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# State Quality-Adjusted Life Expectancy for U.S. adults from 1993 to 2008

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**Abstract**

*Purpose* Quality-Adjusted Life Expectancy (QALE) is a summary measure of mortality and health-related quality of life (HRQOL) across different stages of life. This study developed a method to calculate state-level QALE for U.S. adults.

*Methods* Population HRQOL data came from the Behavioral Risk Factor Surveillance System (BRFSS). Using age-specific deaths from the Mortality Summary File, this study constructed life tables to estimate life expectancy and QALE for all 50 States and the District of Columbia by sex and race from 1993 through 2008.

*Results* From 1993 to 2008, the QALE of an U.S. adult at 18 years old had increased from 51.2 to 52.3 years. In 2006, states with the highest QALE were Hawaii (56.2), Minnesota (55.2), North Dakota (54.9), Iowa (54.7), and Nebraska (54.4), while the states with the lowest QALE were West Virginia (47.1), Mississippi (48.2), Alabama (48.5), Kentucky (48.5), and Oklahoma (49.0).

*Conclusions* Because population HRQOL values and mortality statistics are available from existing and publicly accessible data and because formulas for the calculation of QALE and its standard error are easy to incorporate in a spreadsheet, State and local Health Departments can calculate QALE as a routine surveillance measurement for tracking their population's health over time.

**Keywords** Health-Related Quality of Life (HRQOL) · Life expectancy · Quality-Adjusted Life Expectancy (QALE) · Mortality · Morbidity

**Abbreviations**

| | |
|---|---|
| QALE | Quality-Adjusted Life Expectancy |
| HRQOL | Health-Related Quality of Life |
| QALYs | Quality-Adjusted Life Years |
| CDC | The U.S. Centers for Disease Control and Prevention |
| NCHS | The National Center for Health Statistics |
| BRFSS | The Behavioral Risk Factor Surveillance System |
| MEPS | The Medical Expenditure Panel Survey |

## Introduction

The U.S. Centers for Disease Control and Prevention (CDC) and the State and local Health Departments routinely collect and use both morbidity and mortality data such as cases and deaths from diseases and/or conditions for the tracking the health of their populations and analyzing the burden of disease and the degree to which risk can be prevented or reduced [1, 2]. However, as noted by the Secretary's Advisory Committee on National Health Promotion and Disease Prevention, a single measure such as the Quality-Adjusted Life Expectancy (QALE) would be particularly useful in quantifying the overall health impact

The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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of risk factors associated with both morbidity and mortality using one number [3]. Such a measure summarizes the overall health for the population and provides comparisons among local regions as well as monitors changes over the time [4].

Life expectancy is a summary measure of the age-specific mortality rates in a population [5, 6]. Health-related quality of life (HRQOL) assesses a person's perception of her/his health. Since HRQOL differs across different stages of life, calculating life expectancy adjusted by HRQOL would provide a more complete measure for assessing overall health [4, 7]. Besides personal perceptions, preference-based measurements of HRQOL assess how much a person values one health state vs. another state using a summary score (also called a utility value) [4]. For example, the EuroQoL Group's EQ-5D health state preference instrument uses three levels of five health dimensions—mobility, self-care, usual activities, pain or discomfort, and anxiety or depression—to distinguish 243 health states, each with its own utility. Preference-based HRQOL measures are anchored at 0 (dead) and 1 (perfect health) [7, 8]. The QALE combines utilities from such preference-based measurements with life expectancy to yield a summary score in expected years of life [7]. Thus, 1 year of life lived at a utility value of 0.8 is equal to 0.8 Quality-Adjusted Life Years (QALYs), and the QALE at age x is the total QALYs through the remainder of expected life (i.e., from age x to the life expectancy) [4, 5, 8].

To date, the QALE has not been used as a health surveillance measurement in the United States because preference-based HRQOL data are not routinely collected at the national, State, or local levels. In April 2008, an expert panel reviewed the CDC HRQOL Team's activities and provided guidance for improving the use and the usefulness of HRQOL surveillance in public health [9]. One panel suggestion was to "develop and disseminate methodology for calculating health-related quality of life–adjusted life expectancy for public health practitioners at the county and state levels who have limited resources for such analyses." Because more than 3,100 U.S. counties exist and because many less populous counties each year have too few survey respondents for QALE estimation, this study will focus on only the 50 States and the District of Columbia.

The main objective of this study is to develop and apply a methodology to calculate QALE at the national and State levels using currently available legacy data. Specifically, this study estimated QALEs and their standard errors for adults aged 18 years and older from 1993 to 2008 and for all fifty U.S. states and the District of Columbia. This study also provided such estimates by sex and for blacks and whites in States with sufficient sample sizes and compared these healthy life expectancies among the States.

## Materials and methods

*HRQOL data:* Population HRQOL data were from the 1993 to 2008 Behavioral Risk Factor Surveillance System (BRFSS), an ongoing state-based survey of representative samples of non-institutionalized civilian adult residents (18 years and older) from each of the fifty states and the District of Columbia [10, 11]. The BRFSS was designed to monitor population health status and risky health behaviors associated with premature death at the State level and to identify trends over time [10, 11]. Annual sample sizes ranged from 102,263 in 1993 to 406,749 in 2008, and the total sample size used in this analysis was 3,590,540.

The BRFSS includes four questions (HR-QOL4) that asked respondents to report their general health status (excellent, very good, good, fair, or poor) and the numbers of their physically unhealthy days, mentally unhealthy days, and days with activity limitation during the past 30 days [12]. However, because these questions are not preference-based measures of HRQOL, they cannot be used to calculate QALYs directly [8, 9, 13]. Recognizing this limitation, the HRQOL Surveillance Expert Panel convened by the CDC's HRQOL Team suggested calibrating HR-QOL4 measures to preference-based HRQOL scores [9]. Two published studies had examined the possibility of a statistical crosswalk between the HR-QOL4 questions and health utility values and had derived multivariable conversion formulas for estimating utility values from these questions [14, 15]. This analysis used results from a previously constructed algorithm to obtain values from the EQ-5D a preference-based HRQOL measure for respondents in the BRFSS, based on their age and answers to the HR-QOL4 questions [14]. For example, for those 18-24 years old who reported 0 days for each of the three unhealthy days questions and reported "excellent" general health, the estimated EQ-5D index is 0.997. Because the fit was not exact between the observed EQ-5D values and the EQ-5D index estimated from age and the answers to the HR-QOL4 questions, QALEs calculated from observed EQ-5D values would differ from those calculated from these EQ-5D estimates. However, the authors believe these differences would be small. Moreover, because different health preference measures yield broadly similar mean utility values across population subgroups [14–16], QALEs estimated from these different measures, though not tested here, would probably also be very similar because the health preference measures are closely correlated and indicate one underlying "health" factor [17].

