Timeliness of provisional U.S. mortality data releases during the COVID-19 pandemic: delays are associated with electronic death registration system and weekly mortality

Running title: Timeliness of U.S. mortality data

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Abstract

All-cause mortality counts allow public health authorities to identify populations experiencing excess deaths from pandemics, natural disasters, and other emergencies. Further, delays in the completeness of mortality counts may contribute to misinformation because death counts take weeks to become accurate. We estimate the timeliness of all-cause mortality releases during the Covid-19 pandemic for the dates April 3-September 5, 2020 by estimating the number of weekly data releases of the NCHS Fluview Mortality Surveillance System until mortality comes within 99% of the counts in the March 19, 2021 provisional mortality data release. States' mortality counts take 5 weeks at median (interquartile range 4--7 weeks). The fastest states were Maine, New Hampshire, Vermont, New York, Utah, Idaho, and Hawaii. States that hadn't adopted the electronic death registration system (EDRS) were 4.8 weeks slower to achieve complete mortality counts, and each weekly death per hundred million (range 1-10, median 2) was associated with a 0.8 week delay. Emergency planning should improve the timeliness of mortality data by improving state vital statistics digital infrastructure.

Introduction

Natural disaster mortality is often underestimated (1). Excess mortality greater than the official death counts has been observed from causes including influenza (2), extreme temperatures (3), and hurricanes (4). During natural disasters, pandemics, and other emergencies, policymakers can use estimates of excess mortality to assess the number of deaths that resulted from the emergency and identify populations at continued risk. During the Covid-19 pandemic, the U.S. Centers for Disease Control and Prevention has found that excess mortality exceeds the official Covid-19 mortality count (5). In the early pandemic, Covid-19 was not fully characterized, so Covid-19 deaths may have been under-counted due to underdiagnosed Covid-19 due to low test access including lack of surveillance testing to characterize the disease fully (6), atypical disease presentation, sudden Covid-19 declines (7) and deaths (8), not seeking care because many Covid-19 patients didn't perceive their extent of lung damage (9), or etiologically nonspecific death reporting (10) due to guidelines that limited post-mortem testing (11). Additional excess deaths may be due to delayed healthcare seeking for acute non-Covid-19 conditions such as stroke or heart attack (12).

Excess mortality can provide a more complete impact of a natural disaster than the counts attributed to the emergency because these counts are frequently underestimated . Accurate and timely estimation of excess mortality allows policymakers and clinicians to formulate appropriate responses to mitigate excess mortality, such as providing appropriate guidance about health care seeking for Covid-19 and acute non-Covid-19 illness and encouraging the population to adhere to non-pharmaceutical interventions, such as social distancing and wearing masks (9).

Public health statisticians often estimate excess mortality from weekly provisional all-cause mortality data from the National Vital Statistics System, which exclude deaths not yet reported and are updated in successive weekly releases (16). States differ from each other in the timeliness of death reporting, in part because states vary in the extent of adoption of the Electronic Death Registration System (17). The timeliness of death reporting has improved in recent years: within 13 weeks, all-cause death data were 84% complete in 2015 (16) and 95% complete in 2017 (18). We estimate the time until all-count mortality counts for each state are complete. Past research does not explore a variety of reasons for the timeliness of provisional mortality estimates, so in an exploratory analysis, we also evaluate some potential explanations for timeliness, such as h the extent of electronic death registration adoption, death investigation system, weekly mortality, and state resources measured by GDP and public health budget. The mortality measure of interest is all-cause mortality because weekly all-cause mortality is used to estimate excess mortality for a variety of emergencies.

Methods

Data

We archived 35 weeks of provisional mortality counts by state from the National Vital Statistics System between April 3 and December 4, 2020 from the National Center for

Health Statistics Mortality Surveillance System (i.e., Fluview, https://gis.cdc.gov/grasp/fluview/mortality.html). The provisional mortality count data are updated every Friday. The provisional counts are stratified into 52 jurisdictions: all 50 states, with New York City (NYC) and non-NYC New York State separated, and the District of Columbia included.

Measures

Primary outcome

Our primary outcome is the delay until mortality counts are complete for each of the 23 weeks from April 3-September 5, 2020. This estimation resulted in 1196 mortality delay observations from 52 jurisdictions. We **measure delay as the number of weekly data releases until mortality counts were at least 99% of the counts in the most recent provisional data release: March 19, 2021.** The ending date September 5, 2020 was chosen 12 weeks before the most recent data release at the time of the first analysis, December 4, 2020.

For example, the April 17, 2020 release is the first provisional data release for deaths during the week of April 3, 2020. A 4 week delay until completeness would mean that the provisional count of deaths for April 3 in exceeded 99% of the count in the most recent provisional release 4 weeks later, on May 8.

We assessed the face validity of these mortality reporting delay estimates by comparison with a spaghetti plot for each jurisdiction, where each line represents a weekly release (Supplementary Appendix).

Primary predictor

The primary predictor variable was adoption of the electronic death registration prior to the starting point of this data, which was assessed in two forms: as a binary variable and as an ordered categorical variable. In 2020, prior to the pandemic,4 states did not use electronic death registration (CT, NC, RI, WV) [CITES]; the binary indicator of non-adoption of electronic death registration was coded as 1 for these four states and otherwise 0. In addition to this binary indicator of adoption of electronic death registration, we used an ordered categorical variable from the most recent report of the extent of electronic record adoption assessed in 2018 (8):9 states and New York City (NYC) have fewer than 75% death certificates filed with electronic death registration (AR, CO, MD, MI, MS, NY, PA, TN, VA), and the 38 remaining jurisdictions (37 states and DC) file more than 75% of death certificates with electronic death registration (17). We don't have data about the percentage of death certificates filed electronically, but it is reasonable to believe that the closer jurisdictions get to 100% of death certificates filed electronically, the smaller the delay to mortality count completeness. Electronic death registration implementation was confirmed with each state's public health vital statistics website.

