

Trends in Recorded Influenza Mortality: United States, 1900–2004

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Three influenza pandemics occurred in the 20th century: in 1918–1919, 1957–1958, and 1968–1969. Today, there is widespread concern, in the medical community as well as the public, regarding the deadly potential of a future influenza pandemic. Many national governments have begun to prepare for such a future threat. In the United States, this preparation has taken the form of the multi-billion-dollar National Strategy for Pandemic Influenza.

According to the US Centers for Disease Control and Prevention (CDC), “Pandemics are different from seasonal outbreaks or ‘epidemics’ of influenza.”^{1(p1)} “The hallmark of pandemic influenza is excess mortality.”² One recent official US death toll projection^{3(p1)} suggested that the next pandemic will kill 6 to 56 times more Americans than the CDC currently estimates die in an average nonpandemic influenza season.⁴ The World Health Organization (WHO), in a “relatively conservative estimate,”⁵ predicted that the next influenza pandemic could claim 4 to 30 times more lives worldwide than a typical nonpandemic season.⁶

Despite the widespread concern over a future influenza pandemic, there has been little research on the more than 100 years of recorded influenza death data in the United States—a period that includes both pandemic and nonpandemic seasons. I present an analysis of these data to describe trends in influenza mortality and, in particular, to compare pandemic and nonpandemic influenza seasons in ways that may inform present planning for the prevention and control of influenza.

METHODS

Mortality Statistics and Influenza

In the United States, statistics on annual underlying cause of death have been published continuously since 1900.⁷ Initially, however, the system collected data only from selected regions in the country, known as the “registration area.”

Objectives. I sought to describe trends in historical influenza mortality data in the United States since 1900 and compare pandemic with nonpandemic influenza seasons.

Methods. I compiled a database of monthly influenza-classed death rates from official US mortality tables for the years 1900 to 2004 (1905–1909 excluded), from which I calculated adjusted influenza season (July 1–June 30) mortality rates.

Results. An overall and substantial decline in influenza-classed mortality was observed during the 20th century, from an average seasonal rate of 10.2 deaths per 100 000 population in the 1940s to 0.56 per 100 000 by the 1990s. The 1918–1919 pandemic stands out as an exceptional outlier. The 1957–1958 and 1968–1969 influenza pandemic seasons, by contrast, displayed substantial overlap in both degree of mortality and timing compared with nonpandemic seasons.

Conclusions. The considerable similarity in mortality seen in pandemic and nonpandemic influenza seasons challenges common beliefs about the severity of pandemic influenza. The historical decline in influenza-classed mortality rates suggests that public health and ecological factors may play a role in influenza mortality risk. Nevertheless, the actual number of influenza-attributable deaths remains in doubt. (*Am J Public Health.* 2008;98:939–945. doi:10.2105/AJPH.2007.119933)

It was not until 1933 that all states were included in reports on national mortality statistics.

Since 1900, influenza as a distinct disease category has been included in mortality statistics. It should not be assumed, however, that all deaths attributed to influenza in historical or contemporary mortality records were associated with influenza virus infection. Single-cause mortality tables were tabulated on the basis of information that appeared on death certificates. It was only in the early 1930s that influenza’s viral etiology was first determined.⁸ Even afterwards, and for most of the 20th century, influenza continued to be reported on death certificates despite the absence of laboratory confirmation of influenza virus infection. In the current (10th) revision of the *International Classification of Diseases (ICD)*,⁹ there are 2 categories for influenza: J10 for influenza, virus identified, and J11 for influenza, virus not identified.

Definitions of Influenza Seasons

In the United States, influenza is a seasonal illness, and virus circulation peaks at unpredictable times. Elevated mortality thus

can occur across calendar years.⁴ For those years for which full monthly data were obtainable, I have defined an influenza season as the 12-month period between July 1 and June 30.

Subsequently, I categorized influenza seasons as either pandemic or nonpandemic. Pandemic influenza seasons are those in which “a new influenza A virus appears or ‘emerges’ in the human population, causes serious illness, and then spreads easily from person to person worldwide,” as defined by the CDC.^{1(p1)} All other seasons are “nonpandemic.”

