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Short-Term Birth Sequelae of the 1918–1920 Influenza Pandemic in the United States: State-Level Analysis

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This paper examines short-term birth sequelae of the influenza pandemic of 1918–1920 in the United States using monthly data on births and all-cause deaths for 19 US states in conjunction with data on maternal deaths, stillbirths, and premature births. The data on births and all-cause deaths are adjusted for seasonal and trend effects, and the residual components of the 2 time series coinciding with the timing of peak influenza mortality are examined for these sequelae. Notable findings include: 1) a drop in births in the 3 months following peak mortality; 2) a reversion in births to normal levels occurring 5–7 months after peak mortality; and 3) a steep drop in births occurring 9–10 months after peak mortality. Interpreted in the context of parallel data showing elevated premature births, stillbirths, and maternal mortality during times of peak influenza mortality, these findings suggest that the main impacts of the 1918–1920 influenza on reproduction occurred through: 1) impaired conceptions, possibly due to effects on fertility and behavioral changes; 2) an increase in the preterm delivery rate during the peak of the pandemic; and 3) elevated maternal and fetal mortality, resulting in late-term losses in pregnancy.

1918; deaths; fertility; influenza; mortality; pandemic; preterm births; United States

Accounting for an estimated 675,000 deaths in the United States and 50 million deaths worldwide, the 1918–1920 influenza pandemic dealt a severe blow to populations across the world (1). While the mortality effects of the pandemic have received substantial attention, its effects on a second key demographic driver—births—are not well studied. Yet we know that epidemic influenza had profound impacts on those planning to get pregnant, pregnant women, and fetal outcomes. For example, a 1919 study of maternal mortality during the pandemic found that "in cases complicated by pneumonia, 50 percent of patients died," (2, p. 980) (see also Titus and Jamison (3)). In addition, a report from the Bureau of the Census revealed a noticeable decline in the birth rate in 1919 (4), suggesting that, even after adjusting for maternal deaths, births declined.

Viewed in this context, an understanding of the associations between the pandemic and subsequent patterns of births can shed light on a variety of significant health phenomena: 1) the risks posed to the developing fetus from the influenza virus (5); 2) the implications of infection for preterm births and preparedness for such outcomes; 3) vaccination policy for pregnant women; 4) effects of infection on fertility (6); and 5) possible behavioral interruptions that may affect conceptions in a time of widespread illness (7–9). The aim of this paper is to explore the short-term birth sequelae of the influenza pandemic of 1918–1920 in the United States with a view to parsing out the various mechanisms, listed above, linking influenza to subsequent births. In order to ascertain the robustness of the findings, we examined not only the well-recognized October 1918 wave of the pandemic but also the subsequent and hitherto ignored February 1920 wave.

METHODS

Data

In order to explore associations between the 1918–1920 influenza pandemic and patterns of births, we collected state-level time-series data on monthly births and all-cause deaths for the years 1916–1921, for a total of 72 observations for each series for each state. We chose to use excess all-cause deaths rather than deaths from respiratory illnesses as an indicator of the timing of the pandemic for 2 reasons. First, the toll of the pandemic was manifested by elevated mortality from a long list of causes. A report from Massachusetts, for example, listed 85 different conditions as possible causes of pandemic-related mortality, among them influenza, 3 types of pneumonia, tuberculosis, meningitis, heart disease, and "accidents" of pregnancy and labor (10, p. 180–89). Second, the

Table 1. States in the National Births and Deaths Registration Area in 1918, With Corresponding Populations and Geographic Locations, United States, 1910–1920

State	Population in 1910 (59)	Population in 1920 (60)	Geographic Region (61)	Subregion (61)
Connecticut	1,114,756	1,380,631	Northeast	New England
Indiana	2,700,876	2,930,390	Midwest	East North Central
Kansas	1,690,949	1,769,257	Midwest	West North Central
Kentucky	2,289,905	2,416,630	South	East South Central
Maine	742,371	768,014	Northeast	New England
Maryland	1,295,346	1,449,661	South	South Atlantic
Massachusetts	3,366,416	3,852,356	Northeast	New England
Michigan	2,810,173	3,668,412	Midwest	East North Central
Minnesota	2,075,708	2,387,125	Midwest	West North Central
New Hampshire	430,572	443,083	Northeast	New England
New York	9,113,614	10,385,227	Northeast	Middle Atlantic
North Carolina	2,206,287	2,559,123	South	South Atlantic
Ohio	4,767,121	5,759,394	Midwest	East North Central
Pennsylvania	7,665,111	8,720,017	Northeast	Middle Atlantic
Utah	373,351	449,396	West	Mountain
Vermont	355,956	352,428	Northeast	New England
Virginia	2,061,612	2,309,187	South	South Atlantic
Washington	1,141,990	1,356,621	West	Pacific
Wisconsin	2,333,860	2,632,067	Midwest	East North Central

states that reported monthly statistics on mortality from respiratory diseases did not do so in a uniform manner.