Additional predictor variables

We hypothesized that during weeks with more all-cause deaths, the completeness of mortality counts would have greater delays, due to the resources needed for processing additional deaths; we tested whether weekly deaths or weekly deaths per hundred million were associated with delay. Weekly deaths per population to hundred million ranged from 1-10, with a median of 2, so coefficients were most interpretable on this scale.

We hypothesized that states with more economic resources would have faster death certificate processing because they have more money to upgrade state vital statistics infrastructure. We measured economic resources for the 50 states and the District of Columbia using the Bureau of Economic Analysis's 2018 per capita GDP. Although New York State's delay excludes NYC death certificates, the tax base of New York State includes NYC. We retrieved public health budget per million residents from public records and used it as a separate measure of economic resources.

To assess whether our delay measure is associated with a prior measure of data completeness, we used a 2017 measure of the percent of death certificates available within 13 weeks as a covariate (18).

We also hypothesized that death investigation systems may be associated with delay: medical examiners offices may be more professionalized (19) and thus more efficient than coroners. For deaths that occurred outside a physician's supervision, death investigation systems identify the cause of death. States differ in whether death investigations are centralized in a state office as opposed to being conducted at the county level. States also differ in whether death investigations are conducted by appointed, physician medical examiners or elected coroners, who are usually non-physicians with no special qualifications, except in 4 states (Kansas, Louisiana, Minnesota, and Ohio). Having a medical examiner is a marker of a professionalized death investigation system (19). To assess whether the type of death investigation system was associated with delay, we used the CDC's coding of death investigation system type (20): centralized medical examiner system, county- or district-based medical examiner system, county-based system with a mixture of coroner and medical examiner office, or a county-, district-, or parish-based coroner system. Separately, we included a variable for whether death investigation was based in county/district versus centralized in the state. Separately, we included a variable for the CDC's designation of whether there is a physician state medical examiner; the variable is coded as true for states designated as having a state medical examiner or for states that require a coroner to be a physician and false otherwise (20). New York City, the location with the first centralized medical examiners system in 1918, was coded as having county/district medical examiners and having a medical examiner system (19).

We also evaluated whether the month of the year was associated with delay because states may learn from each other. We created indicators for the month: April, May, June, July. The reference category was August and the first two weeks of September. The April indicator were coded as 1 for dates during April and 0 otherwise, and likewise for the other months. We also used date as a continuous variable.

Statistical Analysis

We used Poisson regression with weeks of delay as the outcome variable, with varying intercept by states (21).. We plotted these varying intercepts for the null model (Figure 1) (22). The residuals were not over-dispersed, based on the estimated dispersion factor for general linear mixed model (23). We estimated the delay associated with paper-based systems using fixed slope and varying intercept regression models (21). The first model used only a binary indicator for no electronic death registration adoption. he second model used a categorical variable for no adoption, less than 75% adoption, and more than 75% adoption assessed in 2017 (17). The models' results yielded similar estimates.

In exploratory analysis using a log-likelihood test to identify variables that improve the fit of the model, we evaluated additional covariates: weekly mortality per hundred million population, state gross domestic product (GDP) per capita, population, state public health budget per capita, the 4-level death investigation variable, whether the state has a medical examiner, whether a state uses only coroners, the 2017 completeness measure, date, and month of the year. Weekly mortality per hundred million population was associated with delay, but the other variables were not.

This study is an analysis of publicly available data from United States federal sources in broad categories such that individuals cannot be identified, so it is not human subjects research and is exempt from requiring human subjects board review. We have made the raw data and code publicly available.

All analyses were performed in R 4.0.3 between April and December 2020 with revisions in March 2021.

Results

On average, all-cause mortality counts take 5.6 weeks to become complete with less than 1% increases subsequently. Figure 1 shows a plot of delay in reporting all-cause mortality count completeness from all 52 jurisdictions, the outcome variable for the regression.

Figure 2 shows the average number of weeks of delay until mortality count completeness for all 52 jurisdictions. The slowest states are North Carolina, Alaska, Connecticut, and West Virginia, which are respectively delayed by 12.4, 11.1, 10.9, and 10.9 weeks on average, and the fastest states are Maine, New Hampshire, and Vermont, which are delayed by 2.5, 2.8, and 3.0 weeks, a gap of almost 10 weeks between the slowest and fastest states.

The jurisdictions with quicker than average time until mortality counts are complete were Pennsylvania, Illinois, Florida, Arizona, Wisconsin, New Jersey, New York City (NYC), Washington, Massachusetts, Hawaii, Idaho, Utah, New York State (excluding NYC), Vermont, New Hampshire, and Maine (Figure 1). The states with average time until completeness are Ohio, Oregon, Texas, Iowa, Wyoming, Minnesota, Mississippi, North Dakota, Virginia, Nebraska, Arkansas, Tennessee, Michigan, South Carolina, Maryland, Kansas, Montana, Colorado, and California (Figure 1).

Adjusted for weekly deaths, the jurisdictions that were quicker than average and average were the same as unadjusted for weekly deaths, but the order changed (Figure 3).

Table 1 shows the regression results predicting delay in mortality count completeness with varying intercept by state. Compared with full electronic death registration adoption (greater than 75% of death certificates reported electronically), states without electronic death registration adoption took 85% longer (1.85, 95% confidence interval (1.31, 2.61)), which translates to 4.8 weeks longer. The delay for states with partial electronic death registration did not differ from states with full electronic death registration adoption.

Weekly deaths per 100 million population ranged from 0.9--9.6 with a median of 1.9 deaths per 100 million; the interquartile range was 1.7 to 2.2 weekly deaths per 100 million population. Each additional weekly death per 100 million population was associated with 14% more weeks of delay (95% CI (1.09, 1.20)), which translates to 0.8 more weeks.

