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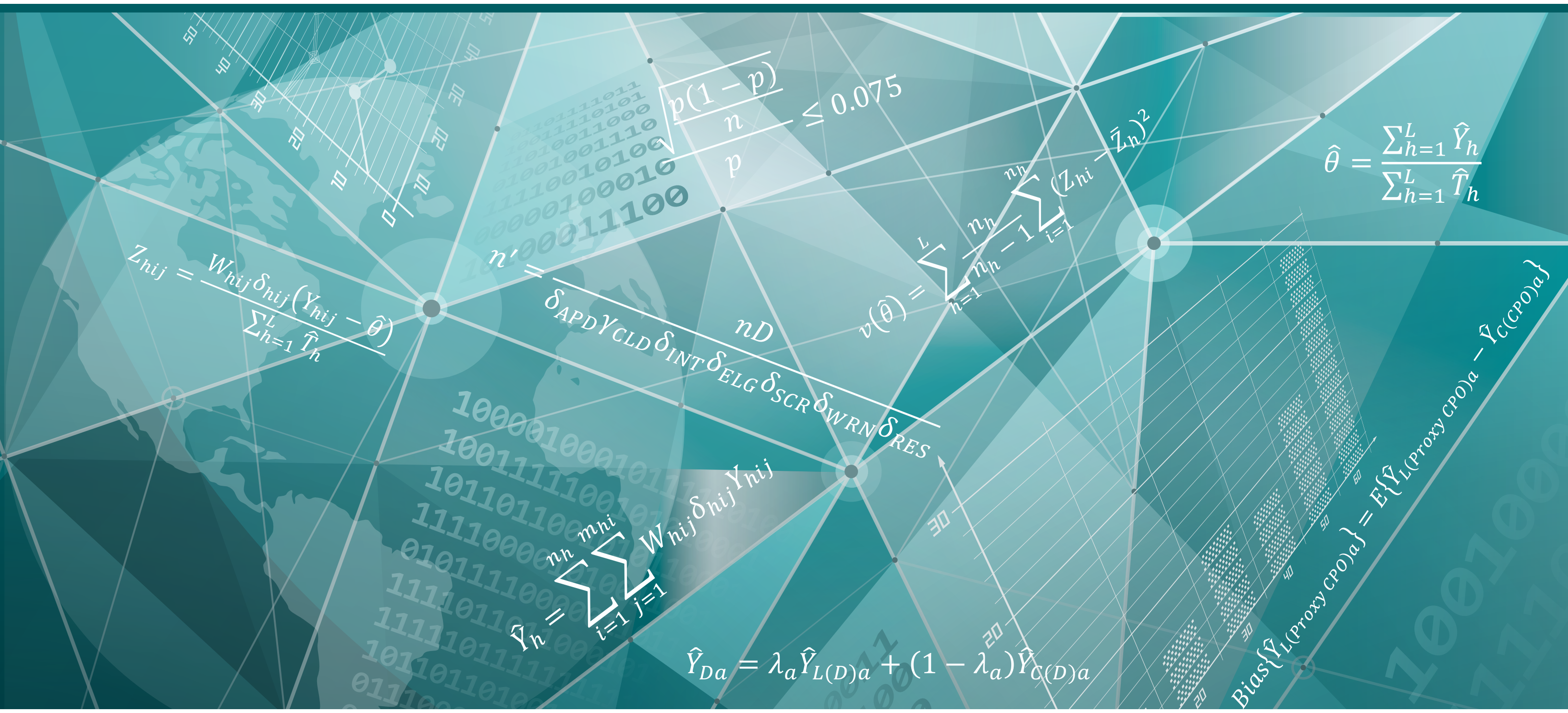

Evaluation of an Enhanced Modified Kalman Filter Approach for Estimating Health Outcomes in Small Subpopulations

Data Evaluation and Methods Research

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Data Evaluation and Methods Research

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Center for Health Statistics

Hyattsville, Maryland
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Evaluation of an Enhanced Modified Kalman Filter Approach for Estimating Health Outcomes in Small Subpopulations

by Lauren M. Rossen, Ph.D., M.S., Makram Talih, Ph.D., Priyam Patel, M.S.P.H., Morgan Earp, Ph.D., Jennifer D. Parker, Ph.D.

Abstract

Background

Historically, the National Center for Health Statistics has published statistics on a variety of health outcomes by population subgroup, supporting efforts to assess and monitor health disparities in the U.S. population. With small sample or population sizes, however, direct estimates from the Center's data systems may lack precision, limiting the information available for small subpopulations. Small-domain estimation is a methodological approach that can be used to provide more precise model-based estimates of outcomes for small subgroups.

Methods

This report describes the performance of an updated methodology to estimate health outcomes in small subpopulations using the enhanced modified Kalman filter (eMKF). The eMKF procedure borrows strength across subgroups and over time to produce more precise estimates of health outcomes in small subpopulations. This report evaluates the performance of the eMKF procedure under different scenarios based on simulated data, to quantify differences in accuracy and precision of model-based estimates compared with direct estimates.

Results

Using simulated data, model-based estimates using the eMKF Bayesian model averaging approach presented marked improvements in root mean squared error compared with direct estimates, with larger improvements seen for smaller sample sizes. Improvements were seen across a wide array of analytic scenarios, including outcomes with higher or lower prevalence, trends that varied from linear to cubic, trends that were shared or varied by group, as well as trends that involved unequally spaced time points. In all cases, relative root mean squared errors were smaller for eMKF estimates than direct estimates. Gains in equivalent sample size of up to 420% were observed.

Conclusions

Model-based estimates of health outcomes among small subpopulations, where direct estimates may be statistically unreliable, can help inform policies and programs to address disparities in the United States.

Keywords: disparities • inequities • small-domain estimation • National Health Interview Survey • National Health and Nutrition Examination Survey

Introduction

Historically, the National Center for Health Statistics (NCHS) has published statistics on a variety of health outcomes by population subgroup, supporting efforts to assess and monitor health disparities across the U.S. population. With small sample or population sizes, however, direct estimates from NCHS data systems may not meet existing data presentation standards based on factors including sample size, width of confidence intervals, and design effects (in the context of survey estimates) (1,2). As a result, statistically reliable estimates may not be readily available for some subgroups, limiting the information available to quantify disparities among some subpopulations. Additionally, estimates for small subgroups may have large standard errors or confidence intervals, potentially leading to between-group differences that may be large in magnitude but not statistically significant.

Often, solutions to this challenge rely on combining (aggregating) data across time periods, larger subgroups, or geographic areas. However, this can adversely impact the timeliness, granularity, and relevance of information available for public health surveillance, research, and practice. Aggregating data over time or across larger groups can make it difficult to assess trends in disparities or to quantify within-group variation in health outcomes (as in differences in health by Hispanic-origin subgroup or by detailed urban–rural group within the larger metropolitan and nonmetropolitan categories). Another approach involves oversampling of certain groups in the survey design and sampling phase, to provide sufficient data to obtain statistically reliable direct estimates. However, this approach is costly and not feasible for all subpopulations that may be of interest.

Alternatively, model-based approaches such as small-domain estimation can be used to provide estimates of outcomes for small subgroups by borrowing strength across groups and over time (3–8). Although these model-based estimates may be less accurate than direct estimates when the latter are unbiased, such estimates are often more precise (that is, smaller standard errors or 95% confidence intervals) and can be especially useful when direct estimates for subgroups of interest do not meet existing statistical reliability standards. A recent report described enhancements to an existing small-domain estimation tool, the modified Kalman filter (MKF) (8–12).

MKF

The earlier MKF procedure and accompanying SAS macro implemented a) mixed-effects models that assumed a linear trend over time in the true health state of each population subgroup (borrowing strength over time) and b) shared random effects that captured deviations from each group's linear trend (borrowing strength across groups). Additionally, when two correlated health outcomes were considered, the earlier MKF procedure and macro allowed for model-based estimates from one outcome to inform the estimation of the other outcome (borrowing strength across health outcomes) (8–12).

Previous evaluations of the earlier MKF procedure and macro using simulated data demonstrated that, even in cases where estimated model parameters were subject to bias and estimation error, the MKF procedure improved overall estimate accuracy (as in root mean squared error) compared with direct estimates, at little cost other than computational time (9,10). Using cardiovascular health data from the National Health Interview Survey (NHIS), reductions in root mean squared error were shown to be equivalent to a sixfold increase in sample size, on average, across the different racial and ethnic groups considered (10).

Despite these gains in accuracy, precision, and efficiency (that is, percentage increase in equivalent sample size) with model-based estimates derived from the earlier MKF procedure, MKF has not been widely adopted to produce estimates for small subpopulations. This may be due, in part, to some features of the earlier MKF procedure and macro that limited their utility for analyses of NCHS data. Specifically, the earlier MKF procedure and macro were limited to cases where temporal trends were linear, time periods were equally spaced, and sample variances were assumed to be fixed or known. A recent report (8) describes several enhancements to the earlier MKF procedure and macro to make this modeling approach more accessible and relevant across various analytic scenarios commonly encountered with NCHS data. These enhancements are briefly described below.

Enhancements to the MKF

The enhanced MKF procedure and macro accommodate nonlinear time trends, irregularly spaced time points, and random sampling variances for the underlying population subgroup means, rates, or proportions. Bayesian estimation in the enhanced MKF macro is implemented adaptably and transparently using PROC MCMC and related SAS 9.4 procedures, instead of relying on an associated external executable file with precompiled C code as with the original macro. Model averaging in the enhanced MKF macro, which renders predictions more robust to polynomial trend misspecification, uses a Bayesian mixture prior approach instead of a maximum likelihood-based approach. Various other features in the enhanced MKF macro also improve its functionality, flexibility, and usability relative to the earlier macro; a detailed description of the differences between the earlier and enhanced MKF procedures and macros is available elsewhere (8).

This report describes an evaluation of the performance of the enhanced modified Kalman filter (eMKF) macro for producing model-based estimates of health outcomes for small subgroups using NCHS data. Simulations were conducted to evaluate the performance of the eMKF procedure under different scenarios commonly encountered in analyses of NCHS data to quantify differences in accuracy and precision of model-based estimates relative to direct estimates. These simulated scenarios included: 1) a range of sample sizes, including very small subgroup samples; and 2) linear, quadratic, and cubic trends that are shared or unique across subgroups. Additionally, simulations under each of these scenarios examined outcomes that were more prevalent or less prevalent to determine whether accuracy and precision of model-based estimates may differ according to outcome prevalence. Finally, an applied analysis of NHIS data was conducted to compare model-based estimates obtained from the enhanced MKF macro and method with estimates derived from original MKF procedures (9).

Methods

Data

To evaluate the performance of the eMKF procedure, simulated data sets were constructed based on two NCHS data systems, NHIS and the National Health and Nutrition Examination Survey (NHANES). Applied analyses of actual NHIS data were also conducted to assess the performance of the eMKF procedure in generating model-based estimates for small subgroups of interest across a range of outcomes, similar to methods used in earlier evaluations of the original MKF macro (9).

NHIS

Data from the 2019–2021 NHIS were used to construct simulated data sets representing samples of different sizes (and corresponding ranges of estimate uncertainty) based on the year and quarter of interview. Additionally, annual data from the 1999–2018 NHIS were used to evaluate the performance of the eMKF procedure in relation to the previous MKF procedure, based on applied analyses of several health outcomes included in an earlier report representing a range of sample sizes and outcome prevalences (9).

NHIS is a nationally representative household survey of the U.S. civilian noninstitutionalized population, capturing data on health status, healthcare, health behaviors, and other factors. Due to the impact of the COVID-19 pandemic, data collection for NHIS was predominantly done by telephone in 2020 and 2021, in contrast to in-person interviews in preceding years. Additionally, NHIS underwent a sample redesign in 2016 and a questionnaire redesign in 2019 (13). As a result, analyses examining the most recent trends in outcomes using NHIS data are typically limited to 2019 and later.

Simulated NHIS data

To create simulated data representing a range of sample sizes, NHIS data from 2019–2021 were limited to sample adults, and the demographic variables used included age group (18–49, 50–64, and 65 and older) and race and ethnicity—American Indian or Alaska Native non-Hispanic (subsequently, American Indian or Alaska Native), Asian non-Hispanic (subsequently, Asian), Black non-Hispanic (subsequently, Black), White non-Hispanic (subsequently, White), other or multiple race non-Hispanic (subsequently, other or multiple race), and Hispanic or Latino. For the simulated data sets, the three smallest racial and ethnic groups were combined into one group to establish sufficiently reliable direct estimates for comparison in the various simulated data sets. This resulted in four racial and ethnic groups: Black, White, other or multiple race, and Hispanic. Simulations were based on two outcome variables, diagnosed diabetes and history of smoking. Diagnosed diabetes was assessed based on the survey question, “Has a doctor ever told you that you have diabetes?” (not including gestational diabetes or prediabetes). History of smoking was assessed based on the question, “Have you smoked at least 100 cigarettes in your entire life?”

Applied analysis of 1999–2018 NHIS data

For the applied analysis of 1999–2018 NHIS data to compare the earlier MKF procedures to the eMKF procedures, annual NHIS data for adults from 1999 to 2018 were used (14). Ten outcomes were examined that were analyzed in a previous report, representing a range of higher and lower prevalence outcomes with different temporal trends (9). These outcomes included: 1) the proportion of adults with any functional limitations, 2) the proportion of adults ever diagnosed with hypertension, 3) the proportion of adults ever diagnosed with asthma, 4) the proportion of adults ever diagnosed with heart disease, 5) the proportion of adults with a history of cancer, 6) the proportion of adults who are current smokers, 7) the proportion of adults diagnosed with kidney disease in the past 12 months, 8) the proportion of adults with a history of stroke, 9) mean body mass index (BMI) among adults, and 10) mean number of bed days due to illness or injury among adults.

Any functional limitations were defined as having any difficulty doing one or more of the following activities by oneself and without any special equipment: going out to shopping, movies, sporting events, or similar activities; participating in social activities, such as visiting friends, attending clubs and meetings, and going to parties; doing things to relax at home or for leisure (reading, watching TV, sewing, or listening to music); walking one-quarter of a mile (or three city blocks); climbing 10 steps without resting; standing for 2 hours; sitting for 2 hours; stooping, bending, or kneeling; reaching over one’s head; using one’s fingers to grasp or handle small objects; lifting or carrying a 10-pound object (such as a full bag of groceries); and pushing or pulling a large object (such as a living room chair).

Hypertension was defined as having been told by a doctor or other health professional that one was hypertensive (or with high blood pressure) on at least two different visits. Lifetime asthma prevalence was defined as ever having been told by a doctor or other health professional that one had asthma. Heart disease was defined as ever having been told by a doctor or other health professional that one had coronary heart disease, angina, heart attack, or any other heart condition or disease. Cancer was defined as ever having been told by a doctor or other health professional that one had cancer or malignancy of any kind.

Current smoking was defined as having smoked at least 100 cigarettes in one’s lifetime and currently still smoking. Kidney disease was defined as having been told in the last 12 months by a doctor or other health professional that one had weak or failing kidneys (excluding kidney stones, bladder infections, or incontinence). Stroke was defined as having been told by a doctor or other health professional that one had had a stroke.

The mean BMI was calculated from information that respondents supplied in response to survey questions regarding height and weight and defined as BMI = weight (kilograms) / $[\text{height (meters)}]^2$. The mean number of bed days per person was calculated from information that respondents supplied in response to the question, “During the past 12 months, about how many days did illness or injury keep you in the bed more than half of the day (include days while an overnight patient in a hospital)?”

Each of these 10 outcomes was estimated by selected race and Hispanic ethnicity categories, consistent with those used in the earlier study (9), to include the following single-race non-Hispanic populations: American Indian or Alaska

Native, Asian of Chinese origin, Asian of Filipino origin, Asian of Indian origin, Black, and White; as well as the following Hispanic or Latino subgroups: Hispanic of Puerto Rican origin, Hispanic of Mexican or Mexican American origin, Hispanic of Cuban origin, and Hispanic of all other national origins, including multiple origins. The category "All other population subgroups" included the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.

NHANES

Data from the 1999–March 2020 NHANES were used to construct simulated data sets representing different temporal trend forms (linear, quadratic, and cubic) with unequally spaced time intervals. NHANES is a nationally representative survey of the U.S. civilian noninstitutionalized population capturing both self-reported health data through in-person interviews as well as measured health status assessed through health examinations and laboratory tests. Since 1999, NHANES has been conducted as a continuous survey, released in 2-year cycles. However, the COVID-19 pandemic led to a pause in field operations in early 2020. As a result, only partial data from the 2019–2020 cycle was available. To provide nationally representative data for those years, the data collected from 2019 through March 2020 were combined with data from the preceding cycle (2017–2018, which is also separately available as a 2-year cycle). This data set is referred to as the prepandemic data file (15). The pandemic-related disruption and subsequent data file release created unequal time intervals when the prepandemic data file (2017 through March 2020) is used in combination with previous 2-year cycles of NHANES (1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, 2011–2012, 2013–2014, and 2015–2016). While restricted data may have year of examination available within the data files, the public-use files only have 2-year cycles—as a result, this report defines time as the midpoint of the cycles. In addition to the prepandemic data file creating unequally spaced time periods, the last prepandemic cycle covers a 3.2-year period instead of the usual 2-year cycle.

Simulated NHANES data

To create simulated trend scenarios, NHANES data from 1999–March 2020 were limited to adults age 18 and older, and the demographic variables used included age group (18–24, 25–44, 45–64, and 65 and older) and race and ethnicity (Mexican American, other Hispanic, Black non-Hispanic, White non-Hispanic, and other or multiple race non-Hispanic). The main outcome for the simulated data sets was BMI, where various trends in population-level BMI were simulated (described below). Two outcomes were derived from these simulated BMI estimates: 1) the prevalence of obesity (BMI ≥ 30 kg/m^2) and 2) the prevalence of severe obesity (BMI ≥ 40 kg/m^2). The prevalence of each of these two outcomes was estimated by population subgroup and time period (the midpoint of each data cycle).

Statistical Analysis

Simulations

Several different simulated data sets were used to examine the performance of the eMKF macro under different scenarios: evaluating 1) the impact of sample size (and relatedly, estimate precision) and 2) the shape of the underlying trend over time (linear, quadratic, and cubic) and whether trends were common or distinct across subgroups. For each of these two main scenarios, outcomes with different prevalence (lower compared with higher) were included.

The performance of the eMKF macro was also assessed by several criteria to describe the accuracy and precision of the model-based estimates compared with the simulated direct estimates. Overall accuracy was assessed by the root mean squared error (RMSE) and relative RMSE (RRMSE). Precision was assessed using the width of 95% confidence intervals (95% CI). Additionally, standardized differences between the model-based and direct estimates were examined to quantify the magnitude of the differences between them. The goal of evaluating performance under these various simulated scenarios was to inform different analytic choices that data users may make and to identify situations where producing model-based estimates using the eMKF macro may not be advised (as when sample sizes are too small, or the outcome is too rare, to get accurate or precise model-based estimates).

Simulation scenario 1: Sample size and estimate precision

Quarterly data from the 2019–2021 NHIS were used to evaluate the performance of the eMKF macro by sample size and to potentially determine a rule of thumb regarding either sample size or precision (as in 95% CI width) where reasonable model-based estimates cannot be obtained. These data were treated as the true population, and several subsamples were drawn representing increasingly smaller sample sizes (and correspondingly larger levels of uncertainty) when stratified by population subgroup. The largest subsample size consisted of 40% of the adult NHIS sample, the medium subsample size was 20% of the adult sample, and the small subsample size was 10% of the adult sample. For each of these three subsample sizes, 1,000 replicate subsamples were simulated.

The total sample sizes averaged 765, 1,515, and 3,019 for the small, medium, and large scenarios, respectively (Table A). While these total subsample sizes may not be considered very small, the subsample sizes by age and population group varied from 12 to 746 and reflected situations commonly encountered by NCHS data analysts, where estimates for some larger subgroups may meet presentation standards but estimates for smaller subgroups would be suppressed.

Each of these three simulated scenarios (large, medium, or small samples) were applied to two outcomes, one more prevalent (ever smoked 100 or more cigarettes) and one less

Table A. Unweighted sample sizes, by simulation scenario, age group, and population group: National Health Interview Survey, 2021, Quarter 4

Sample scenario and population group	18–49	50–64	65 and older
Total sample			
Total	3,289	1,896	2,354
Non-Hispanic:			
Black	350	225	210
White	1,856	1,295	1,832
Other or multiple race	397	146	128
Hispanic	686	230	184
Large subsample (40%)			
Total	1,316	758	945
Non-Hispanic:			
Black	137	91	85
White	746	515	732
Other or multiple race	157	58	52
Hispanic	276	94	76
Medium subsample (20%)			
Total	657	383	475
Non-Hispanic:			
Black	67	47	42
White	378	258	370
Other or multiple race	77	31	26
Hispanic	135	47	37
Small subsample (10%)			
Total	331	194	240
Non-Hispanic:			
Black	33	21	22
White	190	131	187
Other or multiple race	40	17	12
Hispanic	68	25	19

NOTE: Estimates reflect average unweighted sample sizes by age and subgroup across 1,000 simulated subsamples.

SOURCE: National Center for Health Statistics, National Health Interview Survey, 2021, Quarter 4.

prevalent (diagnosed diabetes), for a total of six simulated scenarios. Direct estimates from the total NHIS sample were used as a gold standard to compare with subsample model-based estimates and subsample direct estimates.

Simulation scenario 2: Trend form

To evaluate how well the eMKF procedures capture various nonlinear trends, data from the 1999–March 2020 NHANES were used to simulate linear, quadratic, and cubic trends in the prevalence of obesity and severe obesity.

Linear

Linear trends in BMI as a continuous variable were simulated by first taking the mean BMI (BMI_g) by age group, race and ethnicity, sex, and income-to-poverty ratio (excluding 8% of respondents with missing values) and then simulating a linear trend for year (β_1), based on a normal distribution with mean 0.5 and standard deviation of 0.5. Error terms (ε) were simulated from a normal distribution with mean 0 and standard deviation of 10:

$$Y_{sim} = BMI_g + \beta_1 \bullet year + \varepsilon \qquad (1)$$

Quadratic

Similarly, quadratic trends were simulated using,

$$Y_{sim} = BMI_g + \beta_1 \bullet year + \beta_2 \bullet year^2 + \varepsilon \qquad (2)$$

where β_2 was simulated from a normal distribution with mean –0.03, standard deviation of 0.03, and year centered at 2010.

Cubic

Finally, cubic trends were simulated using,

$$Y_{sim} = BMI_g + \beta_1 \bullet year + \beta_2 \bullet year^2 + \beta_3 \bullet year^3 + \varepsilon \qquad (3)$$

where β_3 was simulated from a normal distribution with mean –0.005, standard deviation of 0.005, and year centered at 2010.

In each of the above scenarios, the trends for each population subgroup were drawn from the same distribution (that is, common trends). A second set of simulated trends was generated where the trends varied by age group and race and ethnicity (that is, unique trends). In these scenarios, the linear trend component was multiplied by a factor unique to each population subgroup, such that the resulting simulated slope of the linear trends varied by group but the shape of the trend (linear, quadratic, or cubic) remained consistent across all groups.

Based on these six simulated trend data sets—linear, quadratic, and cubic, and trends common across groups or unique by group (age group and race and ethnicity)—the prevalence of obesity and severe obesity were then estimated based on a BMI ≥ 30 kg/m^2 and a BMI ≥ 40 kg/m^2, respectively. This provides a total of 12 simulated scenarios.

The eMKF Bayesian model averaging implementation

For each of the 18 simulated data sets (6 sample size scenarios based on NHIS data and 12 trend scenarios based on NHANES data), the Bayesian model averaging (BMA) up to cubic trends option was used in the eMKF macro. The model-based estimates and RMSEs were obtained for each racial and ethnic group, age group, and time period (quarter or year) and used to construct Wald 95% CIs.

The SAS code (call) to run the eMKF macro can be seen in the following sample code, using 20,000 burn-in iterations (`nbi`) and a Markov chain Monte Carlo (MCMC) sample of 25,000 after thinning (25,000 = 50,000/2 = `nmc/thin`):

```
%mkf(data          = sim1,
     group         = race,
     by            = agegroup,
     time          = year,
     outcome       = diabetes,
     se            = se_diabetes,
     neff          = neff_diabetes,
     Bayesmodel    = bma_cubic,
```

```
   nbi          = 20000,
   nmc          = 50000,
   thin         = 2,
   seed         = 44,
   mcmcplot     = YES,
   GRthreshold  = 1.1,
   modelprint   = YES,
   out          = sm_bmac);
```

Four chains are used by default for Bayesian estimation in the eMKF macro, and values of the Gelman–Rubin diagnostic above 1.1 flag potential issues with model convergence. A seed was set to ensure results could be replicated across repeated analyses. Detailed diagnostic statistics and plots are requested using the `mcmcplot` and `modelprint` macro parameters. Technical guidance regarding the eMKF macro parameters and settings is available (8).

