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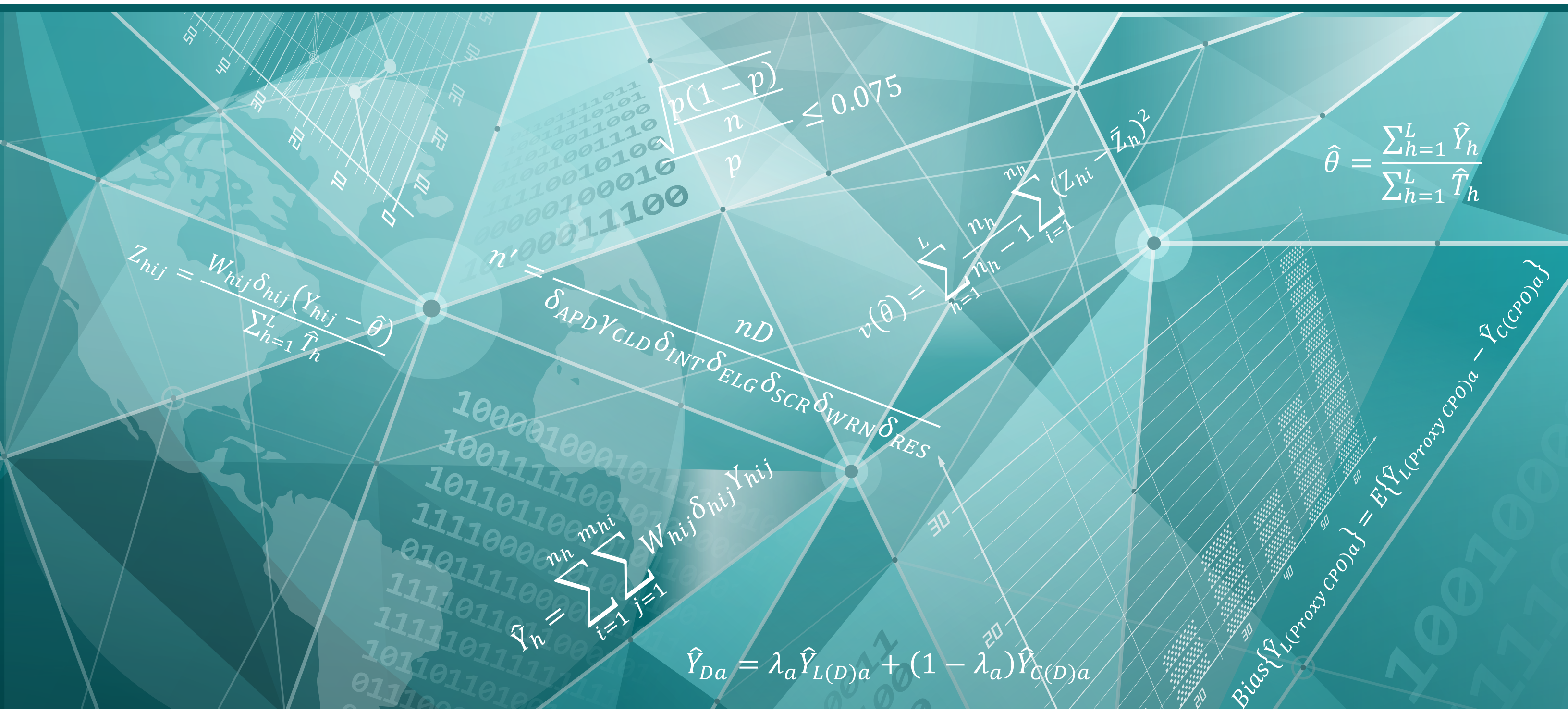

Evaluation of the National Center for Health Statistics Data Presentation Standards for Rates From Vital Statistics and Sample Surveys

Data Evaluation and Methods Research

Centers for Disease Control and Prevention
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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
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Evaluation of the National Center for Health Statistics Data Presentation Standards for Rates From Vital Statistics and Sample Surveys

by Makram Talih, Ph.D., Katherine E. Irimata, Ph.D., Guangyu Zhang, Ph.D., and Jennifer D. Parker, Ph.D.

Abstract

Background

The National Center for Health Statistics (NCHS) recently developed multistep standards for the presentation of rates (referred to as the "Standards"). Statistically reliable rates have a sample size or effective sample size of 10 or more for both numerator and denominator, a relative width of 160% or less for appropriate 95% confidence intervals (CIs), and, when applicable, degrees of freedom of 8 or higher.

Objectives

For the CIs used in the Standards for rates from vital statistics and complex health surveys, this report evaluates coverage probability, relative width, and the resulting percentage of rates flagged as statistically unreliable when compared with previously used standards. Additionally, the report assesses the impact of design effects and the denominator's sampling variability, when applicable.

Methods

Case studies and simulations using data from the National Vital Statistics System and the National Ambulatory Medical Care Survey were implemented.

Results

The gamma-based 95% CIs used in the Standards for crude and age-adjusted vital rates maintained nominal coverage, while the 160% threshold for their relative widths remained consistent with a sample size of 10 or more. Log Student's *t* CI used for period- and cohort-linked infant mortality rates also maintained nominal coverage, even as the correlation between numerator and denominator varied. Simulations that varied in numerator sample size, survey weight variability, and denominator variance showed that log Student's *t* CIs used for health care surveys retained nominal coverage when the effective sample size was 10 or more and the relative CI width was at most 160%. More rates were presented under the multistep NCHS standards than would be presented under standards that relied on sample size alone or in addition to relative standard error.

Conclusion

The CIs used in the Standards maintain nominal coverage in representative simulation studies and, on average, lead to statistically reliable rates being presented for more granular data than under previously used standards.

Keywords: gamma confidence interval • log Student's *t* confidence interval • statistical reliability • population subgroups • National Vital Statistics System • National Health Care Surveys

Introduction

The National Center for Health Statistics (NCHS) disseminates information on a broad range of health topics through diverse publications. The use of clear and thorough presentation standards is essential to inform users of NCHS products about the statistical reliability (or lack of reliability) of published estimates. NCHS released the "National Center for Health Statistics Data Presentation Standards for Proportions" (1) and the "National Center for Health Statistics Data Presentation Standards for Rates and Counts" (2). These reports present the criteria and rationale for determining whether to publish a proportion (or percentage), rate, or count in NCHS reports and other products based on statistical reliability.

As with the NCHS standards for proportions, the NCHS standards for rates and counts (referred to as the “Standards”) required extensive methodological and analytic evaluations before they were finalized. Rates are disseminated by NCHS principally in two areas: vital statistics (death and birth rates) (3,4) and health care visits (hospitalization and ambulatory care visit rates) (5,6). The Standards include criteria for assessing rates from both data sources (2). Consequently, this report describes case studies and simulations using data from the National Vital Statistics System (NVSS) and the National Ambulatory Medical Care Survey (NAMCS) that were implemented to evaluate the criteria used in the Standards for determining the statistical reliability of rates.

Definition of Rates

A rate is defined as the number of events for a population (numerator) divided by a count for the population at risk (denominator). Rates are usually expressed per population size. The number of events (numerator) is usually estimated from vital records or a survey. The population at risk (denominator) typically is based on census decennial estimates or postcensal or intercensal estimates (3–6). In these cases, the denominator is relatively free of sampling variability. The population at risk also can be a count obtained from a population survey, such as the U.S. Census Bureau's American Community Survey (7) or the National Health Interview Survey (NHIS) (8). In these cases, the denominator is subject to sampling variability, which impacts calculations of measures of variability around the rate.

Even when the number of events in the numerator or the size of the population at risk in the denominator is recorded and free from sampling variability, realized values are subject to random variability (9). The number of vital events is traditionally assumed to follow a Poisson distribution (10). In practice, the variability of denominators that are enumerated from a decennial census or postcensal or intercensal population estimate is negligible and does not need to be considered in calculations.

Rates at NCHS

Rates regularly produced from NVSS and the National Health Care Surveys include birth and death rates (3,4), and hospital and health care provider visit rates (5,6), respectively. For rates from NVSS, the counts in the numerator are obtained from the register of events. For rates from the National Health Care Surveys, the counts in the numerator are estimated using appropriate statistical methods for complex surveys. In most cases, the denominator for rates from NVSS and the National Health Care Surveys is a decennial census or postcensal or intercensal population estimate, whose variability is negligible in calculations. However, for rates from NVSS for some population subgroups (by Hispanic origin, marital status, or education level), the denominator is estimated from a complex survey such as the American Community Survey or the Census Bureau's Current Population Survey (7,10). Similarly, for condition-specific visit rates from the National Health Care Surveys, the denominator can be estimated from a complex survey such as NHIS (8). In those cases, calculations need to account for the nonnegligible sampling variability of the denominator.

Previous NCHS Presentation Standards for Rates

Unlike the multistep approach used in the Standards, summarized in the next section, previous presentation standards for NVSS relied only on sample size or only on the relative standard error (RSE). RSE is calculated as the standard error divided by the estimate, and is expressed as a percentage. When using decennial census or postcensal or intercensal population denominators, rates were presented when the numerator was based on 20 events or more (3). This threshold of 20 events for vital rates corresponded to an RSE of 23%, assuming a Poisson distribution. When using census population denominators that were estimated from the Current Population Survey or American Community Survey, RSE was calculated to account for the sampling variability of the denominators, and rates were presented when their RSE was less than 23% (10).

Age-adjusted death rates, which are weighted averages of age-specific rates with weights taken proportional to the relative sizes of the underlying age groups in a reference population, were treated similarly and presented if the number of events on which the rate was based was 20 or more, or, when the denominator population was estimated from a complex survey, when their RSE was less than 23% (3,10–12).

Denominators for most of the rates that were estimated from the National Health Care Surveys are census population counts, whose variability is negligible in calculations. Previous presentation standards for rates from the National Health Care Surveys were based on sample size and RSE. Rates were presented when 30 or more sample observations were in the numerator, but they were flagged as statistically unreliable if their RSE was greater than 30% (referred to informally as the 30/30 rule) (5,6).