*Death and population data:* The National Center for Health Statistics (NCHS) has prepared the summary statistics of U.S. deaths (accessible at http://wonder.cdc.gov/mortSQL.html). State-level age-specific deaths for recent years (the most recent year is 2006) are available by sex and race. Age-specific death rates were obtained by dividing numbers of deaths by census and intercensal population estimates prepared by the US Census Bureau (available till 2008 and accessible at www.census.gov/popest/states/asrh/).

*Life expectancy and QALE:* To illustrate the calculation of life expectancy and QALE, let $d_i$ and $N_i$ be the deaths and populations for age $i$ to $i + 1$ years. The observed age-specific death rate is $m_i = d_i/N_i$, and the probability of dying in one year (i.e., mortality rate) is $q_i = 1 - e^{-m_i}$ [5, 6, 18]. Let $A_0$ be a hypothetical population of 100,000 at the first age interval (i.e., 18 years) and $A_i$ be the number of the population surviving to age $i$ ($i \geq 18$). Assuming that those who died during a 1-year interval lived an average ½ years, the Life Years between age $i$ and $i + 1$, $D_i$, is $(1 - q_i/2)A_i$. For those in the last age interval (i.e., aged 85+), the total life years is approximately $D_{85} = A_{85}/m_{85}$ by assuming an exponential distribution of survival time [19]. The life expectancy at age $x$ is the total Life Years above age $x$ divided by the population surviving to age $x$ or

$$\mathrm{LE}_i = \frac{\sum_{i \geq x} D_i}{A_i} \tag{1}$$

Suppose that $y_i$ is the average HRQOL utility score (EQ-5D index) at age $i$; then, the quality-adjusted life years between age $i$ and $i + 1$ is $D_i y_i$ [4, 7, 8]. Therefore, the QALE at age $x$ is

$$\mathrm{QALE}_i = \frac{\sum_{i \geq x} D_i y_i}{A_i} \tag{2}$$

Applying the delta method and assuming $\mathrm{COV}(m_i, m_j) = 0$ and $\mathrm{COV}(y_i, y_j) = 0$ if $i \neq j$ and $\mathrm{COV}(m_i, y_j) = 0$ for all $i, j$ [5, 6, 19], the variance of the estimated QALE is approximately:

$$\begin{aligned}\mathrm{VAR}(\mathrm{QALE}_x) &= \sum \left[ \left( \frac{\partial \mathrm{QALE}_x}{\partial q_i} \right)^2 \mathrm{VAR}(q_i) + \left( \frac{\partial \mathrm{QALE}_x}{\partial y_i} \right)^2 \mathrm{VAR}(y_i) \right] \\ &= \frac{\sum_{i=x}^{84} \left[ A_i^2 \left( \frac{y_i}{2} + \mathrm{QALE}_{i+1} \right)^2 \mathrm{VAR}(q_i) + A_i^2 \left( 1 - \frac{q_i}{2} \right)^2 \mathrm{VAR}(y_i) \right]}{A_x^2} \\ &\quad + \frac{\mathrm{VAR}(L_{85}) y_{85}^2 + D_{85}^2 \mathrm{VAR}(y_{85}) + \mathrm{VAR}(L_{85}) \mathrm{VAR}(y_{85})}{A_x^2}\end{aligned} \tag{3}$$

where $\mathrm{VAR}(q_i) = q_i^2(1 - q_i)/d_i$ for age <85 and $\mathrm{VAR}(L_{85}) = \frac{\left( e^{-\sum_{k<85} m_k} \right)^2}{d_{85} m_{85}^2} A_{18}^2$. $\mathrm{VAR}(y_i)$ are the variances of $q_i$ and of the mean $y_i$, respectively.

*Estimates for small states:* The estimated life expectancy and QALE in some small states and some small demographic subgroups can be unreliable because of (1) few or no deaths in a particular age category; and/or (2) insufficient data in the BRFSS samples to make reliable estimates of the mean EQ-5D scores in some age categories.

According to the NCHS, the estimated death rate is unreliable if the number of deaths is fewer than 20 [18]. For those age groups in which the number of deaths was fewer than 20, we aggregated data into a larger age interval and used a 3-year moving average to obtain more reliable estimates of deaths and death rates. If no death was reported in a 10-year age interval for 3 consecutive years or if the expected death in a single-year age interval was less than 0.1 per year, we did not provide an estimate of life expectancy for this state. Since 2007 and 2008 death data were not available, we provided predictions for these 2 years through a time-series autoregressive moving average model (ARMA) from the 1993 to 2006 data [20]. For the 2007 and 2008 model predictions, the variance of estimated age-specific mortality, $q_i$, should be adjusted for the uncertainty of these predictions:

$$\mathrm{VAR}(q_i) = \frac{q_i^2(1 - q_i)}{d_i} + (1 - q_i)^2 \mathrm{VAR}(\hat{m}_i) \tag{4}$$

where $\mathrm{VAR}(\hat{m}_i)$ was the variance of model-based estimates of death rate.

To obtain reliable estimates of the mean EQ-5D score (i.e., $y_i$ in Eqs. 2, 3) from the BRFSS, a reasonably large sample size was required. Because the complete life table (in single-year age intervals) constructed the QALE calculation and the uncertainty of EQ-5D estimates from each one-year age interval contributed very little to the total variance of estimated QALE, a sample size $n > 10$ was considered adequate for this analysis. For ages with smaller sample sizes, we aggregated the data into a larger age category and used a 3-year moving average to provide more reliable estimates [8]. If the combined sample size was fewer than 10 for a 10-year age interval over 3 years, we did not provide estimates of QALE for the state. Also, since we used the estimated EQ-5D values for the BRFSS data instead of observed EQ-5D values, we adjusted the uncertainty of the estimated EQ-5D by

$$\mathrm{VAR}(y_i) = \mathrm{VAR}(\bar{y}_i) + \mathrm{MSE}(y)/n_i, \quad (5)$$

where $\mathrm{VAR}(\bar{y}_i)$ is the variance of estimated mean EQ-5D index from the BRFSS and $\mathrm{MSE}(y)$, the mean squared error of the mapping algorithm developed previously. The value of $\mathrm{MSE}(y)$ was $0.106^2 = 0.011236$ for the algorithm we used in this study and $n_i$ is the sample size [15].

## Results

In 2006, life expectancy for an 18 year old U.S. adult was 61.1 years (SE = 0.004 years), and the QALE for the same individual was 52.3 years (SE = 0.04 years). Figure 1 shows the trend of life expectancy and QALE for US adults at 18 years old from 1993 to 2008 by the four sex-by-race subgroups (estimates of life expectancy for ages older than 18 years are available upon request). During this 16-year interval, white women had the longest life expectancy (63.8 years in 2008; Fig. 1a); black women, the next longest (60.7 years); then white men (58.9 years); and black men, the shortest life expectancy (53.5 years). Although QALE was strongly related to life expectancy (average $r = 0.840$ for the same age, race, and sex), the order of QALE in these four sex-by-race subgroups differed from that for life expectancy (Fig. 1b): White women (54.1 years in 2008) > white men (51.1 years) > black women (50.5 years) > black men (46.1 years).