Model-based estimates were then compared with the direct estimates. Plots of the model-based and direct estimates by time period, age group, race and ethnicity, and outcome were generated, along with the corresponding 95% CIs. These plots were used to visually inspect how well the model-based estimates captured the temporal trends in the simulated data sets. Several other metrics were used to compare estimates, including:

- *RMSE*—Defined as the square root of the mean squared error. The mean squared error measures the average squared difference between the estimate and the actual value assumed under the model, which is readily available from the updated (posterior) samples that are drawn in the Bayesian framework. Because mean squared error can be written as the sum of the squared standard error (SE) and the squared bias of an estimate, RMSE is seen to provide a measure of overall accuracy and takes into account the bias–variance tradeoff. For example, a model-based estimate with a small increase in bias but a large reduction in variance may be preferable to a direct estimate with presumably zero bias but a large variance that jeopardizes its statistical reliability.
- *RRMSE*—The relative RMSE is calculated as the ratio of the model-based and direct RMSEs (eMKF RMSE / direct RMSE). Generally, the direct estimate is assumed to be unbiased, in which case, direct RMSE = direct SE. However, in the case of the simulated NHIS subsample estimates, bias of direct estimates was estimated by taking the average of the difference between the 1,000 replicate subsample estimates and the true gold-standard estimate from the full NHIS sample. Smaller RRMSE values (less than 1) indicate that the model-based estimates result in improved overall estimate accuracy and precision.
- *Standardized difference*—Measures the difference between the model-based and direct estimates and is calculated as (MKF estimate – direct estimate) / direct SE. For example, standardized differences less than 1 indicate that the model-based estimates are within one SE of the corresponding direct estimates.
- *Absolute 95% CI width*—Illustrates the difference in uncertainty associated with the direct and model-based estimates.
- *Percentage increase in equivalent sample size*—Defined as 100 × [(1 / RRMSE) – 1], reflecting the relative increase in sample size that would be needed to obtain the same level of precision as the eMKF estimate.

Applied analysis of 1999–2018 NHIS data to compare original MKF macro procedures with eMKF

Performance of the eMKF procedures was also compared with the performance of the original MKF procedures. For these comparisons, annual NHIS data for adults from 1999 to 2018 were used to estimate the prevalence of 10 health outcomes, covering a range of prevalence estimates and relative standard errors. Direct estimates and SEs for the last year of data, 2018, were design-based, using only the 2018 NHIS. MKF estimates and RMSEs for 2018 were model-based, using all 20 survey cycles from 1999 to 2018. Three sets of model-based estimates were calculated, gradually relaxing assumptions about sampling variances as well as the underlying trend model.

First, estimates and RMSEs based on the fully Bayesian linear trend model with fixed variances were obtained as in the earlier version of the MKF procedure and macro. Second, estimates and RMSEs based on the fully Bayesian linear trend model with random variances used the eMKF macro to account for the design-based variability in the sampling variances. Third, estimates and RMSEs based on cubic BMA also 1) used the eMKF macro to account for variability in the sampling variances and 2) were calculated as weighted posterior averages over samples drawn under the Bayesian framework from all seven available models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only (no trend) model.

Results

Simulation Scenario 1: Patterns by Group Size

Based on simulated quarterly NHIS data for 2019–2021 by age group and population subgroup, model-based estimates using eMKF BMA up to cubic trends and direct estimates for the three different sample size scenarios were compared with direct estimates from the total NHIS (which are assumed to be the true estimates or gold standard) for the prevalence of diagnosed diabetes and reported history of smoking.

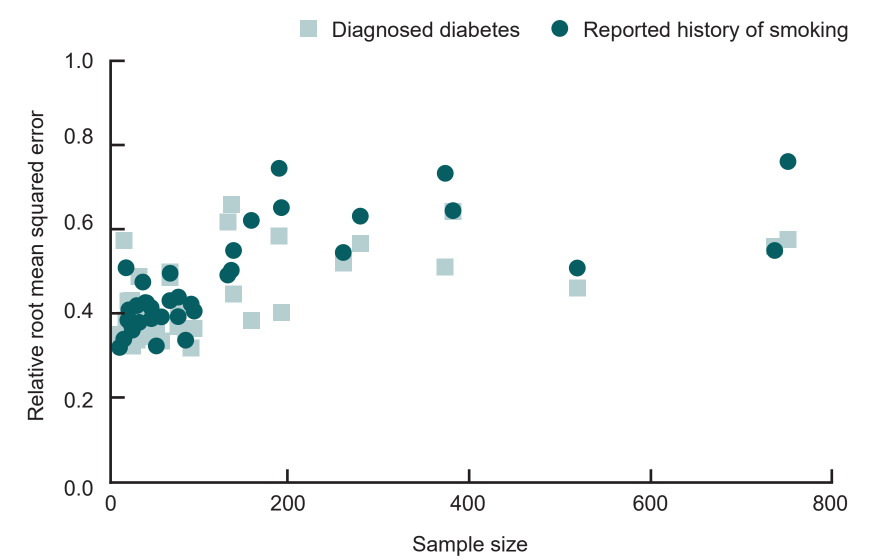
Across all sample size scenarios, the eMKF BMA estimates presented marked improvements in accuracy, as indicated by RRMSEs all less than 1 for both diagnosed diabetes and history of smoking (Figure 1).

In the large subsample (40% of NHIS data), RRMSEs for eMKF BMA estimates were 0.39 for diagnosed diabetes and 0.48 for history of smoking (Table B), on average across all of the age and population subgroups. Similar average RRMSEs were seen for the medium (0.44) and small (0.43) subsample size scenarios for diagnosed diabetes and reported history of smoking (0.47 for the medium subsample and 0.51 for the small subsample). These improvements in RMSE corresponded to large increases in equivalent sample size across the various subsample sizes. Average percentage increases in equivalent sample sizes of 174% (large subsample), 158% (medium subsample), and 174% (small subsample) were seen for diagnosed diabetes. Average increases were slightly smaller for smoking: 121% for the large subsample, 124% for the medium subsample, and 120% for the small subsample.

The average standardized differences between the model-based estimates and the gold-standard (true) NHIS estimates from the total sample ranged in absolute value from about zero to 1.39. For diagnosed diabetes, the average standardized differences between the true NHIS direct estimates and the model-based estimates across all the age and population subgroups were –0.44 for the large subsample, –0.79 for the medium subsample, and –1.39 for the small subsample. By comparison, the average standardized differences between the direct estimates of diagnosed diabetes for the true NHIS and the simulated subsample direct estimates were about zero for the large and medium scenarios and –0.76 for the small subsample. For reported history of smoking, the average standardized differences for the model-based estimates varied from –0.28 to 0.26, compared with –0.16 to 0.13 for the direct subsample estimates, indicating that the standardized differences between the direct subsample and model-based estimates, relative to the true NHIS direct estimates, were generally similar in absolute magnitude. Larger average standardized differences were generally seen for smaller sample sizes, with both the eMKF BMA model-based estimates and the subsample direct estimates having smaller standardized differences from the true NHIS direct estimates as sample size increased.

Comparisons across these metrics by specific age and population subgroup and outcome can be seen in Tables C and D. Figures 2 and 3 illustrate the model-based estimates, direct subsample estimates, and corresponding 95% CIs relative to the true estimates for adults age 65 and older (Figure 2) and adults ages 18–49 (Figure 3). Patterns for other age groups were very similar and consequently are not shown.

Figure 1. Relative root mean squared error of model-based estimates compared with direct estimates, by sample size of each age and population subgroup using simulated data: National Health Interview Survey, 2021, Quarter 4



NOTE: Each plotted point represents a distinct age and population subgroup for each outcome.
SOURCE: National Center for Health Statistics, National Health Interview Survey, 2021, Quarter 4.

The largest gains in RMSE and equivalent sample size were generally seen for the smallest subgroups, where direct estimates would typically not meet NCHS data presentation standards. For example, when subsample sizes were smaller than 50, increases in equivalent sample sizes of 77%–419% were observed for estimates of diagnosed diabetes prevalence among Hispanic, Black, and other or multiple race persons (Table C). In contrast, for the largest racial and ethnic group, White, where the direct estimates typically meet data presentation standards, increases in equivalent sample size were generally smaller (about 15%–140% for diagnosed diabetes and 32%–104% for history of smoking) (Table D). These patterns can also be seen in Figures 2 and 3, where direct and model-based estimates of diagnosed diabetes and history of smoking, along with 95% CIs, are very similar for the White category. In contrast, the model-based 95% CIs for other racial and ethnic groups are narrower than the direct estimate 95% CIs across both outcomes and all subsample size scenarios.

Simulation Scenario 2: Patterns by Trend Form

Common Trends by Group

Based on simulated trends in obesity and severe obesity by population group derived from NHANES data, model-based estimates using eMKF BMA up to cubic trends were compared with direct estimates across the three different trend scenarios.

Across all simulation scenarios, the eMKF BMA estimates presented marked improvements in overall accuracy, as indicated by RRMSE values less than 1 for obesity and severe obesity (Figures 4 and 5, Table E). On average, RRMSE values were 0.63–0.90

Table B. Enhanced modified Kalman filter procedure performance across various subsample size simulation scenarios: National Health Interview Survey, 2021, Quarter 4

Characteristic	Diagnosed diabetes			Reported history of smoking		
	Large subsample	Medium subsample	Small subsample	Large subsample	Medium subsample	Small subsample
Average standardized difference between direct subsample estimate and true NHIS estimate	0.02	0.01	-0.76	-0.08	-0.16	0.13
Average standardized difference between model-based subsample estimate and true NHIS estimate	-0.44	-0.79	-1.39	0.26	0.01	-0.28
Average RRMSE (RMSE_eMKF/RMSE_subsample)	0.39	0.44	0.43	0.48	0.47	0.51
Average percent increase in equivalent sample size (%)	174	158	174	121	124	120

NOTES: Estimates reflect averages of each metric across all age and population subgroups within each subsample size scenario and outcome. NHIS is National Health Interview Survey, RRMSE is relative root mean squared error, and eMKF is enhanced modified Kalman filter. The large subsample was 40% of the total NHIS sample, the medium subsample was 20% of the total, and the small subsample was 10%. The true NHIS estimates were calculated using the total NHIS sample.

SOURCE: National Center for Health Statistics, National Health Interview Survey, 2021, Quarter 4.

compared with direct estimates. These values corresponded to a 12% to 69% increase in equivalent sample size when trends were simulated to be common across groups. Generally, improvements in accuracy (lower RRMSEs) were smaller for cubic trends than linear trends. The absolute value of the average standardized differences between the model-based and direct estimates were generally less than 0.5 for all trend scenarios and outcomes, indicating that model-based estimates were within 0.5 SE of direct estimates.

Unique Trends by Group

When the slopes of the trends were simulated to be unique by demographic subgroup, average RRMSEs were larger than when trends were shared across groups. When trends were unique by group, average RRMSEs ranged from 0.80 to 0.92, with corresponding increases in equivalent sample size of 9%–27%. Similarly, increases in equivalent sample size were smaller than when trends were shared. In both cases, improvements were smaller for cubic trends than for linear or quadratic trends.

Comparisons across these metrics by demographic subgroup and outcome can be seen in Tables F–J. Across both outcomes, temporal trends in eMKF BMA estimates aligned very closely with the simulated trend forms for all population subgroups (Figures 6–9).

Applied analysis of 1999–2018 NHIS to compare original MKF macro results with eMKF

Using annual NHIS data on 10 outcomes and 11 racial and ethnic groups, results from the original MKF macro (fully Bayesian linear trends with fixed variances) were compared with two eMKF procedures: fully Bayesian linear trends with random variances, and BMA up to cubic trends with random variances. The three sets of model-based estimates were compared with the direct estimates for each outcome, along with the corresponding standardized differences, RMSEs, RRMSEs, and the percentage increase in equivalent sample sizes.

Regardless of which MKF model was used, model-based estimates improved on the direct estimates considerably, as measured by a percentage increase in equivalent sample size ranging from 8% to about 600% across all 10 outcomes and 11 population groups, including for the 10 direct 2018 estimates shown in Appendix Tables I–X that did not meet NCHS standards of reliability.

Across most racial and ethnic subgroups and health outcomes from NHIS data, the eMKF BMA up to cubic trends with random variances offered the largest percentage increase in equivalent sample size across the three different model-based estimates (Appendix Tables I–X). A total of 110 estimates were made across 10 outcomes and 11 racial and ethnic groups, and of those, the eMKF BMA model had the largest percentage increase in equivalent sample size in 74 cases (67%). Similarly, the eMKF BMA model had the lowest RMSE in 74 cases (67%) and the smallest SEs in 80 cases (73%). In a few outcomes, the eMKF BMA was not the most accurate or efficient model across most racial and ethnic groups: heart disease, cancer, and kidney disease. These were among the less prevalent outcomes (generally less than 15%); however, other outcomes were more or equivalently rare (stroke, less than 5%), where the eMKF BMA model did outperform the other models. Consequently, the outcome prevalence does not appear to be what drove the underperformance of the eMKF BMA model relative to the linear model options.

For heart disease (Appendix Table IV), the three models performed similarly, and differences in RMSE and percentage increase in equivalent sample size were small in magnitude. For cancer and kidney disease (Appendix Tables V and VII), the linear models outperformed the eMKF BMA option across most racial and ethnic groups, with somewhat larger differences in RMSE and percentage increase in equivalent sample size.

Table C. Simulated subsample sizes, prevalence of diagnosed diabetes, and 95% confidence interval: National Health Interview Survey, 2021 Quarter 4

			Sample direct estimate				Model-based estimate					
Age group and race and ethnicity	Sample size	True estimate	Direct estimate	Standard error	Standardized difference[1]	95% confidence interval[2]	Model-based estimate	RMSE[3]	Standardized difference	95% confidence interval[4]	RRMSE[5]	Percent increase in equivalent sample size
18–49						Large subsample (40%)						
Non-Hispanic:												
Black	137	3.7	5.5	2.2	1.6	2.1–11.5	4.5	0.7	0.7	3.1–5.8	0.3	214.3
White	746	2.9	2.5	0.6	-0.9	1.4–4.0	2.4	0.4	-1.1	1.6–3.2	0.7	50.0
Other or multiple race	157	3.0	4.1	2.7	0.8	0.6–13.1	1.7	0.7	-1.0	0.2–3.1	0.3	285.7
Hispanic	276	3.3	3.7	1.2	0.6	1.7–6.9	4.0	0.6	1.0	2.9–5.2	0.5	100.0
50–64												
Non-Hispanic:												
Black	91	19.6	18.5	4.6	-0.3	10.3–29.4	18.0	1.5	-0.5	15.0–21.0	0.3	206.7
White	515	11.7	10.0	1.5	-1.5	7.3–13.4	10.8	0.8	-0.8	9.3–12.3	0.5	87.5
Other or multiple race	58	14.9	16.1	5.5	0.3	6.9–30.1	13.3	1.7	-0.5	9.9–16.7	0.3	223.5
Hispanic	94	19.2	21.3	5.3	0.7	11.7–33.9	18.1	1.7	-0.3	14.9–21.4	0.3	211.8
65 and older												
Non-Hispanic:												
Black	85	35.2	31.8	5.7	-0.9	21.0–44.3	27.7	1.9	-1.9	24.0–31.5	0.3	200.0
White	732	16.5	17.0	1.6	0.5	14.0–20.3	17.0	0.8	0.6	15.4–18.7	0.5	100.0
Other or multiple race	52	24.5	24.1	6.4	-0.1	12.6–39.3	26.0	2.3	0.4	21.5–30.6	0.4	178.3
Hispanic	76	33.9	31.8	7.2	-0.5	18.2–48.1	26.6	2.2	-1.7	22.3–30.9	0.3	227.3
18–49						Medium subsample (20%)						
Non-Hispanic:												
Black	67	3.7	5.2	3.4	1.3	0.7–16.8	3.6	1.1	-0.1	1.5–5.7	0.3	209.1
White	378	2.9	2.5	0.9	-0.9	1.1–4.9	2.4	0.6	-1.1	1.2–3.6	0.7	50.0
Other or multiple race	77	3.0	1.2	1.2	-1.3	0.0–7.1	1.7	0.8	-0.9	0.2–3.3	0.7	50.0
Hispanic	135	3.3	4.2	1.8	1.3	1.4–9.3	3.9	0.9	0.8	2.2–5.6	0.5	100.0
50–64												
Non-Hispanic:												
Black	47	19.6	17.2	7.3	-0.7	5.5–36.7	17.3	2.2	-0.7	13.0–21.7	0.3	231.8
White	258	11.7	7.3	1.7	-4.0	4.3–11.3	9.6	1.2	-2.0	7.2–11.9	0.7	41.7
Other or multiple race	31	14.9	19.4	8.3	1.3	6.1–41.2	11.9	2.3	-0.9	7.3–16.4	0.3	260.9
Hispanic	47	19.2	17.1	5.0	-0.7	8.4–29.4	17.3	2.2	-0.6	13.1–21.5	0.4	127.3
65 and older												
Non-Hispanic:												
Black	42	35.2	41.7	9.1	1.7	24.0–61.2	27.9	2.6	-1.9	22.7–33.0	0.3	250.0
White	370	16.5	18.3	2.1	2.0	14.4–22.9	17.1	1.1	0.6	14.9–19.2	0.5	90.9
Other or multiple race	26	24.5	16.8	7.0	-1.7	5.1–36.5	20.6	2.8	-0.9	15.2–26.0	0.4	150.0
Hispanic	37	33.9	42.3	13.2	2.0	17.3–70.7	25.7	3.0	-1.9	19.7–31.6	0.2	340.0

See footnotes at end of table.

Table C. Simulated subsample sizes, prevalence of diagnosed diabetes, and 95% confidence interval: National Health Interview Survey, 2021 Quarter 4—Con.

			Sample direct estimate				Model-based estimate					
Age group and race and ethnicity	Sample size	True estimate	Direct estimate	Standard error	Standardized difference[1]	95% confidence interval[2]	Model-based estimate	RMSE[3]	Standardized difference	95% confidence interval[4]	RRMSE[5]	Percent increase in equivalent sample size
18–49						Small subsample (10%)						
Non-Hispanic:												
Black	33	3.7	6.2	5.3	2.2	0.3–26.3	4.3	1.1	0.6	2.2–6.5	0.2	381.8
White	190	2.9	1.9	1.2	-2.2	0.3–6.0	1.8	0.5	-2.5	0.8–2.7	0.4	140.0
Other or multiple race	40	3.0	2.2	2.2	-0.6	0.0–12.3	1.8	0.8	-0.9	0.3–3.3	0.4	175.0
Hispanic	68	3.3	3.7	2.1	0.5	0.6–11.3	3.9	0.8	0.8	2.3–5.5	0.4	162.5
50–64												
Non-Hispanic:												
Black	21	19.6	17.7	10.2	-0.6	3.0–46.7	13.7	3.8	-1.8	6.2–21.1	0.4	168.4
White	131	11.7	5.0	2.2	-6.1	1.7–11.2	6.9	1.9	-4.4	3.1–10.7	0.9	15.8
Other or multiple race	17	14.9	21.0	10.6	1.7	4.7–49.6	10.2	4.3	-1.3	1.8–18.6	0.4	146.5
Hispanic	25	19.2	11.5	6.2	-2.5	2.5–30.0	14.1	3.5	-1.6	7.2–20.9	0.6	77.1
65 and older												
Non-Hispanic:												
Black	22	35.2	28.4	9.5	-1.8	11.7–51.0	22.1	3.6	-3.4	15.0–29.1	0.4	163.9
White	187	16.5	18.0	3.0	1.6	12.5–24.6	17.7	1.8	1.3	14.2–21.2	0.6	66.7
Other or multiple race	12	24.5	16.6	11.2	-1.8	1.8–50.0	21.7	4.1	-0.6	13.7–29.7	0.4	173.2
Hispanic	19	33.9	35.1	22.3	0.3	3.1–84.0	22.0	4.3	-2.8	13.6–30.4	0.2	418.6

0.0 Quantity more than zero but less than 0.05.
[1]The standardized difference for the enhanced modified Kalman filter (eMKF) (model-based) or direct estimates is calculated as (eMKF or direct estimate minus true estimate) divided by true standard error (SE).
[2]Korn–Graubard 95% confidence interval.
[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) SE. For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance tradeoff.
[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[5]Relative RMSE is calculated as the ratio: eMKF RMSE divided by direct RMSE.

SOURCE: National Center for Health Statistics, National Health Interview Survey, 2021, Quarter 4.

Table D. Simulated subsample sizes, prevalence of smoking history, and 95% confidence interval: National Health Interview Survey, 2021, Quarter 4

			Sample direct estimate				Model-based estimate					
Age group and race and ethnicity	Sample size	True estimate	Direct estimate	Standard error	Standardized difference[1]	95% confidence interval[2]	Model-based estimate	RMSE[3]	Standardized difference	95% confidence interval[4]	RRMSE[5]	Percent increase in equivalent sample size
						Large subsample (40%)						
18–49												
Non-Hispanic:												
Black	137	19.8	18.0	3.8	-1.6	11.1–26.8	19.6	2.1	-0.1	15.5–23.7	0.6	81.0
White	746	31.9	33.6	2.0	3.6	29.6–37.8	34.0	1.5	1.5	31.0–36.9	0.8	33.3
Other or multiple race	157	17.2	23.2	4.2	4.2	15.4–32.7	23.8	2.2	2.8	19.5–28.1	0.5	90.9
Hispanic	276	19.7	20.2	3.1	0.8	14.5–27.0	19.6	1.9	0.0	15.9–23.3	0.6	63.2
50–64												
Non-Hispanic:												
Black	91	27.2	25.3	5.1	-0.6	15.8–36.8	32.1	2.1	1.4	28.0–36.2	0.4	142.9
White	515	45.3	47.4	2.6	1.9	42.1–52.7	46.2	1.3	0.6	43.6–48.8	0.5	100.0
Other or multiple race	58	25.1	18.2	4.7	-2.0	9.4–30.3	27.4	2.3	0.6	22.8–32.0	0.5	104.3
Hispanic	94	35.1	35.2	5.9	0.0	23.8–48.0	28.8	2.1	-1.8	24.7–33.0	0.4	181.0
65 and older												
Non-Hispanic:												
Black	85	41.2	39.1	7.0	-0.5	25.5–54.1	40.5	2.2	-0.2	36.1–44.8	0.3	218.2
White	732	47.6	47.8	2.2	0.2	43.5–52.2	49.3	1.2	1.2	47.0–51.6	0.6	83.3
Other or multiple race	52	38.0	29.7	7.4	-1.9	16.1–46.6	26.7	2.4	-2.1	22.0–31.4	0.3	208.3
Hispanic	76	37.3	31.1	6.0	-1.4	19.8–44.5	34.0	2.4	-0.7	29.4–38.7	0.4	150.0
						Medium subsample (20%)						
18–49												
Non-Hispanic:												
Black	67	19.8	18.3	6.5	-1.3	7.4–34.9	19.6	2.3	-0.1	15.2–24.1	0.4	182.6
White	378	31.9	37.3	3.0	11.6	31.4–43.6	34.5	1.8	1.9	31.0–37.9	0.6	66.7
Other or multiple race	77	17.2	23.3	5.8	4.3	12.9–36.8	23.4	2.4	2.7	18.8–28.0	0.4	141.7
Hispanic	135	19.7	23.7	4.8	5.8	14.8–34.6	19.3	2.0	-0.2	15.3–23.2	0.4	140.0
50–64												
Non-Hispanic:												
Black	47	27.2	31.2	8.9	1.2	15.0–51.7	31.9	3.0	1.3	26.1–37.7	0.3	196.7
White	258	45.3	44.5	3.8	-0.7	36.9–52.2	45.5	1.9	0.1	41.7–49.2	0.5	100.0
Other or multiple race	31	25.1	14.2	6.2	-3.1	4.4–31.5	24.1	3.2	-0.3	17.8–30.3	0.5	93.8
Hispanic	47	35.1	31.4	7.5	-1.2	17.5–48.3	26.3	2.9	-2.5	20.5–32.0	0.4	158.6
65 and older												
Non-Hispanic:												
Black	42	41.2	46.8	9.5	1.5	27.7–66.5	42.1	3.9	0.2	34.5–49.7	0.4	143.6
White	370	47.6	46.8	3.1	-0.9	40.6–53.0	48.6	2.2	0.7	44.2–52.9	0.7	40.9
Other or multiple race	26	38.0	15.4	8.9	-5.1	2.7–41.5	23.4	4.0	-2.8	15.6–31.3	0.5	122.5
Hispanic	37	37.3	21.6	8.1	-3.7	8.0–42.0	32.5	4.0	-1.1	24.7–40.3	0.5	102.5

See footnotes at end of table.