Current NCHS Presentation Standards for Rates

Table A summarizes the Standards as they apply to rates. Once the sample size criteria described in the first row of Table A are met, the Standards are based on a relative width of 160% or less for an appropriate 95% CI. As summarized in Table B, different approaches for calculating 95% CIs are needed for vital statistics and complex health surveys, as well as for different types of denominators, to ensure nominal coverage (0.95 or greater probability that a 95% CI covers the true value). The CI calculations described in

Table A. Current National Center for Health Statistics presentation standards for rates

Statistic	Standard
Sample size threshold	Estimated rates should be based on a minimum sample size and effective sample size (when applicable) of 10 in both the numerator and in the denominator.
Confidence interval	If the sample size criteria are met, calculate a 95% two-sided confidence interval using the appropriate method (see Table 2 in this report) and obtain its relative width. Estimated rates should have a relative confidence interval width of 160% or lower.
Degrees of freedom	When applicable for complex surveys, if the sample size and confidence interval criteria are met for presentation and the survey degrees of freedom are fewer than 8 for either the numerator or the denominator, then the rate should be flagged for statistical review by the clearance official. This review may result in presentation or suppression of the rate.

SOURCE: National Center for Health Statistics Data Presentation Standards for Rates and Counts, 2023.

Table B. Current National Center for Health Statistics presentation standards for rates: Confidence interval calculation, by data system and type of denominator

Data system	Type of denominator	Confidence interval calculation
National Vital Statistics System	Variability of the denominator is negligible: Denominator can be treated as a constant in calculations.	Calculate 95% gamma confidence interval where the lower limit is the 0.025 quantile of the standard gamma, where x = number of events and with the parameters $\alpha = x$ and $\beta = 1$. The upper limit is the 0.975 quantile of the standard gamma with parameters $\alpha = x + 1$ and $\beta = 1$. The Fay–Feuer approximation should be applied for age-adjusted vital rates.
	Denominator is from the American Community Survey, the Current Population Survey, or another population survey, with nonnegligible sampling variability.	Calculate a 95% Student's t confidence interval for the logarithm of the rate with variance estimated using method supplied with survey data source. The confidence interval for the rate is obtained by reverse-transformation. Confidence interval for age-adjusted rates can be formed using weighted combinations of age-specific estimates.
	Denominator is from births file and is subject to nonnegligible random variation, such as for period- or cohort-linked infant mortality.	Calculate a 95% Student's t confidence interval for the logarithm of the rate, accounting for the denominator's Poisson variance. The confidence interval for the rate is obtained by reverse-transformation.
Complex health surveys	Variability of the denominator is negligible: Denominator can be treated as a constant in calculations.	Calculate a 95% Student's t confidence interval for the logarithm of the rate. The confidence interval for the rate is obtained by reverse-transformation. Confidence interval for age-adjusted rates can be formed using weighted combinations of age-specific estimates.
	Denominator is from other population surveys, with nonnegligible sampling variability.	Calculate a 95% Student's t confidence interval for the logarithm of the rate, accounting for the denominator variance. The confidence interval for the rate is obtained by reverse-transformation. Confidence interval for age-adjusted rates can be formed using weighted combinations of age-specific estimates.

SOURCE: National Center for Health Statistics Data Presentation Standards for Rates and Counts, 2023.

Table B are detailed in "National Center for Health Statistics Data Presentation Standards for Rates and Counts" (see reference 2, Appendix I).

This report describes the series of simulations and case studies from vital statistics and NAMCS that were implemented to evaluate the criteria used in the Standards for determining the statistical reliability of rates. The simulations and case studies investigate whether the nominal coverage probability is maintained by the 95% CIs used in the Standards (Table B); whether the 160% threshold for their relative widths (Table A) is necessary, consistent across various settings, and concordant with sample size-based rules of thumb; and whether the resulting percentage of rates flagged as statistically unreliable is generally lower, indicating that more estimates would be presented when compared with previously used standards. The section "Evaluation of Standards for Rates From Vital Statistics" compares gamma CI thresholds for crude and age-specific rates to related metrics, summarizes results of a simulation examining Fay–Feuer gamma CI thresholds for age-adjusted death rates, and evaluates log Student's t CI for the period- and cohort-linked infant mortality rates. The section "Evaluation of Standards for Rates From Sample Surveys" evaluates log Student's t CI for rates from NAMCS under various conditions, including varying sample sizes generated from different survey cycles; assesses the impact of alternative approaches for calculating the design effect; and evaluates log Student's t CIs for age-specific and age-adjusted rates when both the numerator and denominator are subject to sampling variability.

Additionally, this report compares the percentage of estimates that are presented under the Standards with the percentage of estimates that would be presented under a sample size-based standard alone or in addition to an RSE criterion, as in the previous presentation standards for rates. For vital statistics, sparse county-level mortality data by race and Hispanic origin are used for illustration (13). For rates from NAMCS, the percentages of statistically unreliable rates are evaluated from the previous simulations (see “Evaluation of Standards for Rates From Sample Surveys”).

Evaluation of Standards for Rates From Vital Statistics

CI Thresholds for Crude and Age-specific Vital Rates

Thresholds for crude and age-specific vital rates are based on the direct correspondence between the CI width and the sample size, which are related in a closed-form mathematical expression when the underlying distribution is a Poisson distribution (14,15).

Figure 1 compares numerator-based and CI-based thresholds for the presentation of crude and age-specific death rates where the number of deaths (numerator) is assumed to follow a Poisson distribution, and the denominator is relatively free of random variation. The corresponding RSE is shown for context. For Figure 1, the “exact” gamma 95% CI is calculated as shown in Table B and described in “National Center for Health Statistics Data Presentation Standards for Rates and Counts” (see reference 2, Appendix I).

In Figure 1, the number of deaths is on the *x* axis and the corresponding percent RSE and relative CI width are shown on the *y* axis. The vertical line at $x = 20$ indicates the previous guidelines for presenting crude and age-specific rates whenever the total number of underlying events was 20 or greater. At $x = 20$, the corresponding RSE is 22.4%, and the corresponding relative width for the gamma CI is 93.4%. The vertical line at $x = 10$ identifies the current Standards for rates. At $x = 10$, the RSE is 31.6%, and the relative CI width is 135.9%, which is well below the 160% threshold from Table A.

CI Thresholds for Age-adjusted Vital Rates

The Fay–Feuer 95% CI (16) is used in the Standards for age-adjusted vital rates; see Table B. Unlike for crude and age-specific vital rates, no direct correspondences between the Fay–Feuer CI thresholds and the RSE or number of events can be made for age-adjusted vital rates. No closed-form mathematical expressions exist to relate the Fay–Feuer CI width to either the RSE or the number of events on which the age-adjusted vital rate is based. Consequently, results here are based on simulation.

Simulated data were based on the median annual crude and age-specific all-cause death rates in the United States from 2010 to 2019. The crude all-cause death rate was estimated at 833.8 per 100,000 population. For each age group, under 1 year, 1–4, 5–14, 15–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75–84, and 85 and over (17), the corresponding median annual probabilities of death were estimated as 0.009, 0.001, 0.002, 0.011, 0.018, 0.028, 0.066, 0.132, 0.181, 0.239, and 0.313, respectively. Figure 2 shows the comparison between numerator-based and CI-based thresholds for statistical reliability of age-adjusted death rates, where age-specific numerators are Poisson-distributed, and denominators have negligible variances and are treated as constants. Under the previous guidelines for presenting age-adjusted rates whenever the total number of underlying events was 20 or greater, the corresponding RSE and relative Fay–Feuer CI are approximately the same as for the age-specific rates, described previously. For presenting rates with 10 underlying events or more, corresponding to the sample size criteria in the current Standards, the corresponding RSE is about 33.3%, and the relative width of the Fay–Feuer CI is approximately 160%, which is the threshold used in the Standards; see Table A.

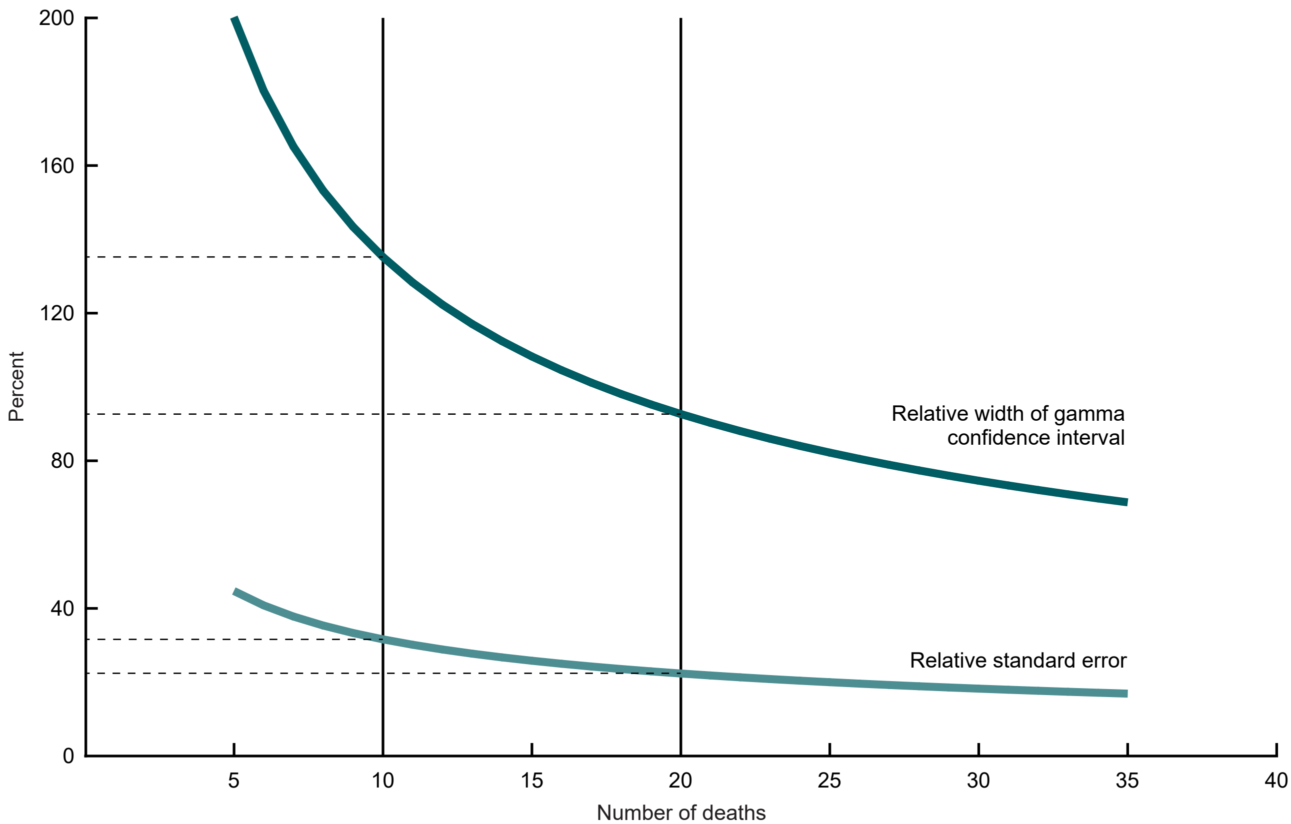
CI Thresholds for Infant Mortality Rates

As described in “National Center for Health Statistics Data Presentation Standards for Rates and Counts” (see reference 2, Appendix I), an infant mortality rate may be seen as a ratio X / Y of Poisson random variables, and log Student's *t* 95% CI is used to ensure adequate coverage; see Table B. A simulation study was conducted to allow the numerator X and the denominator Y to arise from a bivariate Poisson model (18), and to allow for varying the degree of correlation between X and Y to assess its impact on the relative width and coverage of log Student's *t* CI.