Although both life expectancy and QALE increased progressively from 1993 to 2008, the increases in the QALE were much smaller than the increases of life expectancy in all four sex-by-race subgroups, probably due to the fact that HRQOL scores decreased during the same time period (data not shown, but reported previously) [21]. Of the four sex-by-race subgroups, black men had the largest increases in both life expectancy and QALE, which increased 10.1 and 8.1% respectively across the 16-year interval. White men and black women had similar increases for both life expectancy (5.1 and 5.4%, respectively) and QALE (3.0 and 3.3%, respectively). White women had the smallest increases in these two measures (2.3 and 0.4%, respectively).

QALE differed statistically significantly at the state level (Fig. 2). For example, at 18 years old in 2006, the most recent year that death data were available, the Appalachian and Mississippi Delta states had the lowest QALE, while the West North Central States had the highest QALE. States with the highest QALE were Hawaii (56.2), Minnesota (55.2), North Dakota (54.9), Iowa (54.7), and Nebraska (54.4), while the states with the lowest QALE were West Virginia (47.1), Mississippi (48.2), Alabama (48.5), Kentucky (48.5), and Oklahoma (49.0). The range of state QALE, 9.1 years (from 47.1 to 56.2), exceeded the range of state life expectancy, 6.4 years (from 57.5 to 63.9).

Although the annual state-specific QALE has been calculated by gender and race from 1993 through 2008 (available on request), only results for 3 years—1993, 2006, and 2008—and the percentage changes from 1993 to 2006 are reported here (Tables 1 and 2). The overall percentage increase in QALE from 1993 to 2006 for men was 4.0%. The District of Columbia had the biggest increase in QALE among men (+13.5%), but in two states (Alabama and Oklahoma), QALE decreased more than 2% among men. For women, the overall QALE were relatively stable during this period (+0.5%), but at the state level, the percentage changes in QALE ranged from a decrease of −5.7% in Oklahoma to an increase of +3.7% in New York.

Blacks had a larger percentage increase in QALE (+5.4%) from 1993 to 2006 than whites (+1.6%). For individual states, the QALE among blacks increased the most in Rhode Island, New Jersey, New York, and Florida but decreased more than 3% in three states: West Virginia, Oklahoma, and Alabama. Among whites, states with the biggest QALE increases were New York, Minnesota, North Dakota, Vermont, and Massachusetts, and states with the biggest QALE decreases were Oklahoma, Alabama, West Virginia, and Mississippi.

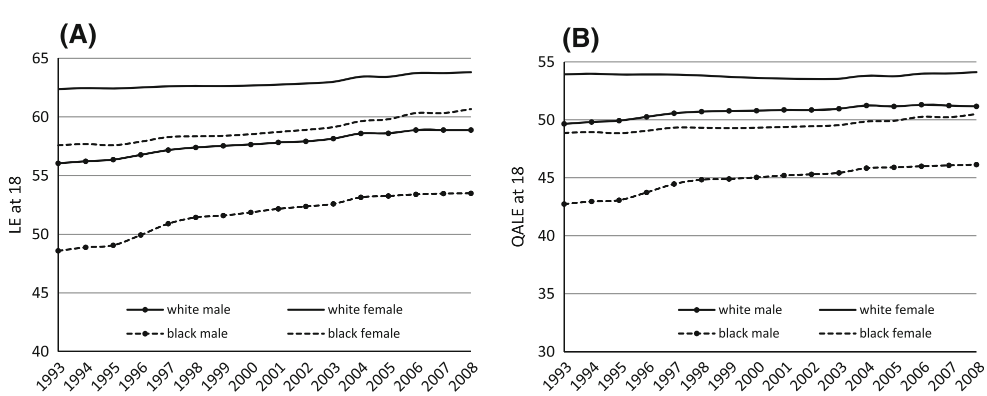


**Fig. 1** Life expectancy (**a**) and QALE (**b**) at 18 years old for U.S. adults by sex and race, from 1993 to 2008

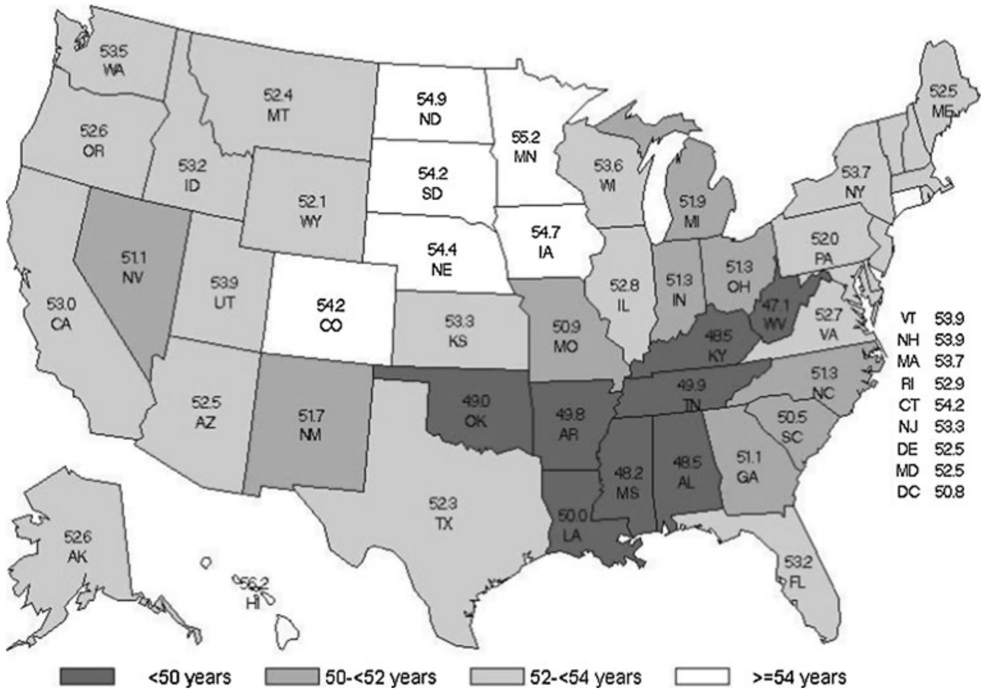


**Fig. 2** QALE at 18 years older for total U.S. adults in 2006

The reliability of life expectancy and QALE estimates was examined and reported in Table 3. Of the 126 sets of life expectancy estimates at 18 years old for the whole U.S. from 1993 to 2006 (14 years by 3 sex categories [both, male, female] by 3 race categories [both, white, black]), the standard errors were all less than 0.02 years, with an average standard error less than 0.01 years. The standard errors of the QALE for the same groups were much larger but still very precise (all less than 0.3 years). At the state level, as expected, these standard errors were larger than those at the national level. However, 99.5% of the 2,142 estimated standard errors were less than 0.5 years for the QALE estimates of combined races. When calculated separately by race (white and black), a larger proportion of these state estimates (mostly among blacks) were either unavailable (due to the small number of deaths or the small number of BRFSS respondents) or unreliable with large standard errors ($\geq$0.5 years). Of the 4,284 possible state-level estimates by race (14 years by 51 states by 3 sex categories by 2 race categories), 670 (15.6%) life expectancy estimates were unavailable and 30 (0.7%), unreliable (SE $>$ 0.5 years or margin of error $>$ 1 year). For QALE, 877 (20.5%) estimates were unavailable and 65 (1.5%) estimates were unreliable (SE $>$ 0.5 years). Ninety-four percent of these unavailable or unreliable estimates were among blacks. Nonetheless, for estimates among blacks, 69.3% of state-level life expectancy estimates and 58.5% of QALE estimates were reliable (SE $<$ 0.5 years).

