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Cervical Cancer Screening & Morality: Two Analyses using BRFSS Data

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By

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B.S., The American University, 2020

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Abstract

Cervical Cancer Screening & Morality: Two Analyses using BRFSS Data

By Hannah E. Fuchs

BACKGROUND: Cervical cancer is the most preventable cancer through screening yet is still a leading cause of cancer death among young women in the US. Contemporary trends in hysterectomy-corrected cervical cancer mortality were examined by age, race/ethnicity, and state. An updated assessment of cervical cancer screening among LGBTQ+ women is also presented.

METHODS: Annual hysterectomy prevalence was estimated using the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System (BRFSS 1990-2020), with missing data years approximated via two-year averages of adjacent years. Age-specific cervical cancer deaths (20-49, 50-64, ≥65 years) by race/ethnicity were obtained from the National Center for Health Statistics (1990-2019). Age-standardized hysterectomy-corrected mortality rates per 100,000 women were calculated by dividing death counts by the estimated female population with an intact uterus for each stratum. Joinpoint regression quantified the annual and 5-year average annual percent change (AAPC) and 95% confidence intervals (CI). The association between sexual orientation and screening compliance was examined in data from BRFSS female respondents (2014-2020) aged 21-29 and 30-65, and expressed as logistic regression-generated odds ratios adjusted for age, education, relationship status, income, race/ethnicity, smoking and insurance status.

RESULTS: Cervical cancer death rates declined continuously from 1990-2019, with contemporary declines largest among ages ≥65 years (AAPC: -1.7% [95% CI: -2.0%, -1.3%]) and smallest among ages 20-49 years (AAPC: -0.5% [95% CI: -0.8%, -0.2%]). Mortality from 2015-2019 was highest in Alabama, Arkansas, Mississippi, and Oklahoma, where most age groups experienced stable trends. Morality increased among young women in Indiana (4.8% per year 2009-2019 [95% CI: 0.9%, 8.9%]), NHW women in Alabama (1.9% per year 2003-2019 [95% CI: 0.4%, 3.4%]), and NHW young women in Kansas (2.2% per year 1996-2019 (95% CI: 0.5%, 3.9%]). The odd ratios comparing screening adherence non-straight women to straight referents were 0.58 (95% CI: 0.45, 0.75) and 0.80 (95% CI: 0.66, 0.97) in 21-29- and 30-65-year age groups, respectively.

CONCLUSION: Cervical cancer mortality declined for all ages of women in most states, but progress has lagged in states with the highest burden. Non-straight women were less likely than their straight counterparts to be screening compliant.

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INTRODUCTION:

The overwhelming majority of cervical cancer deaths are preventable through screening and, more recently, HPV vaccination.[1] Since the mid-1970s, cervical cancer mortality has dropped by more than half, mostly as a result of widespread screening uptake. Nevertheless, cervical cancer is expected to cause 4,280 deaths in the United States in 2022 and is consistently a leading cause of death among young women, with more than one woman in her 20s or 30s dying each day from the disease in 2019.[2] As data on sexual orientation are not collected systematically, it is difficult to quantify the burden of cancer among lesbian, bisexual, transgender, queer, and other sexual orientation/gender identity (LGBTQ+) women. However, cervical cancer disparities based on sexual orientation warrant consideration because LGBTQ+ women are more likely than straight women to have inadequate Pap smear rates,[3] which may result in increased cervical cancer incidence and thus mortality. Based on 2021 estimates, 7.1% of the American population identifies as LGBTQ+, and the proportion is expected to continue to rise as younger generations are more likely to identify as non-heterosexual.[4]

When evaluating cervical cancer health disparities, it is also important to keep in mind that cervical cancer mortality rates that do not exclude women who have had their cervix removed through hysterectomy from the at-risk population underestimate mortality risk. Previous studies that account for the proportion of women who have had a hysterectomy have demonstrated that racial and ethnic heath disparities are underestimated in uncorrected rates.[5-8] This issue is especially relevant in this study given that prevalence of hysterectomy differs by age[7] and geography. Although cancer control primarily occurs at the local or state level, few

studies have investigated the impact of hysterectomy correction on mortality trends by age and state over time.

To better understand the burden of cervical cancer, it is vital to have accurate information on cancer screening and mortality. The purpose of this analysis is to investigate how trends in hysterectomy-corrected cervical cancer mortality rates have changed over the past thirty years by race/ethnicity, age, and geography. We also aim to assess the contemporary association between sexual orientation status and cervical cancer screening compliance.

METHODS & MATERIALS:

Hysterectomy-Corrected Cervical Cancer Mortality

Data Sources

Annual cervical cancer death counts from 1990 to 2019 were obtained by age and race/ethnicity (non-Hispanic White [NHW], non-Hispanic Black [NHB], Hispanic) for all 50 states and the District of Columbia from the National Center for Health Statistics via the National Cancer Institute's SEER*Stat software (version 8.3.9).[9] Information on Hispanic origin is incomplete on death certificates for Louisiana in 1990, New Hampshire in 1990-1992, and Oklahoma in 1990-1996 so data from these state-years were excluded from the analysis by race/ethnicity. Corresponding population estimates were obtained from US Census Bureau population estimates.[10]

Age-specific annual hysterectomy prevalence estimates for the study period were obtained by age and race/ethnicity from the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System (BRFSS).[11] The BRFSS is a health-related survey of all 50 states and territories and was established in 1984 using random-digit-dialling of landline

phones until 2010 and later with landline and cellular phones from 2011 onward. Survey weighting methods changed in 2011 to accommodate the new dual-frame sampling design, documentation of which has been detailed elsewhere.[12, 13] Since 1989, the BRFSS has asked assigned-female-at-birth participants, "Have you had an operation to remove the uterus or womb?" This question was asked nationally from 1991-1999 and in even years from 2000 onwards, but only in a subset of states in 1990 and odd years from 2001 forward. As such, data from 1991 was substituted for the 1990 estimate and data from 2012 was used for 2011 to account for survey methods changes; all other module years were imputed using two-year weighted averages of adjacent even years. Hysterectomy estimates were considered unstable if less than 50 individuals answered the question or if the relative standard error (standard error divided by the estimate) was greater than 0.30. Three-year moving average estimates were used for a subset of states (n=15) with unstable estimates in particular years.