All states that did not yet implement EDRS used a centralized state-based medical examiner. Delay is associated with death investigation system type: centralized state medical examiner offices (median (M) 6 weeks, interquartile range (IQR) 3--9 weeks), county-based mixture of medical examiner and coroner offices (M 5 weeks, IQR 4--6 weeks), county/district-based coroner offices (M 5 weeks, IQR 4--6 weeks), and county/district-based medical examiner offices (M 4 weeks, IQR 4--5 weeks) (Kruskal-Wallis test p<0.001) (Figure 4). The association between death investigation system and delay remained after excluding states that did not implement EDRS (Kruskal-Wallis test p<0.001), but there was no association in the Poisson regression with varying intercept by state.

In Poisson regression with varying intercept by state, delay was also not associated with state resources, per capita GDP, per capita public health budget, all-cause mortality completeness within 13 weeks in 2017, population, date, or month, based on likelihood ratio tests of nested models that included these variables.

Discussion

All-cause mortality is an important metric for estimating deaths due to natural disasters and health emergencies when causes of death may not be coded accurately. Delays in reporting mortality result in provisional counts lower than actual mortality. Perceived risk of disease is an important determinant of health behavior (24), so delays in reaching complete provisional mortality counts may contribute to the pandemic misinformation that Covid-19 mortality was exaggerated (13) and reduce public adherence to non-pharmaceutical interventions such as mask-wearing (14) (9).

These delays in reaching complete mortality counts are not attributable to state resources: high-resource states are no faster than low-resource states. The three slowest states --- North Carolina, Connecticut, and Alaska --- are the 33rd, 4th, and 8th richest states, and the three fastest states, Maine, Vermont, and New Hampshire, are the 43rd, 36th, and 18th richest states.

County-based medical examiner death investigation systems are fastest on average, which may be because medical examiner systems are more professionalized than coroner-based systems (19). State-based medical examiner offices are the slowest at median, so they may be under-staffed relative to county-based offices or require more steps for investigation.

Connecticut and North Carolina began to pilot electronic systems respectively in July 2020 (25) and October 2020 (26). However, our results suggest that substantial delays in all-cause death counts occur even in states that fully implemented electronic death registration. Further, Connecticut's delays decreased in mid-May when mortality decreased, rather than in July when the electronic system began implementation; among Connecticut's 5 weeks with the largest delays (12+ weeks), 4 weeks were also the highest mortality weeks.

Strengths and Limitations

This measure of completeness that we estimate captures delays not captured by previous measures of completeness. Alaska is considered to be a full adopter of electronic death registration (8) with 95% completeness within 13 weeks in 2017 (9), but Alaska was among the slowest states by our measure of number of weeks of delay. Alaska is likely sui generis because it is uniquely disadvantaged among US states by the lack of roads to the most remote locations in the state, which may explain the lack of timeliness.

We could not measure the delay in reporting each death --- that is, the time between a death occurred and the death certificate was counted --- but we were able to assess the delay until mortality counts came within 1% of the count in the March 19, 2021 provisional mortality release.

It is also possible that these delays were due specifically to the Covid-19 pandemic. We do not have access to states' internal documentation regarding death reporting procedures. If states required additional review steps because of the Covid-19 pandemic. After the Covid-19 pandemic, future research can evaluate mortality reporting delays in order to evaluate the need for state reforms to improve timeliness. Also, National Center for Health Certificates reviews death certificates, and if NCHS differentially reviews some states more than others, this differential review could affect delays, rather than the states themselves (27).

The ordered categorical variable for the extent of adoption of electronic death records dated from 2018, which may explain why states categorized in 2018 as filing less than 75% of death certificates electronically did not differ in mortality count timeliness. However, the binary indicator of non-implementation of electronic death records was accurate as of the time of the data in 2020, and the results were the same using this variable (Table 1).

Public health implications

As suggested after earlier pandemics (28), increasing resources to improve the timeliness of mortality data is necessary for pandemic planning. Improving mortality data timeliness will also benefit natural disaster planning, when excess deaths can be used for mortality estimation. The vital statistics infrastructure is under-funded (29). State and federal pandemic planning should seek resolution for delays in mortality reporting so that all-cause deaths can be used to estimate excess deaths to identify areas and populations in need of additional intervention.

The specific features that make a vital statistics system highly efficient likely includes many details that we couldn't measure. Likely, there are many details known primarily to the career civil servants that run state vital statistics systems. States could likely benefit from consulting more efficient but otherwise similar states. For example, Utah has substantially lower delay than 4 of its 6 neighboring states.

Funeral directors, who enter demographic information, adopted electronic death registration quickly, but medical examiners have lagged (17). California and Arizona allowed electronic death registration submissions by fax machine (17), and our analysis found that these states were faster than average. States that consider unconventional approaches for electronic death registration submission that meet the needs of all stakeholders may have similar success.

The CDC includes percent completeness metrics in the Mortality Surveillance System, defined as the number of deaths divided by the average number of deaths from the most recent 4 years. This completeness measure cannot measure completeness accurately during a period of excess deaths, which is when these measures are most crucial and subject to the most public scrutiny. Data completeness measures that can remain accurate during periods of high mortality may reduce misinformation, such as claims that mortality counts are exaggerated.

Conclusions

This exploratory analysis found that the time for states' provisional mortality counts to become complete varies greatly between states: the quickest states had complete provisional mortality counts within 4 weeks, and the slowest states took 3 times as long as the fastest states. Three of the slowest states have adopted the electronic death registration systems since these data were collected. Given the importance of provisional mortality counts to understand excess mortality during health emergencies, all states should improve the timeliness of vital statistics reporting by replicating more efficient states with similar characteristics. Funding to improve vital statistics infrastructure should be included in emergency planning budgets because vital statistics systems are crucial for understanding all emergencies that increase mortality.