Note that for most rates produced by NCHS, the correlation between X and Y in the ratio X / Y is generally expected to remain nonnegative (for example, the number of events in the numerator increases as the population at risk in the denominator increases). As a result, the calculation of the second-order Taylor series approximation (19) for the variance of the ratio X / Y can be simplified by dropping the covariance term, resulting, at worst, in a conservative (larger) estimate of variance and a wider CI. If in some exceptional circumstances, or for other ratio estimators, the correlation between X and Y is negative, then the covariance term should not be dropped because the resulting variance estimate for ratio would be anticonservative.

Table 1 shows simulated relative widths and coverage probabilities for log Student's *t* 95% CI for the ratio $R = X / Y$ when X and Y are generated from a bivariate Poisson model with varying degrees of nonnegative correlation. Poisson

Figure 1. Comparison between numerator-based, relative standard error-based, and confidence interval-based criteria for statistical reliability of crude and age-specific death rates



NOTES: Vertical solid lines at 10 and 20 deaths indicate the current and previous numerator-based criteria for statistical reliability, respectively. Horizontal dotted lines are leader lines indicating the y-axis values (percent) corresponding to the points of intersection of the curves traced by the relative standard error and relative gamma confidence interval width values with the two vertical lines.
SOURCE: National Center for Health Statistics.

counts were truncated to ensure the minimum sample size criteria $X \geq 10$ and $Y \geq 10$ described in Table A are met. On average, relative CI widths remained well below the 160% threshold used in the Standards, and coverage probabilities remained at or above 0.95. RSEs also shown in Table 1 for comparison generally remained at or below the 30% cutoff used elsewhere in RSE-based presentation standards.

Evaluation of Standards for Rates From Sample Surveys

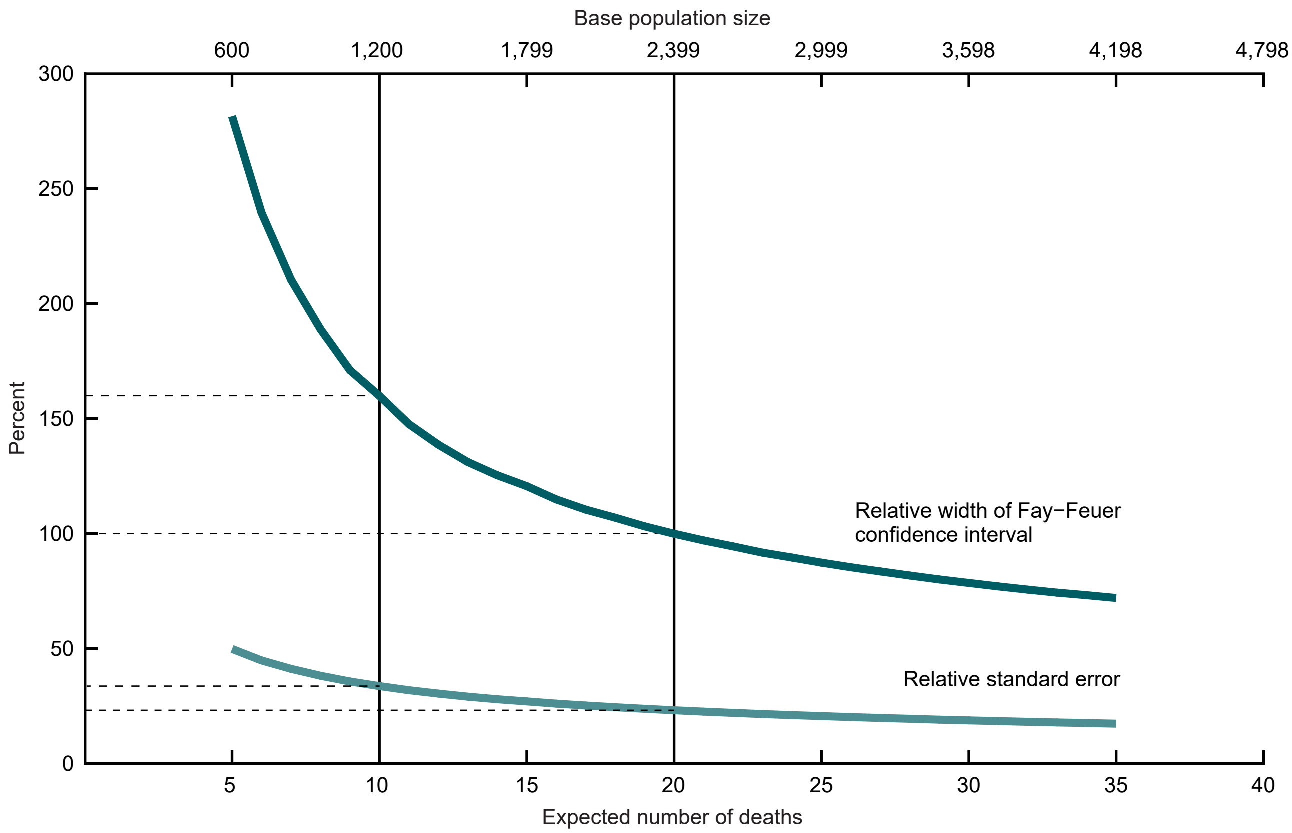
For rates derived from sample surveys, the Standards use log Student's *t* CI, with adaptations for complex surveys; see Table B. For a design-based estimate with mean *r* and variance *v*, a Taylor series approximation of the variance of the natural logarithm of *r* is used, given by v / r^2, and log Student's *t* CI is given by

$$\exp\{\ln(r) \pm t_{\alpha/2,df}\sqrt{v}/r\}$$

with degrees of freedom (*df*) for the *t*-critical value calculated as the effective sample size minus 1 (or sample size minus 1 if the sample size is smaller than the effective sample size). Note that the *df* for the *t*-critical value differs from the *df* used in the Standards to decide whether to flag an estimate for statistical review; the latter *df* is calculated as the number of primary sampling units minus the number of strata, which is the design *df* for variance estimation for complex survey data (20,21).

The NAMCS data structure (22–27) was used for the simulation studies described below. NAMCS is a national survey designed by NCHS to collect objective reliable information on the use of ambulatory medical care services in the United States. Information on patient visits, including patient demographic characteristics (age, sex, race, and ethnicity) and visit characteristics (patient's reason for visit, physician's diagnosis, services ordered or provided, and treatments), are collected from randomly sampled physicians. Sampling weights for physicians and patient visits are derived by NCHS for physician-level and visit-level statistical analyses, respectively. More detailed information on the NAMCS sampling frame and methodology is available (28).

Figure 2. Comparison between numerator-based, relative standard error-based, and confidence interval-based criteria for statistical reliability of age-adjusted death rates using the Fay–Feuer gamma 95% confidence interval in simulated data based on an underlying crude death rate of 833.8 per 100,000 population



NOTES: Vertical solid lines at 10 and 20 expected deaths indicate the current and previous numerator-based criteria for statistical reliability, respectively. Horizontal dotted lines are leader lines indicating the y-axis values (percent) corresponding to the points of intersection of the curves traced by the relative standard error and relative Fay–Feuer gamma confidence interval width values with the two vertical lines. Tick marks on the top horizontal axis indicate the base population size, ranging from 600 to 4,798, corresponding to the expected number of deaths indicated at the bottom horizontal axis (ranging from 5 to 40) given the fixed crude rate of 833.8 per 100,000 population.
SOURCE: National Center for Health Statistics.

Because most survey-based rates published by NCHS are produced by the National Health Care Surveys, the Standards were not evaluated for other sample surveys, such as NHIS or the National Health and Nutrition Examination Survey, although they apply to all survey-based rates produced by NCHS.

The following sections use simulations to evaluate the case where the denominator is a decennial census or postcensal or intercensal population estimate and whose variability is negligible in calculations, except "Relative CI Width and Coverage Probability When Both Numerator and Denominator Subject to Sampling Variability," which evaluates the case where the denominator is from NHIS and subject to sampling variability. These simulations evaluate different aspects of the Standards, including the variability of survey sampling weights, two methods for calculating design effects to determine the effective sample size for rates from sample surveys, and the use of the Standards for age-specific and age-adjusted rates. Detailed descriptions of the conditions for each simulation are reported in the Appendix.

Impact of Sample Size and Variability of Survey Sampling Weights on Relative CI Width and Coverage Probability

In NAMCS, differences in survey design, sample sizes, and nonresponse rates can lead to variations in the sampling weights across survey years. To investigate the impact of the sample size and the variability of survey sampling weights on the relative width and coverage probability of log Student's *t* CI, numerator sample sizes ranging from 10 to 35 (in increments of 5) were selected as visits paid by Medicare from NAMCS survey years 2011 through 2016, for 1,000 iterations per condition. The denominators for the visit rates were 2000 Census-based postcensal estimates of the U.S. civilian noninstitutionalized population as of July 1 of the corresponding NAMCS survey year, whose variability was negligible and could be treated as constants in standard error calculations.