Statistical Analysis

Annual hysterectomy-corrected cervical cancer death rates were calculated for each age and race/ethnicity stratum by multiplying the general population estimate from the US Census Bureau by the proportion of women estimated to have an intact uterus (1 - estimated hysterectomy prevalence) and thus at risk for cervical cancer. Corrected rates were expressed per 100,000 women and age-standardized to the 2000 US standard population as follows, where *i* indicates each of the 14 five-year age groups used for age standardization (20-24, 25-29 … 80-84, 85+) within each broader age group *j* (20-49, 50-64, 65+) used for hysterectomy prevalence estimates, with hysterectomy assumed to be constant across all age groups *i* within each age group *j*:

$$\text{Rate}_j = \sum_{i=1}^{I} \left[\frac{count_i}{\text{population}_i * (1 - estimated\ prevalence_j)} * \frac{\text{standard population}_i}{total\ standard\ population} \right] * 100{,}000$$

Confidence intervals (95%) and rate ratios comparing state versus US mortality rates were calculated Tiwari et al. (2006) modifications.[14]

Hysterectomy adjustments were conducted using Statistical Analysis Software version 9.4 (SAS Institute, Cary, NC).[15] Trends in corrected cervical cancer mortality rates were analyzed with Joinpoint regression software (version 4.9.0.1),[16] which fits a series of segmented log-linear regression models to data using the weighted least squares method.[17] Up to five joinpoints were allowed with a minimum of four observations between each two joinpoints. The annual percent change (APC) and contemporary trends for the most recent 5-year (2015-2019) and 10-year (2010-2019) periods, expressed as an average annual percent change (AAPC), were calculated. A two-sided Monte Carlo Permutation method was used to test for statistical significance of trends with an alpha value of 0.05. If the test was non-significant, the trend was considered stable. Figures were created using R (v.4.1) ggplot2 (v.3.3.5), tmap (v. 3.3-2), and tigris (v.1.6) packages. IRB approval was not required as the project was not deemed human subjects research.

Sexual Orientation and Screening Compliance Analysis

Study Population

Analysis was conducted using data from the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System (BRFSS) in even years from 2014 to 2020. Survey respondents were included in the analysis if they were assigned female-at-birth, were in the screening eligible age group (21 to 65 years) and provided information on all variables of interest.

Independent variable of interest

Since 2014, the BRFSS has included questions comprising the Sexual Orientation and Gender Identify module, which is not used uniformly across the US. The module coverage has increased from 19 states in 2014—mostly in the Northeast and parts of the Midwest— to 32 states in the 2020 survey. Sexual orientation status is collected based on self-reported response to the following question: "Which of the following best represents how you think of yourself?" Possible answers are "straight, that is not gay", "lesbian/gay", "bisexual", "something else", "I don't know", or "refused to answer." Participants who refused to answer were excluded from analysis. Due to the relatively small proportions of specific LGBTQ+ categories, a binary exposure variable (straight vs not straight) was created for analysis.

Outcome

BRFSS questions on cervical cancer screening are asked during even years and include "How long has it been since you had your last Pap test?" and "How long has it been since you had your last HPV test?" The binary outcome variable of interest was compliance with 2012 age-specific cervical cancer screening guidelines from the American Cancer Society.[18] For women aged 21 to 29 years at risk for cervical cancer, guideline compliance was defined as having had a Pap test within the past 3 years. Participants aged 30-65 were considered guideline compliant if they had undergone either a Pap test within the past 3 years or both an HPV and a Pap test within past 5 years.

Covariates

Covariates for model adjustment were selected based on *a priori* knowledge about the association with either the independent variable or the outcome of interest. Models were adjusted for demographic factors including age (continuous) and race/ethnicity (non-Hispanic white, non-Hispanic Black, Hispanic, other). Level of education is often associated with ability to obtain

work (and thereby employer-provided health insurance) as well as health literacy levels. Women who have obtained higher levels of education frequently experience higher rates of cervical cancer screening compliance.[19] BRFSS participants answer, "What is the highest grade or year of school you completed?" and possible answers range from "never attended school or only kindergarten" to "College 4 or more years (College graduate)." For the purposes of this analysis, education was expressed as a three-category variable: "high school graduate or less", "some college education", and "college graduate". Similarly, employment (employed/self-employed; student/homemaker/retired; unemployed/unable to work) and annual family income (< $15,000 per year; $15,000 to $50,000 per year; > $50,000 per year) were presented as three-level categorical variables.

Insurance status ("yes"/"no") was used to control for healthcare access of any kind (private, Medicare, HMO, etc.). Models were also adjusted for current smoking status ("yes"/"no") because smokers also often experience lower levels of cervical cancer screening[20] and smoking is more prevalent among LGBTQ+ populations.[21] Personal relationship status (likely a reflection of available support) has also been associated with cervical cancer screening compliance in previous studies.[22] As LGBTQ+ groups were not granted the right to marry in the United States until 2015, the relationship status was defined as a binary variable: "partnered" (married or a member of an unmarried couple) or "not partnered."

Statistical Analysis

Survey-weighted logistic regression was implemented to assess the association between sexual orientation and cervical cancer screening compliance. Survey weights were provided by the BRFSS and methods of calculation can be found elsewhere.[12] Due to weighting, sample

characteristics are presented as population-representative proportions instead of population numbers.

Two-way interactions of each covariate and the exposure variable were included in the initial model. ANOVA tests were implemented to assess if interaction terms could be removed from the model ($p < 0.05$). The model was stratified by covariates within remaining significant interaction terms until no significant interactions remained. The results of regression analyses were expressed as adjusted odds ratios (OR) and their 95% confidence intervals (CI). Modeling was conducted using the R (v.4.1) survey (v.4.1-1) package. OR contrasts were calculated using the multcomp (v.1.4-18) package. Figures were created using the ggplot2 (v. 3.3.5) package. IRB approval was not required as it was not deemed human subjects research.

RESULTS:

Hysterectomy-Corrected Cervical Cancer Mortality

The increase in cervical cancer mortality rates due to hysterectomy correction was larger for earlier years, older age groups, and NHB women, reflecting the higher hysterectomy prevalence in those groups (Figure 1). For example, the cervical cancer mortality rate during 2015-2019 rose from 1.94 per 100,000 (95% CI: 1.90, 2.00) before correction to 2.09 (95% CI: 2.03, 2.14) after correction among women aged 20-49 versus from 5.39 per 100,000 (95% CI: 5.26, 5.51) before correction to 9.72 per 100,000 (95% CI: 9.50, 9.94) among women aged ≥65 years. For women aged 20+, the rate increased from 2.85 per 100,000 (95% CI: 2.80, 2.91) to 3.97 per 100,000 (95% CI: 3.90, 4.04) after correction for non-Hispanic White (NHW) women compared an increase from 4.72 per 100,000 (95% CI: 4.56, 4.87) to 7.64 per 100,000 (95% CI: 7.39, 7.90) for non-Hispanic Black (NHB) women (Table 1).