Influenza Mortality Data

Monthly total US influenza and all-cause death figures were obtained for the years 1900 through 1904 and 1910 through 2004. For the years 1900 through 1904 and 1910 through 1936, monthly death figures were obtained through the annual *Mortality Statistics* reports published by the Bureau of the Census.¹⁰ I obtained additional figures for the years 1937 through 1993 and 1999 through 2004 from *Vital Statistics of the United States* or other mortality reports

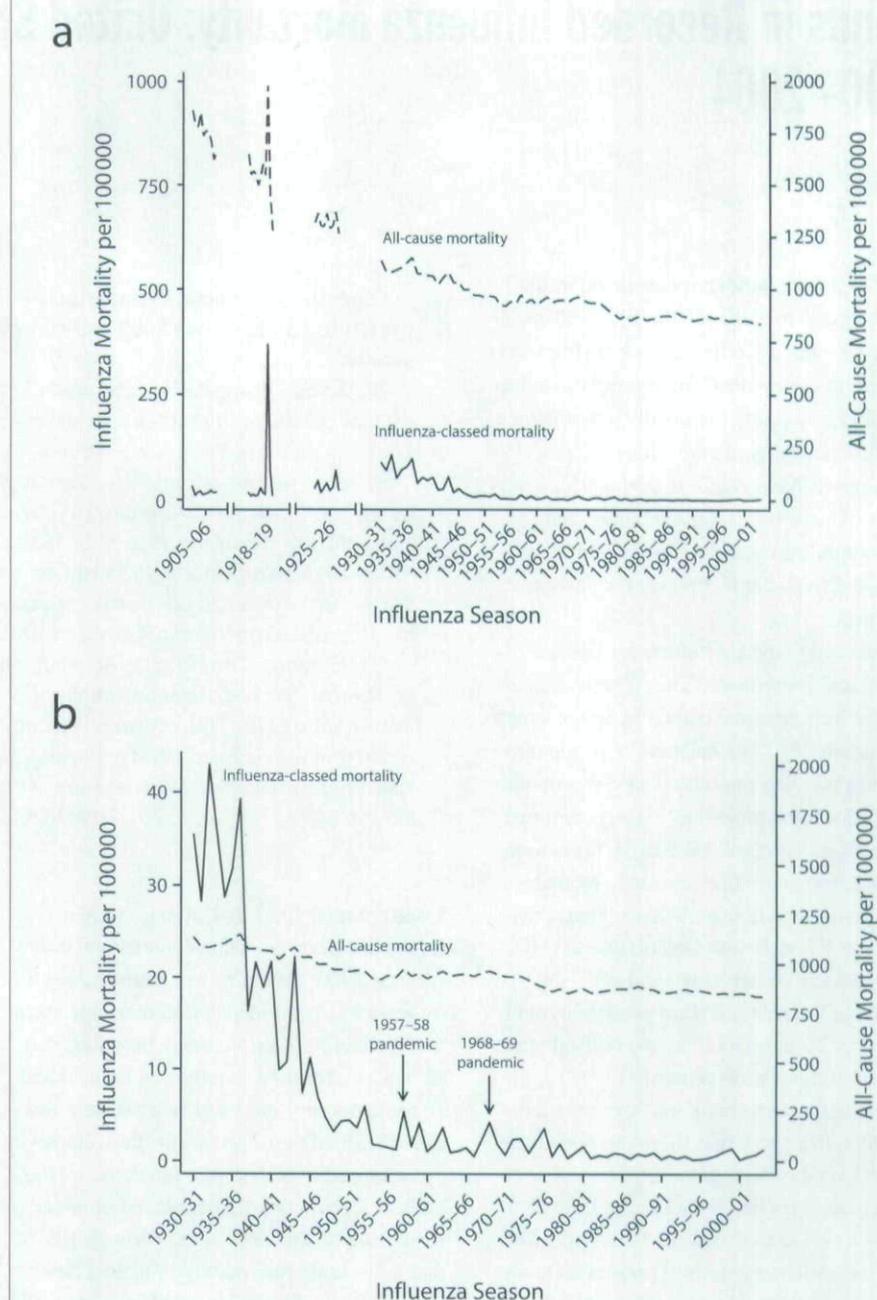
maintained or produced by the CDC's National Center for Health Statistics.¹¹⁻¹³ Finally, I obtained monthly death statistics for 1994 through 1998 through the online DataFerrett utility.¹⁴ For reasons unknown, the Bureau of the Census did not publish statistics on the causes of death by month for 1905 through 1909, but did both before and after this period. For these years, only annual (January–December) death figures could be located.¹⁰