For each of the NAMCS survey structures evaluated (2011 through 2016), Table 2 shows the unweighted number of patient visits, mean and standard deviation of sampling weights, and the coefficient of variation (CV; ratio of the standard deviation to the mean) of the sampling weights for age group 15–24. In the NAMCS visit data, CV of the sampling weights ranged from 0.76 (2016) to 1.59 (2015) within the 15–24 age group.

Table 3 shows the average relative width and average coverage probability for log Student's *t* 95% CI by NAMCS year and the simulated number of visits paid by Medicare. The corresponding rates of visits paid by Medicare for the 15–24 age group varied by year, ranging on average from 0.29 (2012, $n = 10$) to 5.95 (2016, $n = 35$) per 100 population. For comparison, the average RSE for the simulated rates ranged from 21.7% (2016, $n = 35$) to 49.0% (2015, $n = 10$).

As expected, the relative CI width decreased and the coverage probability increased as the numerator, the number of visits paid by Medicare, increased, although the performance varied by NAMCS year. In NAMCS 2011, 2012, 2013, 2014, and 2016, log Student's *t* CI achieved the nominal 95% coverage for as few as 10 visits paid by Medicare. Log Student's *t* CI did not achieve nominal coverage for 10 visits paid by Medicare in NAMCS 2015, although this survey had the largest CV among the 6 years (1.59; see Table 2). As the CV of the sampling weights increased, the minimum sample size needed to achieve the desired coverage probability and relative CI width increased. Log Student's *t* CI required a numerator sample size greater than 35 to achieve a relative width less than 160% in 2015 compared with sample sizes of approximately 15 to 20 in other years.

The simulation results suggest that reduced CI coverage, increased relative CI width, or both could be related to a larger CV of the sampling weights. In addition, unlike with rates from vital statistics, where the relative CI width criterion used in the Standards (Table A) was sometimes redundant once the sample size criterion was met, the simulation results shown here clearly demonstrate the importance of the multistep approach adopted in the Standards for ensuring statistical reliability of estimates.

Impact of Design Effect Calculation Method on Relative CI Width and Coverage Probability

The design effect (DEFF) is needed to calculate the effective sample size, which, in turn, determines the *df* used to calculate log Student's *t* CI for rates from sample surveys. While the ROW DEFF, based on the row percentage estimate, is more readily available from statistical packages and may in some cases provide a reasonable approximation, the TOTAL DEFF is preferred because the numerator of a rate is a total estimate (29). These two approaches for calculating DEFF were evaluated in a simulation to provide a better understanding of their impact on relative CI width and coverage probability. Note that the previous simulation based on NAMCS data used the TOTAL DEFF.

DEFF for totals

Let *K* be the variable of interest (for example, $K = 1$ if Medicare payment, $K = 0$ if not), and let w^s be the sampling weight. The numerator for a rate is the weighted frequency (or sum) of *K*, denoted as *X*, as follows:

$$X = \sum_{i=1}^{n} w_i^s k_i = \frac{\sum_{i=1}^{n} w_i^s k_i}{\sum_{i=1}^{n} w_i^s}\left(\sum_{i=1}^{n} w_i^s\right) = \left(\sum_{i=1}^{n} w_i^s\right)\bar{k}_w$$

where

$$\sum_{i=1}^{n} w_i^s$$

is the sum of sampling weights (over all subjects), and $\bar{k}_w$ is the weighted mean of *K*.

To estimate DEFF for *X*, two standard errors (SEs) are needed:

1. The SE of *X* under the complex survey design, denoted as $SE(X)_{design}$, which can be estimated from survey procedures for weighted frequencies.
2. The SE of *X* under simple random sampling (srs), denoted as $SE(X)_{srs}$, which can be estimated as:

$$SE(X)_{srs} = SE\left[\left(\sum_{i=1}^{n} w_i^s\right)\bar{k}_w\right]_{srs} = \left(\sum_{i=1}^{n} w_i^s\right)SE(\bar{k}_w)_{srs}$$

where $SE(\bar{k}_w)_{srs}$ is the SE under *srs* of the weighted mean of *K*.

The DEFF for *X* based on totals, denoted as TOTAL DEFF, is derived as:

$$\text{TOTAL DEFF} = \left(\frac{SE(X)_{design}}{SE(X)_{srs}}\right)^2$$

DEFF for row percentage

The row percentage is given by

$$\Pr(K = 1) = \frac{\sum_{i=1}^{n} w_i^s k_i}{\sum_{i=1}^{n} w_i^s} = \bar{k}_w$$

and the DEFF for the row percentage, denoted as ROW DEFF, is derived as

$$\text{ROW DEFF} = \left(\frac{SE(\Pr(K = 1))_{design}}{SE(\Pr(K = 1))_{srs}}\right)^2$$

ROW DEFF can be estimated from survey procedures for proportions and is readily available from statistical software packages.

Simulation

The 2015 NAMCS data set was used to select samples of 25, 30, 35, and 40 subjects, with the 2000 Census-based postcensal estimate of the U.S. civilian noninstitutionalized population as of July 1, 2015, as the denominator. The average relative CI width and coverage probability were calculated across 500 replicates for each sample size. In addition, the median relative CI width over the 500 replicates was derived because there were extremely large relative CI widths for some estimates and means were sensitive to such extremes. Results are shown in Table 4.

The means of TOTAL DEFF were larger than the means of ROW DEFF across all sample sizes. At sample size 25, the mean relative CI width using TOTAL DEFF was much larger than using ROW DEFF because there were some very large mean relative CI widths using TOTAL DEFF. As the sample size increased, the means of the relative CI widths decreased for both methods. The medians of the relative CI widths (less sensitive to extreme values) were similar using the TOTAL and ROW DEFFs when the sample size reached 30, and the medians of the relative CI widths were below 160% using both DEFFs at sample sizes 30 or more. Coverage probabilities were above 95% using either TOTAL DEFF or ROW DEFF for all sample sizes.

In summary, both TOTAL DEFF and ROW DEFF yielded CI coverage at 95% or higher for log Student's *t* CI. Although the TOTAL DEFF is a little larger than the ROW DEFF, resulting in relatively larger (more conservative) CIs, it also yielded CI coverage above the 95% nominal level and a median relative CI width below 160% for a sample size of 30.

Relative CI Width and Coverage Probability When Both Numerator and Denominator Subject to Sampling Variability

To evaluate the relative CI width and coverage probability using the Standards for rates when both numerator and denominator are subject to sampling variability, a final series of simulations using the NAMCS data structure was implemented, where the 2015 NAMCS and 2015 NHIS Sample Adult data sets were used to select the numerator and the denominator, respectively. For those simulations, the survey DEFF was calculated using the TOTAL DEFF, as described in the previous section, and both age-specific and age-adjusted rates were considered where these rates and the associated variances were calculated, as shown in the next section.

Age-specific rate

Let $r_i = x_i / y_i$ be the age-specific rate for age group i, where the numerator x_i is the sample weighted number of events (the total sampling weights of the selected NAMCS sample), and the denominator y_i is the weighted at-risk population (the total sampling weights of the selected NHIS sample). The variances of r_i and the natural logarithm of the rate $\ln r_i$ are approximated using Taylor series linearization:

$$Var(r_i) = Var(x_i / y_i) \approx \frac{E(x_i)^2}{E(y_i)^2}\left(\frac{Var(x_i)}{E(x_i)^2} + \frac{Var(y_i)}{E(y_i)^2}\right)$$

$$Var(\ln r_i) \approx \frac{Var(r_i)}{E(r_i)^2} \approx \frac{Var(x_i)}{E(x_i)^2} + \frac{Var(y_i)}{E(y_i)^2}$$

where x_i and y_i are assumed to be independent.

Age-adjusted rate

The age-adjusted rate $r' = \sum w_i r_i$ is the population-weighted sum of the age-specific rates, with weights shown in Table 5. The variances of r' and $\ln r'$ are estimated as:

$$Var(r') = Var\left(\sum w_i r_i\right) = \sum w_i^2 Var(r_i)$$

$$Var(\ln r') \approx \frac{Var(r')}{E(r')^2} \approx \frac{\sum w_i^2 Var(r_i)}{\left(\sum w_i r_i\right)^2}$$

Simulations

A total of 12 simulation settings were considered, where settings 1–6 assumed equal sample sizes in the numerator $n_{1,i}$ and the denominator $n_{2,i}$ with sample sizes selected within each age group i ranging from 15 to 100. Settings 7–12 used the same sample sizes for the numerator, however, assuming a much larger sample size within each age group for the denominator ($n_{2,i}$ = 1,000). For each sample size combination ($n_{1,i}$ / $n_{2,i}$), 100 replicates were generated. The average relative CI widths and coverage probabilities based on the current Standards for rates were calculated over 100 replicates. Results are shown in Table 6.

When both the numerator and the denominator were small (settings 1–6), the age-specific rates yielded large average relative CI widths for all age groups when the sample size within an age group was 50 or less (settings 1–4). When the sample size within an age group reached 75 (setting 5), average relative CI widths were less than 160% for all age groups, and coverage probabilities across age groups were around the 95% nominal level. When the sample size within an age group reached 100 (setting 6), average relative CI widths ranged from 105% to 122%, and coverage probabilities were 95% or higher. The age-adjusted rate yielded an average relative CI width of 156% and a coverage probability of 98% when the sample sizes of the numerator and the denominator were both 75 (setting 1). When the sample size reached 100 (setting 2), the age-adjusted rate yielded an average relative CI width of 127% and a coverage probability of 99%. When sample sizes reached 150 or more (settings 3–6), the age-adjusted rate yielded small average relative CI widths (less than 100%) and coverage probabilities above 95%.

Similar patterns were observed for settings 7–12 where the denominator sample size was set to 1,000 within each age group. Compared with simulations with the same numerator sample sizes, the larger denominator sample size helped reduce average relative CI widths and improve coverage probabilities. Specifically, when the numerator sample size reached 75, the age-specific (setting 11) and age-adjusted (setting 7) rates yielded average relative CI widths below 160% and coverage probabilities around 95%. When numerator sample sizes reached 100, average relative CI widths were small (less than or equal to 106%) and coverage probabilities were around 95% for both the age-specific (setting 12) and the age-adjusted (settings 8–12) rates.

Impact of Standards on Percentage of Rates Deemed Statistically Unreliable

Case Study Using Sparse County-level Mortality Data by Race and Hispanic Origin

For the purpose of this case study, county-level yearly counts for 1999–2019 underlying cause-of-death data by bridged-race categories were obtained and aggregated as single multiyear counts over the entire 20-year period for 3,147 U.S. counties (13). Bridged-race categories are single-race categories collapsed from multiple-race categories for statistical purposes (17).