The cervical cancer mortality rate decreased continuously from 1990 to 2019, with the largest 10-year drop (2010 to 2019) among ages ≥65 years (AAPC: -1.7% [95% CI: -2.0%, -1.3%) and the smallest among ages 20-49 (AAPC: -0.5% [95% CI: -0.8% to -0.2%]). NHW women displayed the smallest declines in mortality across all ages, including stable rates for 20- to 49-year-olds. The steepest declines per age group were observed for NHB women aged 20-49 (-3.2% [95% CI: -3.6% to -2.9%]), Hispanic women aged 50-64 (-3.3% [95% CI: -3.7% to -2.9%]), and Hispanic women aged 65+ (-2.8% [95% CI: -3.2% to –2.3%]) (Table 2).

Examining mortality rates from 1990 to 2019 by state reveals that declines were not uniform geographically. Southern states were more likely than states in other regions to experience the slowest declines in mortality rate or a stable trend. Mortality rates in Alabama, Arkansas, Mississippi, and Oklahoma remated in the remained the highest quintile (> 7.63 deaths per 100,000) across entire 30-year study period (Figure 2). At least two of the three age groups within each of these four states experienced stable trends in mortality rates from 1990 to 2019. Furthermore, Arkansas experienced the slowest continuous decline during 1990-2019 in cervical cancer mortality rate among women ages 20+ of -0.5% per year (95% CI: -1.0%, 0.0 (see Supplemental Table 1). Mississippi also experienced a slow continuous decline of -0.8% per year (95% CI: -1.4%, -0.2%) and during 1990-2019.

Slowly declining or stable trends among these four southern states resulted in a widening gap between state-level and national level-mortality rates. In the contemporary period (2015-2019), Mississippi had a cervical cancer mortality rate 95% higher than the national rate (RR: 1.95 [95% CI: 1.72, 2.19]) – the highest difference across the US—up from 45% during 1990-2019 (RR: 1.45 [95% CI: 1.29, 1.63]). Mortality rate ratios rose from 1.41 (95% CI: 1.28, 1.55) to 1.89 (95% CI: 1.72, 2.08) in Alabama, from 1.15 (95% CI: 1.01, 1.30) to 1.82 (1.62, 2.06) in

Arkansas, and from 1.40 (95% CI: 1.25, 1.56) to 1.78 (95% CI: 1.61, 1.99) in Oklahoma during 1990-1994 and 2015-2019, respectively. Further stratification of contemporary state mortality rate ratios (2015-2019) by race/ethnicity revealed that cervical cancer mortality rates were highest among NHW women in Southern states regardless of age. Young (20-49 years) NHW women in ten southern states had 48% to 115% higher cervical cancer death rates than the overall US (Figure 3).

Moreover, a few populations saw persistent increases in cervical cancer mortality. From 2009 to 2019, the cervical cancer death rate among women aged 20-49 in Indiana increased by 4.9% per year (95% CI: -0.9%, 8.9%) on average, translating to 2.7 deaths per 100,000 women in 2019, up from 2.1 in 2009. Among NHW women, women in Kansas aged 20-49 and women in Alabama aged 20+ experienced increasing mortality rates. From 1996 to 2019, mortality rose by 2.2% annually (95% CI: 0.5%, 3.9%) among NHW women ages 20-49 years in Kansas. This equated to a change from 0.88 deaths to 3.69 deaths per 100,000 women within this population. The contemporary death rate (2015-2019) among NHW women in Kansas aged < 50 years was 1.61 times the national rate (95% CI: 1.21, 2.10) (Figure 3). In Alabama, death rates for NHW women aged 20+ rose on average by 1.9% annually (95% CI: 0.5%, 3.4%) during 2003-2019, from 10.16 to 11.23 deaths per 100,000 women (see Supplemental Table 2). During the most recent five years (2015-2019), the death rate among NHW women in Alabama was 1.88 times that of NHW women in the US overall (95% CI: 1.67, 2.11) (Figure 3).

Sexual Orientation and Screening Compliance Analysis

Among BRFSS female respondents ages 21 to 65 during 2014-2020, an estimated 8.1% (95% CI: 7.8%, 8.3%) identified with a sexual orientation other than straight (Table 3). Most women were employed (63.3% [95% CI: 63.0%, 63.6%]), non-Hispanic white (59.2% [95% CI:

58.8%, 59.5%]), in a partnership (58.4% [95% CI: 58.1%, 58.7%]), and insured (86.2% [95% CI: 85.9%, 86.4%]). Most women (91.2% [95% CI: 91.1%, 91.4%]) were compliant with cervical cancer screening guidelines. Population characteristics after stratification by screening status mirrored those among the overall population, although non-compliant women were more likely than compliant women to have fewer years of education (high school or less, 45.2% [95% CI: 44.1%, 46.2%] vs 31.8% [95% CI: 31.4%, 32.1%]) and to be uninsured (holds any form of insurance, 73.6% [95% CI: 72.6%, 74.6%] vs 88.6% [95% CI: 88.4%, 88.9%]).

Fitting a multivariate, survey-weighted logistic regression model with 13 exposure/covariate interaction terms showed no association between sexual orientation and screening compliance (OR = 0.66 [95% CI: 0.32, 1.36]). Significant interaction was observed between sexual orientation and age as well as smoking status. For example, among non-smokers, the odds of compliance among non-straight women were 0.66 (95% CI: 0.32, 1.36) times the odds among straight women. Conversely, among smokers, the corresponding OR was 0.92 (95% CI: 0.70, 2.46) (Table 4).

As significant interaction was observed by age and screening recommendations differed for younger and older women during most of the study period, the logistic regression model was stratified: one for women ages 21 to 29 and another for those ages 30 to 65. Approximately one-fifth (21.8% [95% CI: 21.6%, 22.1%]) and four-fifths (78.1% [95% CI: 77.9%, 78.4%]) of the population fell within the younger and older age groups, respectively. Among each age category, the proportion of women who were screening compliant mirrored that of the overall population. However, non-compliant women in both groups were almost two times as likely as their compliant counterparts to be smokers (Table 5). Within both models, all interaction terms were found to be insignificant (ANOVA test of full model with interactions vs reduced model with no

interactions p-value: 0.88 and 0.71 for the models for women aged 21-29 and 30-65, respectively), and thus were removed from final models.