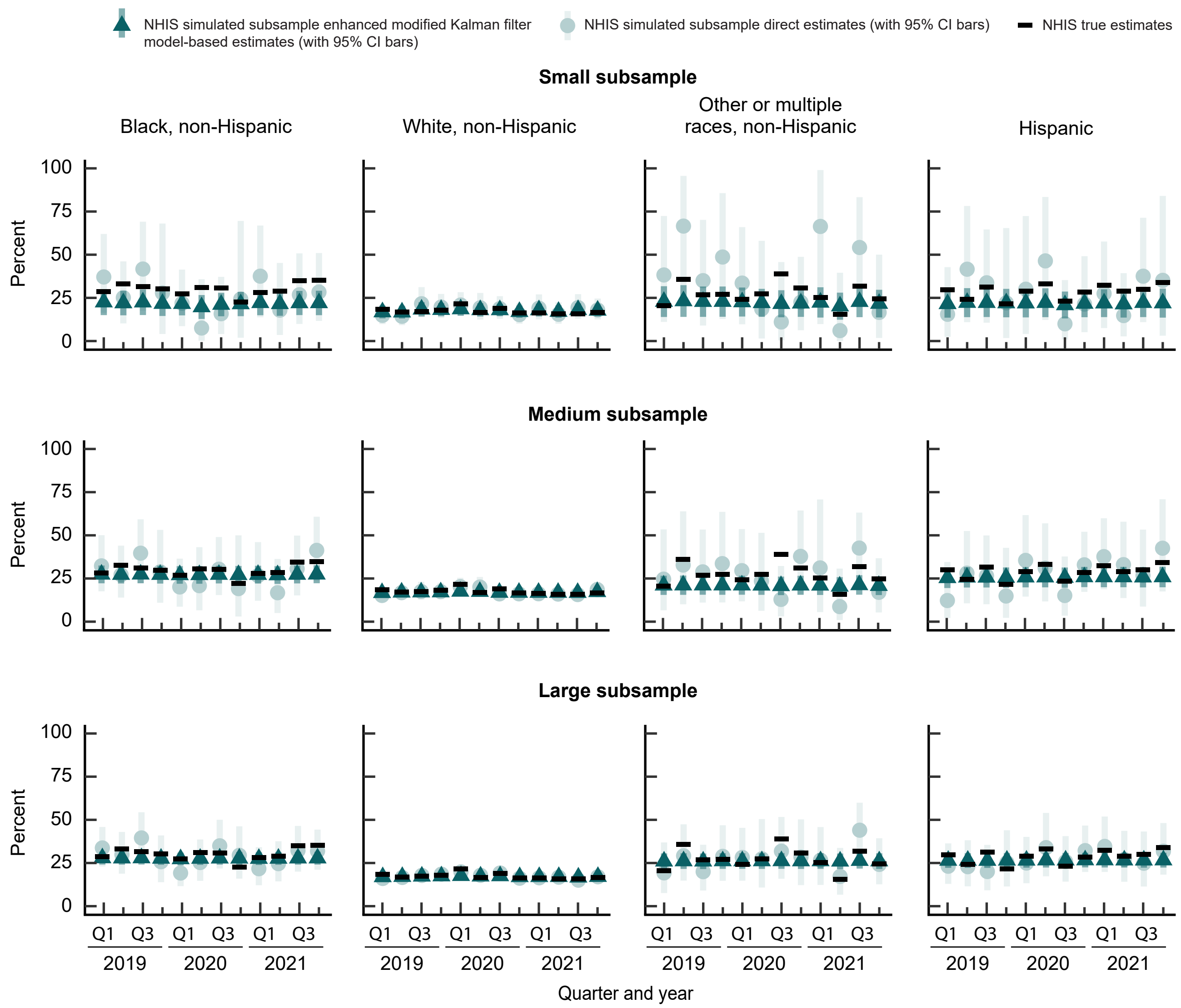
Table D. Simulated subsample sizes, prevalence of smoking history, and 95% confidence interval: National Health Interview Survey, 2021, Quarter 4—Con.

Age group and race and ethnicity	Sample size	True estimate	Sample direct estimate: Direct estimate	Sample direct estimate: Standard error	Sample direct estimate: Standardized difference[1]	Sample direct estimate: 95% confidence interval[2]	Model-based estimate: Model-based estimate	Model-based estimate: RMSE[3]	Model-based estimate: Standardized difference	Model-based estimate: 95% confidence interval[4]	RRMSE[5]	Percent increase in equivalent sample size
						Small subsample (10%)						
18–49												
Non-Hispanic:												
Black	33	19.8	10.7	8.4	-8.0	0.7–39.1	16.8	2.9	-1.2	11.1–22.5	0.4	189.7
White	190	31.9	40.1	4.3	17.4	31.6–49.0	35.6	2.5	2.8	30.7–40.5	0.6	72.0
Other or multiple race	40	17.2	29.5	8.7	8.5	13.8–49.7	23.5	3.2	2.7	17.2–29.7	0.4	171.9
Hispanic	68	19.7	21.0	5.7	2.0	10.9–34.7	19.6	2.6	0.0	14.5–24.6	0.5	119.2
50–64												
Non-Hispanic:												
Black	21	27.2	29.1	13.1	0.6	7.5–61.2	34.3	4.2	2.0	26.0–42.5	0.3	211.9
White	131	45.3	45.2	5.3	-0.1	34.6–56.1	45.5	2.6	0.1	40.4–50.6	0.5	103.8
Other or multiple race	17	25.1	5.7	3.5	-5.5	0.2–26.6	11.7	2.9	-3.3	5.9–17.4	0.8	20.7
Hispanic	25	35.1	28.6	12.2	-2.1	8.2–58.5	24.8	4.0	-2.9	17.0–32.7	0.3	205.0
65 and older												
Non-Hispanic:												
Black	22	41.2	54.2	11.3	3.4	30.5–76.5	38.9	5.6	-0.5	28.0–49.8	0.5	101.8
White	187	47.6	48.5	4.1	0.9	40.2–56.9	48.8	3.1	0.8	42.7–54.8	0.8	32.3
Other or multiple race	12	38.0	5.8	5.8	-7.3	0.0–37.0	13.8	4.5	-4.6	5.1–22.6	0.8	28.9
Hispanic	19	37.3	44.4	17.3	1.7	12.6–80.1	40.4	6.1	0.7	28.4–52.4	0.4	183.6

0.0 Quantity more than zero but less than 0.05.
[1]The standardized difference for the enhanced model Kalman filter (eMKF) (model-based) or direct estimates is calculated as: (eMKF or direct estimate minus true estimate) divided by true standard error (SE).
[2]Korn–Graubard 95% confidence interval.
[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) SE. For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[5]Relative RMSE (RRMSE) is calculated as the ratio: eMKF RMSE divided by direct RMSE.

SOURCE: National Center for Health Statistics, National Health Interview Survey, 2021, Quarter 4.

Figure 2. Direct and model-based estimates of prevalence of diagnosed diabetes and 95% confidence intervals for adults age 65 and older, by simulated sample size, race and ethnicity, and quarter: National Health Interview Survey, 2019–2021



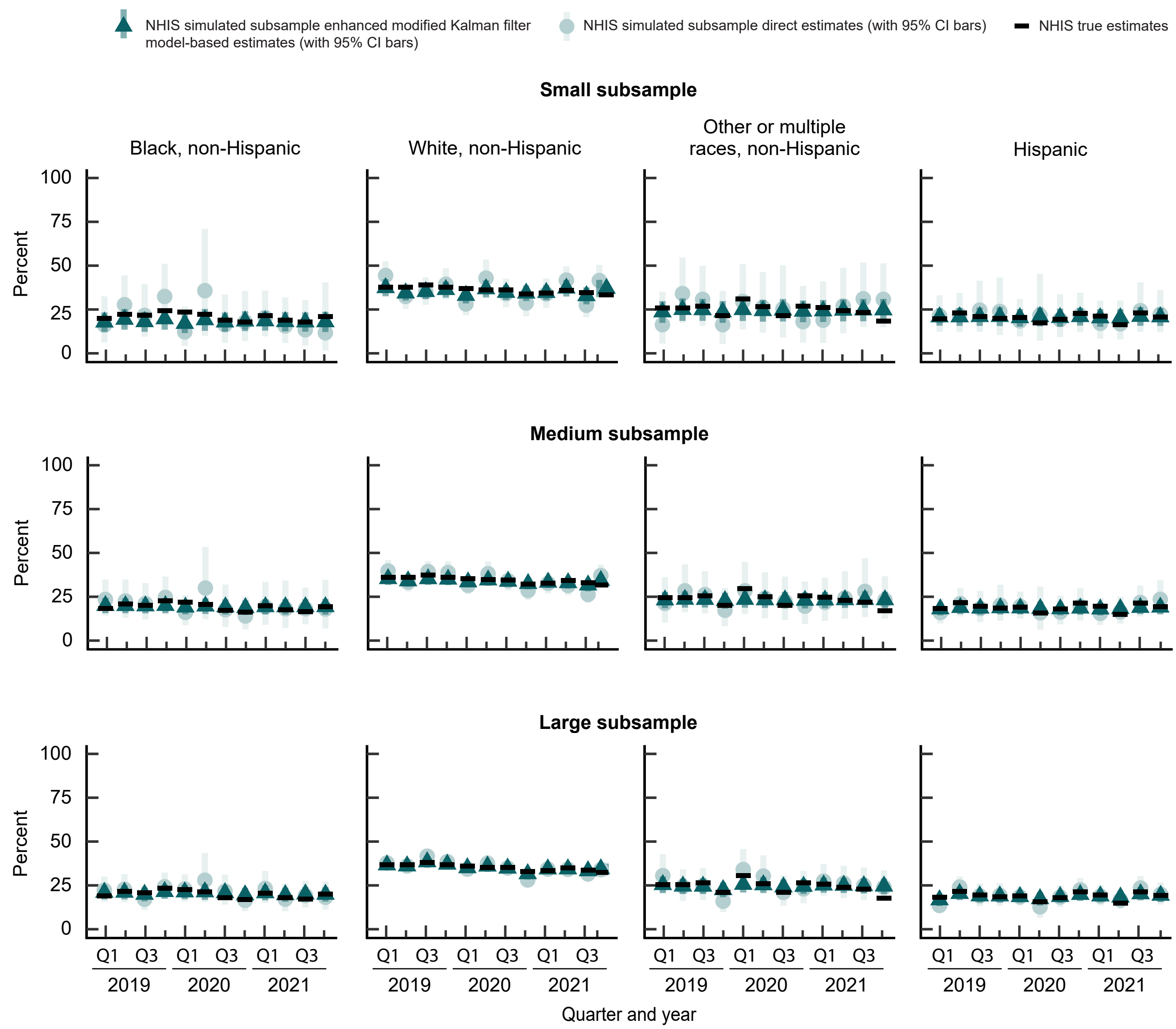
NOTES: NHIS is National Health Interview Survey; CI is confidence interval. The small subsample is 10% of the total NHIS sample, the medium subsample is 20%, and the large subsample is 40%. The true NHIS estimates were calculated using the total NHIS sample for each quarter and survey year.
SOURCE: National Center for Health Statistics, National Health Interview Survey, 2019–2021.

Discussion

This report evaluates the performance of an eMKF approach for estimating health outcomes for small subpopulations where statistical reliability may be of concern. To evaluate the performance of the eMKF approach under various scenarios commonly encountered by NCHS analysts, several simulated data sets were constructed reflecting a range of sample sizes, high or low prevalence outcomes, and linear and nonlinear trend forms with unequally spaced time intervals, along with shared or unique temporal trends by population subgroup. Like evaluations of the original MKF macro and procedures (9,10), findings suggest that using the eMKF approach offers substantial gains in estimate accuracy and precision (that is, lower RMSE) in nearly all cases examined in these simulations, with larger gains for smaller subgroups.

When evaluating the RMSE relative to the true direct NHIS estimates from the total sample, RMSEs were smaller for the model-based estimates compared with the direct subsample estimates. This suggests that the eMKF estimates offer advantages in terms of overall accuracy and precision relative to the direct estimates from smaller samples when compared with the true population values. This should reassure analysts who are considering using the eMKF macro to generate model-based estimates with NCHS data systems. More accurate and precise estimates can be obtained

Figure 3. Direct and model-based estimates of prevalence of reported ever smoking 100 cigarettes or more and 95% confidence intervals for adults ages 18–49, by simulated sample size, race and ethnicity, and quarter: National Health Interview Survey, 2019–2021

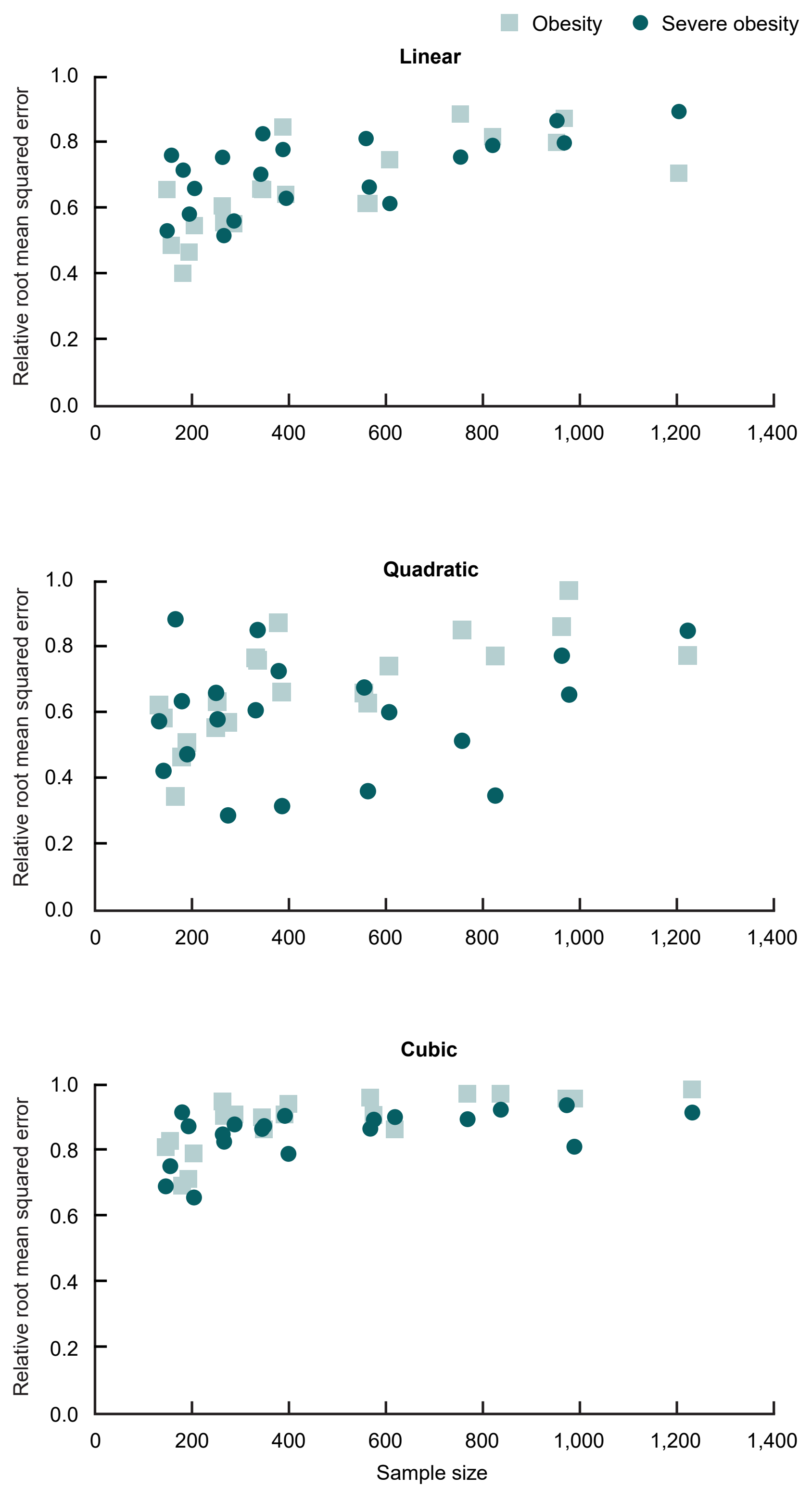


NOTES: NHIS is National Health Interview Survey; CI is confidence interval. The small subsample is 10% of the total NHIS sample, the medium subsample is 20%, and the large subsample is 40%. The true NHIS estimates were calculated using the total NHIS sample for each quarter and survey year.
SOURCE: National Center for Health Statistics, National Health Interview Survey, 2019–2021.

regardless of sample size. However, direct estimates may still likely be preferred when available as they can usually be assumed to be unbiased (16), and this consideration may be of greater importance to analysts and data users than improvements in precision or RMSE. In other cases, between-group comparisons may be of interest, where having more precise estimates would be useful in assessing whether significant differences exist between groups. Results shown in this report suggest that the potential increase in bias associated with using the eMKF approach is likely small on average but varies by subgroup. Model-based estimates were generally within one SE or less of the direct estimates, on average, although larger standardized differences were seen for selected individual subgroups, ranging up to 4.6 in one case where the estimates were based on a sample size of 12 respondents. Percentage increases in equivalent sample size were also variable by subgroup but tended to be larger in magnitude for smaller sample sizes. This is likely an important benefit in using the eMKF approach to generate estimates for smaller racial or ethnic subgroups typically aggregated into a larger other or multiple-race non-Hispanic category or an overall Hispanic or Latino category.

While improvements in precision may not be necessary for large subgroups where direct survey estimates are already sufficiently reliable, results of this evaluation indicate that

Figure 4. Relative root mean squared error of model-based estimates compared with direct estimates, by sample size and population group using simulated data assuming common trends in obesity outcomes: National Health and Nutrition Examination Survey, 2017–March 2020



NOTES: Linear, quadratic, and cubic trends are simulated. Obesity is defined as a body mass index greater than or equal to 30 kg/m^2 and severe obesity as a body mass index greater than or equal to 40 kg/m^2.
SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 2017–March 2020.

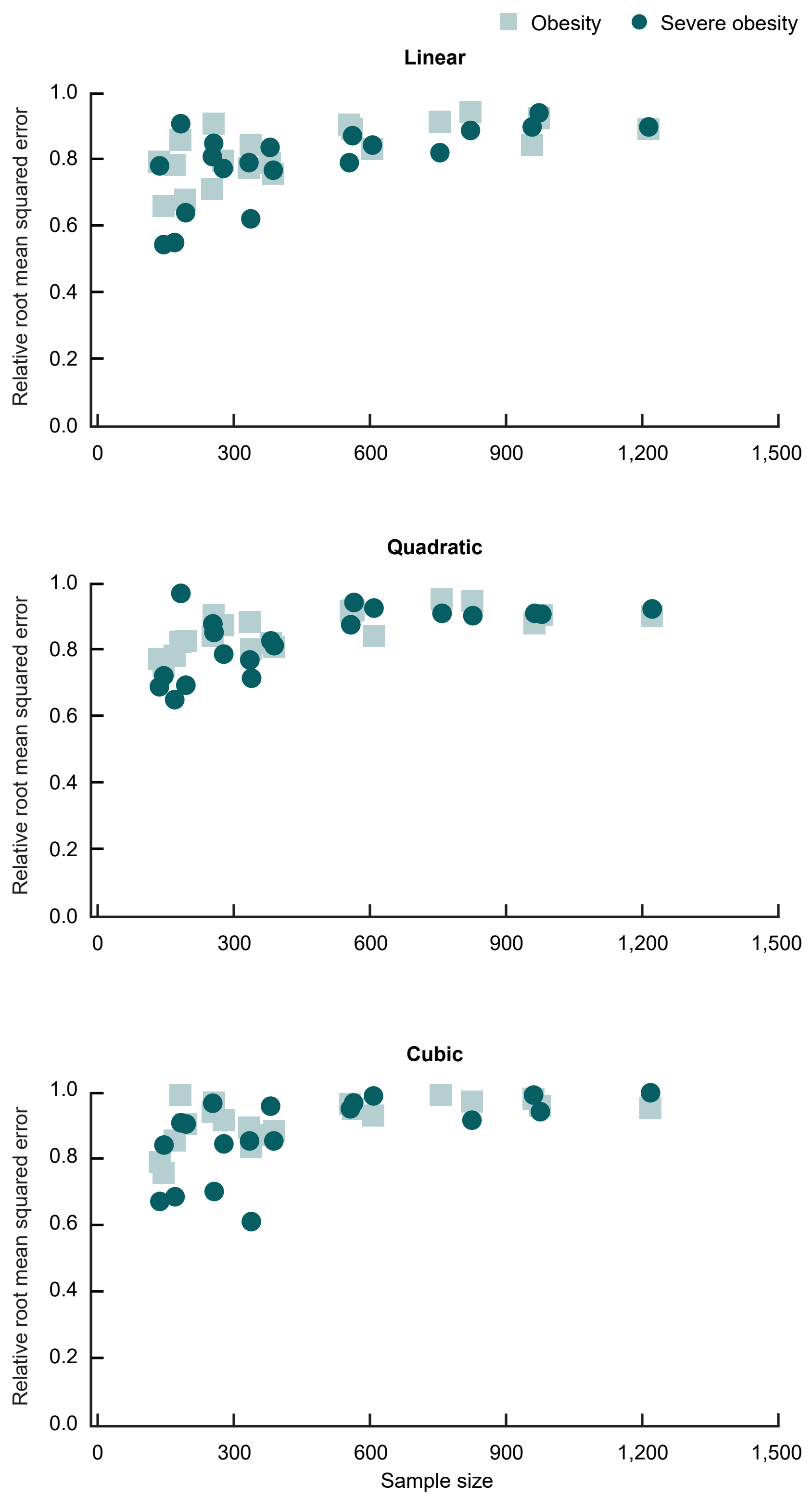
even in those cases, the costs of using the eMKF approach (as in potentially increased bias and computation time) are relatively small compared with the benefits. In previous evaluations of the original MKF macro and procedures, reductions in RMSE could be equivalent to a sixfold increase in sample size, on average, across the different racial and ethnic groups considered (10). In this report, average increases in equivalent sample sizes ranged from 0% to 420% across the various simulation scenarios. Given the cost of oversampling select subgroups to attain statistically reliable estimates for certain subdomains, the eMKF macro offers an exceptionally low-cost alternative.

Comparing the earlier MKF macro with the model averaging option available in the current eMKF macro, results illustrate that in most cases examined, the BMA up to cubic trends with random variances provided the largest increase in equivalent sample sizes and the lowest RRMSE. While a few examples occurred where the linear model outperformed the BMA model, all the model-based approaches offered improvements in precision and increases in equivalent sample size. Results of this comparison suggest that the BMA option with up to cubic trends is likely a reasonable default choice in most cases. An alternative model (linear or quadratic) may be more advantageous in terms of RMSE in some instances, predicting which model will be optimal may be difficult. If it is clear beforehand that underlying trends are truly linear or quadratic, analysts may opt to specify the assumed trend form rather than starting with the BMA up to cubic trends option.

Limitations and Considerations for Using the eMKF Macro

In some cases, RRMSEs could be greater than 1 for larger groups where more bias outweighs the increased precision of the model-based estimates. Generally, in cases where the RRMSE is greater

Figure 5. Relative root mean squared error of model-based estimates compared with direct estimates, by sample size and population subgroup using simulated data assuming unique trends in obesity outcomes: National Health and Nutrition Examination Survey, 2017–March 2020



NOTES: Linear, quadratic, and cubic trends are simulated. Obesity is defined as a body mass index greater than or equal to 30 kg/m^2 and severe obesity as a body mass index greater than or equal to 40 kg/m^2.
SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 2017–March 2020.

than 1, the direct estimates would be preferred over the model-based estimates. Analysts should review the eMKF output closely to identify groups where the model-based estimates may be inferior to the direct estimates, although this would be expected to occur very infrequently. Note also that the output of the eMKF macro shows the RRMSE comparing the model-based estimates to the direct estimates used as input. Although the direct estimates are unbiased under repeated samples, only one sample is observed in practice, and estimates may differ from the true population values. In other words, the observed direct estimates based on a single sample may not represent a true gold standard to compare with model-based estimates, which is why comparisons using simulated data were used in this analysis.