Since 2007 and 2008 estimates used estimated death rates, the standard errors of both measures were larger than the standard errors of same estimates for the years when death data were available (i.e., 1993–2006). However, both life expectancy and QALE estimates were still reliable for national-level estimates and for state-level estimates of combined races. All life expectancy estimates and 99.3% QALE were reliable (SE $<$ 0.5 years). Of the 612 possible state-level estimates stratified by race, 81.7% of the life expectancy estimates and 69.6% of the QALE estimates were reliable.

Finally, sensitivity of the estimated QALE using EQ-5D scores obtained from the mapping algorithm and the Healthy Days Measures was examined. For the 2000–2003 cohort of the Medical Expenditure Panel Survey (MEPS), a nationally representative sample of adults ($N = 72{,}249$) were asked the EQ-5D questions. The sensitivity analysis compared the calculated QALEs using the observed EQ-5D data from the MEPS and the estimated EQ-5D data from the BRFSS (Table 4). In general, the differences were less than 1% between the two methods, and the mean absolute difference was 0.23 years.

## Discussions

This paper reports the development of a method to calculate state-level QALE for U.S. adults using currently available data. Because the proposed method uses legacy data, i.e., the BRFSS and the Mortality Files, investigators are able to analyze the trend of QALE since 1993 and thus demonstrate that QALE can be used as a routine health