Both models revealed a significant association between sexual orientation and screening compliance, although, the magnitude differed by age group. Within the younger age group, the odds of screening compliance among non-straight women were 42% lower than the odds among straight women (OR: 0.58 [95% CI: 0.45, 0.75]). Conversely, among the older age group, the odds of screening compliance among non-straight women were 20% less than the odds among straight women (OR: 0.80 [95% CI: 0.66, 0.97]). Higher family income, greater educational attainment, and committed partnership status were significantly associated with screening compliance among older women, but not younger women. In younger women, odds of compliance for non-Hispanic Black women were 1.60 (95% CI: 1.11, 2.29) times the odds for non-Hispanic white women. In comparison, odds of compliance for non-Hispanic Black women were almost three times the odds among non-Hispanic white women (OR: 2.87 [95% CI: 2.39, 3.45]). Odds of compliance among smokers were 0.72 (95% CI: 0.57, 0.92) and 0.51 (95% CI: 0.47, 0.56) lower than non-smokers among younger and older women, respectively. Insured women, both young and old, had almost three-fold higher odds of compliance than uninsured women (Figure 4).

DISCUSSION:

Our two analyses using BRFSS data for hysterectomy prevalence and cervical cancer screening and NCHS data for cervical cancer mortality rates has revealed four potential target populations for further research and public health program implementation. First, women in several central Southern states (Alabama, Arkansas, Mississippi, and Oklahoma) have higher cervical cancer death rates than the rest of the US due to less progress in reducing cervical cancer

mortality during the study period. Second, during the most recent five-year period (2015-2019), among NHW women younger than 50 years in Alabama, Arkansas, Florida, Kansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas, cervical cancer mortality rates were significantly higher than the national rate and among the highest across all age groups and race/ethnicities evaluated. Third, women younger than 50 years in Indiana and NHW women in Alabama and Kansas have experienced increases in cervical cancer mortality in recent years. Fourth, non-straight women are less likely to be compliant with cervical cancer screening recommendations than straight women.

Without correction for hysterectomy prevalence, precise trends and disparities in cervical cancer mortality are masked.[5, 23] Misinformation is most pronounced for subsets of the population with high hysterectomy prevalence, such as Black women,[24, 25] older age groups,[8] and women who reside in the South and Midwest.[26-28] Our study provides a novel assessment of contemporary trends in hysterectomy-corrected cervical cancer death rates as previous analysis by age- and state-level groups are limited. Additionally, prior analyses of corrected trends by race/ethnicity were limited to White/Black or NHW/NHB groupings.[5, 23] Broadly, correcting for hysterectomy steepened the rate of decline for decreasing trends and attenuated increases because correction had a larger impact on earlier years in the study period due to declining hysterectomy prevalence across racial/ethnic groups. Corrected cervical cancer mortality declined across all age groups for all races/ethnicities combined from 2010 to 2019—in agreement with previous findings[23]—and with larger declines among older women.

Increasing trends were observed among younger women in Indiana since 2009, for NHW women of all ages in Alabama since the mid-2000s, and for younger women in Kansas since the mid-1990s. Although stable rates are expected at some point as rates reach a nadir, increasing

trends are cause of concern. Notably, we found that women aged 20-49 in Indiana are approximately 50% more likely than women of the same age in the overall United States to die from cervical cancer (RR: 1.49 [95% CI: 1.27, 1.74]). Although NHW women represented 79% of the Indiana female population aged 20-49 from 2009 to 2019,[10] the corrected mortality trend among these women was stable. While regression models did not indicate an increasing trend, mortality rates among these women appear to be increasing, and this population should continue to be monitored to see if the trend changes from stable to increasing in the future. The death rate among Alabama women 20+ compared to national women 20+ worsened from the earliest 5-year period (1990-1994 RR: 1.41 [95% CI: 1.28, 1.55]) to the most recent 5-year period (2015-2019 RR: 1.89 [95% CI: 1.72, 2.08]). From 2015-2019, Alabama ranked within the top five highest state mortality rate ratios for NHW women across all age groups (20+: RR = 1.89 [95% CI: 1.67, 2.12]; < 50: RR = 1.76 [95% CI: 1.41, 2.18]; 50+: RR = 1.94 [95% CI: 1.68, 2.23]). Alabama NHB women aged 50+ also experienced higher burden than similarly aged NHB women nationally (RR = 1.63 [95% CI: 1.34, 1.94]), and a stable 10-year trend. In Kansas, NHW women aged 20-49 had a 61% significantly higher cervical cancer mortality rate than their national counterparts (RR: 1.61 [95% CI: 1.21, 2.10]).

In the analysis of cross-sectional population-based data, non-straight women were significantly less likely than straight women, regardless of age, to be compliant with American Cancer Society 2012 cervical cancer screening guidelines,[18] which were in effect until July 2020.[1] The difference in screening compliance was more pronounced among younger women (21 to 29 years of age) than among women aged 30 to 65 years. These findings add to the existing evidence of non-straight women having a lower prevalence of Pap smear testing.[3, 29-32] As a result of lower screening prevalence, it is likely that cervical cancer incidence and mortality

are elevated among LGBTQ+ individuals, but it is impossible to quantify such health disparities because cancer registries do not have record of sexual orientation status. Incorporating this information onto death certificates is difficult for a variety of reasons including difficulties assessing self-reported sexual orientation after a person is dead if they had not disclosed information to their family/friends or educating coroners/medical examiners how to ask questions about sexual orientation status in a sensitive mannor[33] Advocacy to collect sexual orientation status at time of death should continue in order to make mortality among LGBTQ+ people more transparent, but this process may take decades.

Thus, understanding reasons that drive LGBTQ+ cervical cancer screening behaviors is of paramount importance. Major barriers to cervical cancer screening include lack of health insurance, lack of provider recommendation, and lack of knowledge about recommendations.[32] The national proportion of women overdue for cervical cancer screening in the United States increased from 14.4% in 2005 to 23.0% in 2019, with lack of knowledge the most common reason cited for noncompliance across all groups including LGBTQ+ women.[32] During 2008-2014, cross-sectional data has exhibited a decrease of -3.8% per year in screening among women aged 21-29 and -2.3% among those aged 30-31.[34] This likely contributes to recent increasing trends in cervical cancer incidence rates and late-stage diagnoses. Previous surveillance analysis revealed an increase (0.7% per year during 2004-2015) in cervical cancer incidence rates among NHW women aged 40-49, largely driven by trends in cervical adenocarcinoma which increased by 4.4% per year during this period; rates were stable or declining in Hispanic and NHB women.[35] An increase in the annual rate of distant-stage diagnoses during 2001-2015 among NHW women aged 30-49 (3%-4% per year) and Hispanic women of all ages combined (1.2% per year) was also observed. Notably, there has been no improvement in the five-year relative

survival rate for cervical cancer patients in the US over the past four decades (69% during 1975 to 1977 vs 66% during 2011 to 2017)[2] in part due to the lack of major treatment advances for patients with advanced disease.[36, 37] Changes in the disease distribution likely also contribute; the prevalence of squamous cell carcinoma, which is most often detected by cytology and has higher survival rates than adenocarcinoma, has declined due to widespread screening.[35]