For most of the 20th century, monthly influenza-classed mortality broken down by age or age group was not published. The lack of such historical age-specific data precluded investigation of trends in the age distribution of influenza mortality over time.

I used US Census estimates in calculating seasonal and monthly influenza-classified mortality rates. To estimate the monthly rates, I used the mean of July 1 resident population estimates for the 2 consecutive years that a given influenza season spanned. Figures for 1900 through 1932 are limited to the population of the "registration area" as tabulated in Part I of the 1939 edition of the *Vital Statistics of the United States* report, the last report in which population statistics for the entire registration area were presented. For the years 1933 through 2004, the resident population of the continental United States was used, with the populations of Alaska and Hawaii added from the years they became states (1959 and 1960, respectively).¹⁵ Monthly influenza death rates were calculated per 100 000 population on an annual basis.

Comparability Between International Classification of Diseases Revisions

There were 10 different revisions of the *ICD* in the period under review, from *ICD-1* in 1900 to the current *ICD-10*, which was first applied to US national mortality data in 1999. During this time, the classification code for influenza was changed several times (see the table available as a supplement to the online version of this article at <http://www.ajph.org>). I obtained comparability ratios for influenza through published National Center for Health Statistics sources¹⁶ to adjust the data classified under revisions *ICD-4* through *ICD-9* (years



Note. International Classification of Diseases (*ICD*) revision 1 was used from 1900 to 1909, revision 2 from 1910 to 1920, revision 3 from 1921 to 1929. Comparability ratios are unavailable for revisions 1 to 3. Beginning in 1930, influenza mortality rates have been adjusted for changes in *ICD* revisions to reflect conditions in the current *ICD* revision 10.

FIGURE 1—Crude mortality per 100 000 population, by influenza season (July to June of the following year), for seasons 1900–1901 to 2003–2004 (a) and 1930–1931 to 2003–2004 (b), United States.

1930–1998). I adjusted these data to the current *ICD-10* scheme. Comparability ratios were not available for adjustment of data for the years classified under the *ICD-1*, *ICD-2*, and *ICD-3* revisions (years 1900–1929).

Viral Circulation Data

Viral circulation data on influenza as well as other viruses such as respiratory syncytial virus and rhinovirus may be helpful in an analysis of influenza's impact on mortality, because these viruses often co-circulate with

influenza. The CDC maintains such historical viral circulation data through programs such as the National Respiratory and Enteric Virus Surveillance System. Two attempts were made to obtain such data for analysis; however, the CDC responded that such data are only provided on condition of co-authorship, which I refused.

RESULTS

Overall Decline in Death Rate

Influenza death rates in the United States substantially declined across the 20th century, in line with the simultaneous decline in the mortality burden from most infectious diseases, often referred to as the “epidemiological