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Figure 1: Delay in mortality reporting by date and adoption of electronic death registration system, compared with average (dotted line)

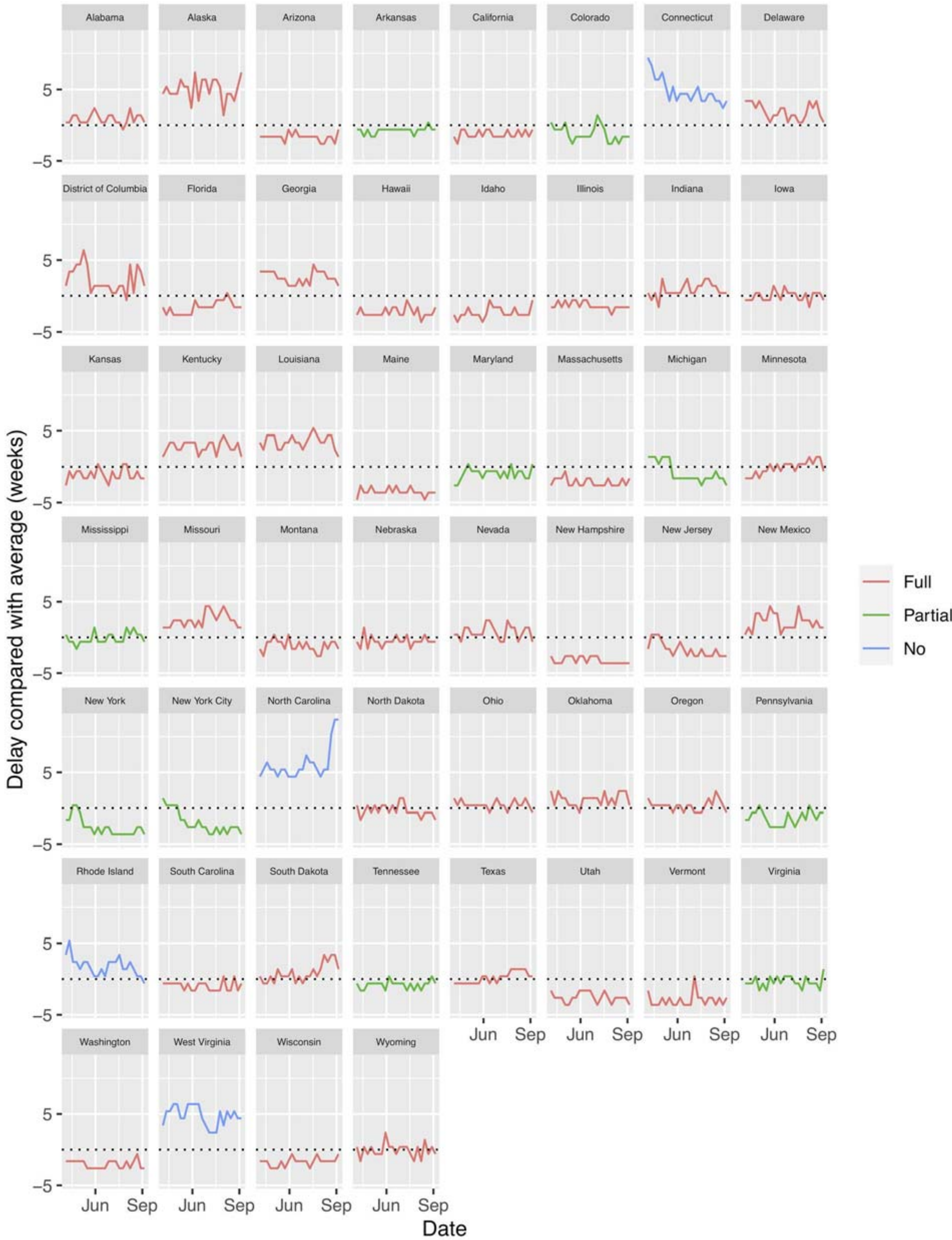


Figure 2: Weeks until all-cause mortality counts are complete for April 3-September 5, 2020. The red line shows the mean delay.