The most recent cervical cancer screening guidelines released by the American Cancer Society[1] and the United States Preventive Services Task Force[38] do not include specifications that non-straight should be identified as a high-priority group for secondary prevention of cervical cancer. Some researchers suggest that these guidelines should be modified to explicitly reference non-straight women with the goal of combatting the misconception that only those that have sex with men are at risk of cervical cancer.[39, 40] Increasing health care provider promotion of screening for LGBTQ+ women would also help these efforts.[31, 41] There is evidence that one of the potential drivers of inadequate screening among LGBTQ+ individuals is experience of stigma and discrimination in health care settings. Previous research reported that non-straight women who regularly received cervical cancer screening felt both they and their partner were more welcomed in health care environments than those who did not screen regularly. Routine screeners were also more likely to have disclosed their sexual orientation to their provider than non-regular screeners.[42, 43] While our analysis did not reveal significant interaction between race/ethnicity and sexual orientation, it should be noted that women with intersectional identities experience higher levels of discrimination and experience more distrust of providers.[44] These findings stress the necessity for increased provider education on LGBTQ+ needs and health disparities.

A major strength of these two cervical cancer analyses is the use of nationally representative data from the BRFSS survey. Within the first project to calculate hysterectomy prevalence estimates, the BRFSS state-level data allowed for assessment of trends by age and state, groups which have had limited coverage in hysterectomy-correction analyses. The present analysis to evaluate the association between sexual orientation and screening compliance takes advantage of the recent BRFSS survey expansion that added data on sexual orientation and gender identity. At its inception in 2014, the sexual orientation and gender identity BRFSS questionnaire was distributed in 19 states; coverage has increased to 32 states as of 2020. The current BRFSS data on sexual orientation and gender identity now include Western and Southern states, thereby increasing the geographic and demographic representation of our findings.

There are, however, several limitations. BRFSS survey weighting methods changed in 2011 and the sample design was expanded to allow for cellular telephone–only respondents; this process increased survey reach to subpopulations experiencing more risk factors, such as groups with lower income, lower education, and younger age,[12] but may have increased estimates of state-level prevalence from 2011 onwards. However, BRFSS hysterectomy estimates from before the methods change and after (2010 and 2018) were not statistically different from those based on the National Health Interview Survey for the same years.[28] While the BRFSS survey relies on self-reported data, prospective cohort data has shown self-reports of hysterectomy status are sufficiently accurate.[45] In addition, the BRFSS data does not distinguish between a full and partial hysterectomy, which excludes the removal of the cervix; however, the proportion of partial hysterectomies has declined to about 10% and thus likely had minimal impact on our estimates.[7, 27, 46-48] Due to sparce data among some racial/ethnic and younger age groups, our hysterectomy-correction analysis required the use of wide age ranges. As such, the proportion of

women removed from mortality rate denominators for correction is likely an underestimate among older women and an overestimate among younger women within each of the three age groups (20-49, 50-64, ≥65 years). Finally, it is important to acknowledge that the BRFSS relies on self-reported data, and due to stigma against LGBTQ+ individuals, it is possible that some women felt uncomfortable sharing their sexual orientation status thereby inducing social acceptability bias.

In this nationwide study of hysterectomy-corrected cervical cancer mortality, we document several Southern states that have not made significant improvements in cervical cancer mortality over the past 30 years, and that these states still experience the highest mortality burden for the disease. Increases in cervical cancer death rates among some groups of women are also of concern. As cervical cancer is one of the most preventable types of cancer, targeted efforts to increase uptake of protective health behaviors are needed to reverse concerning trends and ultimately decrease cervical cancer deaths in the US. Additionally, non-straight women could benefit from increased cervical cancer screening messages. Ensuring that all women, regardless of their sexual orientation, are presented with information on how to protect themselves from cervical cancer will decrease incidence and subsequently mortality of this disease.

References

1. Fontham ETH, Wolf AMD, Church TR, et al. Cervical cancer screening for individuals at average risk: 2020 guideline update from the American Cancer Society. *CA: a cancer journal for clinicians*. 2020-09 2020;70(5):321-346. doi:10.3322/caac.21628
2. Siegel RL, Miller KD, Fuchs HE, Jemal A. Cancer statistics, 2022. *CA: A Cancer Journal for Clinicians*. 2022;72(1):7-33. doi:10.3322/caac.21708
3. Charkhchi P, Schabath MB, Carlos RC. Modifiers of Cancer Screening Prevention Among Sexual and Gender Minorities in the Behavioral Risk Factor Surveillance System. *J Am Coll Radiol*. 2019/04// 2019;16(4 Pt B):607-620. doi:10.1016/j.jacr.2019.02.042
4. Jones JM. LGBT Identification in U.S. Ticks Up to 7.1%. GALLUP. Accessed April 8, 2022. https://news.gallup.com/poll/389792/lgbt-identification-ticks-up.aspx
5. Yoo W, Kim S, Huh WK, et al. Recent trends in racial and regional disparities in cervical cancer incidence and mortality in United States. *PloS One*. 2017 2017;12(2):e0172548. doi:10.1371/journal.pone.0172548
6. Rositch AF, Nowak RG, Gravitt PE. Increased age and race-specific incidence of cervical cancer after correction for hysterectomy prevalence in the United States from 2000 to 2009. *Cancer*. 2014 2014;120(13):2032-8.
7. Merrill RM. Hysterectomy surveillance in the United States, 1997 through 2005. *Med Sci Monit*. 2008 2008;14(1):CR24-31.
8. Merrill RM. Impact of hysterectomy and bilateral oophorectomy on race-specific rates of corpus, cervical, and ovarian cancers in the United States. *Ann Epidemiol*. 2006 2006;16(12):880-7.

9. Surveillance, Epidemiology, and End Results (SEER) Program (www.seer.cancer.gov) SEER*Stat Database: Mortality - All COD, Aggregated With State, Total U.S. (1990-2019) <Katrina/Rita Population Adjustment>, National Cancer Institute, DCCPS, Surveillance Research Program, released April 2021. Underlying mortality data provided by NCHS (www.cdc.gov/nchs).

10. Surveillance, Epidemiology, and End Results (SEER) Program (www.seer.cancer.gov) SEER*Stat Database: Populations - Total U.S. (1990-2019) <Katrina/Rita Adjustment> - Linked To County Attributes - Total U.S., 1969-2019 Counties, National Cancer Institute, DCCPS, Surveillance Research Program, released December 2020.

11. Centers for Disease Control and Prevention (CDC). Behavioral Risk Factor Surveillance System Survey Data. Atlanta, Georgia: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2022.