Age-adjusted death rates and corresponding Fay–Feuer 95% CIs were calculated by race (American Indian or Alaska Native, Asian or Pacific Islander, Black or African American, and White) and Hispanic origin (Hispanic or Latino and Not Hispanic or Latino). Four causes of death were selected to capture varying distributions of age-adjustment weights and age-specific probabilities of death: all causes; external causes of morbidity and mortality (external causes, based on *International Classification of Diseases, 10th Revision* codes V01–Y89); congenital malformations, deformations, and chromosomal anomalies (congenital malformation; Q00–Q99); and Alzheimer disease and other degenerative diseases of the nervous system, not elsewhere classified (Alzheimer disease; G30–G31).

The results in Table 7 show that the change from the previous to current Standards results in the presentation of rates for more counties for all race and Hispanic-origin groups and for each of the cause-of-death categories, although a small number of counties have estimates suppressed under the current Standards that were shown using the previous standards (Table 7, fifth column). The overall impact of the change varies across population subgroups and causes, ranging from a net impact of 0 for all-cause rates for the White, not Hispanic or Latino population to a 65% increase, from 42 to 78 counties, in rates presented for Alzheimer disease for the American Indian or Alaska Native, not Hispanic or Latino population. For the Black or African American, not Hispanic or Latino population in counties with 10 to 19 cause-specific deaths, rates for an additional 111 counties are shown for all-cause mortality, an additional 257 for Alzheimer disease, an additional 187 for congenital malformation, and an additional 166 for external causes.

Findings From NAMCS-based Simulations

Impact of sample size and variability of survey sampling weights

In the simulation described in “Impact of Sample Size and Variability of Survey Sampling Weights on Relative CI Width and Coverage Probability,” each condition was replicated for 1,000 iterations. Table 3 shows the average percentage of suppressed rates based on the Standards and compares it with the average percentage of suppressed rates from a sample-size based standard alone or in addition to the RSE criterion (30/30 rule).

Overall, the Standards resulted in more rates being presented compared with the 30/30 rule. While the 30/30 rule would suppress 100% of the rates with numerator sample sizes less than 30, the Standards allowed most rates to be presented for n = 20 and n = 25 in NAMCS 2011, 2012, 2013, 2014, and 2016. For NAMCS 2011, 2012, and 2016, which had the lowest CVs (0.83, 0.85, and 0.76, respectively), 28% of the rates or less were suppressed for n = 20, and 6.1% of the rates or less were suppressed for n = 25. In addition, there were a few cases where rates with a numerator sample size as low as 10 could be presented (NAMCS 2011 and 2013). For numerator sample sizes greater than 30, the percentage of rates suppressed using both criteria was similar.

Impact of DEFF calculation method

In the simulation described in “Impact of Design Effect Calculation Method on Relative CI Width and Coverage Probability,” the average percentage of suppressed rates based on the Standards was calculated across 500 replicates for each sample size. Results are shown in Table 4 and compared with those from sample-size and RSE-based standards (30/30 rule).

When compared with the current Standards, the 30/30 rule would allow relatively fewer rates to be presented, for example, about 65% and 37% of estimates would be suppressed at sample sizes of 30 and 40, respectively. Additionally, of the two approaches for calculating the DEFFs evaluated, ROW DEFF was more liberal than TOTAL DEFF in that, overall, it allowed relatively more rates to be presented using the Standards. When the sample size reached 30, about 50% of the rates were suppressed using both DEFFs. When the sample size reached 40, 30% of estimates were suppressed using TOTAL DEFF and 21% of estimates were suppressed using ROW DEFF. Because the numerator of a rate is a total estimate, the more conservative TOTAL DEFF was used in the Standards (2).

Impact of sampling variability of both numerator and denominator

In the simulation described in "Relative CI Width and Coverage Probability When Both Numerator and Denominator Subject to Sampling Variability," the average percentage of suppressed rates and age-adjusted rates based on the Standards was calculated over 100 replicates for each sample size. Results are shown in Table 6 and compared with those from the 30/30 rule.

When both the numerator and denominator sample sizes were small (settings 1–6), the 30/30 rule would allow relatively fewer rates to be presented compared with the current Standards. When the sample size within an age group reached 75 (setting 5), using the Standards, less than 10% of replicates were suppressed for age groups 18–24 and 25–44, and 24% to 36% of replicates were suppressed for the remaining age groups. By comparison, using the 30/30 rule, more than 20% of replicates would be suppressed for age groups 18–24 and 25–44, and 35% to 50% of replicates would be suppressed for the remaining age groups. When the sample size within an age group reached 100 (setting 6), 10% of replicates or less were suppressed across age groups using the Standards, whereas, using the 30/30 rule, more than 10% of replicates would be suppressed across age groups except for the 25–44 age group. The age-adjusted rate yielded 33% of replicates that were suppressed when the samples sizes of the numerator and the denominator were both 75 (setting 1) using the Standards; using the 30/30 rule, 90% of replicates would be suppressed.

When the sample size reached 100 (setting 2), the age-adjusted rate yielded 11% of replicates that were suppressed using the Standards, and 20% of replicates would be suppressed using the 30/30 rule. When sample sizes reached 150 or more (settings 3–6), the age-adjusted rate yielded no replicates that were suppressed using the Standards, while 10% of replicates would be suppressed using the 30/30 rule for a sample size of 150. Similar patterns were observed for settings 7–12 where the denominator sample size was set to 1,000 within each age group except for the age-specific rates estimates when the numerator sample size reached 50 (settings 10–12), where the 30/30 rule would allow relatively more rates to be presented compared with the current Standards for several age groups. Larger differences were shown in the 18–24 age group at sample size 50 (setting 10) and the 75 and over age group at sample size 75 (setting 11).

Discussion

The Standards for crude and age-adjusted rates were evaluated in the context of vital statistics and health care surveys, with denominators subject and not subject to sampling variability. For evaluations of the Standards for rates from vital statistics, gamma CI thresholds for crude and age-specific rates were compared with related metrics, and it was shown that the current standards for rates from vital statistics are in line with sample-size based standards used previously. A simulation examining Fay–Feuer gamma CI thresholds for age-adjusted death rates confirmed that the relative CI width threshold of 160% corresponds to a sample size of 10 for the number of underlying events. In addition, an evaluation of log Student's *t* CI for the period- and cohort-linked infant mortality rates showed that coverage probability and relative CI width were adequate. Evaluations of the Standards for rates from sample surveys considered a range of numerator sample sizes (10–35) and a range of NAMCS years (2011–2016) to assess the impact of varying sample sizes and variability of survey sampling weights on log Student's *t* CI, which consistently achieved the nominal 95% coverage for small sample sizes and across survey years. An investigation of the impact of the DEFF calculation showed that both TOTAL DEFF and ROW DEFF yielded coverage at 95% or higher. Although ROW DEFF is the default calculation of DEFFs in some statistical software packages and allows relatively more rates to be presented using the Standards for rates, TOTAL DEFF is more appropriate for rates because the numerator of a rate is a total estimate. Thus, TOTAL DEFF will typically be more conservative in determining which rates to present in NCHS reports and other products, but additional programming effort may be needed to produce TOTAL DEFF. Moreover, age-specific and age-adjusted rates where both numerator and denominator were subject to sampling variability were considered. The variance of such rates tended to be larger than in the previous simulations, so larger sample sizes were needed to achieve nominal 95% coverage and obtain a relative CI width below 160%. Larger denominator sample sizes reduced the mean widths of log Student's *t* CI and improved coverage.

In summary, the gamma-based 95% CIs used in the Standards for crude and age-adjusted vital rates maintained nominal coverage, while the 160% threshold for their relative widths remained consistent with a sample size of 10 or more. Log Student's *t* CI used for infant mortality rates also maintained nominal coverage, even as the correlation between numerator and denominator varied. In NAMCS-based simulations with various conditions and scenarios, log Student's *t* CI retained nominal coverage when the effective sample size was 10 or more and relative CI width was at most 160%. While other CIs may be effective for purposes other than setting data presentation criteria, for example, population subgroup comparisons, the evaluations and simulations presented in this report may not be appropriate for these CIs.

More rates are found to be statistically reliable, and consequently are able to be presented, under the multistep Standards than under standards that rely on sample size alone or in addition to RSE. For vital statistics, this was demonstrated using sparse county-level mortality data by race and Hispanic origin. For rates from NAMCS, the simulations documented in this report also support this finding. Nonetheless, other factors (measurement error, survey response rates, granularity, etc.) may affect the quality of official estimates. Adequate subject-matter and methodological understanding of the underlying data remain essential to the production of timely, relevant, and reliable estimates.

Conclusion

This report documented some of the case studies and simulations used to assess the application of the NCHS data presentation standards for rates to vital statistics and health care surveys. While alternative CI methods were available, the CIs used in the Standards maintain nominal coverage in representative examples and, on average, lead to statistically reliable rates being presented for more granular data than under previously used standards.