Several different simulated scenarios were evaluated in this report to examine performance of the eMKF macro under conditions commonly encountered by analysts of NCHS data, but these simulated scenarios are not exhaustive. Further evaluation of the eMKF macro will be important to identify additional limitations or potential refinements in the future. While one of the objectives of this evaluation was to determine rules of thumb for when the eMKF macro may not be advantageous, no clear thresholds for sample size, prevalence, or underlying trend form clearly resulted in inferior eMKF estimates (relative to the direct estimates). Similarly, no clear rules of thumb were identified to determine which eMKF model would be optimal for a given analysis, though the BMA up to cubic trends option likely offers a reasonable default selection, given that this model captured all trend forms well from linear to cubic, based on simulated NHANES data.

Analysts should be aware that in cases where trends are unique by group (as in different slopes), and when more complicated underlying trends occur (cubic compared with linear or quadratic), smaller gains in precision

Table E. Enhanced modified Kalman filter procedure performance across various trend simulation scenarios: National Health and Nutrition Examination Survey, 1999–March 2020

Characteristic	Obesity			Severe obesity		
	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
			Common trends			
Average standardized difference	0.3	0.5	0.2	-0.2	0.4	-0.1
Average relative root mean squared error	0.66	0.72	0.90	0.71	0.63	0.86
Average increase in equivalent sample size (%)	60.0	46.0	12.0	45.0	69.0	17.0
			Unique trends			
Average standardized difference	-0.1	0.1	0.4	-0.5	-0.1	0.2
Average relative root mean squared error	0.84	0.87	0.92	0.80	0.85	0.89
Average increase in equivalent sample size (%)	21.0	15.0	9.0	27.0	19.0	14.0

NOTES: Estimates reflect averages of each metric across all of the population subgroups within each trend form scenario and outcome. Obesity is defined as a body mass index greater than or equal to 30 kg/m^2, and severe obesity as a body mass index greater than or equal to 40 kg/m^2. Standardized differences were calculated as the difference between the model-based and direct estimate, divided by the direct estimate standard error.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–March 2020.

and overall accuracy were associated with the model-based estimates than when trends were shared across groups (as in common slopes). In these cases where trends are more variable either over time or across subgroups, the advantages of “borrowing strength” are not as large as in simpler cases where common linear trends are shared across groups. Note that given that the eMKF approach borrows strength across subgroups, the magnitude of estimated disparities may be biased for smaller subpopulations subject to more smoothing. For example, estimates for a small subgroup with extremely poor health outcomes may be smoothed toward those of a larger reference group with better health outcomes. In those cases, analysts should be aware that disparities between these groups may be understated.

While the eMKF macro and models provide an approach for generating more precise model-based estimates for subgroups where direct estimates do not meet existing statistical reliability standards, these methods cannot be used when data are completely missing for some subgroups. As a result, if some population groups are not sampled in some time periods, analysts will need to combine or coarsen the data so that at least some sample appears in each time period. In these cases where some coarsening or aggregation may be necessary, consider if the composition of the groups may change over time, which could contribute to increased bias or variance of the estimates. For example, if American Indian or Alaska Native, Asian, and other or multiple race people are included in one larger group, estimates and related trends could be affected by sampling variability or changes in the proportion of that larger group represented by each racial and ethnic subgroup.

Based on the findings presented in this report showing large improvements in precision when using model-based estimates, analysts are advised to avoid filling in suppressed cells with model-based estimates while showing direct estimates for other groups where presentation standards are met. Given the impact of the model-based approach on precision demonstrated in this evaluation, comparing a model-based estimate for one population subgroup with a direct estimate for a larger population subgroup would be inappropriate. Instead, presenting a set of model-based estimates for all groups in addition to available direct estimates would be preferred. The main benefit of using the eMKF approach is anticipated to be in providing more reliable estimates for small subgroups when direct estimates would otherwise be suppressed, or when additional precision may improve statistical power for between-group comparisons when estimates for some subgroups are highly variable. However, the eMKF approach could be more broadly beneficial in applications where analysts would typically need to aggregate data over time, larger groups, or geography to produce statistically reliable estimates. The eMKF approach could be used in those cases to preserve the granularity of the data while improving the precision of the estimates.

Finally, no guidelines or recommendations for standards exist concerning the presentation of model-based estimates, unlike the current NCHS criteria for rate, count, and proportion standards for presentation (1,2). For example, some model-based estimates may have wide 95% CIs or large SEs (that is, greater than 30% relative standard error). Analysts will need to consider whether it is informative to present those estimates along with their associated uncertainty, or whether those estimates should be flagged or not shown.

Conclusions

The eMKF offers substantial gains in estimate reliability and overall accuracy under a wide array of analytic scenarios commonly encountered by NCHS analysts. This tool can provide a relatively straightforward and exceptionally low-cost approach for generating more granular estimates of health outcomes for small subpopulations, compared with alternative approaches like oversampling or aggregating data.

Table F. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in the prevalence of obesity, by age group and race and ethnicity where trends are common across group: National Health and Nutrition Examination Survey, 1999–March 2020

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Linear					
Non-Hispanic:										
Black	268	50.1	3.6	42.9–57.3	54.0	2.0	50.1–57.8	1.1	0.6	80.5
White	349	51.2	2.6	45.9–56.6	50.2	1.7	46.9–53.5	-0.4	0.7	52.6
Other or multiple race	196	48.4	5.4	37.4–59.6	47.3	2.5	42.3–52.2	-0.2	0.5	115.2
Mexican American	183	54.9	5.3	43.9–65.6	51.7	2.1	47.5–55.9	-0.6	0.4	149.4
Other Hispanic	150	51.3	3.3	43.1–59.6	48.2	2.1	44.0–52.4	-1.0	0.7	52.6
25–44										
Non-Hispanic:										
Black	761	64.1	1.7	60.6–67.5	66.0	1.5	63.1–68.9	1.1	0.9	13.1
White	828	59.1	1.4	55.7–62.5	59.3	1.2	57.0–61.6	0.1	0.8	22.7
Other or multiple race	571	50.6	3.2	44.2–57.1	52.3	2.0	48.4–56.1	0.5	0.6	63.1
Mexican American	398	63.9	2.6	58.5–69.1	63.8	1.7	60.5–67.1	-0.1	0.6	56.0
Other Hispanic	289	54.6	4.0	46.3–62.7	60.5	2.2	56.1–64.8	1.5	0.6	81.2
45–64										
Non-Hispanic:										
Black	962	68.9	2.5	63.6–73.8	70.4	2.0	66.4–74.3	0.6	0.8	25.2
White	977	65.7	1.7	62.1–69.1	65.0	1.5	62.0–68.0	-0.4	0.9	14.8
Other or multiple race	614	52.2	3.3	45.6–58.7	54.4	2.4	49.7–59.2	0.7	0.8	34.2
Mexican American	391	62.9	2.2	57.9–67.7	64.3	1.9	60.6–68.0	0.6	0.9	18.3
Other Hispanic	345	57.6	3.8	49.6–65.2	59.1	2.5	54.1–64.0	0.4	0.7	52.2
65 and older										
Non-Hispanic:										
Black	564	65.1	2.7	59.6–70.3	67.1	1.6	63.9–70.3	0.8	0.6	63.3
White	1,216	59.6	1.9	55.7–63.4	60.5	1.4	57.8–63.1	0.5	0.7	41.9
Other or multiple race	265	40.0	3.7	32.7–47.6	46.1	2.2	41.7–50.5	1.7	0.6	65.0
Mexican American	159	60.9	3.7	52.8–68.5	63.5	1.8	60.0–67.1	0.7	0.5	105.7
Other Hispanic	207	68.7	3.7	60.8–76.0	64.7	2.0	60.7–68.7	-1.1	0.6	83.1

See footnotes at end of table.

Table F. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in the prevalence of obesity, by age group and race and ethnicity where trends are common across group: National Health and Nutrition Examination Survey, 1999–March 2020—Con.

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Quadratic					
Non-Hispanic:										
Black	268	45.0	4.0	37.0–53.3	51.2	2.7	45.9–56.5	1.5	0.7	48.4
White	349	44.4	2.5	39.1–49.8	46.3	2.0	42.4–50.2	0.8	0.8	27.2
Other or multiple race	196	39.0	5.7	27.8–51.1	44.6	3.0	38.7–50.4	1.0	0.5	91.6
Mexican American	183	46.1	6.4	33.2–59.5	49.7	2.7	44.5–55.0	0.6	0.4	140.8
Other Hispanic	150	42.0	3.6	34.0–50.4	44.6	2.4	40.0–49.3	0.7	0.7	50.6
25–44										
Non-Hispanic:										
Black	761	58.5	1.5	54.9–62.0	59.0	1.3	56.5–61.4	0.3	0.9	15.2
White	828	50.5	1.8	47.0–54.0	50.8	1.4	48.1–53.6	0.2	0.8	25.4
Other or multiple race	571	44.0	3.0	38.1–50.0	44.6	2.0	40.7–48.5	0.2	0.7	49.5
Mexican American	398	54.1	2.5	49.0–59.1	54.6	1.8	51.1–58.0	0.2	0.7	42.9
Other Hispanic	289	47.1	3.8	39.5–54.8	52.0	2.3	47.4–56.6	1.3	0.6	62.2
45–64										
Non-Hispanic:										
Black	962	62.1	2.4	57.3–66.8	63.2	2.1	59.2–67.3	0.5	0.9	14.0
White	977	58.7	1.7	55.3–62.0	58.2	1.7	55.0–61.4	-0.3	1.0	2.5
Other or multiple race	614	46.3	3.8	38.6–54.1	48.1	2.9	42.3–53.9	0.5	0.8	30.0
Mexican American	391	55.9	2.3	50.9–60.9	57.0	2.0	53.0–60.9	0.5	0.9	12.7
Other Hispanic	345	50.4	3.5	43.4–57.3	51.9	2.7	46.5–57.2	0.4	0.8	26.1
65 and older										
Non-Hispanic:										
Black	564	57.2	2.8	51.4–62.8	58.3	2.0	54.5–62.2	0.4	0.7	43.6
White	1,216	52.1	2.0	48.2–56.0	52.5	1.6	49.5–55.6	0.2	0.8	25.2
Other or multiple race	265	33.8	4.3	25.4–43.0	38.7	2.6	33.6–43.8	1.1	0.6	66.0
Mexican American	159	56.5	3.4	48.4–64.4	56.1	2.1	52.0–60.3	-0.1	0.6	59.1
Other Hispanic	207	60.2	4.7	50.4–69.5	56.4	2.6	51.3–61.6	-0.8	0.6	78.1

See footnotes at end of table.

Table F. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in the prevalence of obesity, by age group and race and ethnicity where trends are common across group: National Health and Nutrition Examination Survey, 1999–March 2020—Con.

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Cubic					
Non-Hispanic:										
Black	268	35.8	3.9	28.2–44.0	38.5	3.6	31.5–45.5	0.7	0.9	9.4
White	349	36.6	3.5	29.7–44.0	36.9	3.1	30.8–42.9	0.1	0.9	14.1
Other or multiple race	196	33.8	5.6	22.9–46.0	33.5	4.1	25.4–41.6	-0.1	0.7	36.4
Mexican American	183	37.9	5.9	26.4–50.5	36.8	4.2	28.5–45.0	-0.2	0.7	40.0
Other Hispanic	150	35.3	4.1	27.2–44.0	34.7	3.4	28.0–41.3	-0.2	0.8	21.3
25–44										
Non-Hispanic:										
Black	761	49.3	1.6	45.7–52.9	49.5	1.6	46.4–52.6	0.1	1.0	2.3
White	828	43.2	1.5	39.8–46.7	43.3	1.4	40.4–46.1	0.1	1.0	2.2
Other or multiple race	571	36.7	3.0	30.9–42.9	36.7	2.7	31.3–42.0	0.0	0.9	9.0
Mexican American	398	43.6	2.5	38.6–48.7	44.2	2.4	39.5–48.9	0.2	1.0	5.5
Other Hispanic	289	39.3	3.6	32.3–46.7	40.9	3.3	34.5–47.3	0.4	0.9	8.8
45–64										
Non-Hispanic:										
Black	962	52.4	2.0	48.3–56.4	52.9	2.0	49.0–56.7	0.2	1.0	3.7
White	977	48.5	1.7	45.0–52.0	48.4	1.7	45.1–51.7	-0.1	1.0	3.8
Other or multiple race	614	36.6	4.0	28.8–45.0	37.5	3.5	30.6–44.3	0.2	0.9	14.2
Mexican American	391	48.4	2.9	42.6–54.3	48.5	2.7	43.2–53.7	0.0	0.9	8.8
Other Hispanic	345	41.8	3.0	35.8–48.0	42.2	2.8	36.8–47.6	0.1	0.9	10.0
65 and older										
Non-Hispanic:										
Black	564	47.5	3.2	41.1–54.0	49.5	3.1	43.4–55.6	0.6	1.0	3.4
White	1,216	44.5	1.7	41.2–47.8	44.8	1.7	41.5–48.0	0.2	1.0	0.9
Other or multiple race	265	26.1	3.7	19.1–34.1	28.9	3.5	22.0–35.8	0.8	1.0	4.7
Mexican American	159	48.6	4.1	40.3–57.0	49.6	3.5	42.8–56.4	0.2	0.8	18.7
Other Hispanic	207	51.7	4.3	42.9–60.5	51.6	3.5	44.7–58.4	0.0	0.8	23.9

0.0 Quantity more than zero but less than 0.05.
[1]Korn–Graubard 95% confidence interval.
[2]Root mean squared error (RMSE) is the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[3]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[4]The standardized difference between the enhanced modified Kalman filter (eMKF) (model-based) and direct estimates is calculated as: (eMKF estimate minus direct estimate) divided by direct SE.
[5]Relative RMSE (RRMSE) is calculated as the ratio: eMKF RMSE divided by direct RMSE.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–March 2020.

Table G. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in the prevalence of severe obesity, by age group and race and ethnicity where trends are common across group: National Health and Nutrition Examination Survey, 1999–March 2020

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Linear					
Non-Hispanic:										
Black	268	20.3	4.5	12.2–30.7	18.6	2.3	14.1–23.1	-0.4	0.5	93.8
White	349	13.6	1.8	10.2–17.7	14.4	1.5	11.5–17.3	0.4	0.8	21.2
Other or multiple race	196	12.9	3.7	6.5–22.2	13.2	2.2	9.0–17.5	0.1	0.6	72.0
Mexican American	183	15.0	2.6	10.1–21.0	15.5	1.8	11.9–19.1	0.2	0.7	40.0
Other Hispanic	150	17.4	4.4	9.6–27.8	15.5	2.3	10.9–20.0	-0.4	0.5	88.4
25–44										
Non-Hispanic:										
Black	761	30.6	1.6	27.3–34.0	30.3	1.2	27.9–32.7	-0.1	0.8	32.6
White	828	24.9	1.5	22.0–28.0	24.7	1.2	22.5–27.0	-0.1	0.8	26.7
Other or multiple race	571	19.0	2.4	14.5–24.2	20.1	1.6	17.0–23.2	0.5	0.7	50.8
Mexican American	398	27.5	2.2	23.2–32.2	27.2	1.4	24.4–29.9	-0.2	0.6	59.0
Other Hispanic	289	24.0	2.8	18.6–30.1	23.8	1.6	20.7–26.9	-0.1	0.6	78.3
45–64										
Non-Hispanic:										
Black	962	33.6	1.5	30.6–36.7	33.1	1.3	30.6–35.6	-0.4	0.9	15.7
White	977	29.8	2.0	25.9–33.9	28.1	1.6	24.9–31.2	-0.8	0.8	25.5
Other or multiple race	614	17.8	3.3	11.7–25.4	19.3	2.0	15.3–23.3	0.5	0.6	63.1
Mexican American	391	29.7	2.1	25.2–34.5	28.4	1.6	25.2–31.5	-0.6	0.8	28.7
Other Hispanic	345	24.4	2.6	19.3–30.0	24.3	1.8	20.7–27.9	0.0	0.7	42.5
65 and older										
Non-Hispanic:										
Black	564	28.6	2.2	24.3–33.3	27.9	1.8	24.3–31.4	-0.3	0.8	23.4
White	1,216	25.6	1.5	22.7–28.8	25.0	1.4	22.3–27.7	-0.4	0.9	12.1
Other or multiple race	265	14.5	2.9	9.3–21.2	16.0	2.2	11.8–20.3	0.5	0.8	32.7
Mexican American	159	24.7	2.7	18.2–32.2	24.8	2.1	20.7–28.8	0.0	0.8	31.6
Other Hispanic	207	32.2	3.8	24.8–40.4	27.2	2.5	22.3–32.2	-1.3	0.7	51.8

See footnotes at end of table.

Table G. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in the prevalence of severe obesity, by age group and race and ethnicity where trends are common across group: National Health and Nutrition Examination Survey, 1999–March 2020—Con.

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Quadratic					
Non-Hispanic:										
Black	268	16.5	3.6	10.0–25.0	16.9	2.3	12.4–21.3	0.1	0.6	59.8
White	349	10.1	1.8	6.8–14.3	11.3	1.6	8.2–14.4	0.7	0.9	15.1
Other or multiple race	196	11.1	3.1	5.7–19.0	11.3	2.1	7.1–15.5	0.1	0.7	48.1
Mexican American	183	10.1	1.7	6.1–15.4	11.2	1.5	8.3–14.1	0.7	0.9	11.4
Other Hispanic	150	14.1	3.7	7.7–23.0	13.3	2.3	8.9–17.8	-0.2	0.6	61.2
25–44										
Non-Hispanic:										
Black	761	27.0	1.3	23.8–30.3	25.9	0.8	24.5–27.4	-0.8	0.6	76.4
White	828	20.2	1.7	17.0–23.8	20.8	0.7	19.4–22.2	0.3	0.4	139.5
Other or multiple race	571	14.4	2.1	10.6–19.0	16.7	0.9	15.0–18.5	1.1	0.4	132.8
Mexican American	398	21.4	2.1	17.3–25.9	22.5	0.8	20.8–24.1	0.5	0.4	157.1
Other Hispanic	289	18.8	2.8	13.5–25.1	20.4	1.0	18.4–22.4	0.6	0.4	174.7
45–64										
Non-Hispanic:										
Black	962	26.7	1.7	23.3–30.2	27.5	1.4	24.8–30.2	0.5	0.8	25.2
White	977	22.4	2.3	18.0–27.3	23.2	1.6	20.0–26.3	0.3	0.7	44.3
Other or multiple race	614	13.6	2.8	8.5–20.3	16.8	1.8	13.2–20.3	1.1	0.6	55.1
Mexican American	391	23.8	1.9	19.7–28.4	24.1	1.5	21.2–26.9	0.1	0.8	32.2
Other Hispanic	345	19.6	2.8	14.4–25.7	21.2	1.8	17.7–24.7	0.6	0.7	53.8
65 and older										
Non-Hispanic:										
Black	564	24.2	2.2	20.0–28.7	24.3	1.5	21.3–27.3	0.1	0.7	40.4
White	1,216	19.5	1.2	17.2–21.9	19.8	1.0	17.8–21.8	0.3	0.9	15.4
Other or multiple race	265	11.1	2.5	6.7–17.0	13.4	1.7	10.0–16.8	0.9	0.7	43.3
Mexican American	159	19.8	4.2	12.1–29.5	21.2	2.0	17.2–25.2	0.3	0.5	106.2
Other Hispanic	207	22.7	3.8	15.7–31.1	22.3	2.0	18.4–26.2	-0.1	0.5	88.5

See footnotes at end of table.

Table G. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in the prevalence of severe obesity, by age group and race and ethnicity where trends are common across group: National Health and Nutrition Examination Survey, 1999–March 2020—Con.

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Cubic					
Non-Hispanic:										
Black	268	10.9	2.7	6.1–17.5	11.3	2.3	6.8–15.8	0.2	0.8	18.9
White	349	7.3	1.8	4.2–11.7	7.5	1.6	4.4–10.6	0.1	0.9	12.9
Other or multiple race	196	7.7	1.8	4.4–12.3	7.2	1.6	4.1–10.4	-0.2	0.9	13.0
Mexican American	183	5.2	1.3	2.5–9.5	5.6	1.2	3.2–8.1	0.3	0.9	8.1
Other Hispanic	150	12.4	3.4	6.4–20.9	10.0	2.4	5.2–14.8	-0.7	0.7	40.4
25–44										
Non-Hispanic:										
Black	761	21.6	1.5	18.7–24.7	20.9	1.3	18.2–23.5	-0.5	0.9	10.5
White	828	14.0	1.3	11.6–16.7	14.0	1.2	11.7–16.3	0.0	0.9	7.2
Other or multiple race	571	10.2	1.5	7.5–13.5	9.9	1.3	7.3–12.6	-0.2	0.9	10.7
Mexican American	398	15.2	2.5	10.6–20.9	15.6	2.0	11.7–19.6	0.2	0.8	24.1
Other Hispanic	289	11.2	1.8	7.8–15.4	11.8	1.6	8.7–14.9	0.3	0.9	12.4
45–64										
Non-Hispanic:										
Black	962	19.9	1.4	17.2–22.9	20.2	1.4	17.5–22.8	0.2	1.0	5.8
White	977	18.9	2.4	14.4–24.1	17.8	2.0	13.9–21.7	-0.5	0.8	21.0
Other or multiple race	614	9.5	1.8	6.2–13.7	9.8	1.7	6.6–13.1	0.2	0.9	9.7
Mexican American	391	20.5	1.7	16.6–24.8	19.6	1.5	16.6–22.5	-0.5	0.9	9.3
Other Hispanic	345	14.7	2.0	10.9–19.2	14.7	1.8	11.2–18.2	0.0	0.9	14.0
65 and older										
Non-Hispanic:										
Black	564	18.2	2.0	14.4–22.6	18.3	1.8	14.8–21.8	0.0	0.9	13.9
White	1,216	14.8	1.4	12.2–17.8	14.7	1.3	12.2–17.3	-0.1	0.9	8.2
Other or multiple race	265	9.4	2.2	5.5–14.7	8.9	1.9	5.2–12.6	-0.2	0.9	16.0
Mexican American	159	15.7	3.3	9.7–23.3	16.1	2.5	11.1–21.1	0.1	0.8	29.8
Other Hispanic	207	19.5	4.1	12.1–28.9	16.6	2.8	11.2–22.0	-0.7	0.7	46.9

0.0 Quantity more than zero but less than 0.05.
[1]Korn–Graubard 95% confidence interval.
[2]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[3]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[4]The standardized difference between the enhanced modified Kalman filter (eMKF) (model-based) and direct estimates is calculated as: (eMKF estimate minus direct estimate) divided by direct SE.
[5]Relative RMSE (RRMSE) is calculated as the ratio: eMKF RMSE divided by direct RMSE.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–March 2020.