12. Pierannunzi C, Town M, Garvin W, Shaw F, Balluz L. Methodologic changes in the Behavioral Risk Factor Surveillance System in 2011 and potential effects on prevalence estimates. *Morb Mortal Wkly Rep*. 2012-06-08 2012;61(22):410-413.

13. Hu SS, Pierannunzi C, Balluz L. Integrating a multimode design into a national random-digit-dialed telephone survey. *Prev Chronic Dis*. Nov 2011;8(6):A145.

14. Tiwari RC, Clegg LX, Zou Z. Efficient interval estimation for age-adjusted cancer rates. *Stat Methods Med Res*. Dec 2006;15(6):547-69. doi:10.1177/0962280206070621

15. SAS Institute Inc 2013. SAS/ACCESS® 9.4 Interface to ADABAS: Reference. Cary, NC: SAS Institute Inc.

16. Joinpoint Regression Program, Version 4.9.0.1 - February 2022; Statistical Methodology and Applications Branch, Surveillance Research Program, National Cancer Institute.

17. Kim HJ, Fay Mp Fau - Feuer EJ, Feuer Ej Fau - Midthune DN, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. (0277-6715 (Print))

18. Saslow D, Solomon D, Lawson HW, et al. American Cancer Society, American Society for Colposcopy and Cervical Pathology, and American Society for Clinical Pathology screening guidelines for the prevention and early detection of cervical cancer. *CA: a cancer journal for clinicians*. 2012 May-Jun 2012;62(3):147-172. doi:10.3322/caac.21139

19. Damiani G, Basso D, Acampora A, et al. The impact of level of education on adherence to breast and cervical cancer screening: Evidence from a systematic review and meta-analysis. *Prev Med*. Dec 2015;81:281-9. doi:10.1016/j.ypmed.2015.09.011

20. MacLaughlan SD, Lachance JA, Gjelsvik A. Correlation between smoking status and cervical cancer screening: a cross-sectional study. *Journal of Lower Genital Tract Disease*. 2011-04 2011;15(2):114-119. doi:10.1097/LGT.0b013e3181f58d0d

21. Emory K, Kim Y, Buchting F, Vera L, Huang J, Emery SL. Intragroup Variance in Lesbian, Gay, and Bisexual Tobacco Use Behaviors: Evidence That Subgroups Matter, Notably Bisexual Women. *Nicotine Tob Res*. Jun 2016;18(6):1494-501. doi:10.1093/ntr/ntv208

22. Hanske J, Meyer CP, Sammon JD, et al. The influence of marital status on the use of breast, cervical, and colorectal cancer screening. *Preventive Medicine*. 2016/08/01/ 2016;89:140-145. doi:https://doi.org/10.1016/j.ypmed.2016.05.017

23. Beavis A, Gravitt P, Rositch A. Hysterectomy-corrected cervical cancer mortality rates reveal a larger racial disparity in the United States. *Cancer*. 2017 2017;123(6):1044-1050. doi:10.1002/cncr.30507

24. Bower JK, Schreiner PJ, Sternfeld B, Lewis CE. Black–White Differences in Hysterectomy Prevalence: The CARDIA Study. *American Journal of Public Health*. 2009-2 2009;99(2):300-307. doi:10.2105/AJPH.2008.133702

25. Kjerulff KH, Guzinski GM, Langenberg PW, Stolley PD, Moye NE, Kazandjian VA. Hysterectomy and race. *Obstetrics and Gynecology*. 1993-11 1993;82(5):757-764.

26. Adam EE, White MC, Saraiya M. Higher prevalence of hysterectomy among rural women than urban women: Implications for measures of disparities in uterine and cervical cancers. *The Journal of Rural Health: Official Journal of the American Rural Health Association and the National Rural Health Care Association*. 2021-06-03 2021;doi:10.1111/jrh.12595

27. Cohen SL, Vitonis AF, Einarsson JI. Updated hysterectomy surveillance and factors associated with minimally invasive hysterectomy. *JSLS*. 2014 2014;18(3)doi:10.4293/JSLS.2014.00096

28. Adam EE, White MC, Saraiya M. US hysterectomy prevalence by age, race and ethnicity from BRFSS and NHIS: implications for analyses of cervical and uterine cancer rates. *Cancer causes & control: CCC*. 2022-01 2022;33(1):161-166. doi:10.1007/s10552-021-01496-0

29. Solazzo AL, Agénor M, Austin SB, Chavarro JE, Charlton BM. Sexual Orientation Differences in Cervical Cancer Prevention among a Cohort of U.S. Women. *Women's*

Health Issues: Official Publication of the Jacobs Institute of Women's Health. 2020/08//Jul - undefined 2020;30(4):306-312. doi:10.1016/j.whi.2020.02.002

30. Lee M, Jenkins WD, Adjei Boakye E. Cancer screening utilization by residence and sexual orientation. *Cancer Causes & Control*. 2020/10// 2020;31(10):951-964. doi:10.1007/s10552-020-01339-4

31. Bustamante G, Reiter PL, McRee A-L. Cervical cancer screening among sexual minority women: findings from a national survey. *Cancer causes & control: CCC*. 2021/08// 2021;32(8):911-917. doi:10.1007/s10552-021-01442-0

32. Suk R, Hong Y-R, Rajan SS, Xie Z, Zhu Y, Spencer JC. Assessment of US Preventive Services Task Force Guideline-Concordant Cervical Cancer Screening Rates and Reasons for Underscreening by Age, Race and Ethnicity, Sexual Orientation, Rurality, and Insurance, 2005 to 2019. *JAMA network open*. 2022-01-04 2022;5(1):e2143582. doi:10.1001/jamanetworkopen.2021.43582

33. Haas AP, Lane AD, Blosnich JR, Butcher BA, Mortali MG. Collecting Sexual Orientation and Gender Identity Information at Death. *American Journal of Public Health*. 2019/02/01 2018;109(2):255-259. doi:10.2105/AJPH.2018.304829

34. Watson M, Benard V, Flagg EW. Assessment of trends in cervical cancer screening rates using healthcare claims data: United States, 2003-2014. *Prev Med Rep*. 2018 2018;9:124-130.

35. Islami F, Fedewa SA, Jemal A. Trends in cervical cancer incidence rates by age, race/ethnicity, histological subtype, and stage at diagnosis in the United States. *Prev Med*. 2019 2019;123:316-323.