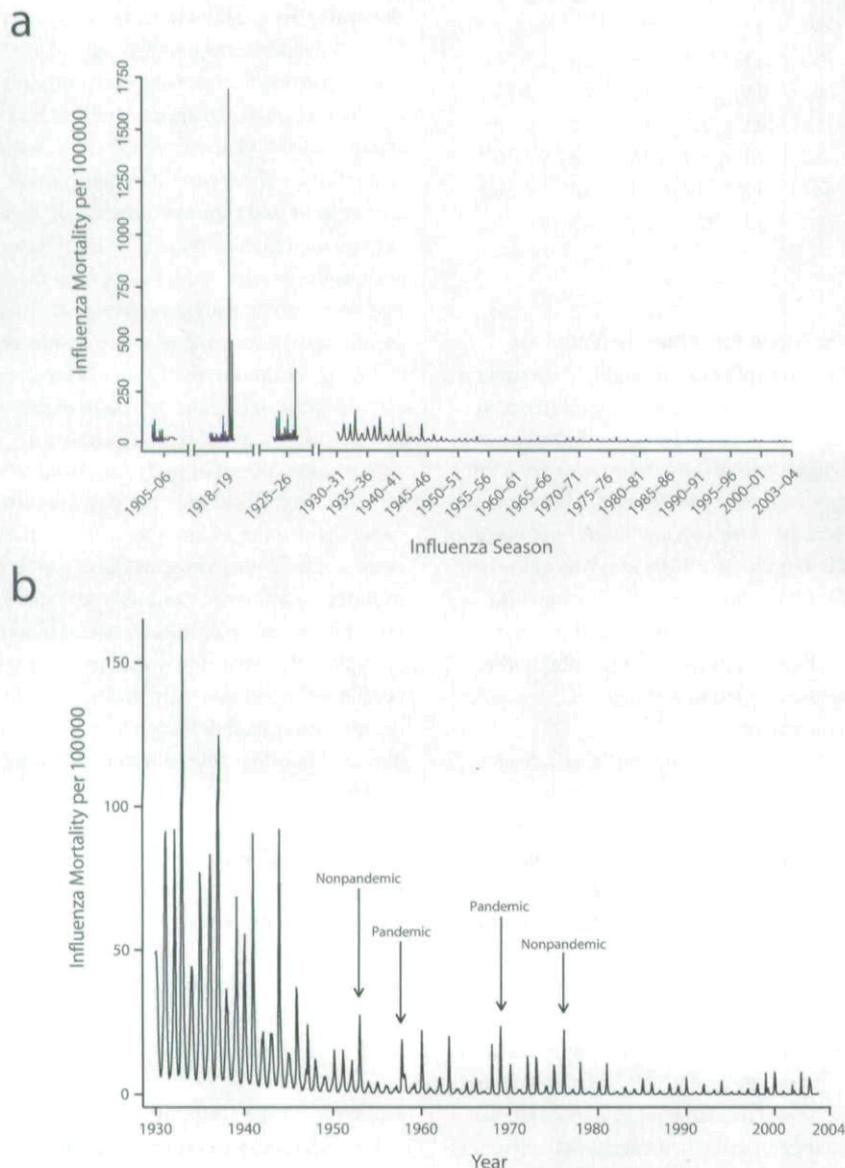
transition.”^{7(p61)} In particular, influenza death rates dropped sharply around the end of World War II (1944–1945; Figure 1).

Similarity Between Pandemic and Nonpandemic Influenza Seasons

With the notable exception of the 1918 pandemic, each influenza pandemic season was less lethal than the prior one, reflecting the overall seasonal trend in influenza deaths. Compared with nonpandemic seasons, the 1957–1958 and 1968–1969 pandemics do not stand out as exceptional outliers, nor were these pandemics visually discernible from nonpandemics in seasonal (Figure 1) or monthly (Figure 2) influenza mortality graphs. In fact, although nonpandemic influenza seasonal death rates never exceeded prior pandemic seasonal death rates, many nonpandemic seasons were *more* deadly than subsequent pandemics. For example, the 1941–1942, 1942–1943, 1943–1944, 1944–1945, 1945–1946, 1946–1947, and 1952–1953 nonpandemic seasons were all deadlier than the 1957–1958 pandemic season. Similarly, the 1959–1960 nonpandemic season was almost as deadly as the 1968–1969 pandemic season (Table 1).