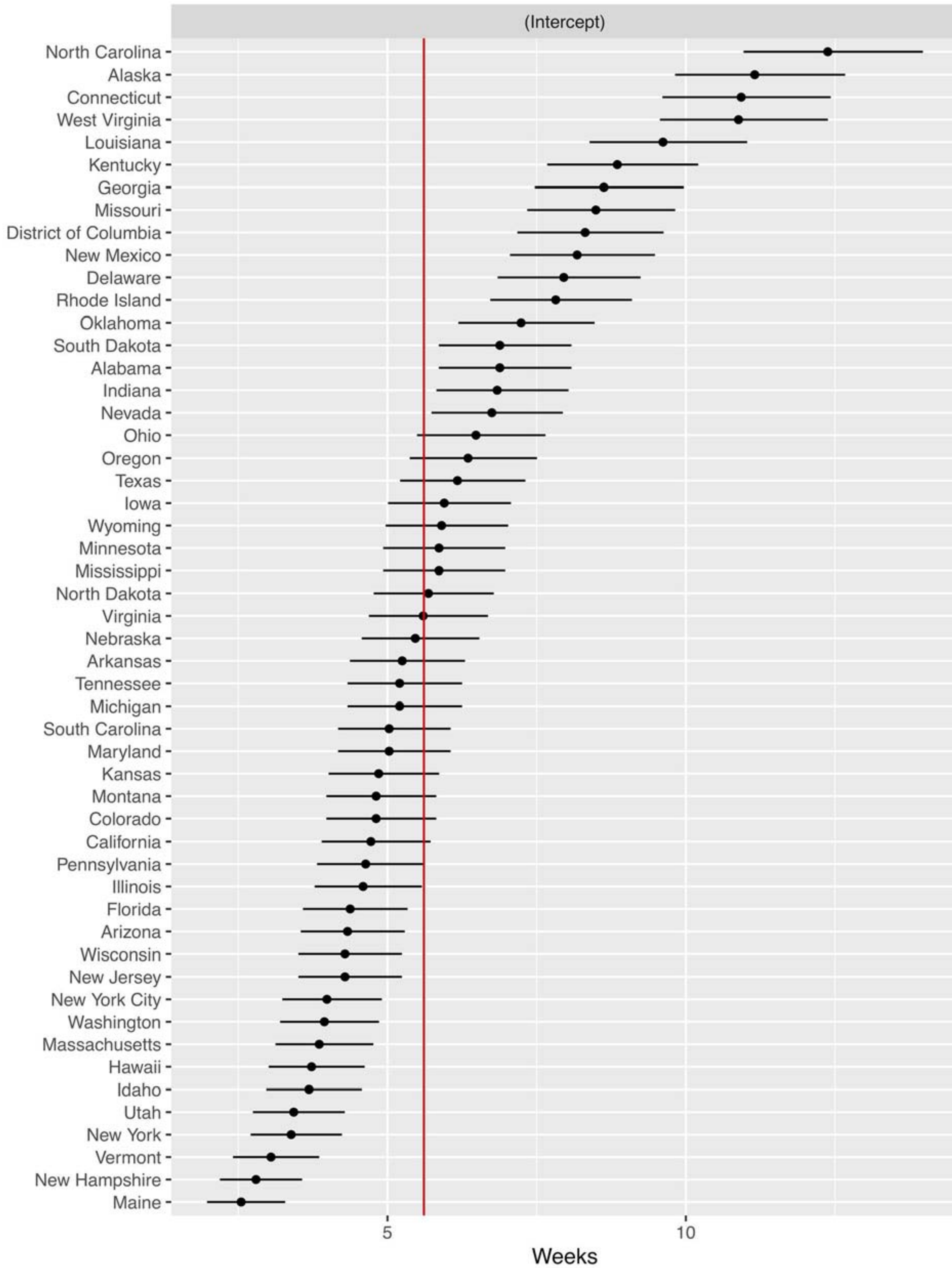


Figure 3: Weeks until all-cause mortality counts are complete for April 3-September 5, 2020, adjusted for deaths per population. The red line shows the mean delay.

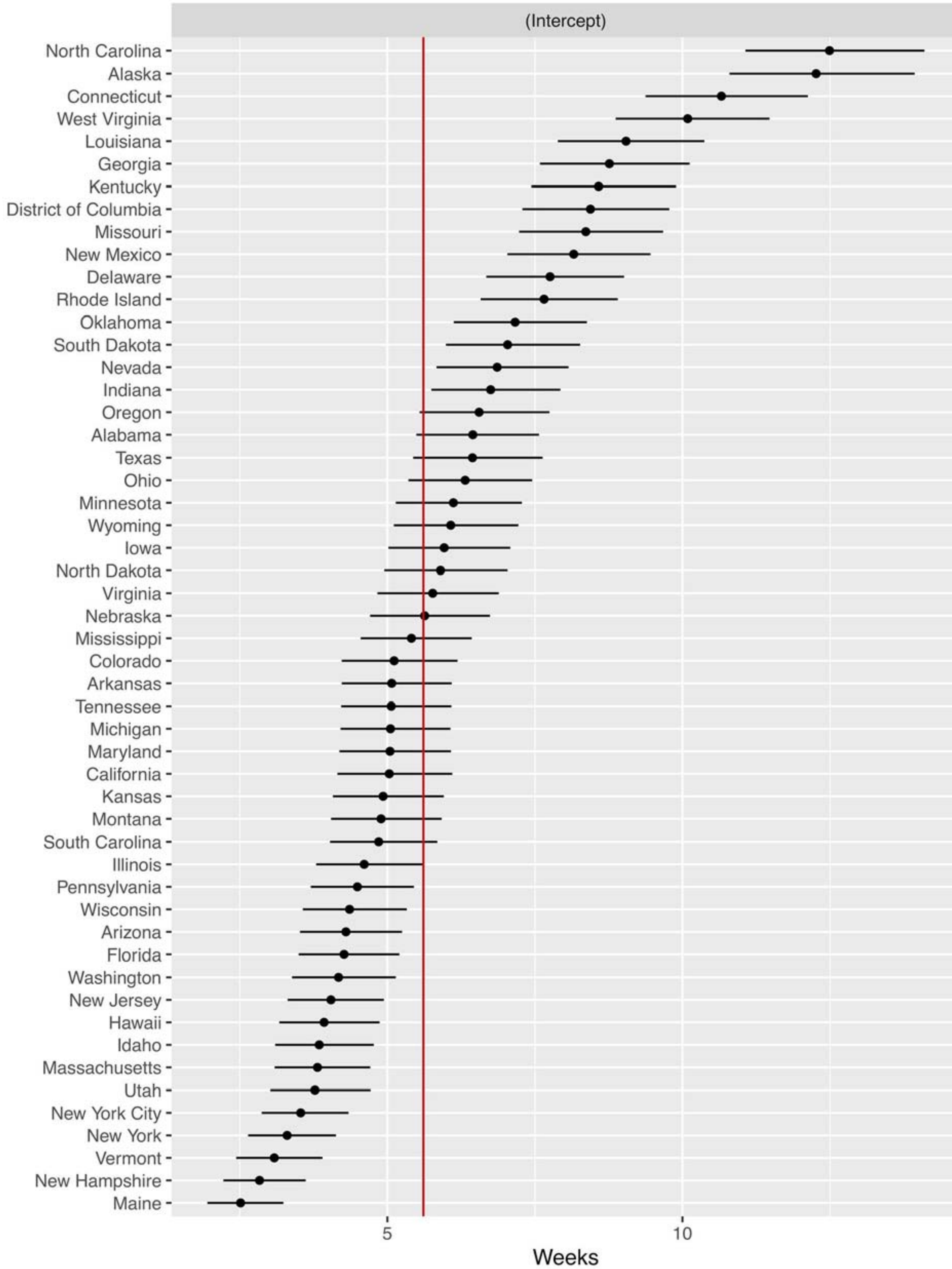
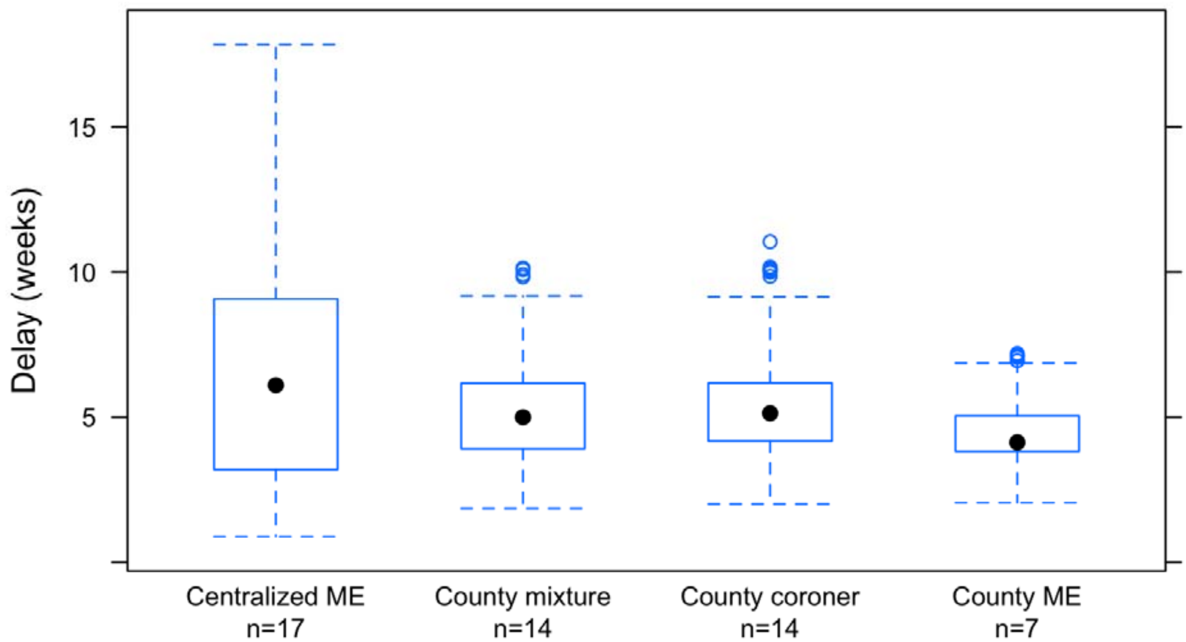


