandemic resurged in the 1980s (11–13), and many studies were published around the centennial of the outbreak. They covered a range of topics, including general significance (5, 14), lessons learned (15–17), and unanswered questions (18). Reconstructing regional nuances can be important for understanding how epidemics spread in populations while preventing the loss of information due to aggregation (19).

The canton of Bern was one of the largest of the 25 cantons of Switzerland in 1918 and recorded the highest number of deaths during the pandemic. In July 1918, cantonal authorities were among the first to impose a reporting obligation for influenza in Switzerland (20). Therefore, unique historical data are available from cantonal archives in Bern and allow for the assessment of regional differences within the canton. The aims of this study were to describe the temporal course of the 1918 influenza pandemic outbreak in the canton of Bern, to explore the association of public health interventions with the containment of epidemic growth across the 2 waves that occurred, and to describe the heterogeneity between Bern's greater regions on the basis of the number of new infections registered by the cantonal health authorities.

Methods

Setting

The summer wave of the 1918 influenza pandemic hit Switzerland predominantly in the west, whereas the autumn wave hit the less densely populated mountain cantons and central and eastern Switzerland more strongly (21). In total, an estimated 24 447 persons died of influenza between July 1918 and June 1919 (6.1 deaths per 1000 inhabitants) (21). Therefore, the 1918 influenza pandemic is considered to be the event with the largest demographic effect in Switzerland in the 20th century (20, 22).

In 1918, Switzerland was a federal republic consisting of 25 cantons. Cantons were administratively divided into districts, and districts were divided into municipalities. Municipalities were the smallest administrative unit. Cantons had full sovereignty to implement public health interventions and could delegate responsibility for decisions on the type, extent, and implementation of interventions to

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municipalities (23). Bern was the second largest Swiss canton by surface area, and in 1920, when the nearest census took place, it was the most populous canton (*n* = 675 156) (24). It consisted of 30 districts that contained 497 municipalities. The 30 districts were grouped into 6 greater regions on the basis of geographic and cultural considerations; these regions were not of administrative relevance (**Supplement Figure 1**, available at Annals.org).

The Bernese cantonal law of 4 November 1898 regulated notifications of 11 infectious diseases, including diphtheria, scarlet fever, measles, and mumps, but not influenza. Physicians had to inform district authorities about notifiable diseases at least once a week; records are stored at the State Archive of Bern (25). The district authorities supervised physicians and could impose fines in cases of nonadherence to reporting obligations. On 16 July 1918, immediately after the beginning of the outbreak, cantonal authorities classified influenza as a notifiable disease; Bern was one of the first cantons to introduce this measure.

Bern was one of the earliest Swiss cantons to be affected by the pandemic. The first cases occurred in late June or early July among military troops in the Jura Mountains (26), with the first cantonal mortality peak occurring in July to August and the second in October to December 1918 (20, 21). The canton had 4658 influenza deaths, the highest number in Switzerland (20–22). The influenza-specific mortality rate was 6.9 deaths per 1000 inhabitants, and approximately 60% of deaths occurred in adults aged 20 to 40 years and in males (20, 27, 28).

Data Collection

We collected all 9335 reports available in the State Archives, including 121 152 cases of influenza-like illness from the canton of Bern registered between 30 June 1918 and 30 June 1919. These reports cover cases from 473 of 497 municipalities (95.2%). We transcribed the number of newly registered cases, date of registration by district authorities, and municipality and district of occurrence of each case. We assigned all municipalities to 1 of the 6 greater regions or 3 major cities (from north to south: Jura, city of Biel, Seeland, Oberaargau, city of Bern, Mittelland, city of Thun, Voralpen, and Oberland) using official census categorizations (**Supplement Figure 1**).

We also collected officially reported daily counts of laboratory-confirmed cases of severe acute respiratory syndrome coronavirus 2 infections and information on public health interventions from the Swiss Federal Office of Public Health (29) to enable a comparison between the 1918 influenza pandemic in the canton of Bern and the COVID-19 pandemic in Switzerland. Additional details on data collection are provided in the**Supplement** (available at Annals.org).