Table H. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in the prevalence of obesity, by age group and race and ethnicity where trends vary by group: National Health and Nutrition Examination Survey, 1999–March 2020

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Linear					
Non-Hispanic:										
Black	268	37.8	3.5	30.9–45.2	39.2	3.3	32.8–45.6	0.4	0.9	8.7
White	349	51.7	3.8	44.0–59.4	48.6	3.3	42.2–55.0	-0.8	0.9	16.8
Other or multiple race	196	25.8	4.8	16.7–36.6	30.5	4.2	22.3–38.7	1.0	0.9	14.9
Mexican American	183	48.3	4.6	38.9–57.8	46.3	3.7	39.0–53.5	-0.4	0.8	25.6
Other Hispanic	150	47.3	4.8	37.7–57.1	43.9	3.8	36.4–51.5	-0.7	0.8	24.1
25–44										
Non-Hispanic:										
Black	761	51.8	2.0	47.9–55.8	52.1	1.8	48.5–55.6	0.1	0.9	8.0
White	828	56.0	1.7	52.6–59.5	54.8	1.7	51.6–58.0	-0.7	1.0	4.9
Other or multiple race	571	40.4	2.3	35.9–45.0	39.8	2.1	35.8–43.8	-0.3	0.9	10.5
Mexican American	398	55.0	4.0	46.7–63.0	53.1	3.1	47.0–59.2	-0.5	0.8	29.7
Other Hispanic	289	52.3	3.6	44.9–59.5	51.4	2.9	45.7–57.1	-0.2	0.8	23.5
45–64										
Non-Hispanic:										
Black	962	50.6	2.3	46.0–55.3	51.5	2.0	47.6–55.4	0.4	0.9	16.9
White	977	54.3	1.7	50.9–57.7	53.6	1.6	50.5–56.7	-0.4	0.9	6.9
Other or multiple race	614	37.2	2.7	31.8–42.8	36.5	2.3	32.0–41.0	-0.3	0.8	18.5
Mexican American	391	56.3	3.0	50.3–62.2	55.4	2.4	50.8–60.1	-0.3	0.8	24.7
Other Hispanic	345	53.7	3.1	47.5–59.8	52.2	2.4	47.4–56.9	-0.5	0.8	27.0
65 and older										
Non-Hispanic:										
Black	564	40.4	2.4	35.6–45.3	42.7	2.2	38.4–47.1	1.0	0.9	9.1
White	1,216	50.6	2.5	45.7–55.6	49.5	2.2	45.1–53.9	-0.4	0.9	10.5
Other or multiple race	265	30.0	5.0	20.5–41.0	32.1	3.6	25.0–39.3	0.4	0.7	38.0
Mexican American	159	49.0	5.3	38.2–59.9	50.0	3.6	43.0–57.1	0.2	0.7	48.1
Other Hispanic	207	49.0	5.2	38.5–59.6	45.9	3.6	38.9–53.0	-0.6	0.7	44.4

See footnotes at end of table.

Table H. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in the prevalence of obesity, by age group and race and ethnicity where trends vary by group: National Health and Nutrition Examination Survey, 1999–March 2020—Con.

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Quadratic					
Non-Hispanic:										
Black	268	31.4	2.6	25.9–37.3	32.2	2.4	27.5–36.8	0.3	0.9	9.4
White	349	44.9	4.3	36.3–53.8	42.5	3.5	35.5–49.4	-0.6	0.8	22.1
Other or multiple race	196	20.7	4.1	13.2–30.1	23.8	3.4	17.0–30.5	0.7	0.8	19.0
Mexican American	183	39.8	4.4	31.1–49.0	39.4	3.5	32.5–46.3	-0.1	0.8	24.8
Other Hispanic	150	39.1	4.8	29.6–49.2	37.8	3.8	30.3–45.3	-0.3	0.8	26.2
25–44										
Non-Hispanic:										
Black	761	44.2	1.8	40.6–47.9	44.7	1.7	41.3–48.1	0.2	1.0	4.5
White	828	48.8	1.8	45.2–52.4	47.9	1.7	44.5–51.3	-0.5	1.0	5.0
Other or multiple race	571	33.1	2.2	28.8–37.7	33.2	2.0	29.2–37.2	0.0	0.9	7.9
Mexican American	398	47.6	3.8	39.9–55.4	47.0	3.2	40.9–53.2	-0.1	0.8	21.1
Other Hispanic	289	46.3	3.0	40.4–52.3	46.3	2.6	41.2–51.5	0.0	0.9	13.0
45–64										
Non-Hispanic:										
Black	962	44.3	2.3	39.7–49.0	45.3	2.1	41.2–49.3	0.4	0.9	12.4
White	977	46.7	2.1	42.5–50.9	46.8	1.9	43.0–50.5	0.0	0.9	9.5
Other or multiple race	614	26.6	3.0	20.9–32.9	27.9	2.5	22.9–32.9	0.4	0.9	16.9
Mexican American	391	50.4	3.0	44.5–56.4	50.6	2.5	45.7–55.4	0.0	0.8	19.6
Other Hispanic	345	45.4	2.3	40.0–50.8	45.4	2.0	41.4–49.4	0.0	0.9	11.9
65 and older										
Non-Hispanic:										
Black	564	36.4	2.5	31.6–41.5	37.8	2.3	33.3–42.3	0.6	0.9	8.3
White	1,216	44.6	2.7	39.3–50.0	44.4	2.4	39.6–49.2	-0.1	0.9	9.7
Other or multiple race	265	23.6	3.7	16.7–31.8	24.8	3.1	18.6–31.0	0.3	0.9	16.9
Mexican American	159	41.0	4.8	31.5–51.0	43.2	3.7	36.0–50.5	0.5	0.8	29.8
Other Hispanic	207	42.8	3.8	35.3–50.6	41.8	3.2	35.6–48.1	-0.3	0.8	18.9

See footnotes at end of table.

Table H. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in the prevalence of obesity, by age group and race and ethnicity where trends vary by group: National Health and Nutrition Examination Survey, 1999–March 2020—Con.

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Cubic					
Non-Hispanic:										
Black	268	25.0	2.3	19.9–30.6	26.4	2.2	22.0–30.7	0.6	1.0	3.7
White	349	38.7	4.4	30.0–48.0	37.0	3.8	29.6–44.4	-0.4	0.9	17.7
Other or multiple race	196	13.6	2.7	8.7–19.7	16.1	2.6	11.0–21.2	1.0	1.0	1.6
Mexican American	183	31.6	4.3	23.2–40.9	32.9	3.8	25.5–40.2	0.3	0.9	15.5
Other Hispanic	150	31.6	5.1	21.9–42.6	32.7	4.1	24.6–40.7	0.2	0.8	23.2
25–44										
Non-Hispanic:										
Black	761	34.6	1.6	31.2–38.1	35.5	1.6	32.4–38.6	0.6	1.0	1.6
White	828	39.7	1.6	36.4–43.1	39.7	1.5	36.7–42.8	0.0	1.0	3.5
Other or multiple race	571	24.4	2.3	20.0–29.3	25.8	2.2	21.5–30.1	0.6	1.0	5.5
Mexican American	398	39.3	3.2	33.1–45.9	40.7	2.8	35.1–46.2	0.4	0.9	12.2
Other Hispanic	289	36.1	2.9	30.3–42.1	37.9	2.7	32.7–43.2	0.6	0.9	8.9
45–64										
Non-Hispanic:										
Black	962	35.0	1.8	31.4–38.7	36.2	1.8	32.7–39.7	0.6	1.0	2.7
White	977	38.4	2.0	34.6–42.4	39.2	1.9	35.6–42.9	0.4	1.0	4.6
Other or multiple race	614	21.8	2.7	16.6–27.7	23.4	2.5	18.5–28.4	0.6	0.9	7.5
Mexican American	391	40.9	3.3	34.3–47.6	43.1	2.9	37.4–48.8	0.7	0.9	13.4
Other Hispanic	345	38.7	3.1	32.7–45.0	39.8	2.8	34.4–45.2	0.3	0.9	11.1
65 and older										
Non-Hispanic:										
Black	564	27.3	2.2	23.1–31.8	28.6	2.1	24.5–32.7	0.6	1.0	4.0
White	1,216	36.9	2.6	31.7–42.3	37.3	2.5	32.4–42.3	0.2	1.0	5.4
Other or multiple race	265	16.2	2.6	11.4–22.1	17.3	2.5	12.4–22.1	0.4	0.9	6.3
Mexican American	159	30.9	5.7	20.1–43.6	35.9	4.5	27.1–44.7	0.9	0.8	27.5
Other Hispanic	207	35.6	3.5	28.7–43.0	35.6	3.2	29.4–41.9	0.0	0.9	10.0

0.0 Quantity more than zero but less than 0.05.
[1]Korn–Graubard 95% confidence interval.
[2]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[3]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[4]The standardized difference between the enhanced modified Kalman filter (eMKF) (model-based) and direct estimates is calculated as: (eMKF estimate minus direct estimate) divided by direct SE.
[5]Relative RMSE (RRMSE) is calculated as the ratio: eMKF RMSE divided by direct RMSE.

SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–March 2020.

Table J. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in prevalence of severe obesity, by age group and race and ethnicity where trends vary by group: National Health and Nutrition Examination Survey, 1999–March 2020

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Linear					
Non-Hispanic:										
Black	268	12.5	2.0	8.8–17.1	12.2	1.7	8.9–15.6	-0.1	0.9	16.1
White	349	21.4	4.3	13.5–31.2	14.3	2.7	8.9–19.6	-1.7	0.6	57.3
Other or multiple race	196	5.9	1.6	3.0–10.2	6.2	1.4	3.3–9.0	0.2	0.9	8.7
Mexican American	183	18.4	4.8	9.8–30.1	13.4	2.7	8.1–18.8	-1.0	0.6	76.9
Other Hispanic	150	11.8	2.6	7.1–18.1	10.4	2.1	6.4–14.5	-0.5	0.8	25.9
25–44										
Non-Hispanic:										
Black	761	18.3	1.9	14.7–22.5	18.7	1.6	15.5–21.9	0.2	0.8	19.9
White	828	20.7	1.6	17.7–23.9	18.8	1.4	16.1–21.6	-1.2	0.9	11.1
Other or multiple race	571	9.6	1.4	7.0–12.7	9.3	1.2	6.9–11.8	-0.2	0.9	13.0
Mexican American	398	21.9	2.3	17.5–26.9	20.1	1.8	16.5–23.6	-0.8	0.8	28.0
Other Hispanic	289	19.3	2.2	14.9–24.3	18.9	1.7	15.5–22.3	-0.2	0.8	27.1
45–64										
Non-Hispanic:										
Black	962	18.2	1.6	15.1–21.6	18.6	1.5	15.7–21.5	0.2	0.9	9.8
White	977	22.5	1.3	19.9–25.2	21.7	1.3	19.2–24.1	-0.6	1.0	5.0
Other or multiple race	614	8.8	2.0	5.2–13.7	8.3	1.7	4.9–11.8	-0.2	0.9	16.7
Mexican American	391	22.4	2.3	18.0–27.3	20.9	1.9	17.1–24.8	-0.6	0.9	17.8
Other Hispanic	345	21.8	2.8	16.5–27.8	18.5	2.2	14.1–22.8	-1.2	0.8	24.3
65 and older										
Non-Hispanic:										
Black	564	13.0	1.8	9.8–16.9	13.8	1.4	11.0–16.5	0.4	0.8	24.4
White	1,216	17.5	1.7	14.3–21.0	15.9	1.5	12.9–18.8	-1.0	0.9	9.7
Other or multiple race	265	7.3	1.7	4.3–11.4	7.4	1.4	4.7–10.1	0.1	0.8	21.6
Mexican American	159	13.0	3.6	6.7–22.0	14.2	2.0	10.2–18.2	0.3	0.6	78.7
Other Hispanic	207	18.6	3.3	12.5–26.2	12.6	2.2	8.3–16.9	-1.8	0.7	52.9

See footnotes at end of table.

Table J. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in prevalence of severe obesity, by age group and race and ethnicity where trends vary by group: National Health and Nutrition Examination Survey, 1999–March 2020—Con.

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Quadratic					
Non-Hispanic:										
Black	268	10.5	2.0	7.0–15.0	10.5	1.7	7.2–13.8	0.0	0.9	15.5
White	349	15.2	2.8	10.1–21.5	12.9	2.0	8.9–16.9	-0.8	0.7	35.2
Other or multiple race	196	4.3	1.1	1.9–8.2	4.7	1.1	2.5–6.8	0.3	1.0	2.6
Mexican American	183	12.4	3.3	6.5–20.6	11.6	2.3	7.1–16.0	-0.2	0.7	47.0
Other Hispanic	150	10.1	3.1	4.8–18.0	9.2	2.2	4.8–13.5	-0.3	0.7	39.6
25–44										
Non-Hispanic:										
Black	761	14.4	1.3	11.8–17.2	15.0	1.2	12.6–17.5	0.5	0.9	8.9
White	828	16.6	1.4	14.0–19.4	15.6	1.2	13.1–18.0	-0.7	0.9	9.6
Other or multiple race	571	6.0	0.9	4.2–8.2	6.2	0.9	4.4–7.9	0.2	1.0	5.4
Mexican American	398	19.3	2.0	15.4–23.6	18.0	1.7	14.7–21.3	-0.6	0.8	20.6
Other Hispanic	289	15.3	2.3	11.0–20.5	15.7	1.9	12.0–19.4	0.2	0.8	24.1
45–64										
Non-Hispanic:										
Black	962	14.1	1.4	11.5–17.1	14.7	1.3	12.2–17.2	0.4	0.9	8.9
White	977	19.3	1.5	16.5–22.4	18.4	1.4	15.7–21.1	-0.6	0.9	9.1
Other or multiple race	614	5.1	1.1	3.2–7.8	5.2	1.0	3.2–7.3	0.1	0.9	7.1
Mexican American	391	18.0	2.1	14.1–22.4	17.3	1.7	13.9–20.7	-0.3	0.8	18.7
Other Hispanic	345	17.2	2.4	12.8–22.5	15.2	1.9	11.5–18.9	-0.9	0.8	26.7
65 and older										
Non-Hispanic:										
Black	564	9.6	1.5	7.0–12.9	10.4	1.3	7.8–12.9	0.5	0.9	12.8
White	1,216	13.9	1.1	11.8–16.2	13.5	1.0	11.5–15.5	-0.3	0.9	7.4
Other or multiple race	265	4.7	1.5	2.2–8.5	5.1	1.3	2.6–7.7	0.3	0.9	12.4
Mexican American	159	9.3	2.5	5.0–15.5	10.8	1.9	7.2–14.5	0.6	0.8	34.1
Other Hispanic	207	11.6	2.8	6.7–18.3	9.4	2.0	5.4–13.3	-0.8	0.7	38.9

See footnotes at end of table.

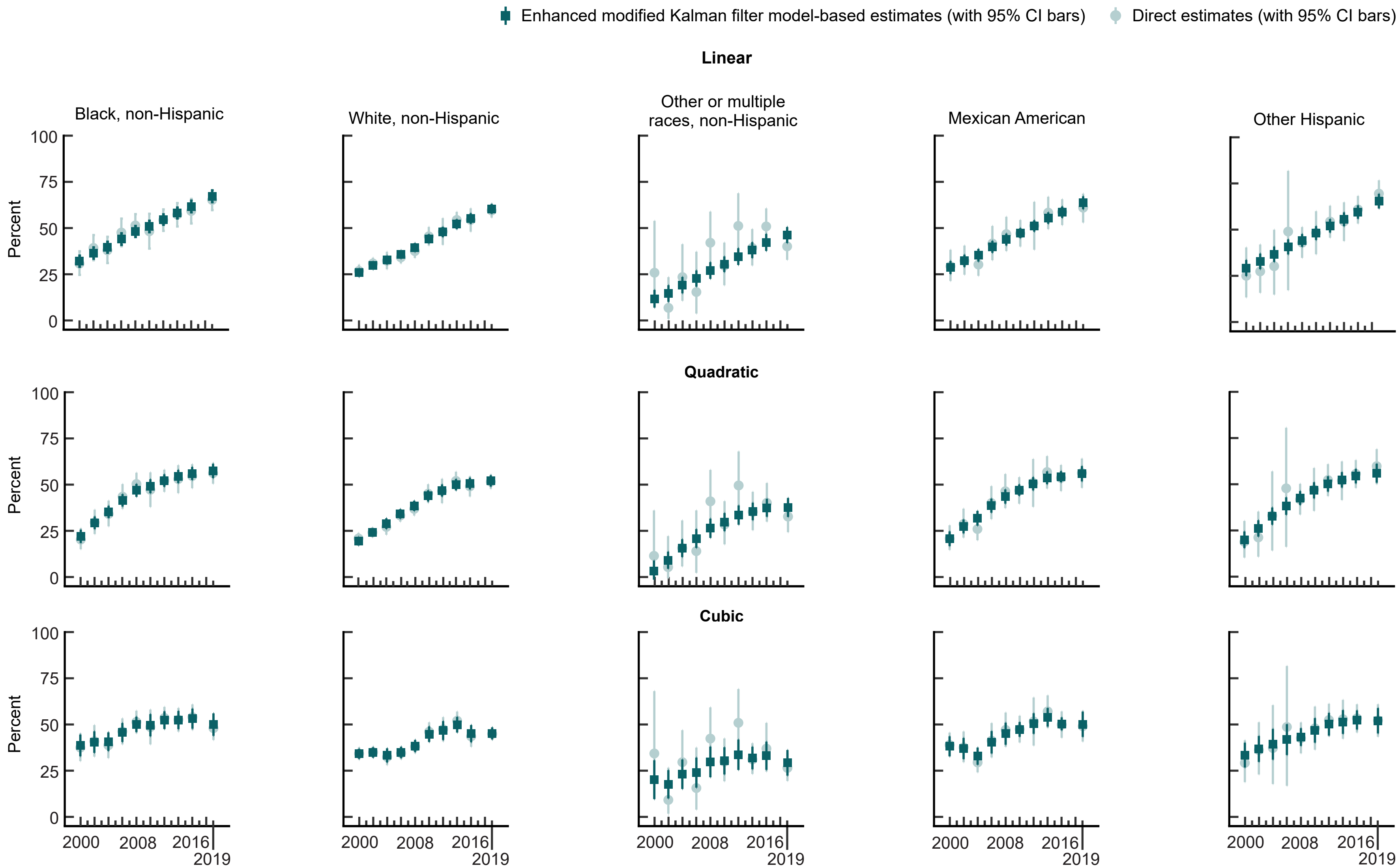
Table J. Comparison of direct estimates to enhanced modified Kalman filter-based estimates for simulated trends in prevalence of severe obesity, by age group and race and ethnicity where trends vary by group: National Health and Nutrition Examination Survey, 1999–March 2020—Con.

Age group and race and ethnicity	Sample size	Direct estimate	Standard error	95% confidence interval[1]	Model-based estimate	RMSE[2]	95% confidence interval[3]	Standardized difference[4]	RRMSE[5]	Percent increase in equivalent sample size
18–24					Cubic					
Non-Hispanic:										
Black	268	9.2	2.0	5.7–14.1	9.7	1.5	6.8–12.6	0.2	0.7	35.7
White	349	11.6	2.8	6.7–18.5	9.6	1.9	5.9–13.2	-0.7	0.7	51.6
Other or multiple race	196	2.0	1.2	0.4–6.0	3.0	1.1	0.8–5.1	0.8	0.9	9.6
Mexican American	183	7.0	2.2	3.3–12.9	8.1	1.6	4.9–11.3	0.5	0.7	38.2
Other Hispanic	150	7.6	2.4	3.6–13.9	7.3	1.7	3.9–10.7	-0.1	0.7	40.5
25–44										
Non-Hispanic:										
Black	761	10.1	1.0	8.1–12.5	11.0	1.0	9.1–12.9	1.0	1.0	-0.1
White	828	11.8	1.3	9.5–14.5	11.8	1.2	9.6–14.1	0.0	0.9	8.7
Other or multiple race	571	4.4	0.8	2.9–6.5	4.7	0.8	3.1–6.3	0.3	1.0	3.8
Mexican American	398	15.4	1.7	12.0–19.4	15.3	1.5	12.4–18.1	-0.1	0.9	15.4
Other Hispanic	289	12.3	2.0	8.7–16.9	14.0	1.7	10.6–17.4	0.8	0.9	16.4
45–64										
Non-Hispanic:										
Black	962	10.4	1.0	8.5–12.5	10.8	1.0	9.0–12.7	0.5	1.0	1.6
White	977	13.7	1.4	11.0–16.7	13.9	1.3	11.3–16.4	0.1	0.9	6.2
Other or multiple race	614	3.1	0.8	1.8–5.0	3.2	0.8	1.7–4.7	0.2	1.0	1.8
Mexican American	391	12.5	1.2	9.4–16.2	12.9	1.2	10.6–15.2	0.3	1.0	4.6
Other Hispanic	345	13.1	2.2	9.1–18.1	13.1	1.9	9.4–16.8	0.0	0.9	15.4
65 and older										
Non-Hispanic:										
Black	564	6.5	1.3	4.3–9.5	7.1	1.2	4.7–9.5	0.4	1.0	5.4
White	1,216	10.1	0.8	8.4–11.9	10.1	0.8	8.4–11.7	0.0	1.0	1.0
Other or multiple race	265	2.4	1.1	0.8–5.5	2.6	1.0	0.6–4.6	0.2	1.0	3.8
Mexican American	159	6.9	2.4	3.0–13.2	8.4	2.0	4.4–12.3	0.6	0.9	16.9
Other Hispanic	207	9.8	2.4	5.6–15.6	8.8	2.2	4.6–13.0	-0.4	0.9	9.9

0.0 Quantity more than zero but less than 0.05.
[1]Korn–Graubard 95% confidence interval.
[2]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[3]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[4]The standardized difference between the enhanced modified Kalman filter (eMKF) (model-based) and direct estimates is calculated as: (eMKF estimate minus direct estimate) divided by direct SE.
[5]Relative RMSE (RRMSE) is calculated as the ratio: eMKF RMSE divided by direct RMSE.

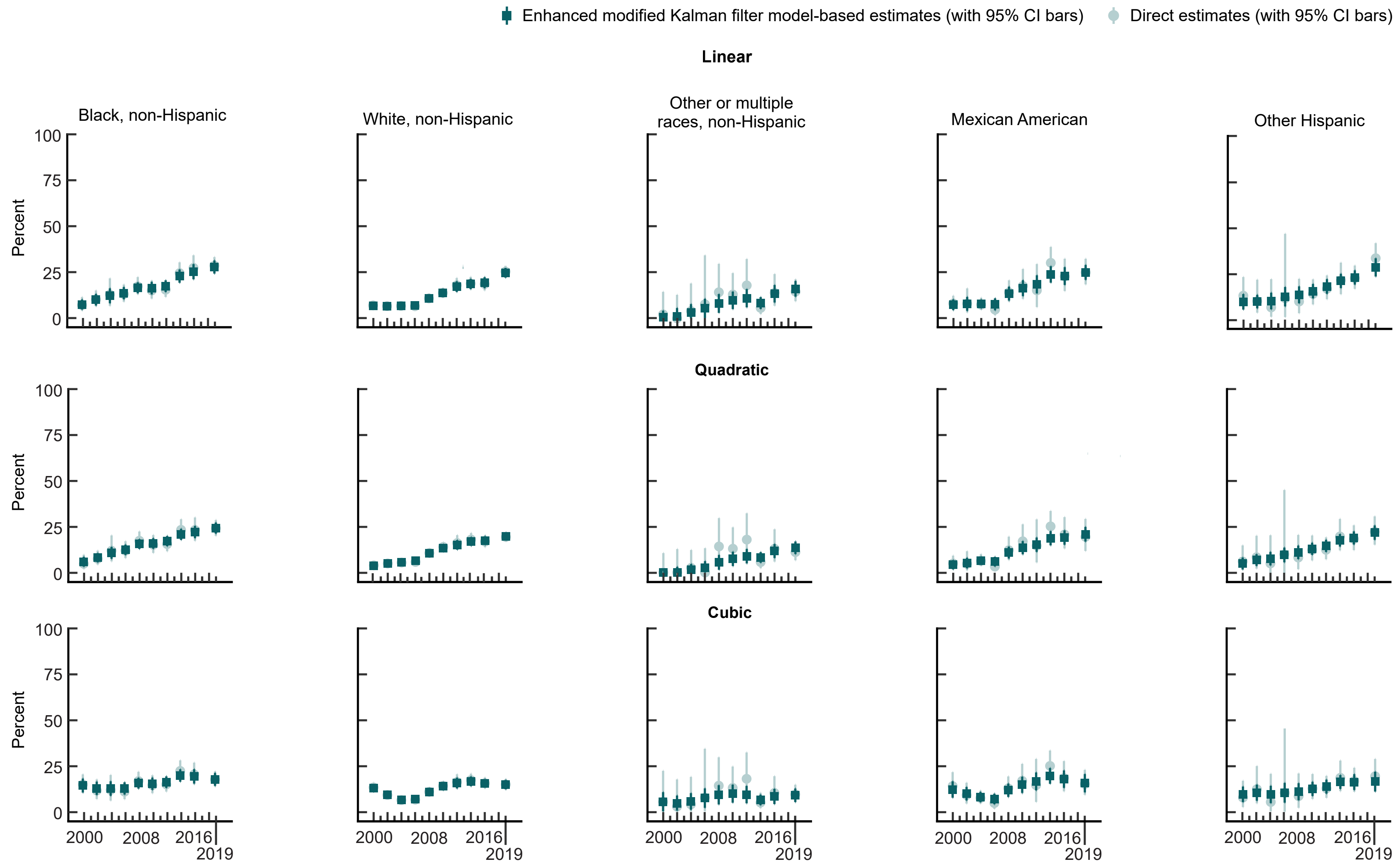
SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–March 2020.