Table 1: Poisson regression to predict delay in mortality reporting with varying intercept by state (n=1196 observations of 52 jurisdictions)

	IRR	95% CI	p	IRR	95% CI	p
Intercept	3.96	(3.42, 4.56)	<0.001	3.83	(3.34, 4.40)	<0.001
Weekly deaths per 10^8	1.14	(1.09, 1.20)	<0.001	1.14	(1.08, 1.20)	<0.001
Full adoption of electronic death registration system	Ref.					
Partial adoption of electronic death registration system	0.84	(0.66, 1.06)	0.1			
No adoption of electronic death registration system	1.85	(1.31, 2.61)	<0.001			
Any adoption of electronic death registration system				Ref.		
No adoption of electronic death registration system				1.92	(1.31, 2.64)	<0.001

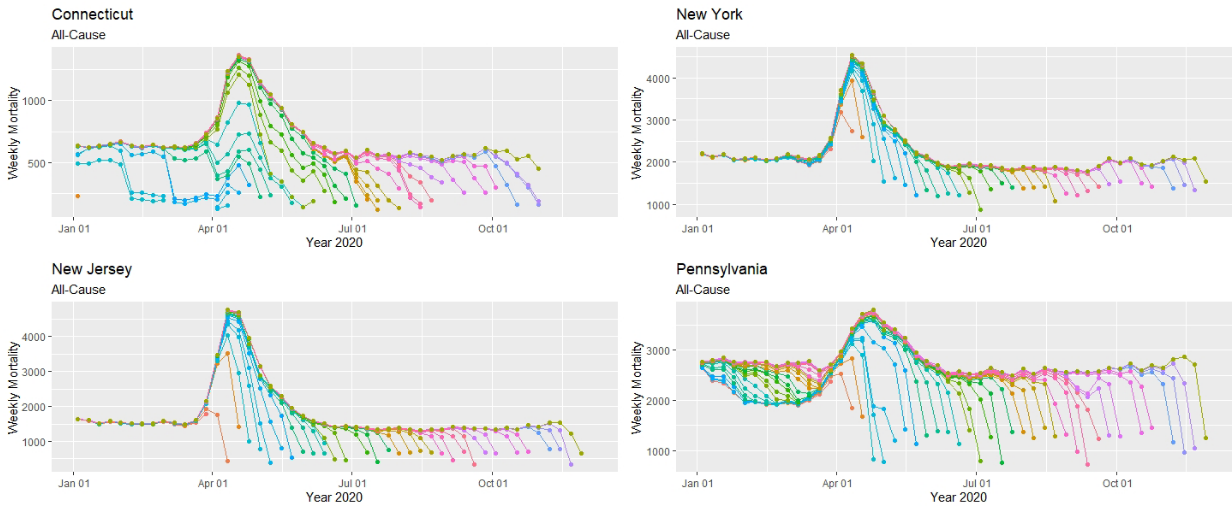
IRR = incidence rate ratio, exponentiated coefficients of Poisson regression
95% CI = 95 percent confidence interval

Figure 4: Association between death reporting system and weeks of delay (n=52: 50 states, NYC, and DC).