Analysis

We calculated the incidence rates per 1000 inhabitants with exact Poisson 95% CIs of overall newly registered cases for the first and second waves and per calendar week. To explore the association between public health interventions and the containment of epidemic growth, we calculated relative incidence rate ratios (RIRRs) with Poisson 95% CIs. We first calculated the incidence rate ratio IRR_i for each calendar week *i*, dividing the incidence rate of week *i* by the incidence rate of the preceding week $i - 1$. Then, we divided the incidence rate ratio of week *i*, IRR_i, by the incidence rate ratio of week $i - 1$, IRR_{i-1}, to derive the RIRR: $RIRR_i = IRR_i / IRR_{i-1}$

This allowed for estimation of the change in slopes of incidence curves associated with public health interventions. An RIRR greater than 1 indicates an acceleration of epidemic growth, whereas an RIRR less than 1 indicates a deceleration. Additional details on statistical analyses are provided in the **Supplement**.

Results

Between 30 June 1918 and 30 June 1919, a total of 121 152 cases were described in 9335 reports from 473 municipalities (incidence per 1000 inhabitants, 179.4 [95% CI, 178.4 to 180.4]). **Supplement Table 1** (available at Annals.org) presents the number of cases, population, number of municipalities and districts, and incidence for each of the 9 greater regions of Bern and for the canton of Bern overall. The incidence per 1000 inhabitants ranged from 105.5 (CI, 103.6 to 107.4) in Jura to 283.8 (CI, 275.1 to 292.7) in the city of Thun.

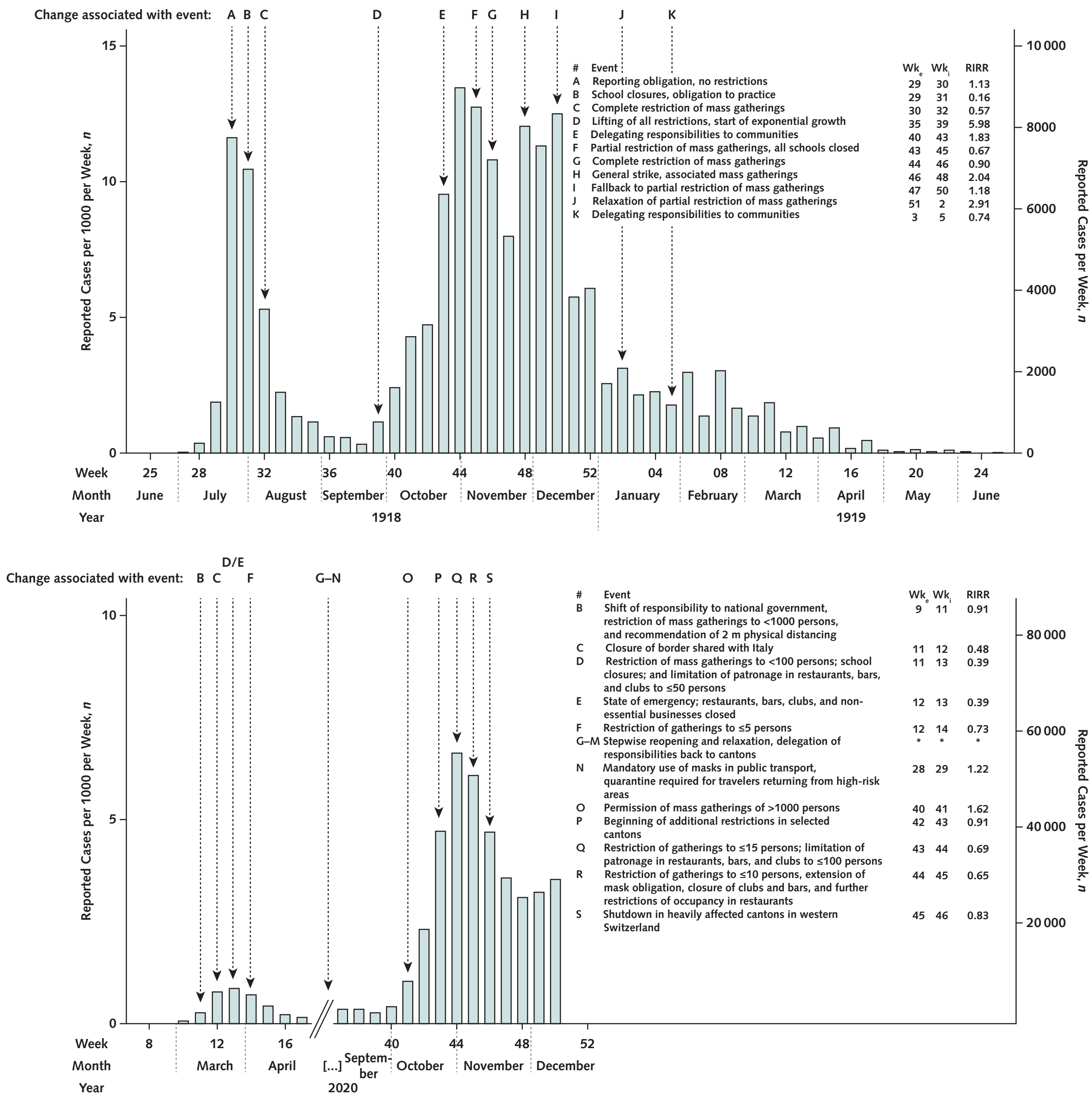
The first cases in the civilian population were reported in early July 1918 (calendar week 27). As the number of registered cases increased, cantonal authorities reacted quickly. On 16 July (week 29), cantonal authorities required physicians to report new influenza cases, compelled all affected municipalities to close schools, and introduced an obligation to practice for nonpracticing physicians. On 23 July (week 30), the canton introduced a restriction of mass gatherings, banning theatre and cinema performances, choir practices and concerts, and other larger gatherings and festivities (**Supplement Table 2**, available at Annals.org). There was no mask requirement, essential and nonessential businesses remained open, and public transport was in operation. The number of newly registered cases exceeded 7000 per week in weeks 30 and 31, when provisional emergency hospitals were established across the canton.