**Table 1** State level QALE at 18 years old by sex for 1993, 2006, and 2008

| State | Male | | | | | | | Female | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | | 2006 | | | 2008 | | 1993 | | 2006 | | | 2008 | |
| | QALE | SE | QALE | SE | % Change | QALE | SE | QALE | SE | QALE | SE | % Change | QALE | SE |
| United States | 48.9 | 0.042 | 50.9 | 0.034 | 4.0 | 50.8 | 0.087 | 53.4 | 0.077 | 53.7 | 0.065 | 0.5 | 53.8 | 0.090 |
| Alabama | 47.6 | 0.202 | 46.6 | 0.173 | −2.1 | 47.3 | 0.354 | 52.5 | 0.354 | 50.2 | 0.193 | −4.4 | 50.3 | 0.299 |
| Alaska | 50.3 | 0.429 | 51.6 | 0.244 | 2.5 | 50.6 | 0.414 | 55.0 | 0.350 | 53.5 | 0.695 | −2.7 | 52.7 | 0.546 |
| Arizona | 49.0 | 0.142 | 50.8 | 0.322 | 3.7 | 51.6 | 0.374 | 53.4 | 0.379 | 54.2 | 0.284 | 1.5 | 55.5 | 0.545 |
| Arkansas | 47.1 | 0.136 | 48.0 | 0.169 | 1.8 | 48.7 | 0.299 | 51.8 | 0.277 | 51.5 | 0.156 | −0.5 | 51.4 | 0.276 |
| California | 49.4 | 0.144 | 51.9 | 0.174 | 5.0 | 51.8 | 0.348 | 53.1 | 0.325 | 54.1 | 0.504 | 1.9 | 54.9 | 0.365 |
| Colorado | 50.2 | 0.144 | 53.0 | 0.185 | 5.7 | 53.2 | 0.269 | 54.9 | 0.134 | 55.4 | 0.180 | 0.8 | 55.1 | 0.204 |
| Connecticut | 51.8 | 0.112 | 52.8 | 0.136 | 2.0 | 52.7 | 0.241 | 55.4 | 0.334 | 55.5 | 0.144 | 0.2 | 56.0 | 0.267 |
| Delaware | 49.1 | 0.099 | 51.2 | 0.267 | 4.4 | 50.9 | 0.322 | 52.5 | 0.341 | 53.7 | 0.262 | 2.3 | 53.3 | 0.328 |
| District of Columbia | 42.6 | 0.086 | 48.3 | 0.158 | 13.5 | 48.4 | 0.430 | 53.8 | 0.173 | 53.0 | 0.209 | −1.4 | 52.9 | 0.374 |
| Florida | 49.0 | 0.170 | 51.5 | 0.143 | 5.1 | 51.6 | 0.198 | 53.7 | 0.387 | 54.9 | 0.161 | 2.3 | 55.0 | 0.227 |
| Georgia | 46.8 | 0.101 | 49.5 | 0.117 | 5.7 | 49.6 | 0.231 | 52.0 | 0.385 | 52.5 | 0.172 | 1.0 | 52.6 | 0.309 |
| Hawaii | 53.2 | 0.190 | 53.9 | 0.211 | 1.4 | 53.0 | 0.276 | 58.6 | 0.319 | 58.5 | 0.284 | −0.1 | 57.8 | 0.435 |
| Idaho | 50.4 | 0.131 | 52.2 | 0.153 | 3.6 | 51.8 | 0.285 | 54.5 | 0.396 | 54.2 | 0.155 | −0.5 | 54.2 | 0.277 |
| Illinois | 49.7 | 0.081 | 51.6 | 0.119 | 3.8 | 51.0 | 0.232 | 54.0 | 0.206 | 54.0 | 0.153 | 0.1 | 53.8 | 0.203 |
| Indiana | 48.6 | 0.112 | 50.0 | 0.109 | 3.0 | 50.1 | 0.245 | 51.4 | 0.312 | 52.6 | 0.162 | 2.2 | 53.1 | 0.308 |
| Iowa | 51.2 | 0.148 | 53.3 | 0.160 | 4.0 | 52.6 | 0.257 | 56.0 | 0.268 | 56.1 | 0.182 | 0.1 | 55.2 | 0.248 |
| Kansas | 51.0 | 0.097 | 52.0 | 0.123 | 1.9 | 52.0 | 0.204 | 55.5 | 0.321 | 54.4 | 0.138 | −2.0 | 54.1 | 0.269 |
| Kentucky | 46.2 | 0.133 | 46.8 | 0.151 | 1.4 | 47.1 | 0.273 | 51.1 | 0.281 | 50.2 | 0.179 | −1.6 | 50.0 | 0.270 |
| Louisiana | 46.6 | 0.079 | 47.9 | 0.117 | 2.7 | 47.6 | 0.240 | 52.2 | 0.293 | 52.1 | 0.149 | −0.3 | 51.5 | 0.237 |
| Maine | 50.0 | 0.133 | 50.7 | 0.226 | 1.5 | 51.0 | 0.294 | 55.1 | 0.209 | 54.1 | 0.216 | −1.9 | 54.4 | 0.324 |
| Maryland | 48.9 | 0.213 | 50.9 | 0.138 | 4.0 | 51.3 | 0.260 | 53.7 | 0.193 | 54.0 | 0.139 | 0.5 | 54.0 | 0.210 |
| Massachusetts | 49.9 | 0.115 | 52.2 | 0.092 | 4.6 | 52.4 | 0.221 | 54.2 | 0.207 | 55.1 | 0.129 | 1.8 | 55.2 | 0.202 |
| Michigan | 49.2 | 0.083 | 50.7 | 0.127 | 3.0 | 50.8 | 0.192 | 53.0 | 0.388 | 53.1 | 0.190 | 0.2 | 53.2 | 0.321 |
| Minnesota | 50.9 | 0.143 | 53.8 | 0.170 | 5.7 | 53.5 | 0.298 | 55.1 | 0.317 | 56.5 | 0.238 | 2.6 | 56.0 | 0.335 |
| Mississippi | 45.9 | 0.127 | 46.4 | 0.171 | 1.1 | 46.9 | 0.250 | 51.8 | 0.647 | 49.9 | 0.147 | −3.6 | 50.5 | 0.265 |
| Missouri | 48.6 | 0.108 | 49.4 | 0.150 | 1.6 | 49.3 | 0.251 | 53.0 | 0.351 | 52.4 | 0.157 | −1.1 | 52.6 | 0.297 |
| Montana | 49.0 | 0.118 | 51.0 | 0.155 | 4.0 | 51.3 | 0.292 | 53.5 | 0.338 | 53.8 | 0.152 | 0.6 | 54.1 | 0.280 |
| Nebraska | 50.5 | 0.137 | 52.8 | 0.132 | 4.5 | 52.6 | 0.265 | 55.6 | 0.215 | 55.8 | 0.134 | 0.5 | 55.4 | 0.222 |
| Nevada | 47.3 | 0.105 | 50.2 | 0.141 | 6.0 | 49.7 | 0.336 | 51.5 | 0.344 | 52.0 | 0.285 | 1.0 | 52.0 | 0.452 |
| New Hampshire | 50.9 | 0.128 | 52.6 | 0.140 | 3.3 | 52.4 | 0.277 | 55.0 | 0.197 | 55.1 | 0.187 | 0.2 | 54.8 | 0.333 |
| New Jersey | 49.8 | 0.071 | 52.0 | 0.123 | 4.5 | 51.6 | 0.248 | 53.5 | 0.284 | 54.4 | 0.189 | 1.6 | 54.3 | 0.354 |
| New Mexico | 50.5 | 0.143 | 49.9 | 0.213 | −1.2 | 49.4 | 0.294 | 54.5 | 0.320 | 53.4 | 0.217 | −2.0 | 53.2 | 0.379 |
| New York | 47.9 | 0.154 | 52.0 | 0.312 | 8.5 | 52.6 | 0.345 | 53.3 | 0.250 | 55.3 | 0.194 | 3.7 | 55.2 | 0.287 |
| North Carolina | 48.5 | 0.078 | 49.8 | 0.096 | 2.6 | 49.5 | 0.201 | 53.6 | 0.353 | 52.6 | 0.186 | −1.8 | 52.9 | 0.311 |
| North Dakota | 51.5 | 0.131 | 53.0 | 0.151 | 2.9 | 53.0 | 0.336 | 54.9 | 0.276 | 56.8 | 0.216 | 3.4 | 56.4 | 0.303 |
| Ohio | 49.4 | 0.115 | 49.8 | 0.173 | 0.7 | 50.0 | 0.192 | 53.5 | 0.311 | 52.6 | 0.207 | −1.7 | 53.0 | 0.232 |
| Oklahoma | 48.6 | 0.099 | 47.6 | 0.107 | −2.1 | 47.9 | 0.233 | 53.5 | 0.243 | 50.4 | 0.134 | −5.7 | 51.0 | 0.216 |
| Oregon | 50.2 | 0.100 | 51.5 | 0.178 | 2.7 | 52.0 | 0.259 | 53.9 | 0.185 | 53.6 | 0.143 | −0.4 | 54.3 | 0.226 |
| Pennsylvania | 49.0 | 0.112 | 50.4 | 0.105 | 2.8 | 50.2 | 0.201 | 52.9 | 0.357 | 53.5 | 0.170 | 1.2 | 53.7 | 0.272 |
| Rhode Island | 48.8 | 0.108 | 51.0 | 0.152 | 4.5 | 51.0 | 0.285 | 54.0 | 0.300 | 54.6 | 0.191 | 1.2 | 54.2 | 0.302 |
| South Carolina | 47.1 | 0.106 | 48.8 | 0.158 | 3.5 | 49.1 | 0.272 | 53.2 | 0.396 | 52.2 | 0.239 | −1.9 | 52.8 | 0.445 |
| South Dakota | 51.3 | 0.116 | 52.5 | 0.124 | 2.4 | 52.2 | 0.299 | 56.3 | 0.217 | 55.9 | 0.155 | −0.8 | 55.4 | 0.302 |
| Tennessee | 47.5 | 0.084 | 48.3 | 0.215 | 1.8 | 47.8 | 0.240 | 52.8 | 0.241 | 51.4 | 0.281 | −2.7 | 50.7 | 0.292 |
| Texas | 48.4 | 0.117 | 51.1 | 0.117 | 5.6 | 50.6 | 0.240 | 53.8 | 0.257 | 53.4 | 0.154 | −0.6 | 52.7 | 0.258 |
| Utah | 52.0 | 0.158 | 53.5 | 0.204 | 2.9 | 52.6 | 0.334 | 54.0 | 0.285 | 54.2 | 0.239 | 0.4 | 54.1 | 0.385 |

**Table 1** continued

| State | Male | | | | | | | Female | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | | 2006 | | | 2008 | | 1993 | | 2006 | | | 2008 | |
| | QALE | SE | QALE | SE | % Change | QALE | SE | QALE | SE | QALE | SE | % Change | QALE | SE |
| Vermont | 49.9 | 0.114 | 52.4 | 0.192 | 5.2 | 52.1 | 0.332 | 54.2 | 0.194 | 55.3 | 0.158 | 2.0 | 55.0 | 0.298 |
| Virginia | 49.3 | 0.094 | 51.2 | 0.149 | 3.9 | 51.3 | 0.236 | 53.6 | 0.502 | 54.2 | 0.175 | 1.1 | 54.3 | 0.345 |
| Washington | 50.6 | 0.084 | 52.3 | 0.096 | 3.5 | 52.2 | 0.191 | 54.6 | 0.202 | 54.5 | 0.111 | −0.1 | 54.3 | 0.200 |
| West Virginia | 46.4 | 0.097 | 45.6 | 0.101 | −1.7 | 46.6 | 0.300 | 51.2 | 0.246 | 48.7 | 0.173 | −5.0 | 50.1 | 0.286 |
| Wisconsin | 50.6 | 0.172 | 52.3 | 0.208 | 3.2 | 52.2 | 0.234 | 54.3 | 0.402 | 54.9 | 0.218 | 1.0 | 54.9 | 0.350 |
| Wyoming | 49.6 | 0.186 | 50.8 | 0.252 | 2.3 | 50.8 | 0.318 | 54.1 | 0.298 | 53.4 | 0.195 | −1.4 | 53.7 | 0.359 |