36. van Meir H, Kenter GG, Burggraaf J, et al. The need for improvement of the treatment of advanced and metastatic cervical cancer, the rationale for combined chemo-immunotherapy. *Anticancer Agents Med Chem*. 2014 2014;14(2):190-203. doi:10.2174/18715206113136660372

37. Fiorica JV. The role of topotecan in the treatment of advanced cervical cancer. *Gynecologic Oncology*. 2003-09 2003;90(3 Pt 2):S16-21. doi:10.1016/s0090-8258(03)00465-7

38. Curry SJ, Krist AH, Owens DK, et al. Screening for Cervical Cancer: US Preventive Services Task Force Recommendation Statement. *Jama*. Aug 21 2018;320(7):674-686. doi:10.1001/jama.2018.10897

39. Quinn GP, Sanchez JA, Sutton SK, et al. Cancer and lesbian, gay, bisexual, transgender/transsexual, and queer/questioning (LGBTQ) populations. *CA: A Cancer Journal for Clinicians*. 2015 2015;65(5):384-400. doi:10.3322/caac.21288

40. Curmi C, Peters K, Salamonson Y. Lesbians' attitudes and practices of cervical cancer screening: a qualitative study. *BMC Women's Health*. 2014/12/12/ 2014;14(1):2. doi:10.1186/s12905-014-0153-2

41. Waterman L, Voss J. HPV, cervical cancer risks, and barriers to care for lesbian women. *Nurse Pract*. 2015/01/16/ 2015;40(1):46-53; quiz 53-54. doi:10.1097/01.NPR.0000457431.20036.5c

42. Johnson MJ, Nemeth LS, Mueller M, Eliason MJ, Stuart GW. Qualitative Study of Cervical Cancer Screening Among Lesbian and Bisexual Women and Transgender Men. *Cancer Nurs*. Nov/Dec 2016;39(6):455-463. doi:10.1097/ncc.0000000000000338

43. Tracy JK, Schluterman NH, Greenberg DR. Understanding cervical cancer screening among lesbians: a national survey. *BMC Public Health*. May 4 2013;13:442. doi:10.1186/1471-2458-13-442

44. Agénor M, Bailey Z, Krieger N, Austin SB, Gottlieb BR. Exploring the Cervical Cancer Screening Experiences of Black Lesbian, Bisexual, and Queer Women: The Role of Patient-Provider Communication. *Women Health*. 2015 2015;55(6):717-736. doi:10.1080/03630242.2015.1039182

45. Gentry-Maharaj A, Taylor H, Kalsi J, et al. Validity of self-reported hysterectomy: a prospective cohort study within the UK Collaborative Trial of Ovarian Cancer Screening (UKCTOCS). *BMJ Open*. 2014/03/01 2014;4(3):e004421. doi:10.1136/bmjopen-2013-004421

46. Jorgensen EM, Modest AM, Hur H-C, Hacker MR, Awtrey CS. Hysterectomy Practice Patterns in the Postmorcellation Era. *Obstetrics & Gynecology*. April 2019 2019;133(4):643–649. doi:10.1097/AOG.0000000000003181

47. Wright JD, Herzog TJ, Neugut AI, et al. Comparative effectiveness of minimally invasive and abdominal radical hysterectomy for cervical cancer. *Gynecol Oncol*. 2012 2012;127(1):11-7.

48. Simms KT, Yuill S, Killen J, et al. Historical and projected hysterectomy rates in the USA: Implications for future observed cervical cancer rates and evaluating prevention interventions. *Gynecologic Oncology*. 09/2020 2020;158(3):710-718. doi:10.1016/j.ygyno.2020.05.030

TABLES

Table 1: Hysterectomy correction impact on death rates & rate ratios by race/ethnicity and age (2015-2019)

Race/Ethnicity & Age (years)	Hysterectomy Prevalence (%)	Death Rate†		Rate Ratio	
		Not Corrected	Corrected	Not Corrected	Corrected
All Race/ Ethnicities	21.45 (21.21, 21.70)	3.10 (3.06, 3.15)	4.35 (4.90, 4.41)	-	-
20-49	6.78 (6.61, 6.96)	1.94 (1.90, 2.00)	2.09 (2.03, 2.14)	-	-
50-64	29.06 (28.64, 29.48)	4.55 (4.45, 4.66)	6.42 (6.27, 6.57)	-	-
65+	44.56 (44.11, 45.01)	5.39 (5.26, 5.51)	9.72 (9.50, 9.94)	-	-
Non-Hispanic White	24.52 (24.24, 24.80)	2.85 (2.80, 2.91)	3.97 (3.90, 4.04)	Ref	Ref
20-49	7.83 (7.60, 8.06)	1.92 (1.85, 1.98)	2.08 (2.01, 2.15)	Ref	Ref
50-64	29.3 (28.86, 29.74)	4.11 (3.99, 4.23)	5.81 (5.64, 5.98)	Ref	Ref
65+	44.84 (44.39, 45.29)	4.60 (4.47, 4.73)	8.34 (8.11, 8.58)	Ref	Ref
Non-Hispanic Black	22.28 (21.52, 23.06)	4.72 (4.56, 4.87)	7.64 (7.39, 7.90)	1.65* (1.59, 1.72)	1.92* (1.85, 2.00)
20-49	7.62 (7.11, 8.17)	2.32 (2.18, 2.47)	2.51 (2.36, 2.68)	1.21* (1.13, 1.30)	1.21* (1.12, 1.30)
50-64	35.75 (34.43, 37.09)	6.94 (6.59, 7.32)	10.81 (10.25, 11.39)	1.69* (1.59, 1.80)	1.86* (1.75, 1.98)
65+	52.17 (50.52, 53.82)	10.34 (9.80, 10.91)	21.63 (20.49, 22.81)	2.25* (2.12, 2.39)	2.59* (2.44, 2.76)
Hispanic	12.18 (11.54, 12.86)	3.52 (3.40, 3.66)	4.65 (4.47, 4.83)	1.23* (1.19, 1.29)	1.17* (1.12, 1.22)
20-49	4.62 (4.23, 5.04)	2.07 (1.96, 2.20)	2.17 (2.05, 2.30)	1.08* (1.01, 1.16)	1.05 (0.98, 1.12)
50-64	23.91 (22.35, 25.54)	4.82 (4.52, 5.14)	6.34 (5.95, 6.76)	1.17* (1.09, 1.26)	1.09* (1.02, 1.17)
65+	37.15 (34.85, 39.51)	7.02 (6.55, 7.53)	11.18 (10.42, 11.99)	1.53* (1.42, 1.65)	1.34* (1.24, 1.45)

ABBREVIATIONS: Ref = reference group for rate ratio comparison
†Age-adjusted to the US 2000 standard population and expressed per 100,000 women
*Statistically significant ($p < 0.05$)

Table 2: Trends in cervical cancer mortality by race/ethnicity and age (1990-2019)