The temporal course of the weekly incidence of newly registered cases and the likely effect of enactments on the incidence are shown in the **Figure** (*top*), with details on prespecified time lags between enactment and registration of influenza cases shown in Supplement Table 2. The median estimated time from enactment of public health interventions to registration of cases was 13 days (range, 10 to 20 days). The reporting obligation enacted during week 29 may have contributed to the acceleration of epidemic growth (RIRR, 1.13 [CI, 0.97 to 1.32]) in week 30 (**Figure** [*top*, event A]; **Supplement Table 3** [available at Annals.org]). School closures in week 29 were likely associated with a strong deceleration of epidemic growth in week 31 (RIRR, 0.16 [CI, 0.15 to 0.17]) (**Figure** [*top*, event B]). The restriction of mass gatherings enacted during week 30 was likely associated with a deceleration in week 32 (RIRR, 0.57 [CI, 0.54 to 0.61]), when the number of registered cases was nearly half that in the previous week (**Figure** [*top*, event

C]). At the end of August (week 35), the ban on gatherings was lifted and schools reopened.

In total, 24 421 cases (20.2% of all cases) had been registered by the end of the first wave (week 38), with an incidence per 1000 inhabitants of 36.2 (CI, 35.7 to 36.6) (**Supplement Table 4**, available at Annals.org). After a stochastic phase of approximately 3 weeks, with a low number of cases despite lifting of all restrictions, the incidence began to increase again at the end of September in week 39 (**Figure** [*top*, event D]). Cantonal authorities

Figure. Temporal course of the weekly incidences of newly registered cases and the likely effect of public health enactments during the 1918 influenza pandemic in Bern and the 2020 COVID-19 pandemic in Switzerland.



COVID-19 = coronavirus disease 2019; RIRR = relative incidence rate ratio; Wke = week of event; Wki = week of change associated with event. **Top.** Temporal development of the 1918 influenza pandemic outbreak in the canton of Bern between June 1918 and June 1919 on the basis of the number of reported cases per calendar week (incidence). The vertical dashed lines indicate the likely change associated with events A to K after the time lags between enactment or event and registration of cases specified in Supplement Table 2. **Bottom.** Temporal development of the COVID-19 pandemic outbreak in Switzerland between February and December 2020 for comparison. The *x*-axis is broken to enable alignment of first and second waves between influenza and COVID-19 outbreaks.

* Details found in Supplement Table 7.

reacted with more hesitancy at the beginning of this second wave than in the first wave. At the beginning of October in week 40, cantonal authorities delegated the responsibility to enact public health measures to the municipalities. The number of cases continued to increase despite variable measures enacted at the municipal level, such as school closures, even though the slope of the epidemic curve was less pronounced than during the first wave. Compared with the first wave, the second wave took longer to reach its peak in week 44, but its eventual peak number of cases was higher.