Monthly influenza death rates revealed no trends in the temporal distribution of influenza mortality, for both pandemic and nonpandemic seasons (see figure available as a supplement to the online version of this article at <http://ajph.org>). Influenza-classed deaths occurred most heavily in the winter months, as was expected, but their spread was at times narrow and at other times broad. In the 1967–1968 nonpandemic, for example, the death rate increased from 3.0 deaths per 100 000 population in December to 17.1 per 100 000 in January and declined to 4.2 per 100 000 in February. By contrast, in the 1957–1958 pandemic, the influenza death rate remained above 5.5 per 100 000 population for 6 months, peaking at 18.8 deaths per 100 000 in November. Two years later, however, in the 1959–1960 season, the influenza death rate was elevated only for 3 months, showing that mortality impact can vary widely from season to season (Table 1).

Pandemic years were difficult to distinguish from nonpandemic seasons, even in terms of peak monthly mortality. For example, in



Note. International Classification of Diseases (ICD) revision 1 was used from 1900 to 1909, revision 2 from 1910 to 1920, revision 3 from 1921 to 1929. Comparability ratios are unavailable for revisions 1 to 3. Beginning in 1930, influenza mortality rates have been adjusted for changes in ICD revisions to reflect conditions in the current ICD revision 10.

FIGURE 2—Crude influenza-classed mortality per 100 000 population, by month, for 1900–2004 (a) and 1930–2004 (b), United States.

TABLE 1—Comparison of Adjusted Influenza Death Rates for 12 Influenza Seasons: United States, 1941–1976

Season	Type	Influenza Deaths per 100 000 Population												
		Mean	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1941–1942	Nonpandemic	9.9	3.4	2.8	2.9	5.2	9.7	12.1	18.9	19.5	21.5 ^a	12.7	7.0	3.4
1942–1943	Nonpandemic	10.8	2.7	2.5	3.7	6.9	9.1	14.8	20.9 ^a	19.7	20.8	15.0	8.8	4.4
1943–1944	Nonpandemic	22.2	3.1	3.0	3.2	6.5	9.0	78.8	92.0 ^a	29.4	19.4	11.9	6.6	3.5
1944–1945	Nonpandemic	7.4	2.5	2.5	2.8	5.3	7.2	11.7	14.2 ^a	14.0	12.2	7.1	5.8	3.5
1945–1946	Nonpandemic	11.2	2.2	2.1	3.0	4.3	8.4	36.9 ^a	34.2	19.3	11.6	5.6	4.1	2.6
1946–1947	Nonpandemic	6.9	1.3	1.4	2.0	3.2	4.0	6.7	8.7	7.0	24.0 ^a	18.2	4.8	1.8
1952–1953	Nonpandemic	5.9	0.9	0.7	0.8	1.6	2.2	3.3	19.1	27.1 ^a	9.4	3.5	1.7	0.8
1957–1958	Pandemic	5.4	0.6	0.8	1.7	13.1	18.8 ^a	6.2	5.6	6.9	6.2	2.8	1.2	0.6
1959–1960	Nonpandemic	4.1	0.4	0.4	0.6	0.8	1.1	1.8	10.1	21.9 ^a	9.4	1.9	0.9	0.4
1967–1968	Nonpandemic	2.3	0.2	0.2	0.2	0.4	0.6	3.0	17.1 ^a	4.2	1.2	0.4	0.2	0.2
1968–1969	Pandemic	4.2	0.1	0.2	0.2	0.5	1.0	16.4	23.3 ^a	4.8	2.6	0.9	0.4	0.2
1975–1976	Nonpandemic	3.6	0.2	0.1	0.2	0.3	0.3	0.4	0.8	12.8	22.1 ^a	4.5	0.6	0.3

^aDenotes peak monthly mortality during given season.

March of the 1975–1976 nonpandemic season (the season prior to the swine flu scare), the recorded influenza death rate was 22.1 per 100 000 population, nearly as high as the 1968–1969 pandemic peak of 23.3 per 100 000 in January 1969. Likewise, the influenza monthly mortality rate reached 21.9 per 100 000 in February 1960 (a nonpandemic year), surpassing the peak mortality rate of the 1957–1958 pandemic (18.8 per 100 000) 2 years earlier (Table 1).

DISCUSSION

The heightened concern over the threat of a future influenza pandemic largely rests on the assumption that the hallmark of pandemic influenza is excess mortality. However, this study indicates that the mortality impact of pandemic and nonpandemic seasons has been similar, with considerable overlap in both seasonal and peak monthly mortality rates.