Most US states were not part of the national births and deaths registration area by 1918 (11, 12). Therefore, we used monthly data on deaths and births for the 19 states that had joined the registration area by 1917 to study these patterns (Table 1). This balanced the need for data from a geographically diverse array of states with the need for including a mix of pre- and postpandemic data with which to establish baseline patterns of births and deaths. These data were obtained from birth and mortality statistics produced by the US Bureau of the Census (4, 11–20). We also used a geographically and temporally sparse set of monthly data on numbers of preterm births, mortality from preterm births, stillbirths, and maternal mortality to interpret the findings on births and deaths (10, 21–28; Table 2).

A common limitation of data on births and deaths is underreporting. However, the emphasis of this paper is not on the number of births and deaths but rather on the timing of peaks and troughs in births and deaths. Therefore, even if births and deaths were being systematically underreported, significant one-time fluctuations would be captured in the data, as evidenced by the October 1918 and February 1920 spikes in mortality (Figure 1A–1D).

Statistical methods

The original monthly time-series data on deaths and births were decomposed into 3 components using the SAS (SAS Institute, Inc., Cary, North Carolina) PROC X12 seasonal decomposition algorithm (29, 30) with outlier detection. These included the seasonal (wavelength of 12 months), trend (long wavelength), and irregular (residual or nonseasonal/nontrend) components. This method is appropriate for filtering out those components of births and deaths that were attributable to systematic seasonal (such as seasonal influenza) or trend (such as long-term improvements

Table 2. Availability of Monthly Data on Premature Births, Stillbirths, and Deaths Associated With Childbirth and Prematurity, Eastern United States, 1917–1920

Variable	Location		
	Buffalo, New York	State of New York	State of Massachusetts
Premature births	1917, 1918, 1919		
Prematurity-associated deaths		1917, 1920	1917, 1918, 1919, 1920
Stillbirths	1917, 1918, 1919	1917, 1920	
Childbirth-associated deaths		1917, 1920	1917, 1918, 1919, 1920