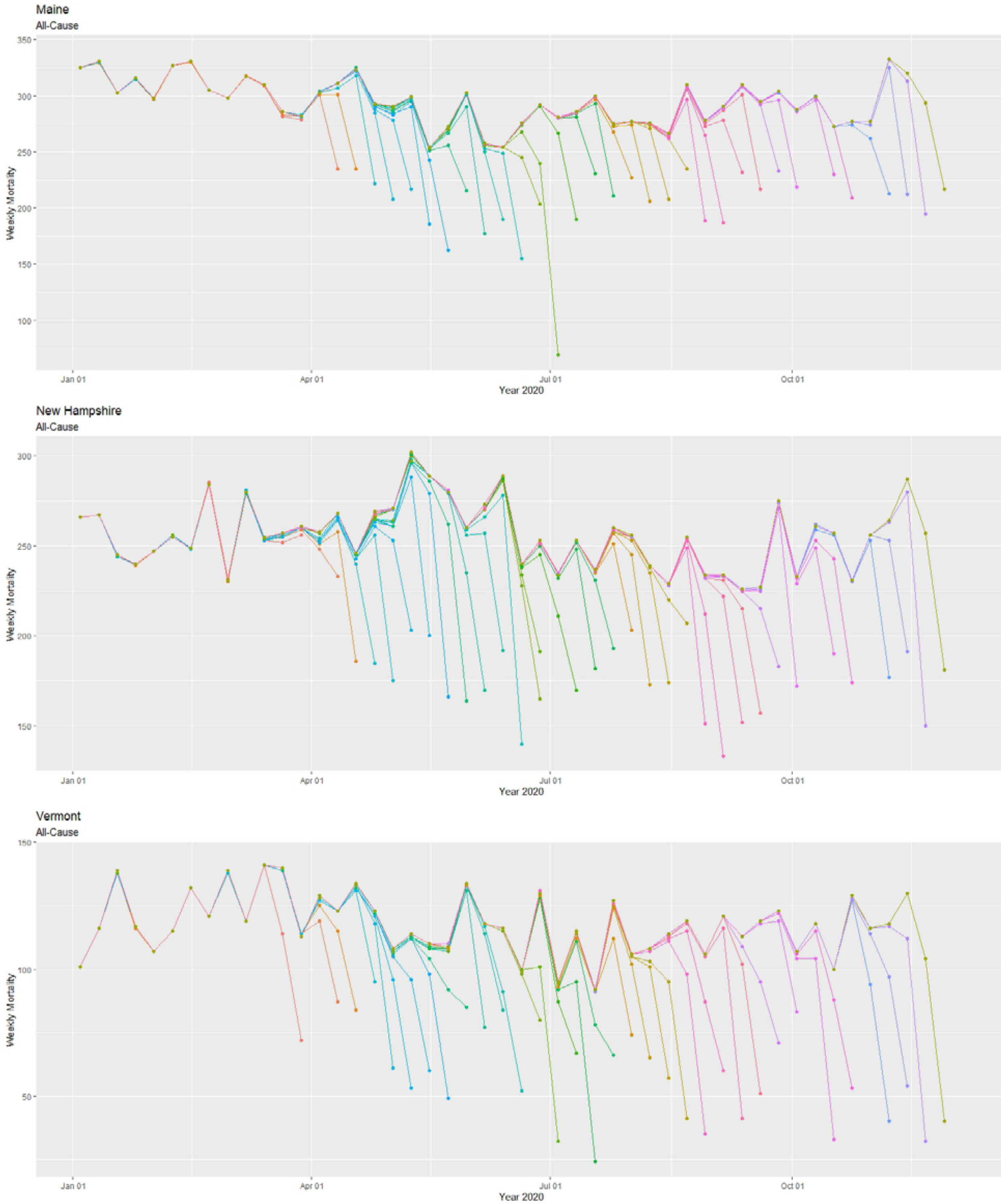
Centralized ME: Centralized state medical examiner office (median (M) 6 weeks, interquartile range (IQR) 3--9 weeks, n=17)
County mixture: County-based mixture of medical examiner and coroner offices (M 5 weeks, IQR 4--6 weeks, n=14)
County coroner: County/district-based coroner offices (M 5 weeks, IQR 4--6 weeks, n=14)
County ME: County/district-based medical examiner offices (M 4 weeks, IQR 4--5 weeks, n=7)

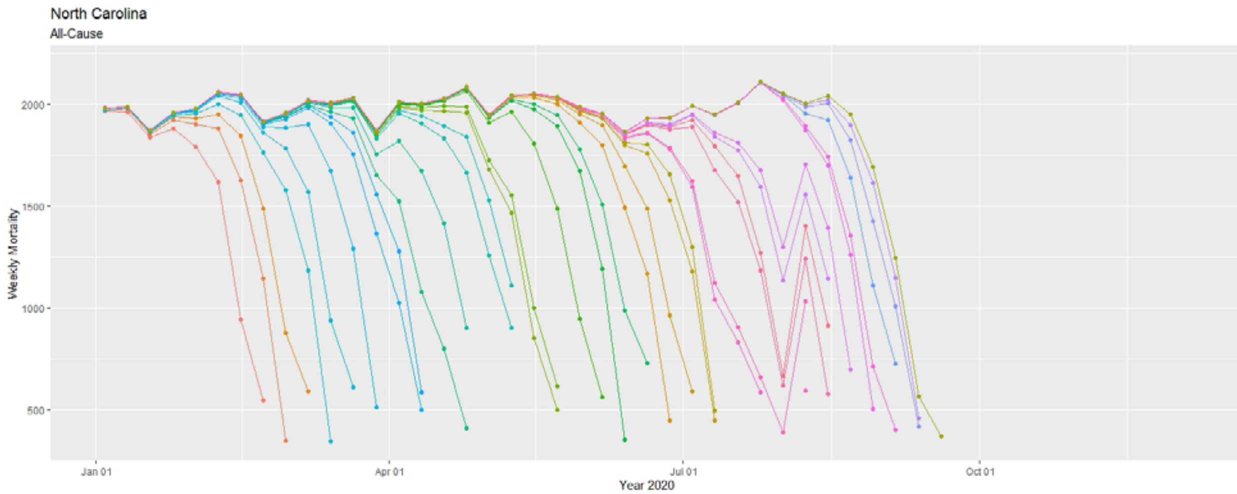
Supplementary Figure 1: Spaghetti plot of weekly releases of all-cause mortality for four states in the same region: Connecticut reports deaths 4.8 weeks slower than average, and New York State (minus New York City), New Jersey, and Pennsylvania report deaths 2.5, 1.6, and 1.3 weeks faster than average.