In the 1918–1919 pandemic, which stands out for its high mortality rate, although perhaps 10% to 15% of deaths were attributed to acute respiratory distress syndrome,¹⁷ many if not most of fatal cases are believed to have occurred because of secondary bacterial complications.¹⁸ Had no other aspect of modern medicine but antibiotics been available in 1918, there seems good reason to believe that the severity of this pandemic would have been far reduced.

Implications for Influenza Vaccines

Historical influenza mortality data contain many relevant implications for influenza vaccination campaigns. The overall decline in influenza-attributed mortality over the 20th century cannot be the result of influenza vaccination, because vaccination did not become available until the 1940s and was not widely used until the late 1980s.¹⁹ This rapid decline, which commenced around the end of World War II, points to the possibility that social changes led to a change in the ecology of influenza viruses.

I found that declining mortality rates occurred simultaneously with expanded influenza vaccine coverage since 1980, especially for the elderly (65 years and older).¹⁹ However, recent research suggests that vaccination is an unlikely explanation of mortality trends. A 2005 US National Institutes of Health study of over 30 influenza seasons “could not correlate increasing vaccination coverage after 1980 with declining mortality rates in any age group.”^{19(p265)} Other research has reviewed available international studies of inactivated influenza vaccine effectiveness and efficacy. One study concluded that “evidence from systematic reviews shows that inactivated vaccines have little or no effect on the effects measured.”^{20(p915)} Considered in light of the data presented here, these studies imply that other causes—such as an improvement in living conditions or naturally ac-

quired immunity from similar strains of influenza virus—may have been partially responsible for the declining trends in recorded influenza mortality.

The Multifactorial Nature of Influenza Risk

The present concern over H5N1 avian influenza²¹ has highlighted the degree to which the risk of influenza (particularly pandemic influenza) is being assessed almost solely on the basis of the perceived pathogenicity of influenza viruses. Such a view, however, risks overlooking other significant microbial and nonmicrobial host and environmental factors that influence the course of human disease. The severity and clinical expression of disease depend on a multiplicity of additional factors, such as the novelty of the pathogen to the host, age, cocirculating pathogens, living conditions, physiological status, and access to treatment.

Living conditions, public health measures, physiological status, and access to improved treatments (e.g., antibiotics and antiviral agents) have all significantly improved in the industrialized world over the past century. Naturally acquired immunity from similar strains of influenza virus may also play a role in reducing influenza morbidity and mortality risk. The inability of influenza vaccination to explain the clear downward trend in recorded influenza mortality during the 20th century suggests that these other factors may play an important role in historical influenza epidemiology.

Another possible factor affecting seasonal variation in influenza mortality is the weather, especially cold temperatures.²² The present study of the entire United States, however, considers too large a geographical area to meaningfully test the impact of weather. All of these possibilities require further research.

Hospital Surge Capacity

Beyond vaccines and drugs, increasing the health care infrastructure's capacity is a major feature of many governments' planning for a future pandemic of influenza. Those stressing the importance of erring on the side of caution have pointed to hospital surge capacity as a major concern. Emergency department overcrowding and ambulance redirect orders are

situations that proper planning might help avoid, but it should be kept in mind that such needs are not unique to influenza.

Influenza, like many respiratory viruses, circulates annually, and thus its timing is an important aspect to consider in decisions regarding hospital surge capacity. An influenza season with deaths and hospitalizations spread out evenly over 4 months will tax the medical infrastructure differently than if the same number of hospitalizations and deaths were to occur in a single month.

Compared with annual or seasonal data, the monthly influenza mortality data I used in this study allowed more-detailed analysis of the actual timing of influenza seasons and their impact. In the monthly data from over 70 influenza seasons since the 1930–1931 season (the earliest time for which adjusted figures could be calculated), the peak monthly death rates in the 1957–1958 and 1968–1969 pandemic seasons were no higher than (and were sometimes exceeded by) those for severe nonpandemic seasons (Table 1). If these trends extend into the future, it follows that if the health care infrastructure has been capable of handling nonpandemic influenza, it will also be able to deal with pandemic influenza.