Figure 6. Direct and model-based prevalence of obesity and 95% confidence intervals for adults age 65 and older, by race and ethnicity and year using simulated data under three trend shapes where groups had a common underlying trend: National Health and Nutrition Examination Survey, 1999–March 2020



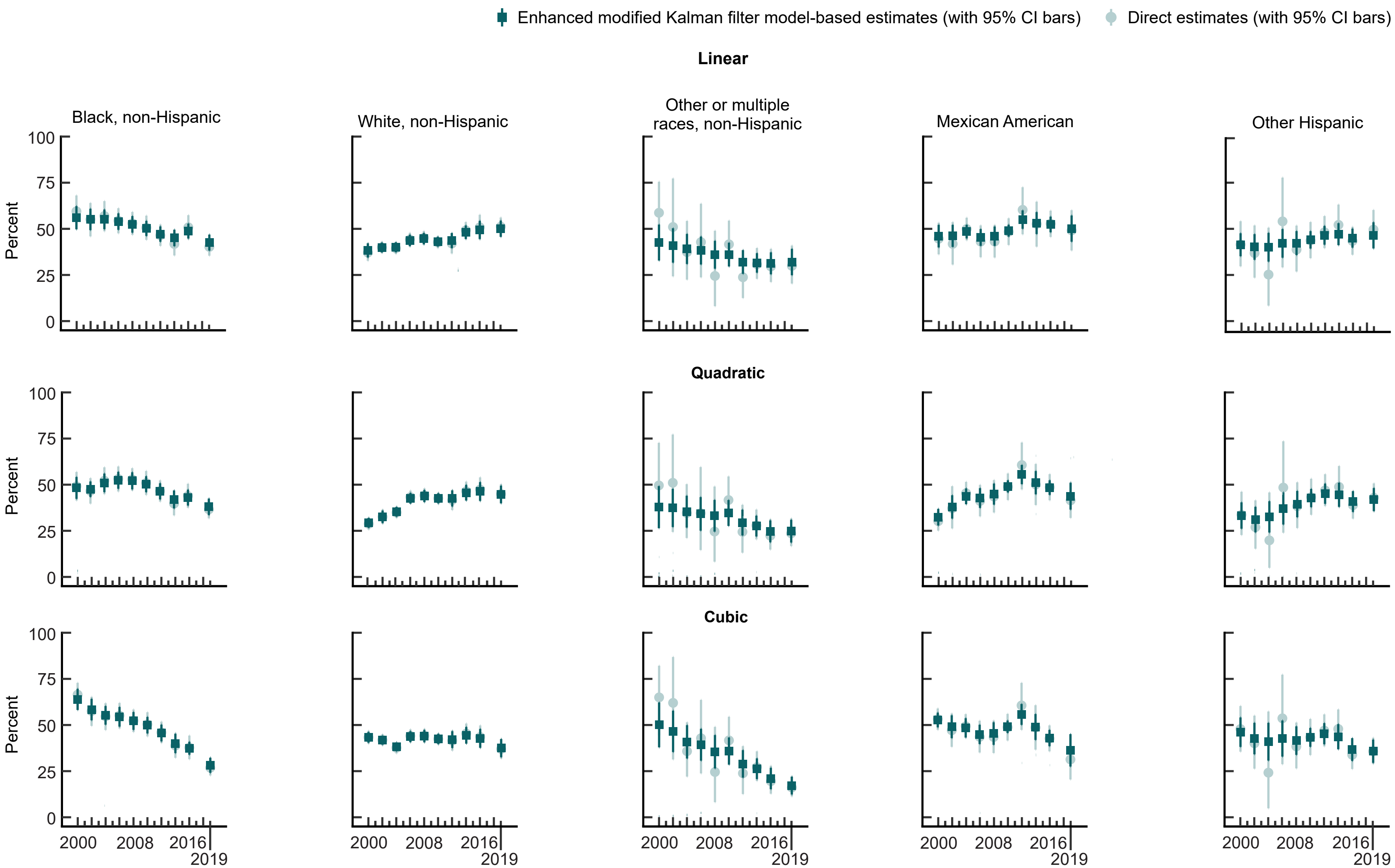
NOTES: CI is confidence interval. Linear, quadratic, and cubic trends are simulated. Obesity is defined as a body mass index greater than or equal to 30 kg/m^2. All but one of the time points on the x-axis represent standard 2-year survey data cycles—for example, 2000 represents the 1999–2000 data cycle. The exception is the last data cycle, where 2019 includes data from 2017 through March 2020.
SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–March 2020.

Figure 7. Direct and model-based prevalence of severe obesity and 95% confidence intervals for adults age 65 and older, by race and ethnicity and year using simulated data under three trend shapes where groups had a common underlying trend: National Health and Nutrition Examination Survey, 1999–March 2020



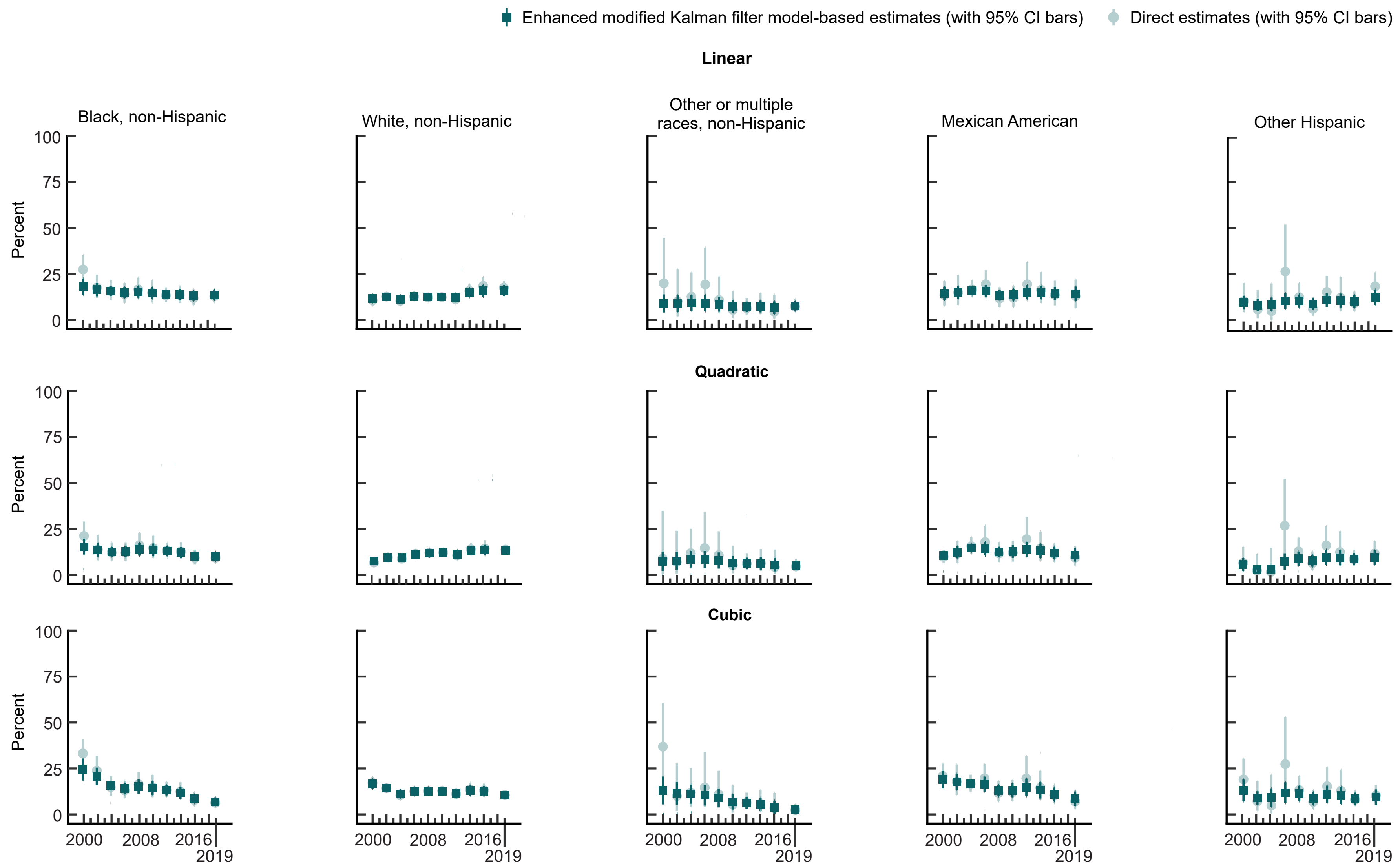
NOTES: CI is confidence interval. Linear, quadratic, and cubic trends are simulated. Severe obesity is defined as a body mass index greater than or equal to 40 kg/m^2. All but one of the time points on the x-axis represent standard 2-year survey data cycles—for example, 2000 represents the 1999–2000 data cycle. The exception is the last data cycle, where 2019 includes data from 2017 through March 2020.
SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–March 2020.

Figure 8. Direct and model-based prevalence of obesity and 95% confidence intervals for adults age 65 and older, by race and ethnicity and year using simulated data under three trend shapes where groups had a unique underlying trend: National Health and Nutrition Examination Survey, 1999–March 2020



NOTES: CI is confidence interval. Linear, quadratic, and cubic trends are simulated. Obesity is defined as a body mass index greater than or equal to 30 kg/m^2. All but one of the time points on the x-axis represent standard 2-year survey data cycles—for example, 2000 represents the 1999–2000 data cycle. The exception is the last data cycle, where 2019 includes data from 2017 through March 2020.
SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–March 2020.

Figure 9. Direct and model-based prevalence of severe obesity and 95% confidence intervals for adults age 65 and older, by race and ethnicity and year using simulated data under three trend shapes where groups had unique underlying trends: National Health and Nutrition Examination Survey, 1999–March 2020



NOTES: CI is confidence interval. Linear, quadratic, and cubic trends are simulated. Severe obesity is defined as a body mass index greater than or equal to 40 kg/m^2. All but one of the time points on the x-axis represent standard 2-year survey data cycles—for example, 2000 represents the 1999–2000 data cycle. The exception is the last data cycle, where 2019 includes data from 2017 through March 2020.
SOURCE: National Center for Health Statistics, National Health and Nutrition Examination Survey, 1999–March 2020.

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Appendix. Supplemental Tables

Table I. Comparison of direct estimates to MKF estimates for the proportion of adults with any functional limitations, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	0.4694	0.0348	(0.4012, 0.5375)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.4580	0.0163	(0.4261, 0.4899)	-0.3259	0.4678	113.8
MKF estimate: Fully Bayesian linear trends with random variances	0.4599	0.0177	(0.4251, 0.4946)	-0.2734	0.5101	96.0
MKF estimate: BMA up to cubic trends with random variances	0.4571	0.0155	(0.4267, 0.4875)	-0.3526	0.4453	†124.6
Asian, Indian origin:						
Direct estimate	0.1928	0.0275	(0.1389, 0.2466)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1920	0.0136	(0.1653, 0.2187)	-0.0286	0.4968	101.3
MKF estimate: Fully Bayesian linear trends with random variances	0.1905	0.0145	(0.1621, 0.2189)	-0.0837	0.5277	89.5
MKF estimate: BMA up to cubic trends with random variances	0.1940	0.0130	(0.1686, 0.2194)	0.0443	0.4722	†111.8
Black:						
Direct estimate	0.3604	0.0119	(0.3370, 0.3839)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.3646	0.0090	(0.3470, 0.3822)	0.3464	0.7502	33.3
MKF estimate: Fully Bayesian linear trends with random variances	0.3651	0.0091	(0.3473, 0.3829)	0.3862	0.7603	31.5
MKF estimate: BMA up to cubic trends with random variances	0.3635	0.0088	(0.3462, 0.3807)	0.2526	0.7364	†35.8
Chinese origin:						
Direct estimate	0.2151	0.0264	(0.1633, 0.2669)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2099	0.0137	(0.1830, 0.2367)	-0.1973	0.5182	93.0
MKF estimate: Fully Bayesian linear trends with random variances	0.2082	0.0146	(0.1795, 0.2368)	-0.2619	0.5523	81.1
MKF estimate: BMA up to cubic trends with random variances	0.2121	0.0130	(0.1867, 0.2375)	-0.1128	0.4910	†103.7
Filipino origin:						
Direct estimate	0.3233	0.0365	(0.2518, 0.3949)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2841	0.0146	(0.2555, 0.3128)	-1.0739	0.4005	149.7
MKF estimate: Fully Bayesian linear trends with random variances	0.2854	0.0155	(0.2550, 0.3159)	-1.0386	0.4253	135.1
MKF estimate: BMA up to cubic trends with random variances	0.2835	0.0139	(0.2562, 0.3109)	-1.0905	0.3819	†161.8
White:						
Direct estimate	0.4155	0.0055	(0.4047, 0.4263)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.4141	0.0050	(0.4042, 0.4240)	-0.2525	0.9139	9.4
MKF estimate: Fully Bayesian linear trends with random variances	0.4142	0.0051	(0.4043, 0.4242)	-0.2338	0.9198	8.7
MKF estimate: BMA up to cubic trends with random variances	0.4140	0.0050	(0.4042, 0.4239)	-0.2689	0.9119	†9.7

See footnotes at end of table.

Table I. Comparison of direct estimates to MKF estimates for the proportion of adults with any functional limitations, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic						
Cuban origin:						
Direct estimate	0.3495	0.0471	(0.2572, 0.4418)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2963	0.0156	(0.2657, 0.3268)	-1.1313	0.3305	202.6
MKF estimate: Fully Bayesian linear trends with random variances	0.2962	0.0166	(0.2637, 0.3287)	-1.1327	0.3517	184.3
MKF estimate: BMA up to cubic trends with random variances	0.2970	0.0147	(0.2681, 0.3258)	-1.1165	0.3130	†219.5
Mexican or Mexican-American origin:						
Direct estimate	0.2632	0.0142	(0.2355, 0.2910)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2674	0.0099	(0.2481, 0.2868)	0.2966	0.6952	43.8
MKF estimate: Fully Bayesian linear trends with random variances	0.2679	0.0100	(0.2483, 0.2875)	0.3289	0.7046	41.9
MKF estimate: BMA up to cubic trends with random variances	0.2667	0.0097	(0.2477, 0.2856)	0.2414	0.6820	†46.6
Puerto Rican origin:						
Direct estimate	0.3685	0.0354	(0.2991, 0.4378)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.3798	0.0144	(0.3516, 0.4081)	0.3219	0.4071	145.6
MKF estimate: Fully Bayesian linear trends with random variances	0.3800	0.0151	(0.3504, 0.4096)	0.3277	0.4270	134.2
MKF estimate: BMA up to cubic trends with random variances	0.3798	0.0137	(0.3529, 0.4066)	0.3202	0.3872	†158.3
Other national origin:						
Direct estimate	0.2730	0.0185	(0.2368, 0.3092)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2670	0.0113	(0.2449, 0.2891)	-0.3242	0.6109	63.7
MKF estimate: Fully Bayesian linear trends with random variances	0.2664	0.0115	(0.2439, 0.2889)	-0.3568	0.6221	60.7
MKF estimate: BMA up to cubic trends with random variances	0.2683	0.0109	(0.2469, 0.2898)	-0.2525	0.5926	†68.7
All other population subgroups[1]						
Direct estimate	0.3533	0.0182	(0.3177, 0.3890)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.3354	0.0116	(0.3127, 0.3581)	-0.9860	0.6362	57.2
MKF estimate: Fully Bayesian linear trends with random variances	0.3340	0.0121	(0.3104, 0.3576)	-1.0631	0.6624	51.0
MKF estimate: BMA up to cubic trends with random variances	0.3378	0.0110	(0.3163, 0.3594)	-0.8520	0.6051	†65.3

See footnotes at end of table.

Table I. Comparison of direct estimates to MKF estimates for the proportion of adults with any functional limitations, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

… Category not applicable.
† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.
[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.
[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.
[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[5]The standardized difference between the MKF-based and direct estimates is calculated as: (MKF estimate minus direct estimate) divided by direct SE.
[6]Relative RMSE (RRMSE) is calculated as the ratio: MKF RMSE divided by direct RMSE.
[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. Any functional limitations is defined as having any difficulty doing one or more of the following activities by oneself without any special equipment: going out to activities like shopping, movies, or sporting events; participating in social activities (such as visiting friends, attending clubs and meetings, and going to parties); doing things to relax at home or for leisure (as in reading, watching TV, sewing, or listening to music); walking one-quarter of a mile (or three city blocks); climbing 10 steps without resting; standing for 2 hours; sitting for 2 hours; stooping, bending, or kneeling; reaching over one's head; using one's fingers to grasp or handle small objects; lifting or carrying a 10-pound object (such as a full bag of groceries); and pushing or pulling a large object (such as a living room chair).

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

Table II. Comparison of direct estimates to MKF estimates for the proportion of adults with hypertension, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	0.2567	0.0350	(0.1881, 0.3253)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.3072	0.0123	(0.2830, 0.3313)	1.4410	0.3521	184.0
MKF estimate: Fully Bayesian linear trends with random variances	0.3072	0.0122	(0.2832, 0.3312)	1.4425	0.3497	186.0
MKF estimate: BMA up to cubic trends with random variances	0.3084	0.0110	(0.2868, 0.3300)	1.4752	0.3148	†217.7
Asian, Indian origin:						
Direct estimate	0.1812	0.0255	(0.1311, 0.2313)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1543	0.0092	(0.1361, 0.1724)	-1.0542	0.3621	176.2
MKF estimate: Fully Bayesian linear trends with random variances	0.1543	0.0092	(0.1361, 0.1724)	-1.0546	0.3618	176.4
MKF estimate: BMA up to cubic trends with random variances	0.1534	0.0083	(0.1371, 0.1696)	-1.0900	0.3250	†207.7
Black:						
Direct estimate	0.3314	0.0116	(0.3087, 0.3540)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.3434	0.0063	(0.3310, 0.3558)	1.0443	0.5471	82.8
MKF estimate: Fully Bayesian linear trends with random variances	0.3433	0.0063	(0.3310, 0.3557)	1.0370	0.5465	83.0
MKF estimate: BMA up to cubic trends with random variances	0.3414	0.0059	(0.3298, 0.3530)	0.8658	0.5127	†95.0
Chinese origin:						
Direct estimate	0.1530	0.0272	(0.0996, 0.2063)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1754	0.0094	(0.1569, 0.1938)	0.8223	0.3454	189.5
MKF estimate: Fully Bayesian linear trends with random variances	0.1754	0.0094	(0.1570, 0.1938)	0.8242	0.3456	189.4
MKF estimate: BMA up to cubic trends with random variances	0.1768	0.0086	(0.1600, 0.1936)	0.8741	0.3147	†217.8
Filipino origin:						
Direct estimate	0.2830	0.0324	(0.2194, 0.3466)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.3016	0.0120	(0.2780, 0.3252)	0.5746	0.3708	169.7
MKF estimate: Fully Bayesian linear trends with random variances	0.3014	0.0118	(0.2782, 0.3246)	0.5674	0.3647	174.2
MKF estimate: BMA up to cubic trends with random variances	0.2962	0.0098	(0.2769, 0.3154)	0.4072	0.3027	†230.4
White:						
Direct estimate	0.2874	0.0043	(0.2789, 0.2959)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2902	0.0035	(0.2834, 0.2971)	0.6531	0.8062	24.0
MKF estimate: Fully Bayesian linear trends with random variances	0.2902	0.0035	(0.2833, 0.2971)	0.6455	0.8074	23.9
MKF estimate: BMA up to cubic trends with random variances	0.2893	0.0034	(0.2826, 0.2960)	0.4406	0.7859	†27.2
Hispanic						
Cuban origin:						
Direct estimate	0.2708	0.0391	(0.1941, 0.3475)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2927	0.0116	(0.2700, 0.3155)	0.5599	0.2966	237.2
MKF estimate: Fully Bayesian linear trends with random variances	0.2929	0.0116	(0.2702, 0.3155)	0.5636	0.2958	238.1
MKF estimate: BMA up to cubic trends with random variances	0.2956	0.0100	(0.2761, 0.3152)	0.6341	0.2553	†291.7

See footnotes at end of table.

Table II. Comparison of direct estimates to MKF estimates for the proportion of adults with hypertension, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic—Con.						
Mexican or Mexican-American origin:						
Direct estimate	0.1902	0.0125	(0.1657, 0.2147)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1875	0.0061	(0.1755, 0.1994)	-0.2191	0.4882	104.8
MKF estimate: Fully Bayesian linear trends with random variances	0.1875	0.0061	(0.1755, 0.1995)	-0.2140	0.4893	104.4
MKF estimate: BMA up to cubic trends with random variances	0.1891	0.0059	(0.1776, 0.2006)	-0.0877	0.4680	†113.7
Puerto Rican origin:						
Direct estimate	0.3089	0.0307	(0.2487, 0.3690)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2651	0.0093	(0.2468, 0.2833)	-1.4268	0.3034	229.6
MKF estimate: Fully Bayesian linear trends with random variances	0.2651	0.0093	(0.2469, 0.2833)	-1.4265	0.3024	230.7
MKF estimate: BMA up to cubic trends with random variances	0.2653	0.0084	(0.2489, 0.2816)	-1.4201	0.2720	†267.6
Other national origin:						
Direct estimate	0.1713	0.0169	(0.1382, 0.2044)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1788	0.0075	(0.1640, 0.1936)	0.4481	0.4468	123.8
MKF estimate: Fully Bayesian linear trends with random variances	0.1789	0.0075	(0.1642, 0.1937)	0.4536	0.4458	124.3
MKF estimate: BMA up to cubic trends with random variances	0.1825	0.0070	(0.1688, 0.1963)	0.6685	0.4164	†140.2
All other population subgroups[1]						
Direct estimate	0.2398	0.0153	(0.2098, 0.2698)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2369	0.0074	(0.2223, 0.2514)	-0.1917	0.4847	106.3
MKF estimate: Fully Bayesian linear trends with random variances	0.2368	0.0074	(0.2223, 0.2514)	-0.1930	0.4852	106.1
MKF estimate: BMA up to cubic trends with random variances	0.2362	0.0069	(0.2227, 0.2498)	-0.2332	0.4526	†120.9

... Category not applicable.

† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.

[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.

[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.

[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.

[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.

[5]The standardized difference between the MKF-based and direct estimates is calculated as: (MKF estimate minus direct estimate) divided by direct SE.

[6]Relative RMSE (RRMSE) is calculated as the ratio: MKF RMSE divided by direct RMSE.

[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. In separate questions, respondents were asked if they had ever been told by a doctor or other health professional that they had hypertension (or high blood pressure), and if they had been told on two or more different visits that they had hypertension or high blood pressure. Respondents are classified as hypertensive (or with high blood pressure) only if they answered yes to both questions.