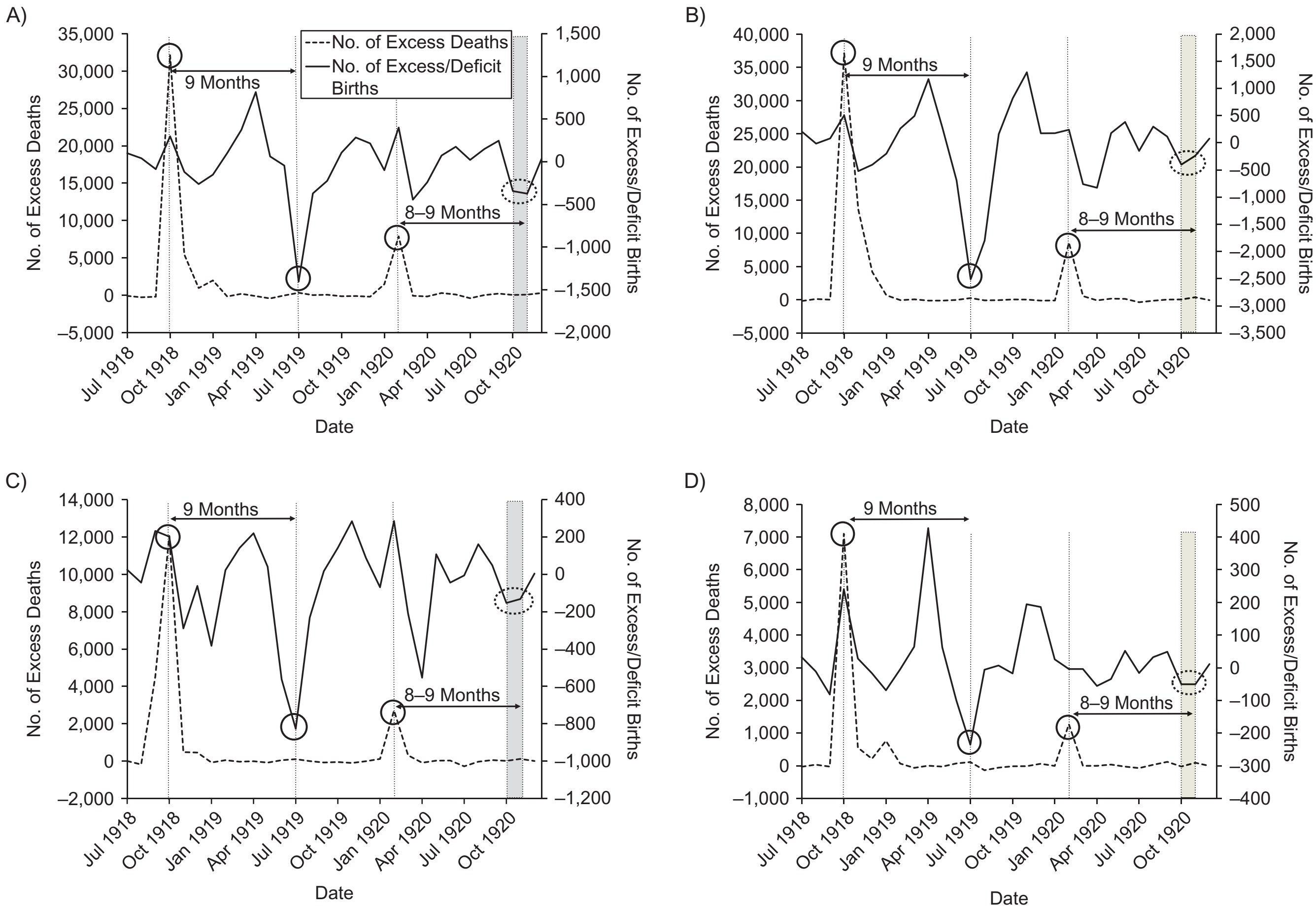

Figure 1. Excess births and deaths in the 4 states with the highest influenza mortality during the 1918 influenza pandemic estimated using the "irregular" component of the seasonally decomposed time series, United States. A) New York; B) Pennsylvania; C) Massachusetts; D) Maryland.

in life-saving health interventions) phenomena, bringing into focus one-time events such as the influenza pandemic. The irregular component of the death series was used as the measure of excess deaths associated with the pandemic. We applied the same methods to the birth data and examined the irregular component of the birth data in the (temporal) vicinity of the pandemic for anomalies whose timing may have been associated with the pandemic. The algorithm provided satisfactory results for the birth data for all 19 states. However, for 7 of the 19 states, the decomposition algorithm allocated a large portion of the excess deaths to the trend component rather than the irregular component. This misallocation occurred for states for which the mortality peak occurred for an extended period of time (2 or 3 months, rather than the more commonly observed 1 month), resulting in the algorithm treating a portion of the deaths occurring at that time as regular. In these cases, the influenza-attributable deaths were computed as the sum of the trend and irregular components of the original series (henceforth "seasonally adjusted" mortality) rather than just the irregular (henceforth "excess" mortality) component, bringing the data into alignment with the data for the other 12 states.

RESULTS

Table 3 provides a summary of the results for the 19 US states considered. Figure 1A–1D shows patterns of excess deaths and births occurring at the time of the pandemic for the 4 states with the highest numbers of excess deaths, estimated using only the irregular component of the original series (New York, Pennsylvania, Massachusetts, and Maryland). These are states for which birth-related sequelae are most likely to be detectable given the greater impact of the pandemic in terms of lives lost and, presumably, infections. The first point to note is how similar the graphs are for the 4 states. All 4 states experienced a major excess mortality peak in October 1918, followed by a second and smaller excess mortality peak in February 1920. The immediate aftermath of the October 1918 mortality peak was marked by a dip in births, followed by a noticeable spike in births peaking at 6 months after the excess mortality peak, and then followed by a precipitous drop in births in July 1919, 9 months after the October 1918 mortality peak. This last phenomenon is also discernible for the United States as a whole in a graph published in the *Birth Statistics* report of 1921 (4), reproduced here

Table 3. Summary of Results on Timing of Influenza-Attributable Excess Deaths and Deficit or Excess Births for 19 States in the United States, 1918