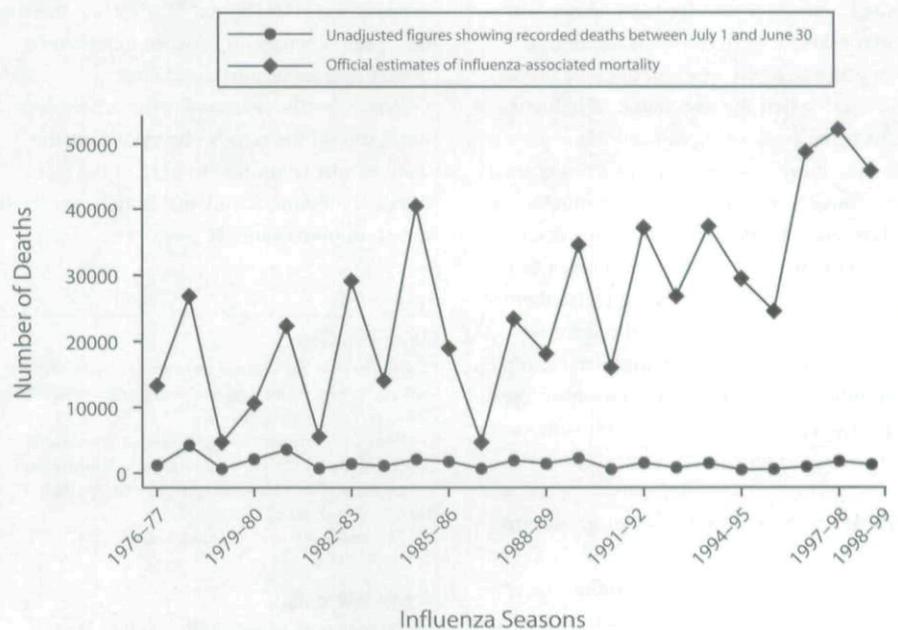
One possible limitation of this study is the lack of any age-specific mortality rates. Over the past decade, there has been some concern that a distinguishing feature of pandemic (vs nonpandemic) influenza seasons is a shift in the age distribution, specifically in the direction of increasing mortality among those younger than 65 years.²³ By contrast, other researchers have found the 1957–1958 and 1968–1969 pandemics to present the usual U-shaped curve of nonpandemic influenza; only the 1918–1919 pandemic exhibited a significantly different age distribution.²⁴ Nevertheless, if an age shift during pandemics is confirmed and of sufficient magnitude, such changes in the mortality distribution may hold relevancy to both public health planning and economic analyses of the impact of pandemic influenza. Because I considered a period for which monthly, age-specific influenza-classed mortality is largely unavailable, this study does not show any potential changes in the age distribution over time.

Assessing the Impact of Influenza

In this study, I have primarily considered the relative (rather than absolute) value of recorded influenza death rate statistics, which allowed me to compare 1 influenza season (or 1 month) with another. The use of the data in this way is supported by the consistent seasonality seen year after year in the monthly recorded influenza death data, which suggests that influenza-classed deaths have a nonrandom distribution. Others have also found recorded influenza-classed deaths to be a good predictor of excess all-cause mortality.²⁵ Nevertheless, knowing the true cause of influenza-classed deaths and developing an accurate numerical assessment of the impact of influenza-related mortality remain problematic.

The CDC⁴ and others²⁶ have argued that recorded influenza deaths underrepresent influenza's true impact on mortality and have offered various statistical models to calculate "influenza-associated mortality." Although the effort to know influenza's true impact is important and relevant from the perspective of

potential public health interventions, there are several points of concern with present modeling efforts. First, current CDC estimates of seasonal influenza-associated mortality consistently dwarf recorded influenza deaths, varying from 5 to 60 times as large. Second, the CDC's model projects that influenza-associated mortality rose 67% from the 1980s to the 1990s; however, over this same period, recorded influenza deaths declined 38%, as shown in Figure 3 and the table available as a supplement to the online version of this article at <http://www.ajph.org>. Third, there are unresolved discrepancies between various published models. For the category "influenza-associated underlying influenza and pneumonia mortality" (a statistic that describes those deaths already classified as caused by influenza or pneumonia but claimed by the CDC to be associated with influenza), the CDC's model estimated around 6000 deaths per season between 1976–1977 and 1998–1999,⁴ but the model of Dushoff et al. estimated over 14 000 deaths per season between 1979 and 2001.²⁶ These