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

Table III. Comparison of direct estimates to MKF estimates for the proportion of adults ever diagnosed with asthma, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	0.1713	0.0316	(0.1093, 0.2333)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1655	0.0114	(0.1432, 0.1879)	-0.1818	0.3606	177.3
MKF estimate: Fully Bayesian linear trends with random variances	0.1655	0.0113	(0.1434, 0.1876)	-0.1814	0.3565	180.5
MKF estimate: BMA up to cubic trends with random variances	0.1655	0.0108	(0.1444, 0.1866)	-0.1825	0.3403	†193.9
Asian, Indian origin:						
Direct estimate	0.0365	0.0092	(0.0184, 0.0547)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0523	0.0071	(0.0383, 0.0663)	1.7007	0.7716	29.6
MKF estimate: Fully Bayesian linear trends with random variances	0.0524	0.0071	(0.0385, 0.0664)	1.7179	0.7698	29.9
MKF estimate: BMA up to cubic trends with random variances	0.0536	0.0070	(0.0399, 0.0673)	1.8489	0.7565	†32.2
Black:						
Direct estimate	0.1476	0.0089	(0.1302, 0.1650)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1505	0.0062	(0.1384, 0.1627)	0.3279	0.6964	43.6
MKF estimate: Fully Bayesian linear trends with random variances	0.1505	0.0062	(0.1384, 0.1626]	0.3229	0.6951	43.9
MKF estimate: BMA up to cubic trends with random variances	0.1493	0.0060	(0.1376, 0.1610)	0.1884	0.6723	†48.7
Chinese origin:						
Direct estimate	*0.0351	0.0139	(0.0079, 0.0622)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0615	0.0085	(0.0449, 0.0781)	1.9052	0.6111	63.6
MKF estimate: Fully Bayesian linear trends with random variances	0.0617	0.0084	(0.0452, 0.0781)	1.9186	0.6058	65.1
MKF estimate: BMA up to cubic trends with random variances	0.0628	0.0082	(0.0468, 0.0788)	1.9996	0.5892	†69.7
Filipino origin:						
Direct estimate	0.1307	0.0280	(0.0758, 0.1857)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1418	0.0108	(0.1206, 0.1629)	0.3935	0.3850	159.7
MKF estimate: Fully Bayesian linear trends with random variances	0.1416	0.0106	(0.1208, 0.1624)	0.3868	0.3787	164.1
MKF estimate: BMA up to cubic trends with random variances	0.1405	0.0100	(0.1208, 0.1602)	0.3482	0.3581	†179.3
White:						
Direct estimate	0.1375	0.0032	(0.1313, 0.1438)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1383	0.0029	(0.1326, 0.1441)	0.2471	0.9177	9.0
MKF estimate: Fully Bayesian linear trends with random variances	0.1383	0.0029	(0.1326, 0.1441)	0.2509	0.9206	8.6
MKF estimate: BMA up to cubic trends with random variances	0.1383	0.0029	(0.1326, 0.1441)	0.2449	0.9193	8.8
Hispanic						
Cuban origin:						
Direct estimate	0.1295	0.0311	(0.0687, 0.1904)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1248	0.0108	(0.1037, 0.1459)	-0.1532	0.3465	188.6
MKF estimate: Fully Bayesian linear trends with random variances	0.1247	0.0106	(0.1038, 0.1456)	-0.1567	0.3429	191.6
MKF estimate: BMA up to cubic trends with random variances	0.1234	0.0099	(0.1040, 0.1429)	-0.1966	0.3192	†213.3

See footnotes at end of table.

Table III. Comparison of direct estimates to MKF estimates for the proportion of adults ever diagnosed with asthma, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic—Con.						
Mexican or Mexican-American origin:						
Direct estimate	0.0866	0.0079	(0.0712, 0.1021)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0934	0.0059	(0.0819, 0.1049)	0.8632	0.7435	34.5
MKF estimate: Fully Bayesian linear trends with random variances	0.0934	0.0059	(0.0819, 0.1049)	0.8633	0.7434	34.5
MKF estimate: BMA up to cubic trends with random variances	0.0933	0.0058	(0.0819, 0.1046)	0.8433	0.7330	†36.4
Puerto Rican origin:						
Direct estimate	0.2280	0.0286	(0.1720, 0.2841)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2263	0.0104	(0.2059, 0.2467)	-0.0606	0.3642	174.6
MKF estimate: Fully Bayesian linear trends with random variances	0.2264	0.0103	(0.2061, 0.2466)	-0.0587	0.3610	177.0
MKF estimate: BMA up to cubic trends with random variances	0.2267	0.0098	(0.2074, 0.2460)	-0.0474	0.3438	†190.9
Other national origin:						
Direct estimate	0.1308	0.0131	(0.1051, 0.1564)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1171	0.0077	(0.1020, 0.1321)	-1.0474	0.5882	70.0
MKF estimate: Fully Bayesian linear trends with random variances	0.1171	0.0076	(0.1021, 0.1320)	-1.0473	0.5839	71.3
MKF estimate: BMA up to cubic trends with random variances	0.1175	0.0074	(0.1030, 0.1321)	-1.0122	0.5682	†76.0
All other population subgroups[1]						
Direct estimate	0.1881	0.0171	(0.1545, 0.2216)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1532	0.0083	(0.1369, 0.1696)	-2.0369	0.4872	105.3
MKF estimate: Fully Bayesian linear trends with random variances	0.1531	0.0083	(0.1369, 0.1693)	-2.0412	0.4825	107.3
MKF estimate: BMA up to cubic trends with random variances	0.1527	0.0080	(0.1369, 0.1685)	-2.0662	0.4697	†112.9

... Category not applicable.
† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.
* Estimate does not meet National Center for Health Statistics standards of reliability.
[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.
[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.
[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[5]The standardized difference between the MKF-based and direct estimates is calculated as: (MKF estimate minus direct estimate) divided by direct SE.
[6]Relative RMSE (RRMSE) is calculated as the ratio: (MKF RMSE divided by direct RMSE.
[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. Respondents were asked if they had ever been told by a doctor or other health professional that they had asthma.

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

Table IV. Comparison of direct estimates to MKF estimates for the proportion of adults with any heart disease, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	0.1456	0.0271	(0.0924, 0.1988)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1287	0.0081	(0.1128, 0.1446)	-0.6227	0.2990	234.4
MKF estimate: Fully Bayesian linear trends with random variances	0.1286	0.0081	(0.1128, 0.1445)	-0.6233	0.2984	235.1
MKF estimate: BMA up to cubic trends with random variances	0.1269	0.0082	(0.1108, 0.1429)	-0.6887	0.3013	231.9
Asian, Indian origin:						
Direct estimate	0.0532	0.0115	(0.0308, 0.0757)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0394	0.0051	(0.0294, 0.0494)	-1.2086	0.4455	124.5
MKF estimate: Fully Bayesian linear trends with random variances	0.0393	0.0051	(0.0292, 0.0493)	-1.2179	0.4481	123.2
MKF estimate: BMA up to cubic trends with random variances	0.0346	0.0044	(0.0260, 0.0432)	-1.6263	0.3821	†161.7
Black:						
Direct estimate	0.0981	0.0062	(0.0861, 0.1102)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1008	0.0031	(0.0948, 0.1068)	0.4258	0.4973	101.1
MKF estimate: Fully Bayesian linear trends with random variances	0.1007	0.0031	(0.0947, 0.1067)	0.4172	0.4983	100.7
MKF estimate: BMA up to cubic trends with random variances	0.0997	0.0037	(0.0925, 0.1070]	0.2600	0.6032	65.8
Chinese origin:						
Direct estimate	0.0638	0.0171	(0.0302, 0.0974)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0577	0.0051	(0.0477, 0.0677)	-0.3575	0.2986	234.9
MKF estimate: Fully Bayesian linear trends with random variances	0.0577	0.0051	(0.0476, 0.0677)	-0.3586	0.2996	233.8
MKF estimate: BMA up to cubic trends with random variances	0.0563	0.0054	(0.0457, 0.0669)	-0.4358	0.3154	217.1
Filipino origin:						
Direct estimate	0.0951	0.0192	(0.0574, 0.1328)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0837	0.0060	(0.0720, 0.0955)	-0.5913	0.3117	220.8
MKF estimate: Fully Bayesian linear trends with random variances	0.0837	0.0060	(0.0720, 0.0954)	-0.5923	0.3117	220.8
MKF estimate: BMA up to cubic trends with random variances	0.0811	0.0059	(0.0696, 0.0926)	-0.7284	0.3051	†227.8
White:						
Direct estimate	0.1429	0.0031	(0.1368, 0.1491)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1404	0.0021	(0.1362, 0.1445)	-0.8115	0.6739	48.4
MKF estimate: Fully Bayesian linear trends with random variances	0.1404	0.0021	(0.1362, 0.1446)	-0.8054	0.6827	46.5
MKF estimate: BMA up to cubic trends with random variances	0.1400	0.0023	(0.1356, 0.1445)	-0.9124	0.7295	37.1
Hispanic						
Cuban origin:						
Direct estimate	0.0820	0.0236	(0.0357, 0.1283)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0889	0.0064	(0.0763, 0.1015)	0.2929	0.2713	268.6
MKF estimate: Fully Bayesian linear trends with random variances	0.0889	0.0064	(0.0764, 0.1015)	0.2944	0.2709	269.1
MKF estimate: BMA up to cubic trends with random variances	0.0890	0.0064	(0.0764, 0.1015)	0.2949	0.2712	268.7

See footnotes at end of table.

Table IV. Comparison of direct estimates to MKF estimates for the proportion of adults with any heart disease, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic—Con.						
Mexican or Mexican-American origin:						
Direct estimate	0.0634	0.0067	(0.0503, 0.0764)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0602	0.0030	(0.0542, 0.0661)	-0.4768	0.4564	119.1
MKF estimate: Fully Bayesian linear trends with random variances	0.0602	0.0031	(0.0542, 0.0662)	-0.4770	0.4589	117.9
MKF estimate: BMA up to cubic trends with random variances	0.0601	0.0035	(0.0532, 0.0671)	-0.4832	0.5319	88.0
Puerto Rican origin:						
Direct estimate	0.1267	0.0246	(0.0786, 0.1749)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1125	0.0056	(0.1014, 0.1235)	-0.5813	0.2298	335.2
MKF estimate: Fully Bayesian linear trends with random variances	0.1124	0.0057	(0.1013, 0.1235)	-0.5842	0.2303	334.2
MKF estimate: BMA up to cubic trends with random variances	0.1104	0.0058	(0.0990, 0.1219)	-0.6633	0.2379	320.3
Other national origin:						
Direct estimate	0.0553	0.0079	(0.0398, 0.0708)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0564	0.0037	(0.0490, 0.0637)	0.1370	0.4720	111.9
MKF estimate: Fully Bayesian linear trends with random variances	0.0564	0.0037	(0.0491, 0.0637)	0.1407	0.4727	111.6
MKF estimate: BMA up to cubic trends with random variances	0.0573	0.0045	(0.0486, 0.0660)	0.2574	0.5643	77.2
All other population subgroups[1]						
Direct estimate	0.1186	0.0123	(0.0946, 0.1427)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0946	0.0044	(0.0859, 0.1032)	-1.9627	0.3589	178.6
MKF estimate: Fully Bayesian linear trends with random variances	0.0946	0.0044	(0.0860, 0.1032)	-1.9612	0.3588	178.7
MKF estimate: BMA up to cubic trends with random variances	0.0950	0.0044	(0.0863, 0.1036)	-1.9312	0.3611	176.9

... Category not applicable.
† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.
[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.
[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.
[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[5]The standardized difference between the MKF-based and direct estimates is calculated as: MKF estimate minus direct estimate) divided by direct SE.
[6]Relative RMSE (RRMSE) is calculated as the ratio: MKF RMSE divided by direct RMSE.
[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. In separate questions, respondents were asked if they had ever been told by a doctor or other health professional that they had coronary heart disease, angina (or angina pectoris), heart attack (or myocardial infarction), or any other heart condition or disease not already mentioned. Any heart disease is defined as coronary heart disease, angina, heart attack, or any other heart condition or disease.

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

Table V. Comparison of direct estimates to MKF estimates for the proportion of adults reporting a history of cancer, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	*0.0768	0.0247	(0.0283, 0.1253)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0497	0.0067	(0.0367, 0.0628)	-1.0935	0.2694	271.2
MKF estimate: Fully Bayesian linear trends with random variances	0.0498	0.0067	(0.0367, 0.0628)	-1.0921	0.2690	271.7
MKF estimate: BMA up to cubic trends with random variances	0.0524	0.0064	(0.0398, 0.0651)	-0.9835	0.2607	†283.6
Asian, Indian origin:						
Direct estimate	0.0233	0.0091	(0.0054, 0.0411)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0102	0.0032	(0.0040, 0.0164)	-1.4383	0.3498	185.9
MKF estimate: Fully Bayesian linear trends with random variances	0.0103	0.0032	(0.0040, 0.0165)	-1.4321	0.3518	184.3
MKF estimate: BMA up to cubic trends with random variances	0.0142	0.0044	(0.0056, 0.0227)	-1.0014	0.4787	108.9
Black:						
Direct estimate	0.0509	0.0044	(0.0424, 0.0595)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0506	0.0023	(0.0461, 0.0550)	-0.0891	0.5167	93.5
MKF estimate: Fully Bayesian linear trends with random variances	0.0505	0.0023	(0.0461, 0.0550)	-0.0937	0.5208	92.0
MKF estimate: BMA up to cubic trends with random variances	0.0499	0.0030	(0.0440, 0.0558)	-0.2448	0.6902	44.9
Chinese origin:						
Direct estimate	0.0308	0.0104	(0.0104, 0.0512)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0323	0.0043	(0.0239, 0.0407)	0.1448	0.4115	143.0
MKF estimate: Fully Bayesian linear trends with random variances	0.0323	0.0043	(0.0239, 0.0408)	0.1448	0.4142	141.4
MKF estimate: BMA up to cubic trends with random variances	0.0299	0.0051	(0.0198, 0.0400)	-0.0899	0.4933	102.7
Filipino origin:						
Direct estimate	0.0698	0.0171	(0.0363, 0.1033)	~~	~~	--
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0524	0.0053	(0.0421, 0.0627)	-1.0192	0.3075	225.2
MKF estimate: Fully Bayesian linear trends with random variances	0.0523	0.0052	(0.0420, 0.0626)	-1.0222	0.3067	226.1
MKF estimate: BMA up to cubic trends with random variances	0.0429	0.0056	(0.0318, 0.0539)	-1.5733	0.3304	202.7
White:						
Direct estimate	0.1239	0.0027	(0.1186, 0.1292)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1235	0.0018	(0.1201, 0.1269)	-0.1576	0.6447	55.1
MKF estimate: Fully Bayesian linear trends with random variances	0.1235	0.0018	(0.1200, 0.1270)	-0.1485	0.6518	53.4
MKF estimate: BMA up to cubic trends with random variances	0.1230	0.0022	(0.1186, 0.1274)	-0.3284	0.8236	21.4
Hispanic						
Cuban origin:						
Direct estimate	*0.0554	0.0210	(0.0143, 0.0965)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0456	0.0059	(0.0341, 0.0571)	-0.4669	0.2806	256.4
MKF estimate: Fully Bayesian linear trends with random variances	0.0456	0.0059	(0.0340, 0.0572)	-0.4666	0.2812	255.6
MKF estimate: BMA up to cubic trends with random variances	0.0487	0.0062	(0.0365, 0.0609)	-0.3198	0.2967	237.0

See footnotes at end of table.

Table V. Comparison of direct estimates to MKF estimates for the proportion of adults reporting a history of cancer, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic—Con.						
Mexican or Mexican-American origin:						
Direct estimate	0.0270	0.0036	(0.0200, 0.0340)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0294	0.0021	(0.0253, 0.0334)	0.6617	0.5781	73.0
MKF estimate: Fully Bayesian linear trends with random variances	0.0294	0.0021	(0.0253, 0.0335)	0.6614	0.5839	71.3
MKF estimate: BMA up to cubic trends with random variances	0.0302	0.0028	(0.0248, 0.0356)	0.8869	0.7702	29.8
Puerto Rican origin:						
Direct estimate	*0.0446	0.0151	(0.0150, 0.0743)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0539	0.0049	(0.0442, 0.0635)	0.6102	0.3247	208.0
MKF estimate: Fully Bayesian linear trends with random variances	0.0538	0.0049	(0.0442, 0.0635)	0.6071	0.3255	207.2
MKF estimate: BMA up to cubic trends with random variances	0.0522	0.0055	(0.0414, 0.0630)	0.4981	0.3653	173.7
Other national origin:						
Direct estimate	0.0324	0.0056	(0.0215, 0.0434)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0300	0.0027	(0.0247, 0.0354)	-0.4324	0.4871	105.3
MKF estimate: Fully Bayesian linear trends with random variances	0.0300	0.0027	(0.0247, 0.0354)	-0.4300	0.4877	105.0
MKF estimate: BMA up to cubic trends with random variances	0.0314	0.0036	(0.0244, 0.0384)	-0.1778	0.6392	56.4
All other population subgroups[1]						
Direct estimate	0.0523	0.0070	(0.0386, 0.0660)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0579	0.0036	(0.0508, 0.0649)	0.7999	0.5151	94.1
MKF estimate: Fully Bayesian linear trends with random variances	0.0578	0.0036	(0.0508, 0.0649)	0.7962	0.5174	93.3
MKF estimate: BMA up to cubic trends with random variances	0.0569	0.0042	(0.0486, 0.0652)	0.6579	0.6071	64.7

* Estimate does not meet National Center for Health Statistics standards of reliability.
... Category not applicable.
† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.
[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.
[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.
[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[5]The standardized difference between the MKF-based and direct estimates is calculated as: (MKF estimate minus direct estimate) divided by direct SE.
[6]Relative RMSE (RRMSE) is calculated as the ratio: MKF RMSE divided by direct RMSE.
[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. Respondents were asked if they had ever been told by a doctor or other health professional that they had a cancer or malignancy of any kind.

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

Table VI. Comparison of direct estimates to MKF estimates for the proportion of adults who are current smokers, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	0.2265	0.0542	(0.1202, 0.3328)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.2474	0.0161	(0.2159, 0.2789)	0.3849	0.2964	237.4
MKF estimate: Fully Bayesian linear trends with random variances	0.2474	0.0160	(0.2159, 0.2788)	0.3847	0.2958	238.1
MKF estimate: BMA up to cubic trends with random variances	0.2559	0.0133	(0.2298, 0.2820)	0.5423	0.2452	†307.8
Asian, Indian origin:						
Direct estimate	0.0383	0.0093	(0.0201, 0.0565)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0333	0.0065	(0.0206, 0.0461)	-0.5392	0.7023	42.4
MKF estimate: Fully Bayesian linear trends with random variances	0.0334	0.0065	(0.0206, 0.0462)	-0.5350	0.7038	42.1
MKF estimate: BMA up to cubic trends with random variances	0.0297	0.0063	(0.0174, 0.0420)	-0.9311	0.6784	†47.4
Black:						
Direct estimate	0.1456	0.0088	(0.1283, 0.1629)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1501	0.0059	(0.1387, 0.1616)	0.5146	0.6640	50.6
MKF estimate: Fully Bayesian linear trends with random variances	0.1501	0.0059	(0.1387, 0.1616)	0.5125	0.6631	50.8
MKF estimate: BMA up to cubic trends with random variances	0.1497	0.0058	(0.1383, 0.1610)	0.4616	0.6571	†52.2
Chinese origin:						
Direct estimate	0.0728	0.0201	(0.0333, 0.1123)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0412	0.0087	(0.0241, 0.0583)	-1.5686	0.4325	131.2
MKF estimate: Fully Bayesian linear trends with random variances	0.0412	0.0087	(0.0241, 0.0583)	-1.5672	0.4330	130.9
MKF estimate: BMA up to cubic trends with random variances	0.0383	0.0085	(0.0217, 0.0549)	-1.7131	0.4203	†137.9
Filipino origin:						
Direct estimate	0.0785	0.0204	(0.0385, 0.1185)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0916	0.0106	(0.0708, 0.1123)	0.6412	0.5198	92.4
MKF estimate: Fully Bayesian linear trends with random variances	0.0917	0.0106	(0.0709, 0.1124)	0.6460	0.5188	92.8
MKF estimate: BMA up to cubic trends with random variances	0.0857	0.0093	(0.0674, 0.1040)	0.3538	0.4582	†118.2
White:						
Direct estimate	0.1496	0.0035	(0.1426, 0.1565)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1504	0.0031	(0.1444, 0.1564)	0.2295	0.8684	15.2
MKF estimate: Fully Bayesian linear trends with random variances	0.1504	0.0031	(0.1443, 0.1564)	0.2315	0.8721	14.7
MKF estimate: BMA up to cubic trends with random variances	0.1503	0.0031	(0.1443, 0.1564)	0.2154	0.8722	14.7
Hispanic						
Cuban origin:						
Direct estimate	0.0838	0.0223	(0.0401, 0.1274)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0952	0.0105	(0.0746, 0.1158)	0.5150	0.4724	111.7
MKF estimate: Fully Bayesian linear trends with random variances	0.0953	0.0105	(0.0746, 0.1159)	0.5168	0.4732	111.3
MKF estimate: BMA up to cubic trends with random variances	0.0988	0.0095	(0.0802, 0.1175)	0.6773	0.4276	†133.9

See footnotes at end of table.

Table VI. Comparison of direct estimates to MKF estimates for the proportion of adults who are current smokers, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic—Con.						
Mexican or Mexican-American origin:						
Direct estimate	0.0970	0.0096	(0.0782, 0.1159)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0958	0.0059	(0.0842, 0.1073)	-0.1299	0.6142	62.8
MKF estimate: Fully Bayesian linear trends with random variances	0.0958	0.0059	(0.0842, 0.1074)	-0.1279	0.6144	62.8
MKF estimate: BMA up to cubic trends with random variances	0.0953	0.0059	(0.0838, 0.1069)	-0.1724	0.6127	†63.2
Puerto Rican origin:						
Direct estimate	0.1483	0.0227	(0.1038, 0.1929)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1602	0.0099	(0.1407, 0.1796)	0.5214	0.4370	128.8
MKF estimate: Fully Bayesian linear trends with random variances	0.1601	0.0099	(0.1406, 0.1796)	0.5192	0.4379	128.4
MKF estimate: BMA up to cubic trends with random variances	0.1616	0.0091	(0.1437, 0.1795)	0.5834	0.4018	†148.9
Other national origin:						
Direct estimate	0.0834	0.0122	(0.0596, 0.1073)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0706	0.0069	(0.0570, 0.0841)	-1.0607	0.5704	75.3
MKF estimate: Fully Bayesian linear trends with random variances	0.0705	0.0069	(0.0570, 0.0841)	-1.0629	0.5693	75.7
MKF estimate: BMA up to cubic trends with random variances	0.0720	0.0068	(0.0587, 0.0854)	-0.9393	0.5595	†78.7
All other population subgroups[1]						
Direct estimate	0.1428	0.0143	(0.1149, 0.1707)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.1464	0.0078	(0.1311, 0.1616)	0.2510	0.5465	83.0
MKF estimate: Fully Bayesian linear trends with random variances	0.1463	0.0078	(0.1311, 0.1616)	0.2476	0.5459	83.2
MKF estimate: BMA up to cubic trends with random variances	0.1484	0.0075	(0.1338, 0.1631)	0.3959	0.5239	†90.9

... Category not applicable.

† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.

[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.

[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.

[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.

[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.

[5]The standardized difference between the MKF-based and direct estimates is calculated as: (MKF estimate minus direct estimate) divided by direct SE.

[6]Relative RMSE (RRMSE) is calculated as the ratio: MKF RMSE divided by direct RMSE.

[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. Current smokers have smoked at least 100 cigarettes in their lifetime and still currently smoke.

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

Table VII. Comparison of direct estimates to MKF estimates for the proportion of adults with kidney disease, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	0.0249	0.0082	(0.0087, 0.0411)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0238	0.0038	(0.0163, 0.0312)	-0.1396	0.4592	117.8
MKF estimate: Fully Bayesian linear trends with random variances	0.0238	0.0038	(0.0164, 0.0312)	-0.1382	0.4583	118.2
MKF estimate: BMA up to cubic trends with random variances	0.0213	0.0034	(0.0147, 0.0279)	-0.4398	0.4076	†145.3
Asian, Indian origin:						
Direct estimate	0.0056	0.0035	(-0.0011, 0.0124)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0029	0.0017	(-0.0004, 0.0063)	-0.7907	0.4951	102.0
MKF estimate: Fully Bayesian linear trends with random variances	0.0029	0.0017	(-0.0005, 0.0063)	-0.7949	0.4959	101.7
MKF estimate: BMA up to cubic trends with random variances	0.0035	0.0021	(-0.0006, 0.0077)	-0.6114	0.6116	63.5
Black:						
Direct estimate	0.0301	0.0032	(0.0238, 0.0364)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0264	0.0016	(0.0233, 0.0295)	-1.1500	0.4874	105.2
MKF estimate: Fully Bayesian linear trends with random variances	0.0264	0.0016	(0.0233, 0.0295)	-1.1518	0.4860	105.8
MKF estimate: BMA up to cubic trends with random variances	0.0253	0.0019	(0.0215, 0.0291)	-1.4958	0.5972	67.4
Chinese origin:						
Direct estimate	*0.0274	0.0132	(0.0016, 0.0532)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0121	0.0028	(0.0066, 0.0176)	-1.1613	0.2138	367.7
MKF estimate: Fully Bayesian linear trends with random variances	0.0121	0.0028	(0.0066, 0.0176)	-1.1616	0.2134	368.6
MKF estimate: BMA up to cubic trends with random variances	0.0092	0.0030	(0.0033, 0.0151)	-1.3826	0.2277	339.2
Filipino origin:						
Direct estimate	*0.0323	0.0145	(0.0040, 0.0607)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0074	0.0021	(0.0033, 0.0114)	-1.7252	0.1424	602.2
MKF estimate: Fully Bayesian linear trends with random variances	0.0074	0.0021	(0.0033, 0.0114)	-1.7250	0.1418	605.2
MKF estimate: BMA up to cubic trends with random variances	0.0054	0.0022	(0.0011, 0.0098)	-1.8601	0.1533	552.3
White:						
Direct estimate	0.0241	0.0014	(0.0213, 0.0269)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0222	0.0010	(0.0202, 0.0243)	-1.3224	0.7373	35.6
MKF estimate: Fully Bayesian linear trends with random variances	0.0222	0.0011	(0.0201, 0.0243)	-1.3353	0.7449	34.2
MKF estimate: BMA up to cubic trends with random variances	0.0226	0.0012	(0.0203, 0.0249)	-1.0438	0.8179	22.3
Hispanic						
Cuban origin:						
Direct estimate	*0.0253	0.0103	(0.0051, 0.0455)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0111	0.0032	(0.0048, 0.0174)	-1.3732	0.3127	219.8
MKF estimate: Fully Bayesian linear trends with random variances	0.0111	0.0032	(0.0048, 0.0175)	-1.3730	0.3136	218.9
MKF estimate: BMA up to cubic trends with random variances	0.0161	0.0031	(0.0100, 0.0222)	-0.8935	0.3015	†231.7

See footnotes at end of table.