State	Excess Deaths			Excess or Deficit Births						Lag (in Months) Between Mortality Peak and Change in Births	
	Peak Month	Peak Deaths, Seasonally Adjusted (Trend Included), No.	Peak Deaths, Irregular Only (Trend Excluded), No.	Lowest Month of Dip	Deficit No. at Lowest Month, Irregular Only (Trend Excluded)	Deficit as % of All Births	Peak Month of Spike in Births	Excess No. at Peak of Spike, Irregular Only (Trend Excluded)	Excess as % of All Births	Dip	Spike
Connecticut	October 1918	7,589	5,489	July 1919	−356	15	May 1919	216	8	9	7
Indiana	October to December 1918	16,884[a]		August 1919	−566	12	March 1919	154	3	8–10	5–7
Kansas	October to December 1918	9,916[a]		August 1919	−297	10				8–10	
Kentucky	October to November 1918	12,399[a]		August 1919	−282	7	May 1919	245	5	9–10	6–7
Maine	October 1918	2,742	1,524	August 1919	−181	16				10	
Maryland	October 1918	9,147	7,100	July 1919	−236	10	April 1919	427	14	9	6
Massachusetts	October 1918	17,273	12,055	July 1919	−827	13	April 1919	219	3	9	6
Michigan	October to December 1918	19,481[a]		August 1919	−553	8	April 1919	261	4	8–10	4–6
Minnesota	October to November 1918	9,489[a]		August 1919	−424	11	April 1919	236	5	9–10	6–7
New Hampshire	October 1918	2,555	1,934	July 1919	−71	12				9	
New York	October 1918	45,333	32,177	July 1919	−1,403	8	April 1919	817	4	9	6
North Carolina	October 1918	8,721	5,841	July 1919	−330	6	April 1919	447	7	9	6
Ohio	October to December 1918	37,370[a]		August 1919	−673	7	April 1919	515	5	8–10	4–6
Pennsylvania	October 1918	48,938	13,600	July 1919	−2,512	17	April 1919	1,172	7	9	6
Utah	October to November 1918	2,097[a]		July to August 1919	−188[a]	10	June 1919	92	8	8–10	7–8
Vermont	October 1918	1,715	1,208	August 1919	−38	7	March to April 1919	60[a]	5	10	5–6
Virginia	October 1918	8,974	5,523	July 1919	−321	7	April 1919	142	3	9	6
Washington	October to December 1918	7,276[a]		July to August 1919	−65[a]	2	May 1919	125	6	7–10	5–7
Wisconsin	October to December 1918	14,481[a]		August 1919	−439	10				8–10	

[a] Sum for multiple months.

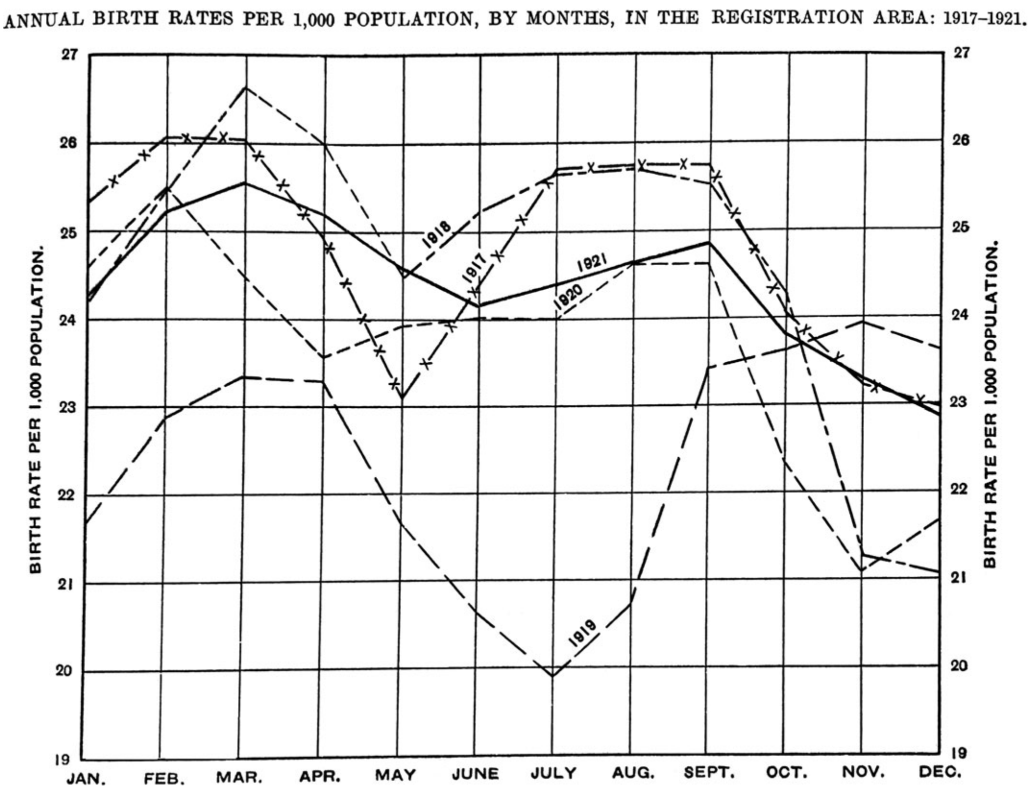

Figure 2. Annual birth rates in the United States, 1917–1920. Reprinted from the Bureau of the Census (4).

as Figure 2. These findings extend to the other states examined, albeit with more variability as states with lower numbers of deaths are included in the sample, as follows:

1. There is a depression in births for 3 months after peak mortality (Figure 1A–1D).
2. There is an apparent spike in births occurring 5–7 months after peak mortality. This phenomenon is seen in 15 of the 19 states. The (arithmetic) mean size of the spike in births in percentage terms across the states is 6% (Table 3). This spike occurs uniformly between March and June 1919; for 10 of the 15 states, it occurs in April 1919 (Table 3). For the 6 largest states (in terms of seasonally adjusted as well as excess mortality), this peak uniformly occurs 6 months after the mortality peak, in April 1919 (Table 3).
3. There is a notable depression in births occurring 9–10 months after peak mortality in all 19 states analyzed. The (arithmetic) mean size of the dip in births in percentage terms across the states is 10% (Table 3), which is related to the decline in the birth rate seen in 1919 in Figure 2, from approximately 23 per 1,000 population to 20 per 1,000 population or 13%. This dip occurs uniformly in July or August 1919 (Table 3).