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Table 1. Simulated relative standard error and relative width and coverage probability for log Student's *t* 95% confidence interval for the ratio $R = X/Y$, with varying degrees of nonnegative correlation between X and Y

Numerator mean $E(X)$	Denominator mean $E(Y)$	Target ratio ($R = X/Y$)	Comonotonicity (θ_{xy})[1]	Sample correlation:[2] 2.5th percentile	Sample correlation:[2] 97.5th percentile	Average RSE(X)	Average RSE(Y)	Average RSE(R)	Average $RSE_0(R)$[3]	Average relative width of log Student's *t* 95% CI[4]	Average coverage probability of log Student's *t* 95% CI[4]
						Percent					
15	15	1.00	0.0	-0.08	0.10	22.5	22.4	30.3	30.2	141.5	97.3
15	15	1.00	0.1	0.05	0.22	21.0	21.1	26.7	28.5	131.3	98.3
15	15	1.00	0.2	0.21	0.35	19.6	19.5	22.7	26.6	121.1	99.0
15	15	1.00	0.3	0.39	0.53	18.3	18.3	18.7	25.1	112.5	99.6
15	15	1.00	0.4	0.57	0.69	17.4	17.4	14.8	23.8	105.8	99.9
15	15	1.00	0.5	0.72	0.79	16.6	16.7	11.4	22.9	100.7	100.0
15	15	1.00	0.6	0.84	0.89	16.3	16.3	8.5	22.4	98.0	100.0
15	15	1.00	0.7	0.91	0.94	16.0	16.0	6.2	22.0	95.4	100.0
15	15	1.00	0.8	0.96	0.97	15.8	15.8	4.2	21.8	94.1	100.0
15	15	1.00	0.9	0.98	0.99	15.6	15.6	2.5	21.5	92.4	100.0
15	30	0.50	0.0	-0.08	0.09	22.4	18.3	28.0	28.0	127.8	96.6
15	30	0.50	0.1	0.03	0.19	21.0	18.2	25.4	26.9	121.7	97.5
15	30	0.50	0.2	0.15	0.31	19.5	18.2	22.8	25.8	116.0	98.3
15	30	0.50	0.3	0.29	0.43	18.3	18.1	20.1	25.0	111.3	98.9
15	30	0.50	0.4	0.43	0.56	17.3	17.8	17.2	24.0	106.3	99.6
15	30	0.50	0.5	0.59	0.69	16.7	17.1	14.0	23.2	101.6	99.9
15	30	0.50	0.6	0.74	0.81	16.3	16.1	10.7	22.3	96.9	100.0
15	30	0.50	0.7	0.86	0.90	15.9	15.1	7.6	21.4	92.6	100.0
15	30	0.50	0.8	0.94	0.96	15.8	14.5	5.0	21.0	90.2	100.0
15	30	0.50	0.9	0.98	0.98	15.6	14.0	3.3	20.5	87.8	100.0
15	60	0.25	0.0	-0.10	0.08	22.5	12.9	25.5	25.5	115.2	97.3
15	60	0.25	0.1	0.03	0.20	20.9	12.9	23.0	24.2	108.4	98.0
15	60	0.25	0.2	0.14	0.32	19.6	12.9	20.5	23.1	102.7	98.6
15	60	0.25	0.3	0.29	0.43	18.3	12.9	18.0	22.1	97.3	99.1
15	60	0.25	0.4	0.41	0.57	17.3	12.9	15.6	21.3	93.1	99.5
15	60	0.25	0.5	0.56	0.66	16.7	12.9	13.4	20.7	90.1	99.8
15	60	0.25	0.6	0.67	0.75	16.3	12.9	11.5	20.4	88.3	100.0
15	60	0.25	0.7	0.78	0.84	16.0	12.7	9.4	20.1	86.5	100.0
15	60	0.25	0.8	0.89	0.92	15.7	12.1	6.9	19.5	83.6	100.0
15	60	0.25	0.9	0.97	0.98	15.7	11.5	5.1	19.2	81.6	100.0
30	15	2.00	0.0	-0.08	0.08	18.2	22.4	27.4	27.5	125.2	96.2
30	15	2.00	0.1	0.03	0.19	18.2	21.0	25.2	26.6	120.4	97.3
30	15	2.00	0.2	0.16	0.31	18.3	19.6	22.8	25.8	116.0	98.2
30	15	2.00	0.3	0.31	0.43	18.1	18.3	20.0	24.9	111.0	99.0
30	15	2.00	0.4	0.45	0.56	17.8	17.3	17.2	24.1	106.5	99.6
30	15	2.00	0.5	0.59	0.70	17.1	16.6	14.2	23.2	101.7	99.9
30	15	2.00	0.6	0.74	0.81	16.0	16.2	10.8	22.2	96.6	100.0
30	15	2.00	0.7	0.86	0.90	15.1	16.0	7.5	21.4	92.6	100.0
30	15	2.00	0.8	0.94	0.96	14.5	15.8	5.0	20.9	89.7	100.0
30	15	2.00	0.9	0.98	0.98	14.0	15.6	3.3	20.5	87.4	100.0
30	120	0.25	0.0	-0.08	0.09	18.3	9.1	20.2	20.2	85.4	95.4
30	120	0.25	0.1	0.02	0.17	18.2	9.1	19.4	20.2	85.2	96.1

See footnotes at end of table.

Table 1. Simulated relative standard error and relative width and coverage probability for log Student's *t* 95% confidence interval for the ratio *R* = *X*/*Y*, with varying degrees of nonnegative correlation between *X* and *Y*—Con.

Numerator mean $E(X)$	Denominator mean $E(Y)$	Target ratio ($R = X/Y$)	Comonotonicity (θ_{xy})[1]	Sample correlation:[2] 2.5th percentile	Sample correlation:[2] 97.5th percentile	Average RSE(X)	Average RSE(Y)	Average RSE(R)	Average $RSE_0(R)$[3]	Average relative width of log Student's *t* 95% CI[4]	Average coverage probability of log Student's *t* 95% CI[4]
						Percent					
30	120	0.25	0.2	0.12	0.28	18.1	9.1	18.5	20.1	84.9	96.9
30	120	0.25	0.3	0.23	0.38	18.2	9.1	17.6	20.2	84.9	97.7
30	120	0.25	0.4	0.33	0.49	17.8	9.1	16.4	19.9	83.6	98.6
30	120	0.25	0.5	0.46	0.58	17.1	9.1	14.6	19.2	80.7	99.3
30	120	0.25	0.6	0.60	0.69	15.9	9.1	12.2	18.2	76.2	99.8
30	120	0.25	0.7	0.73	0.81	15.1	9.1	9.9	17.5	72.9	99.9
30	120	0.25	0.8	0.84	0.88	14.4	9.1	8.0	16.9	70.1	100.0
30	120	0.25	0.9	0.95	0.97	14.0	8.9	6.1	16.5	68.1	100.0
60	15	4.00	0.0	-0.08	0.09	12.9	22.4	24.6	24.6	110.8	96.8
60	15	4.00	0.1	0.02	0.20	12.9	21.0	22.5	23.6	105.6	97.7
60	15	4.00	0.2	0.16	0.31	12.9	19.6	20.1	22.6	100.3	98.4
60	15	4.00	0.3	0.29	0.44	12.9	18.3	17.7	21.6	95.2	99.0
60	15	4.00	0.4	0.42	0.56	12.9	17.3	15.4	21.0	91.8	99.5
60	15	4.00	0.5	0.57	0.67	12.9	16.7	13.2	20.5	89.3	99.8
60	15	4.00	0.6	0.67	0.76	12.9	16.2	11.3	20.2	87.2	100.0
60	15	4.00	0.7	0.77	0.84	12.7	15.9	9.3	19.8	85.3	100.0
60	15	4.00	0.8	0.89	0.92	12.1	15.8	6.9	19.5	83.2	100.0
60	15	4.00	0.9	0.97	0.98	11.5	15.7	5.1	19.0	80.7	100.0
120	30	4.00	0.0	-0.09	0.08	9.1	18.2	19.7	19.7	83.1	94.8
120	30	4.00	0.1	0.01	0.17	9.2	18.3	19.0	19.8	83.3	95.6
120	30	4.00	0.2	0.11	0.29	9.1	18.3	18.2	19.8	83.4	96.4
120	30	4.00	0.3	0.23	0.38	9.1	18.1	17.1	19.6	82.5	97.4
120	30	4.00	0.4	0.33	0.47	9.1	17.7	15.9	19.4	81.4	98.4
120	30	4.00	0.5	0.46	0.59	9.1	17.1	14.2	18.8	78.9	99.2
120	30	4.00	0.6	0.60	0.69	9.1	16.0	12.0	18.0	75.1	99.7
120	30	4.00	0.7	0.74	0.80	9.1	15.2	9.9	17.3	72.1	99.9
120	30	4.00	0.8	0.85	0.89	9.1	14.4	7.9	16.7	69.4	100.0
120	30	4.00	0.9	0.95	0.96	8.8	14.0	6.0	16.2	67.0	100.0

[1]Comonotonicity parameter θ_{xy} in the bivariate Poisson model; see reference 18 in this report.
[2]Because the comonotonicity parameter θ_{xy} in the bivariate Poisson model varies from 0 to 1, the correlation between the numerator *X* and denominator *Y* increases from 0 to a maximal value dependent on the Poisson means of X and *Y*. The range of values of the resulting sample correlations is shown using the 2.5th and 97.5th percentiles.

[3]The relative standard error (RSE_0) is calculated under the assumption of independence between the numerator *X* and denominator *Y*. As a result of this assumption, the correlation term in the expression of the second-order Taylor series approximation of the variance for the bivariate function *X*/*Y* is set to zero, which results in a larger variance (and confidence interval [CI] width) when the true underlying correlation is negative.

[4]The 95% log Student's *t* CI is given by $\exp[\ln(R) \pm t_{0.025,df} \bullet RSE_0(R)]$, where RSE_0 is calculated assuming independence between *X* and *Y* in $R = X/Y$; see footnote 3. The degrees of freedom for Student's *t* CI are defined as $\min(X,Y) - 1$.

NOTES: *X* and *Y* are generated from a bivariate Poisson model, truncated to maintain $X \geq 10$ and $Y \geq 10$. For each selected combination of numerator mean, denominator mean, and comonotonicity parameter, 200 copies of 500 replicates are generated to facilitate the estimation of correlation, RSE, and CI width and coverage.

SOURCE: National Center for Health Statistics, simulation.

Table 2. Unweighted number of visits, mean and standard deviation of sampling weights, and coefficient of variation of sampling weights for age group 15–24, by survey year: National Ambulatory Medical Care Survey, 2011–2016

Year	Number of visits	Mean of sampling weights	Standard deviation of sampling weights	Coefficient of variation
2011	2,319	32,846	27,413	0.83
2012	5,621	12,711	10,858	0.85
2013	4,055	16,521	17,838	1.08
2014	3,281	18,413	18,585	1.01
2015	1,994	38,045	60,575	1.59
2016	901	72,228	54,986	0.76

SOURCE: National Center for Health Statistics, National Ambulatory Medical Care Survey, 2011–2016.