Table VII. Comparison of direct estimates to MKF estimates for the proportion of adults with kidney disease, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic—Con.						
Mexican or Mexican-American origin:						
Direct estimate	0.0200	0.0043	(0.0115, 0.0285)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0191	0.0017	(0.0157, 0.0224)	-0.2180	0.3981	151.2
MKF estimate: Fully Bayesian linear trends with random variances	0.0191	0.0017	(0.0157, 0.0224)	-0.2200	0.3972	151.8
MKF estimate: BMA up to cubic trends with random variances	0.0190	0.0021	(0.0148, 0.0232)	-0.2354	0.4944	102.3
Puerto Rican origin:						
Direct estimate	0.0094	0.0041	(0.0013, 0.0175)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0151	0.0024	(0.0104, 0.0198)	1.3833	0.5794	72.6
MKF estimate: Fully Bayesian linear trends with random variances	0.0151	0.0024	(0.0104, 0.0198)	1.3809	0.5794	72.6
MKF estimate: BMA up to cubic trends with random variances	0.0153	0.0024	(0.0105, 0.0201)	1.4305	0.5936	68.5
Other national origin:						
Direct estimate	0.0178	0.0044	(0.0092, 0.0263)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0134	0.0020	(0.0095, 0.0172)	-1.0098	0.4489	122.8
MKF estimate: Fully Bayesian linear trends with random variances	0.0133	0.0019	(0.0095, 0.0172)	-1.0117	0.4473	123.6
MKF estimate: BMA up to cubic trends with random variances	0.0151	0.0023	(0.0106, 0.0195)	-0.6180	0.5221	91.5
All other population subgroups[1]						
Direct estimate	0.0307	0.0064	(0.0181, 0.0433)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0193	0.0022	(0.0150, 0.0236)	-1.7713	0.3426	191.9
MKF estimate: Fully Bayesian linear trends with random variances	0.0193	0.0022	(0.0149, 0.0236)	-1.7733	0.3432	191.4
MKF estimate: BMA up to cubic trends with random variances	0.0190	0.0025	(0.0142, 0.0239)	-1.8093	0.3835	160.8

... Category not applicable.
† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.
* Estimate does not meet National Center for Health Statistics standards of reliability.
[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.
[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.
[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[5]The standardized difference between the MKF-based and direct estimates is calculated as: (MKF estimate minus direct estimate) divided by direct SE.
[6]Relative RMSE (RRMSE) is calculated as the ratio: MKF RMSE divided by direct RMSE.
[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. Respondents were asked if they had been told in the last 12 months by a doctor or other health professional that they had weak or failing kidneys (excluding kidney stones, bladder infections, or incontinence).

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

Table VIII. Comparison of direct estimates to MKF estimates for the proportion of adults who had a stroke, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	0.0235	0.0095	(0.0049, 0.0421)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0247	0.0037	(0.0175, 0.0319)	0.1288	0.3865	158.7
MKF estimate: Fully Bayesian linear trends with random variances	0.0248	0.0036	(0.0176, 0.0319)	0.1313	0.3844	160.1
MKF estimate: BMA up to cubic trends with random variances	0.0252	0.0035	(0.0184, 0.0320)	0.1788	0.3646	†174.3
Asian, Indian origin:						
Direct estimate	0.0084	0.0073	(-0.0059, 0.0228)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0078	0.0028	(0.0024, 0.0132)	-0.0896	0.3772	165.1
MKF estimate: Fully Bayesian linear trends with random variances	0.0078	0.0028	(0.0024, 0.0132)	-0.0847	0.3770	165.3
MKF estimate: BMA up to cubic trends with random variances	0.0082	0.0028	(0.0027, 0.0138)	-0.0267	0.3875	158.1
Black:						
Direct estimate	0.0404	0.0037	(0.0330, 0.0477)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0397	0.0023	(0.0352, 0.0441)	-0.1907	0.6090	64.2
MKF estimate: Fully Bayesian linear trends with random variances	0.0396	0.0023	(0.0352, 0.0441)	-0.1997	0.6062	65.0
MKF estimate: BMA up to cubic trends with random variances	0.0388	0.0022	(0.0345, 0.0431)	-0.4144	0.5895	†69.6
Chinese origin:						
Direct estimate	0.0136	0.0094	(-0.0048, 0.0320)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0096	0.0029	(0.0040, 0.0153)	-0.4187	0.3091	223.5
MKF estimate: Fully Bayesian linear trends with random variances	0.0097	0.0029	(0.0040, 0.0154)	-0.4141	0.3087	223.9
MKF estimate: BMA up to cubic trends with random variances	0.0108	0.0028	(0.0052, 0.0163)	-0.2990	0.3026	†230.5
Filipino origin:						
Direct estimate	0.0426	0.0126	(0.0180, 0.0672)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0174	0.0033	(0.0109, 0.0239)	-2.0071	0.2632	279.9
MKF estimate: Fully Bayesian linear trends with random variances	0.0174	0.0033	(0.0109, 0.0238)	-2.0086	0.2613	282.7
MKF estimate: BMA up to cubic trends with random variances	0.0174	0.0032	(0.0112, 0.0236)	-2.0046	0.2511	†298.2
White:						
Direct estimate	0.0334	0.0016	(0.0302, 0.0365)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0329	0.0013	(0.0303, 0.0355)	-0.3009	0.8335	20.0
MKF estimate: Fully Bayesian linear trends with random variances	0.0329	0.0013	(0.0302, 0.0355)	-0.2987	0.8361	19.6
MKF estimate: BMA up to cubic trends with random variances	0.0329	0.0014	(0.0303, 0.0356)	-0.2837	0.8380	19.3
Hispanic						
Cuban origin:						
Direct estimate	*0.0253	0.0117	(0.0024, 0.0482)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0179	0.0034	(0.0112, 0.0245)	-0.6337	0.2897	245.2
MKF estimate: Fully Bayesian linear trends with random variances	0.0179	0.0034	(0.0113, 0.0245)	-0.6294	0.2891	245.9
MKF estimate: BMA up to cubic trends with random variances	0.0190	0.0032	(0.0127, 0.0254)	-0.5351	0.2764	†261.8

See footnotes at end of table.

Table VIII. Comparison of direct estimates to MKF estimates for the proportion of adults who had a stroke, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic—Con.						
Mexican or Mexican-American origin:						
Direct estimate	0.0181	0.0032	(0.0119, 0.0243)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0195	0.0021	(0.0154, 0.0235)	0.4164	0.6510	53.6
MKF estimate: Fully Bayesian linear trends with random variances	0.0195	0.0021	(0.0154, 0.0235)	0.4154	0.6498	53.9
MKF estimate: BMA up to cubic trends with random variances	0.0192	0.0020	(0.0152, 0.0233)	0.3479	0.6485	†54.2
Puerto Rican origin:						
Direct estimate	0.0212	0.0081	(0.0053, 0.0371)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0275	0.0033	(0.0211, 0.0339)	0.7805	0.4010	149.4
MKF estimate: Fully Bayesian linear trends with random variances	0.0275	0.0032	(0.0212, 0.0339)	0.7835	0.3992	150.5
MKF estimate: BMA up to cubic trends with random variances	0.0280	0.0031	(0.0219, 0.0342)	0.8427	0.3874	†158.1
Other national origin:						
Direct estimate	0.0232	0.0068	(0.0098, 0.0365)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0177	0.0027	(0.0125, 0.0230)	-0.8013	0.3938	153.9
MKF estimate: Fully Bayesian linear trends with random variances	0.0177	0.0026	(0.0125, 0.0229)	-0.8036	0.3893	156.9
MKF estimate: BMA up to cubic trends with random variances	0.0175	0.0026	(0.0124, 0.0226)	-0.8333	0.3850	†159.7
All other population subgroups[1]						
Direct estimate	0.0312	0.0060	(0.0194, 0.0429)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	0.0280	0.0028	(0.0226, 0.0334)	-0.5307	0.4608	117.0
MKF estimate: Fully Bayesian linear trends with random variances	0.0280	0.0027	(0.0226, 0.0333)	-0.5330	0.4583	118.2
MKF estimate: BMA up to cubic trends with random variances	0.0277	0.0027	(0.0225, 0.0329)	-0.5776	0.4467	†123.9

... Category not applicable.
† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.
* Estimate does not meet National Center for Health Statistics standards of reliability.
[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.
[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.
[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[5]The standardized difference between the MKF-based and direct estimates is calculated as: (MKF estimate minus direct estimate) divided by direct SE.
[6]Relative RMSE (RRMSE) is calculated as the ratio: MKF RMSE divided by direct RMSE.
[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. Respondents were asked if they had ever been told by a doctor or other health professional that they had a stroke.

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

Table IX. Comparison of direct estimates to MKF estimates for adult mean body mass index, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	31.6813	1.0691	(29.5858, 33.7768)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	30.0703	0.2632	(29.5544, 30.5862)	-1.5069	0.2462	306.2
MKF estimate: Fully Bayesian linear trends with random variances	30.0705	0.2631	(29.5549, 30.5862)	-1.5066	0.2461	306.3
MKF estimate: BMA up to cubic trends with random variances	30.0203	0.2404	(29.5490, 30.4915)	-1.5536	0.2249	†344.6
Asian, Indian origin:						
Direct estimate	25.6040	0.2287	(25.1557, 26.0522)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	25.5209	0.1428	(25.2410, 25.8008)	-0.3629	0.6244	60.2
MKF estimate: Fully Bayesian linear trends with random variances	25.5214	0.1436	(25.2399, 25.8029)	-0.3608	0.6279	59.3
MKF estimate: BMA up to cubic trends with random variances	25.5177	0.1420	(25.2393, 25.7960)	-0.3772	0.6209	†61.1
Black:						
Direct estimate	29.4951	0.1780	(29.1462, 29.8440)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	29.6247	0.1203	(29.3889, 29.8605)	0.7280	0.6758	48.0
MKF estimate: Fully Bayesian linear trends with random variances	29.6240	0.1203	(29.3882, 29.8597)	0.7241	0.6757	48.0
MKF estimate: BMA up to cubic trends with random variances	29.6060	0.1196	(29.3716, 29.8403)	0.6228	0.6716	†48.9
Chinese origin:						
Direct estimate	23.2748	0.2832	(22.7198, 23.8298)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	23.3194	0.1597	(23.0064, 23.6323)	0.1574	0.5639	77.3
MKF estimate: Fully Bayesian linear trends with random variances	23.3204	0.1600	(23.0068, 23.6339)	0.1609	0.5650	77.0
MKF estimate: BMA up to cubic trends with random variances	23.3935	0.1575	(23.0849, 23.7021)	0.4191	0.5561	†79.8
Filipino origin:						
Direct estimate	26.1265	0.3642	(25.4128, 26.8402)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	26.1603	0.1784	(25.8107, 26.5099)	0.0928	0.4898	104.2
MKF estimate: Fully Bayesian linear trends with random variances	26.1612	0.1786	(25.8112, 26.5112)	0.0953	0.4904	103.9
MKF estimate: BMA up to cubic trends with random variances	26.1382	0.1736	(25.7980, 26.4784)	0.0321	0.4766	†109.8
White:						
Direct estimate	27.9682	0.0690	(27.8330, 28.1033)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	27.9760	0.0605	(27.8575, 28.0946)	0.1141	0.8770	14.0
MKF estimate: Fully Bayesian linear trends with random variances	27.9762	0.0608	(27.8571, 28.0954)	0.1170	0.8813	13.5
MKF estimate: BMA up to cubic trends with random variances	27.9716	0.0610	(27.8520, 28.0912)	0.0492	0.8848	13.0
Hispanic						
Cuban origin:						
Direct estimate	28.2266	0.6024	(27.0460, 29.4073)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	27.6557	0.2065	(27.2509, 28.0605)	-0.9478	0.3429	191.6
MKF estimate: Fully Bayesian linear trends with random variances	27.6583	0.2079	(27.2508, 28.0657)	-0.9436	0.3451	189.8
MKF estimate: BMA up to cubic trends with random variances	27.7055	0.1984	(27.3166, 28.0943)	-0.8652	0.3293	†203.7

See footnotes at end of table.

Table IX. Comparison of direct estimates to MKF estimates for adult mean body mass index, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic—Con.						
Mexican or Mexican-American origin:						
Direct estimate	28.9188	0.1978	(28.5312, 29.3065)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	28.9621	0.1244	(28.7182, 29.2059)	0.2186	0.6290	59.0
MKF estimate: Fully Bayesian linear trends with random variances	28.9622	0.1249	(28.7174, 29.2070)	0.2192	0.6314	58.4
MKF estimate: BMA up to cubic trends with random variances	28.9487	0.1251	(28.7036, 29.1938)	0.1510	0.6322	58.2
Puerto Rican origin:						
Direct estimate	29.5216	0.4959	(28.5497, 30.4935)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	29.0040	0.1866	(28.6382, 29.3698)	-1.0439	0.3764	165.7
MKF estimate: Fully Bayesian linear trends with random variances	29.0038	0.1870	(28.6373, 29.3703)	-1.0442	0.3771	165.2
MKF estimate: BMA up to cubic trends with random variances	28.9811	0.1801	(28.6280, 29.3342)	-1.0900	0.3633	†175.3
Other national origin:						
Direct estimate	28.1578	0.2812	(27.6068, 28.7089)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	27.9823	0.1541	(27.6802, 28.2843)	-0.6245	0.5480	82.5
MKF estimate: Fully Bayesian linear trends with random variances	27.9826	0.1536	(27.6816, 28.2837)	-0.6232	0.5463	83.0
MKF estimate: BMA up to cubic trends with random variances	27.9579	0.1536	(27.6569, 28.2589)	-0.7111	0.5462	†83.1
All other population subgroups[1]						
Direct estimate	26.9938	0.3298	(26.3474, 27.6401)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	26.5033	0.1622	(26.1854, 26.8211)	-1.4875	0.4917	103.4
MKF estimate: Fully Bayesian linear trends with random variances	26.5045	0.1623	(26.1864, 26.8225)	-1.4839	0.4921	103.2
MKF estimate: BMA up to cubic trends with random variances	26.5200	0.1601	(26.2062, 26.8338)	-1.4367	0.4855	†106.0

... Category not applicable.

† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.

[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.

[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.

[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.

[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.

[5]The standardized difference between the MKF-based and direct estimates is calculated as: (MKF estimate minus direct estimate) divided by direct SE.

[6]Relative RMSE (RRMSE) is calculated as the ratio: MKF RMSE divided by direct RMSE.

[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. Body mass index (BMI) is calculated from information that respondents supplied in response to survey questions regarding height and weight and defined as BMI equals weight (kilograms) divided by height (meters)^2. Note that self-reported height and weight may differ from actual measurements.

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

Table X. Comparison of direct estimates to MKF estimates for mean number of bed days per adult, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Non-Hispanic						
American Indian and Alaska Native:						
Direct estimate	*12.1813	4.8082	(2.7572, 21.6054)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	5.0871	0.6905	(3.7337, 6.4404)	-1.4755	0.1436	596.4
MKF estimate: Fully Bayesian linear trends with random variances	5.0930	0.6923	(3.7360, 6.4500)	-1.4742	0.1440	594.4
MKF estimate: BMA up to cubic trends with random variances	5.0184	0.6864	(3.6731, 6.3638)	-1.4897	0.1428	†600.3
Asian, Indian origin:						
Direct estimate	1.8895	0.4846	(0.9396, 2.8393)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	1.6249	0.3560	(0.9271, 2.3226)	-0.5460	0.7346	36.1
MKF estimate: Fully Bayesian linear trends with random variances	1.6242	0.3570	(0.9245, 2.3239)	-0.5473	0.7366	35.8
MKF estimate: BMA up to cubic trends with random variances	1.5342	0.3536	(0.8411, 2.2273)	-0.7331	0.7297	†37.0
Black:						
Direct estimate	5.1945	0.5656	(4.0860, 6.3031)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	5.4914	0.3914	(4.7243, 6.2585)	0.5249	0.6920	44.5
MKF estimate: Fully Bayesian linear trends with random variances	5.4899	0.3906	(4.7243, 6.2556)	0.5222	0.6907	44.8
MKF estimate: BMA up to cubic trends with random variances	5.4234	0.3901	(4.6588, 6.1881)	0.4047	0.6898	†45.0
Chinese origin:						
Direct estimate	1.1292	0.2356	(0.6674, 1.5910)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	1.2105	0.2191	(0.7811, 1.6399)	0.3451	0.9297	7.6
MKF estimate: Fully Bayesian linear trends with random variances	1.2105	0.2191	(0.7810, 1.6400)	0.3452	0.9300	7.5
MKF estimate: BMA up to cubic trends with random variances	1.1934	0.2180	(0.7662, 1.6207)	0.2726	0.9252	†8.1
Filipino origin:						
Direct estimate	*6.8171	2.8961	(1.1407, 12.4935)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	2.8299	0.5866	(1.6801, 3.9796)	-1.3768	0.2025	393.8
MKF estimate: Fully Bayesian linear trends with random variances	2.8338	0.5850	(1.6873, 3.9803)	-1.3754	0.2020	395.0
MKF estimate: BMA up to cubic trends with random variances	2.5703	0.5721	(1.4489, 3.6917)	-1.4664	0.1976	†406.1
White:						
Direct estimate	5.4587	0.2608	(4.9475, 5.9699)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	5.3853	0.2300	(4.9346, 5.8360)	-0.2813	0.8816	13.4
MKF estimate: Fully Bayesian linear trends with random variances	5.3864	0.2306	(4.9345, 5.8383)	-0.2770	0.8839	13.1
MKF estimate: BMA up to cubic trends with random variances	5.3466	0.2318	(4.8924, 5.8009)	-0.4296	0.8886	12.5
Hispanic						
Cuban origin:						
Direct estimate	3.5083	1.2649	(1.0290, 5.9876)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	2.3797	0.5273	(1.3463, 3.4132)	-0.8922	0.4168	139.9
MKF estimate: Fully Bayesian linear trends with random variances	2.3762	0.5283	(1.3407, 3.4118)	-0.8950	0.4177	139.4
MKF estimate: BMA up to cubic trends with random variances	2.3193	0.5077	(1.3242, 3.3143)	-0.9400	0.4013	†149.2

See footnotes at end of table.

Table X. Comparison of direct estimates to MKF estimates for mean number of bed days per adult, by selected racial background and Hispanic ethnicity groups, from the fully Bayesian linear trend MKF model with fixed variances, the fully Bayesian linear trend MKF model with random variances, and the Bayesian model averaged cubic trend MKF model with random variances: United States, 2018—Con.

Population subgroup[1] and estimation type[2]	Estimate for 2018	RMSE[3]	95% confidence interval[4]	Standardized difference[5]	Relative RMSE[6]	Percent increase in equivalent sample size[7]
Hispanic—Con.						
Mexican or Mexican-American origin:						
Direct estimate	3.9632	0.7140	(2.5637, 5.3627)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	3.6179	0.4321	(2.7710, 4.4649)	-0.4835	0.6052	65.2
MKF estimate: Fully Bayesian linear trends with random variances	3.6209	0.4316	(2.7751, 4.4668)	-0.4793	0.6044	65.5
MKF estimate: BMA up to cubic trends with random variances	3.4873	0.4344	(2.6359, 4.3386)	-0.6665	0.6083	64.4
Puerto Rican origin:						
Direct estimate	6.2665	1.6123	(3.1065, 9.4266)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	5.9941	0.5924	(4.8331, 7.1551)	-0.1690	0.3674	172.2
MKF estimate: Fully Bayesian linear trends with random variances	5.9923	0.5930	(4.8301, 7.1546)	-0.1701	0.3678	171.9
MKF estimate: BMA up to cubic trends with random variances	5.8731	0.5856	(4.7253, 7.0209)	-0.2440	0.3632	†175.3
Other national origin:						
Direct estimate	4.7786	1.2255	(2.3765, 7.1806)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	3.3820	0.5214	(2.3600, 4.4039)	-1.1396	0.4255	135.0
MKF estimate: Fully Bayesian linear trends with random variances	3.3826	0.5204	(2.3626, 4.4025)	-1.1391	0.4246	135.5
MKF estimate: BMA up to cubic trends with random variances	3.3210	0.5198	(2.3021, 4.3399)	-1.1894	0.4242	†135.7
All other population subgroups[1]						
Direct estimate	7.0979	1.5021	(4.1536, 10.0421)	…	…	…
MKF estimate: Fully Bayesian linear trends with fixed variances	4.8836	0.5680	(3.7703, 5.9969)	-1.4740	0.3781	164.5
MKF estimate: Fully Bayesian linear trends with random variances	4.8844	0.5696	(3.7680, 6.0008)	-1.4735	0.3792	163.7
MKF estimate: BMA up to cubic trends with random variances	4.8122	0.5622	(3.7103, 5.9141)	-1.5216	0.3743	†167.2

* Estimate does not meet National Center for Health Statistics standards of reliability.
... Category not applicable.
† Indicates cases where the cubic Bayesian model averaging (BMA) trend model improves on the fully Bayesian model with linear trends.
[1]All population subgroup categories, except the last, are single-race categories. The category All other population subgroups includes the Pacific Islander non-Hispanic only population, other Asian non-Hispanic only subgroups, and multiracial populations.
[2]Direct estimates for 2018 are design-based, using only the 2018 National Health Interview Survey (NHIS). Modified Kalman filter (MKF) estimates for 2018 are model-based, using all 20 survey cycles from 1999 to 2018. Estimates based on the fully Bayesian linear trend model with fixed variances are as in the earlier version of the MKF procedure and macro. Estimates based on the fully Bayesian linear trend model with random variances use the enhanced MKF (eMKF) macro to account for the design-based variability in the sampling variances. Estimates based on cubic BMA also use the eMKF macro to account for the variability in the sampling variances and are weighted updated (posterior) averages over the following models: independent cubic, quadratic, and linear trends; common cubic, quadratic, and linear trends; and the intercepts-only trend model.
[3]Root mean squared error (RMSE) is defined as the square root of the sum of the squared deviations from the mean, which may or may not be the population quantity of interest. For a direct estimate, which is assumed unbiased, RMSE is the estimate's (design-based) standard error (SE). For a model-based estimate, which may be biased, RMSE can be written as the sum of the squared SE and the squared bias, highlighting the bias–variance trade-off.
[4]Wald 95% confidence interval is calculated as: estimate plus or minus 1.96 times RMSE.
[5]The standardized difference between the MKF-based and direct estimates is calculated as: (MKF estimate minus direct estimate) divided by direct SE.
[6]Relative RMSE (RRMSE) is calculated as the ratio: MKF RMSE divided by direct RMSE.
[7]The percentage increase in equivalent sample size is calculated as 100 times (1 divided by RRMSE minus 1) and indicates the mean percentage increase in the equivalent sample size of 2018-only estimates due to the selected MKF model.

NOTES: All estimates shown are crude estimates, not adjusted for age. Respondents were asked, ‘‘During the past 12 months, about how many days did illness or injury keep you in the bed more than half of the day (include days while an overnight patient in a hospital)?"

SOURCE: National Center for Health Statistics, National Health Interview Surveys, 2018.

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