An additional notable finding is that the fall 1918 mortality wave was followed in early 1920 by another wave. This 1920 wave, although also noted in Chile, Japan, Scandinavia, and Taiwan, has not been closely examined in the context of the United States or much of Europe (1, 8, 9, 31). Although the data show that the 1920 wave was less severe than the 1918 wave in most (but not all) locations, it was widespread and reported in both the domestic and international press (32–35). In addition to the states for which we have data, a number of others also experienced the 1920 wave, including Texas and Hawaii (36–38). A *Manchester Guardian* headline referred to “the American influenza epidemic” on January 23, 1920 (35), although press reports indicate that the 1920 wave struck Europe as well (39, 40).

Our analysis found that the 1920 wave occurred in February in 17 of the 19 states for which we have data, and in February and March in the remaining 2 (Table 4). Interestingly, here again we observe 2 dips in births, the first during the 3 months immediately following the February 1920 mortality peak and then again 9 months after the peak (Table 4 and Figure 1A–1D).

DISCUSSION

The effects of influenza on reproductive outcomes can take many forms, only some of which can be directly monitored in vital data of the time. Early fetal deaths are not recorded in any vital data system, and during the period of interest, stillbirths were only occasionally recorded on a monthly basis (10, 21–28). Monthly infant deaths were frequently distinguished in vital data, as were childbirth-associated maternal deaths. Therefore, while monitoring some of the direct effects of reproductive damage from the influenza of 1918 is possible, for other effects it remains difficult.

Table 4. Summary of Results on Timing of Influenza-Attributable Excess Deaths and Deficit Births for 19 States of the United States, 1920 Wave

State	Excess Deaths			Deficit Births			
	Peak Month	Peak Deaths, Seasonally Adjusted (Trend Included), No.	Peak Deaths, Irregular Only (Trend Excluded). No.	Lowest Month of Dip	Deficit No. at Lowest Month, Irregular Only (Trend Excluded)	Deficit as % of All Births	Lag Between Mortality Peak or Dip in Births, months
Connecticut	February 1920	2,680	1,188	November 1920	−55	2	9
Indiana	February 1920	5,348	2,056	December 1920	−150	3	10
Kansas	February 1920	3,172	1,647	November 1920	−189	6	9
Kentucky	February to March 1920	7,201[a]		December 1920	−415	10	9–10
Maine	February 1920	1,668	739	December 1920	−40	3	10
Maryland	February 1920	2,949	1,268	October to November 1920	−101[a]	4	8–9
Massachusetts	February 1920	7,011	2,710	October 1920	−154	2	8
Michigan	February 1920	8,645	4,163	November 1920	−379[b]	4	9
Minnesota	February 1920	3,724	1,670	November 1920	−429	11	9
New Hampshire	February 1920	808	283	September 1920	−15	2	7
New York	February 1920	19,141	7,867	November 1920	−373[c]	2	9
North Carolina	February 1920	4,689	2,259	November 1920	−345[d]	6	9
Ohio	February 1920	11,084	4,936	October 1920	−350	4	8
Pennsylvania	February 1920	17,896	8,609	October 1920	−401	2	8
Utah	February 1920	1,009	636	November 1920	−96	9	9
Vermont	February to March 1920	1,265[a]		November 1920	−25	5	8–9
Virginia	February 1920	4,101	1,795	December 1920	−161[e]	3	10
Washington	February 1920	2,336	1,134	November 1920	−172	9	9
Wisconsin	February 1920	4,319	1,975	November 1920	−254	6	9

[a] Sum for both months.
[b] Figure for October 1920: −314.
[c] Figure for October 1920: −344.
[d] Figure for December 1920: −228.
[e] Figure for November 1920: −140.