**Table 2** State level QALE at 18 years old for whites and blacks for 1993, 2006, and 2008

| State | White | | | | | | | Black | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | | 2006 | | | 2008 | | 1993 | | 2006 | | | 2008[a] | |
| | QALE | SE | QALE | SE | % Change | QALE | SE | QALE | SE | QALE | SE | % Change | QALE | SE |
| United States | 51.8 | 0.051 | 52.7 | 0.044 | 1.6 | 52.6 | 0.074 | 45.9 | 0.115 | 48.3 | 0.080 | 5.4 | 48.3 | 0.144 |
| Alabama | 50.9 | 0.336 | 49.2 | 0.207 | −3.4 | 49.4 | 0.353 | 47.3 | 0.180 | 45.8 | 0.146 | −3.2 | 45.7 | 0.302 |
| Alaska | 53.8 | 0.424 | 53.3 | 0.490 | −0.9 | 52.5 | 0.386 | – | – | – | – | – | – | – |
| Arizona | 51.3 | 0.378 | 52.5 | 0.190 | 2.4 | 53.6 | 0.329 | | – | 47.8 | 0.751 | – | 45.0 | 1.693 |
| Arkansas | 50.3 | 0.200 | 50.4 | 0.130 | 0.2 | 50.7 | 0.224 | 44.3 | 0.156 | 45.4 | 0.171 | 2.5 | 44.4 | 0.406 |
| California | 51.3 | 0.201 | 52.7 | 0.289 | 2.7 | 53.0 | 0.260 | 44.0 | 0.221 | 47.4 | 0.198 | 7.8 | 47.7 | 0.483 |
| Colorado | 52.8 | 0.097 | 54.3 | 0.132 | 2.8 | 54.1 | 0.154 | – | – | 52.6 | 0.390 | – | 50.8 | 0.641 |
| Connecticut | 54.0 | 0.244 | 54.4 | 0.111 | 0.8 | 54.5 | 0.203 | – | – | 51.2 | 0.292 | – | 51.1 | 0.550 |
| Delaware | 51.4 | 0.233 | 53.0 | 0.209 | 3.0 | 52.7 | 0.287 | 46.6 | 0.225 | 49.8 | 0.282 | 6.9 | 48.1 | 0.501 |
| District of Columbia | – | – | 57.8 | 0.328 | – | – | – | 44.5 | 0.125 | 46.4 | 0.145 | 4.1 | 46.1 | 0.367 |
| Florida | 52.2 | 0.195 | 53.5 | 0.118 | 2.6 | 53.5 | 0.179 | 44.2 | 0.248 | 49.2 | 0.301 | 11.2 | 49.1 | 0.465 |
| Georgia | 50.5 | 0.284 | 51.9 | 0.165 | 2.7 | 51.9 | 0.297 | 46.1 | 0.201 | 48.8 | 0.148 | 5.9 | 48.5 | 0.351 |
| Hawaii | 54.8 | 0.276 | 55.4 | 0.197 | 1.0 | 54.3 | 0.318 | – | – | – | – | | – | – |
| Idaho | 52.5 | 0.221 | 53.2 | 0.109 | 1.3 | 53.0 | 0.198 | – | – | – | – | | – | – |
| Illinois | 53.0 | 0.173 | 53.6 | 0.114 | 1.1 | 53.0 | 0.194 | 44.6 | 0.154 | 47.6 | 0.201 | 6.8 | 47.5 | 0.349 |
| Indiana | 50.4 | 0.214 | 51.6 | 0.121 | 2.5 | 52.1 | 0.230 | 45.9 | 0.194 | 47.6 | 0.172 | 3.6 | 45.6 | 0.435 |
| Iowa | 53.7 | 0.175 | 54.8 | 0.130 | 1.9 | 54.1 | 0.195 | 50.5 | 0.326 | 50.6 | 0.337 | 0.2 | 46.4 | 0.675 |
| Kansas | 53.5 | 0.236 | 53.6 | 0.120 | 0.1 | 53.3 | 0.217 | 48.6 | 0.178 | 47.4 | 0.217 | −2.5 | 46.8 | 0.460 |
| Kentucky | 48.7 | 0.188 | 48.6 | 0.110 | −0.1 | 48.6 | 0.187 | 47.5 | 0.204 | 47.5 | 0.285 | 0.1 | 46.9 | 0.523 |
| Louisiana | 50.9 | 0.260 | 51.2 | 0.111 | 0.7 | 50.8 | 0.186 | 45.9 | 0.113 | 46.6 | 0.199 | 1.7 | 45.3 | 0.311 |
| Maine | 52.7 | 0.109 | 52.6 | 0.150 | −0.3 | 52.9 | 0.208 | – | – | – | – | | – | – |
| Maryland | 52.7 | 0.215 | 53.2 | 0.113 | 0.8 | 53.3 | 0.198 | 46.9 | 0.139 | 49.9 | 0.280 | 6.4 | 50.6 | 0.321 |
| Massachusetts | 52.1 | 0.239 | 53.8 | 0.106 | 3.2 | 53.9 | 0.192 | – | – | 50.5 | 0.294 | – | 51.5 | 0.557 |
| Michigan | 52.1 | 0.243 | 52.6 | 0.136 | 0.9 | 52.9 | 0.225 | 45.1 | 0.204 | 47.3 | 0.169 | 5.0 | 47.5 | 0.407 |
| Minnesota | 53.3 | 0.194 | 55.5 | 0.165 | 4.1 | 55.0 | 0.257 | 46.4 | 0.211 | 49.4 | 0.483 | 6.4 | 49.2 | 0.662 |
| Mississippi | 51.0 | 0.137 | 49.4 | 0.123 | −3.2 | 49.7 | 0.212 | 44.8 | 0.220 | 45.8 | 0.195 | 2.1 | 46.2 | 0.305 |
| Missouri | 51.4 | 0.210 | 51.5 | 0.126 | 0.2 | 51.6 | 0.233 | 44.6 | 0.323 | 46.5 | 0.141 | 4.2 | 46.0 | 0.464 |
| Montana | 51.5 | 0.206 | 53.0 | 0.114 | 3.0 | 53.3 | 0.197 | – | – | – | – | | – | – |
| Nebraska | 53.4 | 0.137 | 54.6 | 0.098 | 2.3 | 54.4 | 0.178 | – | – | 50.1 | 0.422 | – | 46.9 | 0.757 |
| Nevada | 49.2 | 0.149 | 50.8 | 0.148 | 3.2 | 50.6 | 0.260 | – | – | 48.9 | 0.467 | – | 43.8 | 0.901 |
| New Hampshire | 53.1 | 0.164 | 53.9 | 0.143 | 1.5 | 53.8 | 0.265 | – | – | – | – | | – | – |
| New Jersey | 52.7 | 0.164 | 53.6 | 0.136 | 1.7 | 53.2 | 0.258 | 43.0 | 0.295 | 49.0 | 0.200 | 14.1 | 48.3 | 0.382 |