Public health measures were enacted at the cantonal level from week 43 onward only. On 25 October 1918 (week 43), cantonal authorities introduced a partial restriction of mass gatherings, which was tightened 5 days later on 30 October (week 44) to also ban funerals and church services. In addition, municipal authorities communicated behavioral recommendations through public advertisements in daily newspapers, such as a recommendation to self-isolate in the case of symptoms and warnings against mass gathering (facsimile in **Supplement Figure 2**, available at Annals.org). The first effect of the partial and subsequently tightened restrictions on mass gatherings in weeks 43 and 44 was detectable in weeks 45 and 46, when the number of cases started to decrease, with RIRRs of 0.67 (CI, 0.64 to 0.71) and 0.90 (CI, 0.85 to 0.95), respectively (**Figure** [*top*, events F and G]).

This decline was likely reversed by the mass gatherings surrounding the Swiss National General Strike (*Landesstreik*), which was called in an attempt to improve working conditions, Social Security, and women's rights. It involved approximately 250 000 strikers in Switzerland, and about 100 000 soldiers were deployed to end the strike (30) . On 8 November, the largest body of troops (12 000 soldiers) was deployed to the canton's capital city, Bern. Mass demonstrations took place from 9 to 14 November, peaking on 13 November (week 46). One week later, on 23 November (week 47), cantonal authorities prematurely reverted to a partial restriction of mass gatherings in response to political and public pressure associated with the strike. The mass gatherings of civilians and troops during the strike in week 46 likely contributed to the resurgence of cases in week 48 (RIRR, 2.04 [CI, 1.92 to 2.17]) (**Figure** [*top*, event H]). The premature relaxation of restrictions of mass gatherings in week 47 was likely associated with another acceleration of epidemic growth in week 50 (RIRR, 1.18 [CI, 1.12 to 1.25]) (**Figure** [*top*, event I]). Thereafter, the numbers decreased substantially. Restrictions were relaxed in a stepwise manner in week 51 of 1918 and week 3 of 1919. A total of 96 731 cases (79.8% of all cases) had occurred in the second wave (incidence per 1000 inhabitants, 143.3 [CI, 142.4 to 144.2]).

The temporal spread of the epidemic was heterogeneous between greater regions (**Supplement Figure 3**, available at Annals.org). The spread occurred rapidly from the northwest toward the southeast. The French-speaking Jura region in the north and the city of Bern were affected first, and the alpine areas in the south were affected slightly later. In all regions, the second wave was 2 to 3 times longer than the first wave. In Jura, the first wave had a higher weekly amplitude than the second wave. In the 3 cities, the amplitudes of both waves were similar. In most other regions, the second wave had a higher amplitude than the first wave (**Supplement Table 4**).

The estimated basic reproductive number at the cantonal level was 2.28 (CI, 2.24 to 2.32) for the first wave and 1.25 (CI, 1.24 to 1.25) for the second wave (**Supplement Table 4**). Despite lower basic reproductive numbers during the second wave, the cumulative incidence was consistently higher during the second wave (**Supplement Figure 4** and **Figure 5**, available at Annals.org). At the level of the greater regions, the overall median increase in cumulative incidence was 3.6-fold, which was also seen in Mittelland, but increases ranged from a 1.9-fold increase in the Jura region in the north to an 8.0-fold increase in Voralpen in the south.

The shapes of the distribution of incident cases and deaths per month were similar at the level of the canton and the 3 available geopolitical areas (city of Bern, district of Fraubrunnen, and district of Signau) (**Supplement Figure 6**, available at Annals.org). The cumulative mortality for the entire epidemic at the cantonal level was 6.9 deaths (CI, 6.7 to 7.1 deaths) per 1000 inhabitants (**Supplement Table 5**, available at Annals.org), resulting in a case fatality rate of 3.8% (CI, 3.7% to 4.0%). As for cumulative incidence, the mortality was higher during the second wave than during the first wave in all greater regions.

Supplement Table 6 (available at Annals.org) shows the results of sensitivity analyses. No relevant changes in RIRRs were found after adjustment for predictable underlying seasonality seen between 1920 and 1929 (**Supplement Figure 7** and **Figure 8**, available at Annals.org). After accounting for heterogeneity between greater regions in a fixed-effects model, we found only 1 RIRR that changed to a relevant extent (event D, week 39, 1918), but our conclusions remained unchanged.