A few authors have examined birth rates in periods surrounding the peak mortality of the epidemic in an attempt to infer the likely effect of the epidemic on the course of pregnancy (5–9). However, ambiguities necessarily attend such an exercise. For example, the US Army was at war in Europe during the height of the pandemic. In November 1918, the draft and mobilization were at full capacity. By May 1918, hundreds of thousands of troops were deploying overseas monthly (41). The extensive mobilization process feeding this system had to be reversed over the course of winter 1918–1919. Thus, troops from overseas did not return in large numbers until late spring and summer 1919, with the last division arriving in September 1919 (42). Based on this chronology, we would expect a steady decline in births starting 9 months after the first sizeable deployments. Such a drawdown would be captured and filtered out in the trend component of the time series. Notably, the draft appears to have had only a slight impact on the birth rate (43) and, as Table 5 shows, there is no evidence in US birth rate statistics of a baby boom in the aftermath of the war.

More important for the purposes of this study, a deficit of births in relation to the epidemic could arise from voluntary postponement due to fear of infection or not wishing to infect the spouse, failure to conceive because of illness or spousal death from influenza or spousal separation associated with the war, from maternal death while pregnant, from fetal death, from preterm birth, or from any combination of these adversities. The timing of the birth deficit, however, might differ among these outcomes. If we use the time of peak mortality as the time when the strongest effects of influenza were felt on men or women of reproductive age, then a deficit of births 9 months later would likely indicate impaired fertility. If the effect on births were partly because of maternal deaths in pregnancy, the deficit in births would be observed whenever, in gestation, influenza during pregnancy was most lethal. The literature of the time (2, 3, 44) suggests that the largest maternal mortality effect occurred in the third trimester of pregnancy, often shortly after delivery of a stillborn infant near term but sometimes without the mother going into labor. Such patterns would be likely to manifest as a birth deficit within the first few months after peak mortality. This phenomenon is also visible in Figure 1A–1D.

The timing of a deficit of births in relation to an effect of influenza on miscarriage or fetal death without maternal death is likely

Table 5. Birth Rate According to Year, United States, 1916–1921

Year	Birth Rate per 1,000 Population
1916[a]	24.8
1917[b]	24.6
1918[b]	24.4
1919[b]	22.3
1920[b]	23.7
1921[b]	24.3

[a] Source is Bureau of the Census, 1921 (14).
[b] Source is Bureau of the Census, 1922 (15).

to be highly variable, depending on when in gestation the principal effect occurred. In reports at the time, pregnancy losses without maternal death seemed for the most part evenly distributed throughout pregnancy (3, 44). This contrasts with the ordinary pattern of pregnancy losses, where first trimester losses exceed later stillbirths by an order of a magnitude. One must keep in mind, however, that the earliest losses were more likely to remain unreported. If influenza increased preterm birth, then one might see an excess of preterm deliveries during the peak mortality, followed by an equivalent deficit in subsequent months.

With these considerations in mind, we now turn to the available monthly data on 4 phenomena: preterm births, deaths attributable to preterm births, stillbirths, and childbirth-associated maternal deaths. Figures 3A–3C, 4, and 5 demonstrate that all 4 numbers spiked during the October 1918 or February 1920 pandemic mortality waves. Viewed in the context of these observations, we offer the following interpretations.

Observation 1

There was a drop in births in the 3 months following each of the mortality peaks of October 1918 and February 1920.

Interpretation: This phenomenon is consistent with the observed excess of preterm births and prematurity-associated mortality during the pandemic (Figures 3A, 4, and 5). Reports of the course of pandemic influenza in pregnancy in recent epidemics have indicated increases in premature labor and preterm births in women with severe disease, in some but not all epidemics (3, 44). The severe Asian influenza of 1957 produced few reports of pregnancy complications. One exception was a series of some 700 pregnant women in Baltimore monitored monthly for influenza symptoms and seroconversion (45). Approximately 83% of the women were found to be seropositive for influenza A/Japan/305-57, with peaks of both reported symptoms and positive serology in October 1957. An overall relative risk of preterm birth of 1.6 (not significant) compared with uninfected women was found, but if infection occurred in the first trimester, the relative risk was 2.4 ($P < 0.05$).

Neonatal mortality rates are greatly influenced by prematurity rates, and further evidence for an effect of influenza on prematurity is seen in a report of elevated neonatal mortality in the United Kingdom in the first half of 1970, especially the first quarter of that year (46). This elevated mortality was linked to the severe Asian influenza (A2, Hong Kong variant) of the winter of 1969–1970. The British report found both an increase in mortality diagnostic codes linked to prematurity and increases in low birthweight prevalence in several parts of the United Kingdom that paralleled the neonatal mortality increase.