**Table 2** continued

| State | White | | | | | | | Black | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | | 2006 | | | 2008 | | 1993 | | 2006 | | | 2008[a] | |
| | QALE | SE | QALE | SE | % Change | QALE | SE | QALE | SE | QALE | SE | % Change | QALE | SE |
| New Mexico | 52.7 | 0.201 | 51.8 | 0.159 | −1.7 | 51.3 | 0.273 | – | – | 52.8 | 0.730 | – | – | – |
| New York | 51.2 | 0.218 | 53.8 | 0.176 | 5.2 | 53.9 | 0.279 | 47.2 | 0.261 | 52.5 | 0.211 | 11.2 | 52.1 | 0.408 |
| North Carolina | 52.3 | 0.198 | 51.9 | 0.120 | −0.7 | 51.8 | 0.211 | 46.7 | 0.233 | 48.2 | 0.119 | 3.1 | 48.4 | 0.309 |
| North Dakota | 53.4 | 0.198 | 55.5 | 0.135 | 3.9 | 55.3 | 0.196 | – | – | – | – | | – | – |
| Ohio | 52.1 | 0.217 | 51.8 | 0.154 | −0.6 | 52.0 | 0.188 | 47.7 | 0.168 | 47.1 | 0.151 | −1.4 | 47.1 | 0.358 |
| Oklahoma | 51.2 | 0.152 | 49.4 | 0.093 | −3.5 | 49.8 | 0.168 | 48.6 | 0.162 | 46.7 | 0.155 | −3.9 | 45.0 | 0.433 |
| Oregon | 52.0 | 0.108 | 52.5 | 0.110 | 0.9 | 53.1 | 0.178 | 46.3 | – | 46.4 | 0.878 | 0.3 | 51.8 | 0.918 |
| Pennsylvania | 51.8 | 0.197 | 52.5 | 0.110 | 1.3 | 52.4 | 0.181 | 43.7 | 0.222 | 46.9 | 0.144 | 7.4 | 47.2 | 0.503 |
| Rhode Island | 51.9 | 0.185 | 52.9 | 0.143 | 1.9 | 52.7 | 0.232 | 42.4 | – | 51.2 | 0.466 | 20.7 | 49.4 | 0.735 |
| South Carolina | 51.7 | 0.237 | 51.7 | 0.155 | 0.1 | 52.1 | 0.281 | 46.2 | 0.181 | 47.1 | 0.132 | 2.0 | 48.0 | 0.326 |
| South Dakota | 54.5 | 0.123 | 55.1 | 0.098 | 1.1 | 54.7 | 0.189 | – | – | – | – | | – | – |
| Tennessee | 50.8 | 0.136 | 50.1 | 0.176 | −1.3 | 49.4 | 0.210 | 46.6 | 0.133 | 47.9 | 0.230 | 2.9 | 47.3 | 0.353 |
| Texas | 51.6 | 0.151 | 52.6 | 0.102 | 2.0 | 52.0 | 0.190 | 45.2 | 0.270 | 47.9 | 0.273 | 6.1 | 46.5 | 0.415 |
| Utah | 52.9 | 0.323 | 53.9 | 0.161 | 1.7 | 53.3 | 0.263 | – | – | – | – | – | – | – |
| Vermont | 52.1 | 0.116 | 54.0 | 0.121 | 3.6 | 53.7 | 0.209 | – | – | – | – | – | – | – |
| Virginia | 52.5 | 0.348 | 53.2 | 0.124 | 1.3 | 53.3 | 0.251 | 46.4 | 0.227 | 49.7 | 0.136 | 7.0 | 49.2 | 0.482 |
| Washington | 52.6 | 0.136 | 53.4 | 0.095 | 1.4 | 53.2 | 0.183 | 46.5 | – | 49.4 | 0.360 | 6.2 | 47.5 | 0.596 |
| West Virginia | 48.7 | 0.148 | 47.0 | 0.116 | −3.4 | 48.2 | 0.215 | 50.7 | 0.144 | 46.8 | 0.262 | −7.6 | 45.4 | 0.866 |
| Wisconsin | 52.9 | 0.224 | 54.1 | 0.160 | 2.2 | 54.1 | 0.236 | 45.8 | – | 45.5 | 0.252 | −0.6 | 45.1 | 0.575 |
| Wyoming | 52.3 | 0.190 | 52.4 | 0.167 | 0.1 | 52.4 | 0.243 | – | – | – | – | | – | – |

[a] Estimates for 2008 were available only if estimates from 2004 to 2006 were available

**Table 3** Descriptive statistics of standard error of life expectancy and QALE estimates

| | 1993–2006 | | | | | | 2007–2008 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | Mean | SD | Min | Max | % < 0.5 | *N* | Mean | SD | Min | Max | % < 0.5 |
| At national level, for total and by sex and race | | | | | | | | | | | | |
| SE for LE18 | 126 | 0.0066 | 0.0039 | 0.0030 | 0.0177 | 100.0 | 18 | 0.0611 | 0.0263 | 0.0271 | 0.1277 | 100.0 |
| SE for QALE18 | 126 | 0.0654 | 0.0435 | 0.0304 | 0.2919 | 100.0 | 18 | 0.1027 | 0.0508 | 0.0521 | 0.2328 | 100.0 |
| At state level, for total and by sex | | | | | | | | | | | | |
| SE for LE18 | 2142 | 0.0437 | 0.0335 | 0.0109 | 0.2824 | 100.0 | 306 | 0.1432 | 0.0695 | 0.0536 | 0.4440 | 100.0 |
| SE for QALE18 | 2142 | 0.1741 | 0.0780 | 0.0459 | 0.7173 | 99.5 | 306 | 0.2499 | 0.0699 | 0.1155 | 0.5458 | 99.3 |
| At state level, by race | | | | | | | | | | | | |
| SE for LE18 | 3614 | 0.0869 | 0.1700 | 0.0111 | 5.7148 | 83.7 | 498 | 0.1762 | 0.1151 | 0.0459 | 0.5971 | 81.7 |
| SE for QALE18 | 3407 | 0.2007 | 0.1391 | 0.0434 | 3.0679 | 78.0 | 494 | 0.3567 | 0.3258 | 0.1216 | 5.0162 | 69.6 |

LE18: life expectancy at 18 years old

QALE18: Quality-Adjusted Life Expectancy (QALE) at 18 years old

*N* number of estimates available. When examined by race at state level, some states may not have estimates due to small samples. For example, in Wyoming, we did not provide estimates for blacks

surveillance measure for tracking population health over time. Additionally, because the formulas for QALE and its standard error calculation can be incorporated into a spreadsheet, State and local Health Departments can easily obtain the QALE of their population using public accessible data. Microsoft-Excel[TM] spreadsheets of abridged and