Note. CDC influenza-associated mortality estimates are from Table 2 in Thompson et al.⁴

FIGURE 3—Comparison of total recorded influenza deaths and current Centers for Disease Control and Prevention (CDC) estimates of influenza-associated mortality for the seasons 1976–1977 to 1998–1999, United States.

problems highlight the weaknesses and inconsistencies in present estimates of influenza-associated mortality.

Further complicating the objective of gauging influenza's true impact on mortality is the confusion between influenza and influenza-like illnesses (ILI). Influenza is but one of scores of respiratory viruses and some bacteria that cause ILI. Without laboratory testing, influenza infection is clinically indistinguishable from other ILI.²⁷ Official annual respiratory viral surveillance data for the seasons 1976–1977 through 1998–1999 have shown that a mean of only 12% of “influenza specimens” actually tested positive for influenza virus.⁴ Between 1999 and 2001, there was positive confirmation of influenza virus for fewer than 10% of deaths recorded as caused by influenza. Although this proportion has increased in recent years (14% in 2002, 23% in 2003, 18% in 2004), in the absence of testing, cause of death is still only speculative.

A related problem stemming from the confusion between influenza and ILI is the use of so-called “excess mortality” or “winter mortality” in the computation of influenza's impact. The historical monthly influenza data presented here show that for most seasons, influenza deaths were recorded for almost every month of the year, an unlikely event considering that the circulation of influenza virus is seasonal, not year-round. It is plausible that many cases and deaths from other (i.e., noninfluenza) ILIs are being misclassified as influenza, particularly when they occur during the winter season. A portion of these deaths are probably associated with other viruses such as rhinovirus and respiratory syncytial virus, which sometimes co-circulate with influenza. Moreover, cold weather itself causes upswings in mortality even without the presence of influenza.²²

Explaining the Gap Between Evidence and Fear

The notion that pandemic influenza's fundamental property is excess mortality is difficult to reconcile with the recorded influenza death data over the past century. There are many possible explanations, one of which may be the tendency to generalize the exception—the 1918–1919 pandemic. In 1918, doctors lacked intensive care units, res-

pirators, antiviral agents, and antibiotics, an important fact in light of historical evidence of interactions between influenza and secondary bacterial respiratory pathogens (e.g., *Haemophilus influenzae*) as a significant cause of death during the pandemic.¹⁸

It is also important to recognize that commercial interests may be inflating the perceived impact of influenza and other infectious “pandemics.”²⁸ There is a clear need for more evidence-based accounts of influenza in the context of historical epidemiology and current social and medical advances.

Another possible explanation for the false assumption that pandemics are necessarily more deadly than nonpandemics may lie in an inaccurate understanding—and inconsistent use—of the word “pandemic.” Influenza virus circulates the globe on an annual basis, but is usually not labeled a pandemic until the strain of virus in wide circulation is substantially novel (i.e., it carries a different hemagglutinin or neuraminidase protein than the strains already in circulation). The 1977–1978 season illustrates this confusion, for although the season is not generally recognized as a pandemic, some have called it a pandemic because of the reemergence of the H1N1 virus.^{29(p2535)} Thus, there is no a priori connection between influenza pandemics and exceptional mortality.

Whatever the reasons for the misconceptions, should the trends observed over the 20th century continue to hold in the 21st, the next influenza pandemic may be far from a catastrophic event. ■

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Human Participant Protection

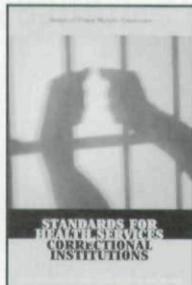
No protocol approval was needed for this study.

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