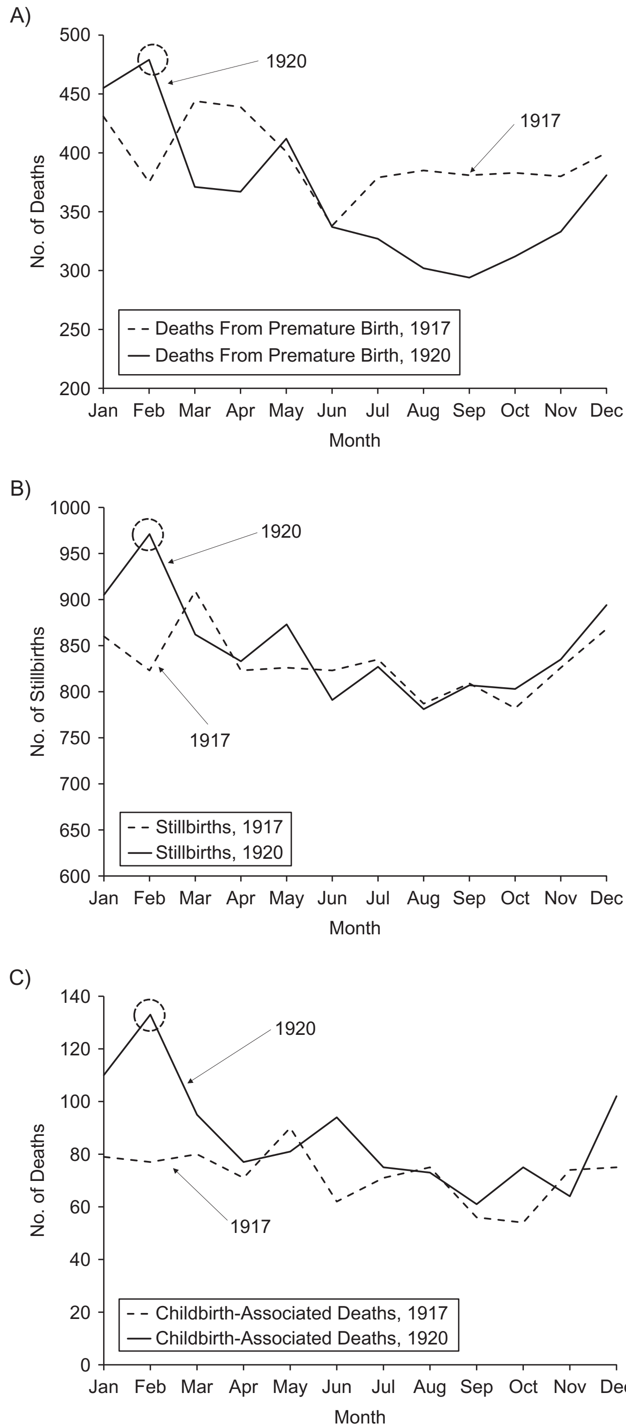

Figure 3. Adverse birth outcomes, New York, 1917 versus 1920. A) Deaths from prematurity; B) stillbirths; C) childbirth-associated maternal deaths (excluding those due to septicemia).

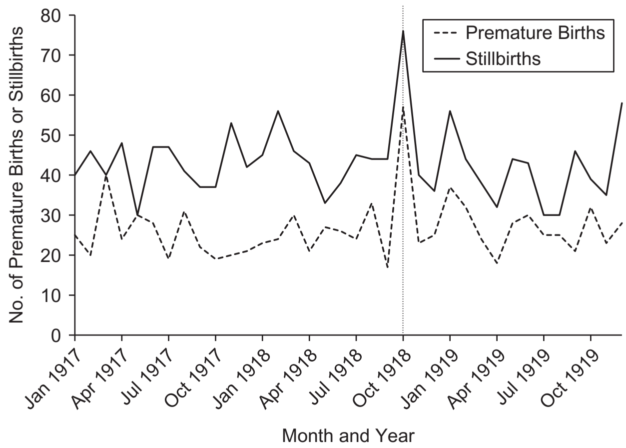

Figure 4. Premature births and stillbirths in Buffalo, New York, 1917–1919.

The occurrence of this excess neonatal mortality only months after the epidemic peak was interpreted as further evidence for an effect on preterm birth. Interestingly, no increase in neonatal mortality was found in UK vital data in relation to 4 earlier severe influenza epidemics in the United Kingdom (1951, 1953, 1959, and 1961). A French report also linked the 1969–1970 influenza to an increase in prematurity (47), but the effect of the Hong Kong influenza on neonatal mortality in other countries was mixed (46), with increases similar to those found in the United Kingdom in New York City, Scotland, Germany, and the Netherlands. However, there were no changes in prematurity rates in Poland or Ireland.

The 2009 pandemic A/H1N1 influenza is the most studied pandemic in recent history. Numerous reports from that epidemic have reported substantial increases in preterm birth, with relative risk ranging from 2 to 5 (48–54), and several series described prematurity rates above 30%. This effect, however, was largely restricted to hospitalized or severely ill pregnant patients. Studies reflecting the general-population experience showed little or no increase in preterm birth (55, 56). The 1918–1919 experience, in which the number of severely affected women was very high, appears to be compatible with the increases in preterm birth found in severely affected women during some pandemics of recent years, especially the pandemics of 1969 and 2009, although the number of severely affected cases in 2009 was apparently too few to change the overall prematurity rate in the general population.