Table 3. Properties of log Student's *t* 95% confidence interval for the rate of Medicare payments for visits by patients aged 15–24: Simulation study based on the National Ambulatory Medical Care Survey, 2011–2016

Survey year	Visits paid by Medicare					
	10	15	20	25	30	35
2011[1]						
Average rate (per 100 population)	0.77	1.16	1.54	1.92	2.30	2.67
Average relative standard error (percent)	40.3	33.4	29.3	26.3	24.2	22.6
Average relative CI width (percent)	1,032.6	174.5	140.7	120.6	107.6	98.9
Average CI coverage probability (percent)	99.7	99.8	99.8	99.8	99.8	99.8
Percentage of simulated rates suppressed	99.7	70.4	28.0	6.1	1.7	0.5
Percentage of simulated rates suppressed using 30/30 rule	100.0	100.0	100.0	100.0	2.2	0.5
2012[2]						
Average rate (per 100 population)	0.29	0.44	0.59	0.74	0.88	1.03
Average relative standard error (percent)	40.3	33.3	29.1	26.1	23.9	22.2
Average relative CI width (percent)	304.0	171.5	138.0	118.6	105.4	96.3
Average CI coverage probability (percent)	99.3	99.4	100.0	99.8	99.9	99.6
Percentage of simulated rates suppressed	100.0	71.6	16.6	5.9	0.6	0.2
Percentage of simulated rates suppressed using 30/30 rule	100.0	100.0	100.0	100.0	0.7	0.3
2013[3]						
Average rate (per 100 population)	0.38	0.57	0.76	0.95	1.13	1.32
Average relative standard error (percent)	41.0	34.5	30.3	27.5	25.4	23.8
Average relative CI width (percent)	8,370.2	914.9	158.4	132.4	116.9	106.6
Average CI coverage probability (percent)	99.4	99.4	98.9	99.2	99.1	98.6
Percentage of simulated rates suppressed	99.8	58.4	35.9	21.4	13.8	5.7
Percentage of simulated rates suppressed using 30/30 rule	100.0	100.0	100.0	100.0	10.3	4.1
2014[4]						
Average rate (per 100 population)	0.42	0.63	0.85	1.06	1.27	1.48
Average relative standard error (percent)	41.2	34.4	30.3	27.4	25.2	23.5
Average relative CI width (percent)	5,474.2	201.2	151.5	128.3	113.9	104.2
Average CI coverage probability (percent)	99.3	98.9	98.9	98.8	98.7	98.9
Percentage of simulated rates suppressed	100.0	66.3	35.0	16.7	6.8	4.3
Percentage of simulated rates suppressed using 30/30 rule	100.0	100.0	100.0	100.0	5.5	2.1
2015[5]						
Average rate (per 100 population)	0.87	1.33	1.77	2.23	2.65	3.11
Average relative standard error (percent)	49.0	42.8	38.6	35.0	32.6	30.6
Average relative CI width (percent)	81,585.6	16,917.9	2,574.2	487.6	227.5	229.9
Average CI coverage probability (percent)	91.8	95.1	96.1	96.1	96.6	97.3
Percentage of simulated rates suppressed	100.0	92.8	79.8	66.1	55.8	44.3
Percentage of simulated rates suppressed using 30/30 rule)	100.0	100.0	100.0	100.0	64.1	47.9
2016[6]						
Average rate (per 100 population)	1.70	2.56	3.41	4.25	5.08	5.95
Average relative standard error (percent)	38.6	32.0	28.0	25.3	23.2	21.7
Average relative CI width (percent)	459.8	162.3	131.7	114.4	102.4	93.9
Average CI coverage probability (percent)	99.9	99.9	99.8	100.0	99.7	99.9
Percentage of simulated rates suppressed	100.0	57.2	15.6	2.6	1.1	0.2
Percentage of simulated rates suppressed using 30/30 rule	100.0	100.0	100.0	100.0	1.0	0.1

[1]For 2011, the simulation is based on a population size of 42,819,210 for the 15–24 age group.
[2]For 2012, the simulation is based on a population size of 42,970,009 for the 15–24 age group.
[3]For 2013, the simulation is based on a population size of 42,976,496 for the 15–24 age group.
[4]For 2014, the simulation is based on a population size of 43,010,105 for the 15–24 age group.
[5]For 2015, the simulation is based on a population size of 42,884,188 for the 15–24 age group.
[6]For 2016, the simulation is based on a population size of 42,543,060 for the 15–24 age group.

NOTES: Rates of Medicare payments are for visits per 100 population. CI is confidence interval. Average rate, relative standard error, relative CI width, CI coverage probability, and suppression percentages are based on 1,000 simulated replicates. The number of visits paid by Medicare for the 15–24 age group is simulated based on the corresponding survey year. Simulated rates were suppressed based on the National Center for Health Statistics standards if they did not meet the criteria listed in Table A of this report. Simulated rates were suppressed using the 30/30 rule if the numerator sample size was less than 30 or the relative standard error was greater than 30.

SOURCE: National Center for Health Statistics, simulations based on survey design of 2011–2016 National Ambulatory Medical Care Survey.

Table 4. Simulation results to assess impact of the design effect calculation method on properties of log Student's *t* 95% confidence interval for the rate of Medicare payments for visits by patients aged 15–24: Simulation study based on the National Ambulatory Medical Care Survey, 2015

DEFF calculation method and numerator sample size	Average DEFF	Average relative CI width	Median relative CI width	Average CI coverage probability	Simulated rates suppressed	Average relative standard error	Simulated rates suppressed using 30/30 rule
TOTAL DEFF		Percent					
25	3.52	1,268.0	184.0	95.4	68.0	34.9	100.0
30	3.28	181.0	152.0	95.4	51.4	32.6	64.6
35	3.50	158.0	143.0	96.6	42.0	30.8	51.2
40	3.56	142.0	132.0	98.6	30.2	29.2	37.4
ROW DEFF							
25	3.01	201.0	174.0	97.6	66.6	34.9	100.0
30	3.05	172.0	156.0	96.2	48.8	32.6	64.6
35	3.16	155.0	140.0	96.2	34.8	30.8	51.2
40	3.10	137.0	129.0	96.2	21.4	29.2	37.4

NOTES: Rates of Medicare payments are for visits per 100 population. DEFF is design effect. CI is confidence interval. TOTAL DEFF is design effect based on totals, and ROW DEFF is design effect based on row proportions. Average DEFF, relative CI width, CI coverage probability, suppression percentages, and relative standard error are based on 1,000 simulated replicates. Simulated rates were suppressed based on the National Center for Health Statistics standards if they did not meet the criteria listed in Table A of this report. Simulated rates were suppressed using the 30/30 rule if the numerator sample size was less than 30 or the relative standard error was greater than 30.

SOURCE: National Center for Health Statistics, simulations based on survey design of 2015 National Ambulatory Medical Care Survey.

Table 5. Standard weights using 2015 U.S. civilian noninstitutionalized census population as the reference population, by age group

Age group (years)	Standard weight (w_i)
18–24	0.12918
25–44	0.34400
45–64	0.34309
65–74	0.10351
75 and over	0.08022

SOURCE: U.S. Census Bureau, 2015 population (available from: https://data.census.gov/cedsci/table?tid=ACSDP5Y2015.DP05).

Table 6. Simulation results to evaluate properties of log Student's *t* 95% confidence intervals for age-specific and age-adjusted rates, where both numerator and denominator are subject to sampling variability: 12 simulation settings based on 2015 National Ambulatory Medical Care Survey numerators and 2015 National Health Interview Survey denominators

Simulation setting and age group (years)	Sample size within age group (NAMCS, NHIS)	Age-specific rates: Average relative CI width	Average CI coverage probability	Simulated rates suppressed	Average relative standard error	Simulated rates suppressed using 30/30 rule
		Percent				
Simulation setting 1						
18–24	15/15	41,744	99	100	56	100
25–44	15/15	41,078	99	100	55	100
45–64	15/15	394,871	100	100	58	100
65–74	15/15	135,997	99	100	56	100
75 and over	15/15	341,802	96	100	57	100
Simulation setting 2						
18–24	20/20	2,120	99	100	48	100
25–44	20/20	23,243	100	100	48	100
45–64	20/20	60,463	100	100	52	100
65–74	20/20	53,292	98	100	50	100
75 and over	20/20	115,826	97	100	52	100
Simulation setting 3						
18–24	30/30	228	97	95	41	100
25–44	30/30	350	97	92	41	100
45–64	30/30	380	100	97	43	100
65–74	30/30	1,935	97	98	43	100
75 and over	30/30	1,425	98	96	44	100
Simulation setting 4						
18–24	50/50	168	99	50	34	90
25–44	50/50	159	98	33	33	77
45–64	50/50	195	98	42	35	84
65–74	50/50	6,780	98	47	35	73
75 and over	50/50	191	98	46	35	80
Simulation setting 5						
18–24	75/75	128	97	6	28	21
25–44	75/75	125	100	9	28	21
45–64	75/75	138	96	24	29	35
65–74	75/75	146	99	29	30	42
75 and over	75/75	146	93	36	30	50
Simulation setting 6						
18–24	100/100	115	98	3	26	12
25–44	100/100	105	100	4	24	3
45–64	100/100	117	98	10	26	13
65–74	100/100	117	98	3	26	10
75 and over	100/100	122	96	5	27	18
Simulation setting 7						
18–24	15/1,000	15,925	91	90	43	100
25–44	15/1,000	13,276	98	95	44	100
45–64	15/1,000	117,162	98	96	46	100
65–74	15/1,000	58,415	91	93	44	100
75 and over	15/1,000	142,378	87	89	45	100
Simulation setting 8						
18–24	20/1,000	1,052	90	79	38	100
25–44	20/1,000	11,039	96	77	38	100
45–64	20/1,000	27,787	98	86	42	100
65–74	20/1,000	26,961	95	77	40	100
75 and over	20/1,000	49,938	90	78	42	100

See footnotes at end of table.

Table 6. Simulation results to evaluate properties of log Student's *t* 95% confidence intervals for age-specific and age-adjusted rates, where both numerator and denominator are subject to sampling variability: 12 simulation settings based on 2015 National Ambulatory Medical Care Survey numerators and 2015 National Health Interview Survey denominators—Con.