**Table 4** Comparison of estimated QALE using observed and estimated EQ-5D index scores

| Year | Sex | QALE use observed EQ-5D[a] | QALE use estimated EQ-5D[b] | % Difference[c] |
|---|---|---|---|---|
| 2000 | All | 51.4 | 51.8 | 0.82 |
| 2001 | All | 51.6 | 51.8 | 0.43 |
| 2002 | All | 51.9 | 51.8 | −0.13 |
| 2003 | All | 52.1 | 51.9 | −0.39 |
| 2000 | Male | 50.1 | 50.3 | 0.43 |
| 2001 | Male | 50.3 | 50.4 | 0.08 |
| 2002 | Male | 50.5 | 50.4 | −0.34 |
| 2003 | Male | 50.7 | 50.5 | −0.49 |
| 2000 | Female | 52.7 | 53.2 | 1.03 |
| 2001 | Female | 52.9 | 53.2 | 0.58 |
| 2002 | Female | 53.2 | 53.2 | −0.08 |
| 2003 | Female | 53.5 | 53.2 | −0.45 |
| Mean | | 51.7 | 51.8 | 0.12 |
| RMSE | | 0.27 | | |
| MAD | | 0.23 | | |
| $R^2$ | | 0.075 | | |

*RMSE* root of mean squared error, *MAD* mean relative absolute difference

[a] QALE is calculated using observed EQ-5D from the MEPS

[b] QALE is calculated using estimated EQ-5D from the BRFSS

[c] Related difference between two methods

complete life tables for the QALE estimation are available upon request.

The current analysis shows good reliability of annual QALE estimates at the national and state levels and for the most demographic subgroups. The proposed method also can be used to calculate QALE and to understand the risk factors and disease burdens in areas as small as counties. Since the BRFSS was designed to provide reliable state-level estimates and estimates for some substate areas, or annual and monthly estimates for larger geographic areas [22], QALE can be calculated for some substate areas such as populous counties or metropolitan statistical areas by applying small area estimation techniques or aggregating data over several years with a careful choice of age intervals for constructing abridged life tables [5, 6, 19, 22].

Because many interventions are implemented at the state and local levels, public health decision makers need tools that allow them to examine the overall health for the population [3, 8]. The most important use of QALE in routine health surveillance is to provide a summary measure of mortality and morbidity statistics that tracks quality and years of healthy life [3]. A single measurement of overall health like QALE is particularly useful for directly comparing regions (within or among states) where a given policy has been implemented [3, 4]. Additionally, QALE can be used both to measure the burden of disease (associated with a particular risk factor, determinant, disease, or injury) and to conduct cost-effectiveness analyses of alternative interventions to reduce the burden on health [8, 22, 23]. For example, this study provides a proof of concept to calculate the burden of disease due to various conditions (i.e., to calculate years of healthy life lost to a disease or a risk factor). Such an analysis can change public health practice, affecting the design of healthy communities and the targeting of subgroups [8, 23, 24]. It is possible that using the mapping algorithm of EQ-5D scores may introduce bias into the cost-effective estimates but methods also exist to reduce the potential bias as well as test the sensitivity of the estimates. The potential benefits of providing these types of cost-effectiveness estimates to national and state policy makers may outweigh the concerns regarding introducing small amounts of bias.

The standard error formula of QALE estimates was derived based on an approximation (i.e., delta method) that assumes that mortality is independent to HRQOL. However, such an assumption may not be true. For example, the mean HRQOL score would be negatively associated with mortality (i.e., the worse HRQOL score, the higher mortality rate). To evaluate the accuracy of this approximation, we applied a computationally intensive bootstrap method to obtain the standard errors of estimates without assuming this independence. The standard errors of estimates for the two estimation procedure were nearly identical ($r = 0.999$ for life expectancy and $r = 0.998$ for QALE), and the standard errors estimated by the delta method were slightly larger than the standard errors estimated by the bootstrap method, about 0.28 and 0.18% larger for life expectancy and QALE, respectively. So, violation of the independence assumption has very little impact on the accuracy of the standard error calculation, and the delta method actually slightly overestimates these standard errors.

For the life expectancy calculation, random errors in mortality estimation will not have a big impact on the reliability of estimates for the national or state-level estimates. However, random errors and biases in the HRQOL estimates (i.e., EQ-5D scores) could strongly affect the reliability of the QALE estimates. Previous studies ignored the unreliability of using predicted EQ-5D scores and the errors of mortality estimates in small cells [8, 25]. This study provides a method to include this extra variability for the standard error estimation. Such corrections allow the use of model-based estimates of death rates and EQ-5D scores for areas with few or no deaths or BRFSS respondents and are particularly important for estimating QALE in small states or in counties [20].

Although QALE among U.S. adults have increased progressively from 1993 to 2008, mainly due to the consistent decline in mortality rates in major population subgroups [18], such improvements of QALE differed across different demographic subgroups and did not occur in all U.S. States. Observed differences among the States in QALE imply differences in state-specific life expectancies, HRQOL scores, or both. Because states with high mortality rates are more likely to have worse HRQOL scores, we would expect the state QALE differences to be even bigger than observed differences in life expectancy and HRQOL alone. Interventions to increase life expectancy, to improve HRQOL, or both may help reduce differences among the States in their progress toward achieving goal 1 of Healthy People 2020, to increase quality and years of healthy life [3].

Besides some inherent limitations of BRFSS data (such as the use of self-reported data, and the omission of persons who use only cell phones or who are in institutions) [9, 11, 12], this study has some other limitations in estimating QALE. First, the QALE estimation uses an estimated preference-based HRQOL score instead of actual observed scores because the BRFSS does not include the EQ-5D questions. The estimated EQ-5D scores may be biased for some demographic subgroups, which in turn can bias the calculated QALE when based on race [13–15, 26]. However, the bias of the mapping algorithm between the BRFSS HRQOL questions and the EQ-5D scores was relatively small for the estimation of mean utility values for the total population and some major demographic subgroups (<0.5%) [15]. Also, the sensitivity analysis demonstrated that the bias associated with using this mapping algorithm had little impact on estimated QALEs (see table 4).

Secondly, the number of BRFSS respondents and the number of deaths might be too small in some states when calculating life expectancy and QALE by race. Estimates in smaller population subgroups may require the construction of abridged life tables for the calculation of life expectancy and QALE [5, 6]. Third, in 2002, 28 states and the District of Columbia did not ask the Healthy Days questions in the BRFSS. The estimated values for these states and District of Columbia were based on 3-year moving averages.

In summary, this paper provided a new method for measuring QALE and tracking changes in the US States. Such a measure is particularly useful because it captures the population overall health associated with both mortality and morbidity using a single value. This study will enable the CDC and the State Health Departments to assess progress in the States toward the first goal of the Healthy People 2020 process, to increase both the quality and the years of healthy life [3].

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