In addition to elevated preterm deliveries, fetal loss coinciding with the pandemic could explain a deficit in births in the first few months after peak mortality if the infection had occurred in the third trimester of pregnancy (i.e., producing stillbirths (Figures 3B and 4) and not early fetal losses). Contemporary accounts of the course of influenza in pregnancy also uniformly describe high maternal mortality, often occurring late in pregnancy, with concomitant fetal loss shortly before death (2, 3, 44, 57; Figures 3C and 5). Thus, this early drop in births may have reflected a combination of preterm births and stillbirths associated with maternal deaths. Among women who died from influenza in pregnancy, only a small fraction appear to have delivered a live infant (2, 3, 44, 57).

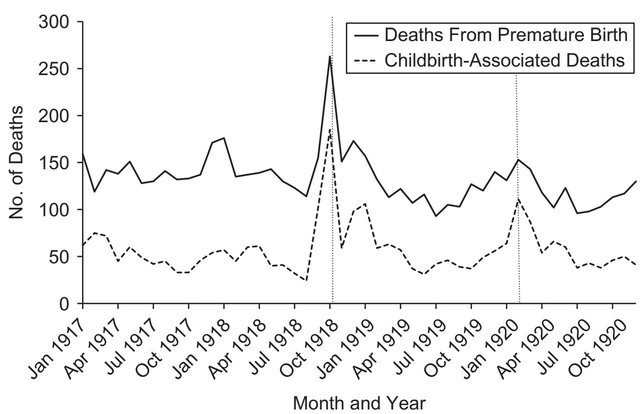

Figure 5. Prematurity-associated deaths and childbirth-associated maternal deaths in Massachusetts, 1917–1920.

Observation 2

There was a noticeable spike in births occurring 5–7 months after peak mortality. This phenomenon was seen in 15 of the 19 states. For the 6 worst affected states (in terms of seasonally adjusted as well as excess mortality), this peak uniformly occurred 6 months after the mortality peak.

Interpretation: This spike reflects a reversion in the direction of normal levels of births for a brief period between the declines in births immediately following the pandemic (observation 1, above) and the subsequent drop 8–10 months after the pandemic (observation 3, below). The seasonal adjustment algorithm identifies this mean reversion as a spike (i.e., excess births) because it is observed against the backdrop of lower levels of births in the preceding and subsequent months. Yet evidence from both birth statistics and birth rates shows that this "spike" merely brought these numbers back into the normal range (see, for example the data for the spring of 1919 in Figure 2).

Observation 3

There was a notable dip in births occurring 8–10 months after peak mortality in 18 of the 19 states analyzed with Washington, the exception, showing a dip 7–10 months after the mortality peak.

Interpretation: This suggests that primary infertility was produced by the epidemic, with fewer conceptions for either behavioral or biological reasons. This dip in births 9 months after the peak mortality month parallels findings on Japan, Taiwan, and Norway (6–9). The behavioral reasons for a drop in conceptions during the peak of the epidemic in October 1918 include voluntary postponement of conceptions due to fear from the pandemic and a wish not to infect the spouse and, among couples not pregnant, spousal sickness or death (6, 7). A biological reason for a decline in conception was the temporary sterility reported among men (but not women) infected by influenza (58).

Conclusion

From our analysis of nationally disaggregated data on pandemic activity, stillbirths, birth rates, preterm births, deaths from preterm births, and childbirth-associated mortality from both the October 1918 and the February 1920 waves of the influenza pandemic, we can conclude, first, that the major impact of the pandemic on reproduction was felt through impaired conceptions. The degree to which this phenomenon can be attributed to effects on fertility and behavioral changes is a topic for future research. Second, a combined phenomenon of elevated preterm delivery and mortality, maternal mortality, and fetal mortality was observed coinciding with peak influenza mortality, followed by a natality depression in the 3 months immediately following the pandemic peaks. This shows that significant fetal losses occurred late in pregnancy. Third, we do not see evidence in these data for early pregnancy loss as hypothesized in earlier research (5), which used nationally aggregated data on pandemic activity, stillbirths, and birth rates to find a natality depression that reached its nadir 6.1–6.8 months after peak influenza activity and concluded that first-trimester miscarriages were responsible for this phenomenon. In other words, the risks posed to the developing fetus from the influenza virus in 1918 and 1920 appear to have stemmed primarily from the mechanisms of maternal mortality, preterm delivery, and fetal infection. These risks could have important implications for vaccination policies relating to pregnant women, indicating the need for a second line of research emerging from our findings.

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