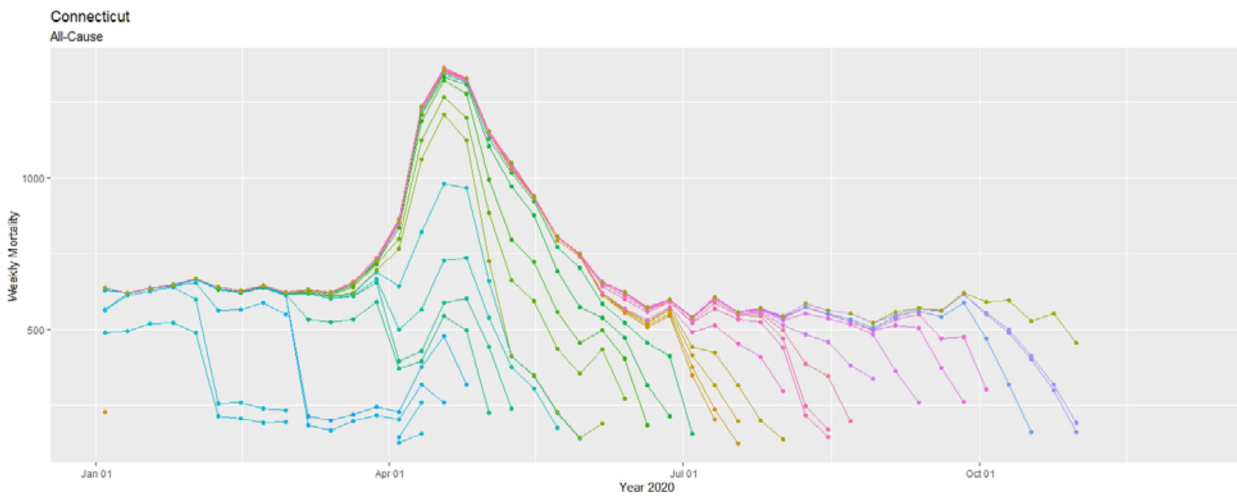


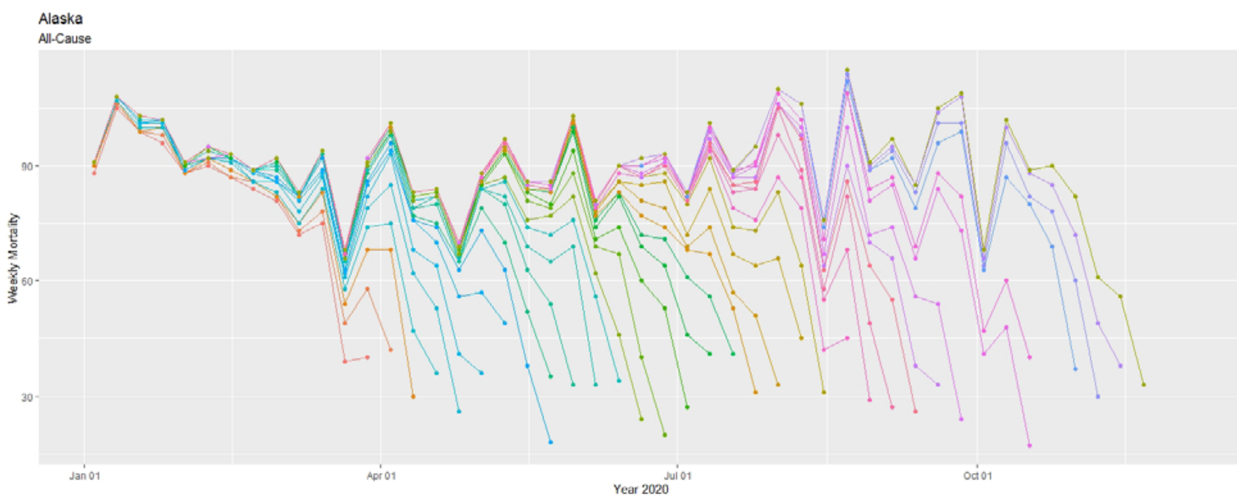
Each data point represents a provisional mortality count for that date. Each color line represents each of the 35 data releases between April 17, 2020 and December 4, 2020 in chromatic order; the chromatic order is used instead of a legend for each of the 35 colors.

Supplementary Figure 2: Spaghetti plot of weekly releases of all-cause mortality for the three fastest states and three slowest states. Each data point represents a provisional mortality count for that date. Each color line represents each of the 35 data releases between April 17, 2020 and December 4, 2020 in chromatic order; the chromatic order is used instead of a legend for each of the 35 colors




North Carolina
All-Cause
Weekly Mortality
500
1000
1500
2000
Jan 01
Apr 01
Jul 01
Oct 01
Year 2020


Connecticut
All-Cause
Weekly Mortality
500
1000
Jan 01
Apr 01
Jul 01
Oct 01
Year 2020


Alaska
All-Cause
Weekly Mortality
30
60
90
Jan 01
Apr 01
Jul 01
Oct 01
Year 2020