The **Figure** (*bottom*) shows the first and second waves of the COVID-19 outbreak in Switzerland, 2020. Timely and stringent public health interventions that were federally enacted between weeks 9 and 12 in 2020 (events B to F) were associated with rapid control of the first wave, which transitioned into a stochastic phase around week 16. The responsibility for public health interventions was delegated to the cantons in week 25. Despite the stepwise lifting of restrictions between week 18 in late spring and week 26 in early summer (**Supplement Table 7** [events G to K, and M], available at Annals.org), the pandemic remained relatively contained until early autumn. However, the last step of permitting mass gatherings of more than 1000 persons in week 40 (event O) was followed by uncontrolled exponential growth in week 41 (RIRR, 1.62 [CI, 1.49 to 1.75]). From week 42 onward, individual cantons implemented their own public health interventions (event P), but their hesitant and uncoordinated approach was associated with an insufficient deceleration of exponential growth. The second wave had a considerably higher amplitude and more prolonged duration than the first wave, with considerably higher hospitalization and mortality rates (**Supplement Figure 9**, available at Annals.org). At the time of submission of this manuscript in December 2020, the pandemic was not contained in Switzerland.

Discussion

During the first wave of the influenza pandemic in summer 1918 in the canton of Bern, we found salient associations between the centrally enacted, canton-wide public health interventions and the early and rapid containment of epidemic growth. During the second wave in autumn, cantonal authorities reacted hesitantly and initially delegated the responsibility to enact public health measures to the municipalities. This hesitant attitude was largely due to concerns about the economic effect of public health interventions experienced during the first wave and the associated political pressure (23). The mass gatherings associated with the Swiss National General Strike and the premature relaxation of restrictions of mass gatherings only 1 week later because of public pressure (23) may have contributed to the length and intensity of the second wave, which was 2.6 times longer than the first wave and responsible for approximately 80% of all cases and deaths. The length of the second wave was akin to a modern-day, nonpandemic wave of seasonal influenza, which fades out without public health interventions (31), whereas the length of the first wave was considerably shorter. Strikingly similar patterns were found in the management of the COVID-19 outbreak in Switzerland in 2020: The second wave had a considerably higher amplitude, prolonged duration, and much higher associated rates of hospitalization and mortality.

During the 1918 influenza pandemic, the greater regions of the canton of Bern varied substantially in both progression over time and peak incidence. The predominantly French-speaking Jura region had a pattern similar to that seen in the French-speaking western cantons of Switzerland, with a higher peak incidence in the first wave than in the second wave. The virus was probably introduced to Switzerland from France (20, 21), which would account for the slightly earlier start date of the outbreak in Jura than the rest of the canton, given its proximity to the French border. The presence of geographic differences in a multiwave pandemic is well established for the 1918 pandemic (17), as well as later influenza pandemics (32, 33). The course of the pandemic also progressed differently among U.S. cities, and evidence suggests that the timing and duration of public health interventions affected the local course of the pandemic (34–36).

The estimated basic reproductive number in the absence of public health interventions was higher during the first wave than the second wave. The lower transmissibility during the second wave may be somewhat explained by a partial immunity of the population after exposure during the first wave (37). Lower levels of immunity could also explain why the southern alpine regions in the canton of Bern experienced a stronger second wave after a comparatively mild first wave. Virus mutations could also have contributed to the observed differences (18, 37–39).

Our study has several limitations. First, the number of newly registered cases of influenza-like illness per week has limited specificity and may be subject to both under- and overreporting by patients and physicians. Second, time lags between the enactment of public health interventions and the registration of cases by district authorities were based on prespecified assumptions and are approximate. Third, our reports did not provide information on sex, age, or socioeconomic status of infected persons (40, 41). However, ecological analyses in the city of Bern indicate that working-class neighborhoods had a higher death toll from the 1918 pandemic than upper-class neighborhoods (20, 42). Finally, our analyses can establish only associations between epidemic growth and public health interventions, not causality.

In conclusion, our analysis of historical epidemiologic data provides insights into epidemic growth and its association with public health interventions during the 1918 influenza pandemic. The pandemic progressed heterogeneously at a regional scale. Aggregating data at the level of larger geopolitical areas, such as countries, states, or even cantons—like in our study—likely conceals important regional nuances (19). The initial hesitancy at the cantonal level, the delegation of public health responsibilities to municipalities, the occurrence of mass gatherings related to the General Strike, and the premature relaxation of restrictions were associated with an increased length and intensity of the second wave. Although these associations do not confirm causality, public health interventions likely played a similar role in containing the 1918 influenza pandemic (34–36) and in containing the COVID-19 pandemic (43–45). A hesitant approach to public health interventions, despite early evidence of uncontrolled exponential growth, was associated with a lack of containment of the second waves of both the 1918 influenza and COVID-19 pandemics.

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