Simulation setting and age group (years)	Sample size within age group (NAMCS, NHIS)	Age-specific rates: Average relative CI width	Average CI coverage probability	Simulated rates suppressed	Average relative standard error	Simulated rates suppressed using 30/30 rule
		Percent				
Simulation setting 9						
18–24	30/1,000	172	95	53	32	68
25–44	30/1,000	265	94	52	33	62
45–64	30/1,000	291	99	64	36	86
65–74	30/1,000	1,257	94	55	36	68
75 and over	30/1,000	983	91	63	37	79
Simulation setting 10						
18–24	50/1,000	135	96	35	28	28
25–44	50/1,000	130	97	27	27	26
45–64	50/1,000	159	91	34	29	31
65–74	50/1,000	4,943	93	36	29	35
75 and over	50/1,000	157	95	37	29	38
Simulation setting 11						
18–24	75/1,000	104	96	5	23	3
25–44	75/1,000	105	100	8	23	5
45–64	75/1,000	117	95	19	25	16
65–74	75/1,000	124	96	23	25	21
75 and over	75/1,000	124	91	34	26	22
Simulation setting 12						
18–24	100/1,000	97	98	3	22	1
25–44	100/1,000	89	100	4	21	2
45–64	100/1,000	100	96	10	23	6
65–74	100/1,000	100	94	3	22	3
75 and over	100/1,000	106	94	5	23	4

Simulation setting	Sample size (NAMCS, NHIS)	Age-adjusted rates: Average relative CI width	Average CI coverage probability	Simulated rates suppressed	Average relative standard error	Simulated rates suppressed using 30/30 rule
		Percent				
1	75/75	156	98	33	36	90
2	100/100	127	99	11	28	20
3	150/150	99	99	0	24	10
4	250/250	76	99	0	19	0
5	375/375	62	100	0	15	0
6	500/500	54	100	0	14	0
7	75/5,000	120	97	20	27	30
8	100/5,000	102	96	4	23	10
9	150/5,000	81	98	0	20	0
10	250/5,000	63	95	0	16	0
11	375/5,000	54	99	0	14	0
12	500/5,000	47	99	0	12	0

NOTES: NAMCS is National Ambulatory Medical Care Survey. NHIS is National Health Interview Survey. CI is confidence interval. Numerators are simulated based on the 2015 NAMCS. Denominators are simulated based on the 2015 NHIS. Age-adjusted rates were adjusted to the 2015 U.S. civilian noninstitutionalized census population, using the weights shown in Table 7 in this report. Average relative CI width, CI coverage probability, suppression percentages, and relative standard error are based on 100 simulated replicates. Simulated rates were suppressed based on National Center for Health Statistics standards if they did not meet the criteria listed in Table A of this report. Simulated rates were suppressed using the 30/30 rule if the numerator sample size was less than 30 or the relative standard error was greater than 30.

SOURCE: National Center for Health Statistics, simulations based on survey designs of 2015 National Ambulatory Medical Care Survey and 2015 National Health Interview Survey.

Table 7. Comparison between previous and current National Center for Health Statistics presentation guidelines for age-adjusted death rates, where denominator treated as constant using aggregate county-level data, by race and Hispanic origin for four causes of death, 1999–2019

Cause of death and race and Hispanic origin	Suppressed, no change from previous presentation guidelines	Presented, no change from previous presentation guidelines	Suppressed, estimates lost relative to previous presentation guidelines	Presented, estimates gained relative to previous presentation guidelines	Suppressed, no change from previous presentation guidelines
	Counties with number of deaths less than 10	Counties with number of deaths greater than or equal to 20 and relative width of Fay–Feuer 95% CI less than or equal to 160%	Counties with number of deaths greater than or equal to 20 and relative width of Fay–Feuer 95% CI greater than 160%	Counties with number of deaths from 10 to 19 and relative width of Fay–Feuer 95% CI less than or equal to 160%	Counties with number of deaths from 10 to 19 and relative width of Fay–Feuer 95% CI greater than 160%
All causes					
American Indian or Alaska Native, not Hispanic or Latino	1,697	1,040	16	244	150
Asian or Pacific Islander, not Hispanic or Latino	1,673	1,028	5	248	193
Black or African American, not Hispanic or Latino	823	2,041	13	111	159
Hispanic or Latino	599	1,929	14	368	237
White, not Hispanic or Latino	1	3,142	1	1	2
Alzheimer disease (G30–G31)					
American Indian or Alaska Native, not Hispanic or Latino	3,026	42	–	78	1
Asian or Pacific Islander, not Hispanic or Latino	2,917	137	–	91	2
Black or African American, not Hispanic or Latino	2,084	800	–	257	6
Hispanic or Latino	2,611	328	–	205	3
White, not Hispanic or Latino	123	2,910	–	78	36
Congenital malformations (Q00–Q99)					
American Indian or Alaska Native, not Hispanic or Latino	3,099	18	–	10	20
Asian or Pacific Islander, not Hispanic or Latino	3,018	57	–	40	32
Black or African American, not Hispanic or Latino	2,597	313	4	187	46
Hispanic or Latino	2,720	224	23	35	145
White, not Hispanic or Latino	1,047	1,371	–	719	10
External causes (V01–Y89)					
American Indian or Alaska Native, not Hispanic or Latino	2,594	367	5	110	71
Asian or Pacific Islander, not Hispanic or Latino	2,593	337	5	93	119
Black or African American, not Hispanic or Latino	1,615	1,276	7	166	83
Hispanic or Latino	1,657	994	50	123	323
White, not Hispanic or Latino	22	3,072	1	35	17

– Quantity zero.

NOTES: CI is confidence interval. Previous National Center for Health Statistics presentation guidelines present data if the number of events is greater than or equal to 20. Current guidelines present data if the number of events is greater than or equal to 10 and the relative width for the Fay–Feuer CI is less than or equal to 160%. *International Classification of Diseases, 10th Revision* codes were used for causes of death: Alzheimer disease and other degenerative diseases of the nervous system, not elsewhere classified (codes G30–G31); congenital malformations, deformations and chromosomal anomalies (Q00–Q99); and external causes of morbidity and mortality (V01–Y89).

SOURCE: National Center for Health Statistics, simulations based on 1999–2019 underlying cause-of-death data from CDC WONDER online database.

Appendix. Sample Survey Simulation Conditions

Impact of Sample Size and Variability of Survey Sampling Weights on Relative Confidence Interval Width and Coverage Probability

The structure of the National Ambulatory Medical Care Survey (NAMCS) visit files was used to simulate and evaluate the rate of visits paid with Medicare per 100 population for patients aged 15–24. Although few patients under age 65 have Medicare coverage, this simulation setting allowed evaluation of the National Center for Health Statistics (NCHS) Standards under a scenario where rates are expected to be unstable. The numerator, the number of visits paid by Medicare, was simulated by selecting a subset of 10–35 visits (by increments of 5) from all visits for the 15–24 age group using simple random sampling. The expected rate, $E(R)$, is,

$$E(R) = \frac{E(x)}{y} = \frac{TW^s \bullet n / N}{y}$$

where x is the numerator (number of visits paid by Medicare), N is the total number of NAMCS participants each year for age group 15–24, TW^s is their total sampling weights, n is the number of subjects selected as "events" from N participants (the numerator sample size, in this simulation, n = 10, 15, 20, 25, 30, or 35), and y (the denominator) is the 2000 Census-based postcensal estimate of the U.S. civilian noninstitutionalized population as of July 1, 2015. The age-specific (15–24) rate of visits paid by Medicare per 100 population, that is, the observed rate, was calculated as 100 • (visit estimate) / (population estimate). Visit estimates were based on the NAMCS sample data weighted to produce annual national estimates. Each simulation condition was replicated for 1,000 iterations.

Impact of Design Effect Calculation on Relative Confidence Interval Width and Coverage Probability

The 2015 NAMCS data set was used to select samples, and the total sample weighted count of the selected samples is the numerator of a rate. Keeping the survey design structure (strata, primary sampling unit, and sampling weights), 25, 30, 35, and 40 subjects were selected within the 15–24 age group. After sample selection, the variance (v / r^2) of the natural logarithm of the observed rate, ln r = ln(x / y), was calculated using the Taylor series linearization described previously ("Age-specific rate"), where the numerator x is the weighted number of events (the total sampling weights of the selected NAMCS sample), and the denominator y is the 2000 Census-based postcensal estimate of the U.S. civilian noninstitutionalized population as of July 1, 2015. For each sample size, 500 replicates were generated.

Relative Confidence Interval Width and Coverage Probability When Both Numerator and Denominator are Subject to Sampling Variability

The 2015 NAMCS and the 2015 National Health Interview Survey (NHIS) sample adult data sets were used to select the numerator and the denominator, respectively. Keeping the survey design structure (strata, primary sampling unit, and sampling weights), $n_{1,i}$ subjects were selected within each age group i in NAMCS, and $n_{2,i}$ subjects were selected within each age group i in NHIS, using a simple random sampling procedure. Because the 2015 NHIS sample adult data set consists of civilian noninstitutionalized participants aged 18 and over, five age groups were used in the simulation (18–24, 25–44, 45–64, 65–74, and 75 and over). The expected age-specific rate $E(r_i)$ for age group i and the expected age-adjusted rate $E(r')$ are as follows:

$$E(r_i) = \frac{TW^s_{1,i} \bullet n_{1,i} / N_{1,i}}{TW^s_{2,i} \bullet n_{2,i} / N_{2,i}}$$

$$E(r') = \sum w_i E(r_i)$$

where $N_{1,i}$ is the total number of NAMCS participants in age group i, $TW^s_{1,i}$ is their total sampling weights, and $n_{1,i}$ is the number of subjects selected within age group i as "events" from $N_{1,i}$ subjects (the numerator). $N_{2,i}$ is the total number of NHIS participants in age group i, $TW^s_{2,i}$ is their total sampling weights, and $n_{2,i}$ is the number of subjects selected within age group i as "at-risk population" from $N_{2,i}$ subjects (the denominator). w_i is the standard weight (proportion) for the reference population for age group i.

The 2015 Census estimates of the U.S. civilian noninstitutionalized population were used as the reference population, with population weights across age groups shown in Table 5.

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The last Series 16 report was published in 1996. All reports are available online; compilations are no longer needed.

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Series 23. Data From the National Survey of Family Growth
Reports contain statistics on factors that affect birth rates, factors affecting the formation and dissolution of families, and behavior related to the risk of HIV and other sexually transmitted diseases. The last Series 23 report was published in 2011; these reports are now included in Series 3.

Series 24. Compilations of Data on Natality, Mortality, Marriage, and Divorce
The last Series 24 report was published in 1996. All reports are available online; compilations are no longer needed.

For answers to questions about this report or for a list of reports published in these series, contact:

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