	10-Year Average Annual Percent Change (2010 to 2019)	
Age (years)	Not Corrected	Corrected
All Race/Ethnicities	-0.8* (-0.9, -0.6)	-1.1* (-2.1, -0.2)
20-49	-0.4* (-0.7, -0.1)	-0.5* (-0.8, -0.2)
50-64	-0.6* (-0.9, -0.2)	-1.2* (-1.6, -0.8)
65+	-1.4* (-1.7, -1.0)	-1.7* (-2.0, -1.3)
Non-Hispanic White	-0.2 (-0.4, 0.1)	-2.3* (-2.5, -2.0)
20-49	0.3 (-0.1, 0.7)	0.8 (-1.1, 2.7)
50-64	-0.1 (-0.7, 0.4)	-2.9* (-3.2, -2.6)
65+	-1.0* (-1.4, -0.6)	-2.0* (-2.4, -1.6)
Non-Hispanic Black	-2.4* (-2.8, -2.1)	-2.5* (-2.9, -2.2)
20-49	-3.1* (-3.5, -2.7)	-3.2* (-3.6, -2.9)
50-64	-1.5* (-2.1, -1.0)	-2.3* (-3.1, -1.6)
65+	-2.8* (-3.4, -2.3)	-2.4* (-2.7, -2.1)
Hispanic	-2.2* (-2.4, -1.9)	-2.7* (-2.9, -2.5)
20-49	0.7 (-1.1, 2.5)	0.5 (-1.3, 2.4)
50-64	-2.3* (-2.6, -1.9)	-3.3* (-3.7, -2.9)
65+	-2.3* (-2.7, -1.9)	-2.8* (-3.2, -2.3)

*Statistically significant ($p < 0.05$)

Table 3: Population characteristics by screening compliance status (2014-2020)

	Overall (% [95% CI])	**Screening status** Not Compliant (8.8 [8.6, 8.9])	Compliant (91.2 [91.1, 91.4])
Not Straight	8.1 (7.8, 8.3)	9.4 (8.3, 10.4)	7.2 (6.9, 7.5)
Age, years [mean (sd)]	41.65 (12.83)	46.27 (12.75)	41.89 (12.41)
Employment Status			
Unemployed	14.3 (14.0, 14.5)	21.1 (20.3, 21.9)	13.1 (12.8, 13.3)
Employed	63.3 (63.0, 63.6)	55.7 (54.6, 56.7)	65.4 (65.1, 65.8)
Student/homemaker/retired	22.5 (22.2, 22.8)	23.2 (22.3, 24.2)	21.5 (21.2, 21.8)
Education			
High school graduate or less	34 (33.7, 34.3)	45.2 (44.1, 46.2)	31.8 (31.4, 32.1)
Some college	32.0 (31.7, 32.3)	33.7 (32.7, 34.7)	31.8 (31.5, 32.2)
College graduate	34.0 (33.8, 34.3)	21.1 (20.4, 21.9)	36.4 (36.1, 36.7)
Income category			
<$15,000	11.8 (11.6, 12.1)	16.7 (15.9, 17.5)	10.5 (10.2, 10.7)
$15,000 to <$50,000	38.2 (37.9, 38.5)	46.6 (45.4, 47.7)	36.4 (36.0, 36.7)
$50,000+	50.0 (49.7, 50.3)	36.8 (35.7, 37.9)	53.2 (52.8, 53.5)
Race/Ethnicity			
Non-Hispanic White	59.2 (58.8, 59.5)	71.6 (70.4, 72.7)	59.9 (59.6, 60.3)
Non-Hispanic Black	12.6 (12.4, 12.9)	7.8 (7.1, 8.4)	13.2 (13.0, 13.4)
Hispanic	19.2 (19.0, 19.5)	14.4 (13.4, 15.3)	19.1 (18.7, 19.4)
Other	9.0 (8.7, 9.2)	6.3 (5.7, 6.9)	7.8 (7.6, 8.1)
In a partnership	58.4 (58.1, 58.7)	54.1 (53.0, 55.1)	61.3 (60.9, 61.6)
Smoker	15.3 (15.1, 15.5)	30.1 (29.2, 31.0)	14.3 (14.1, 14.5)
Insured	86.2 (85.9, 86.4)	73.6 (72.6, 74.6)	88.6 (88.4, 88.9)

ABBREVIATIONS: sd = standard deviation

Table 4: Odds ratios of screening compliance estimated using logistic regression model including all two-by-two exposure-confounder interaction terms (2014-2020)

Contrast	Odds Ratio (95% CI)	
Intercept	10.48 (8.34, 13.16)	***
Not Straight vs Straight	0.66 (0.32, 1.36)	
Age (continuous)	0.96 (0.96, 0.97)	***
Employed vs Unemployed	1.22 (1.10, 1.35)	***
Student/Homemaker/Retired vs Unemployed	1.1 (0.97, 1.24)	
Some College vs HS or less	1.13 (1.03, 1.23)	**
College Grad vs HS or Less	1.53 (1.39, 1.69)	***
Income: $15-50k vs <$15k	1.06 (0.94, 1.2)	
Income: $50k+ vs <$15	1.55 (1.32, 1.82)	***
NHB vs NHW	2.6 (2.19, 3.09)	***
Hispanic vs NHW	2.49 (2.1, 2.95)	***
Other Race vs NHW	1.32 (1.13, 1.53)	***
In a partnership vs Not	1.14 (1.05, 1.24)	**
Smoker vs Not	0.52 (0.48, 0.57)	***
Insured vs Not	3.17 (2.86, 3.53)	***
Interaction Sexual Orientation and Age	1.01 (1.00, 1.02)	*
Interaction Sexual Orientation and Employment (Employed)	0.84 (0.55, 1.29)	
Interaction Sexual Orientation and Employment (Student/homemaker/retired)	1.00 (0.58, 1.73)	
Interaction Sexual Orientation and Education (Some college)	0.78 (0.54, 1.12)	
Interaction Sexual Orientation and Education (College graduate)	0.77 (0.53, 1.13)	
Interaction Sexual Orientation and Income ($15,000-50,000)	1.03 (0.66, 1.61)	
Interaction Sexual Orientation and Income ($50,000+)	1.00 (0.59, 1.72)	
Interaction Sexual Orientation and Race/Ethnicity (NHB)	0.99 (0.59, 1.66)	
Interaction Sexual Orientation and Race/Ethnicity (Hispanic)	0.75 (0.45, 1.25)	
Interaction Sexual Orientation and Race/Ethnicity (Other)	1.09 (0.7, 1.71)	
Interaction Sexual Orientation and Partnered	0.99 (0.72, 1.34)	
Interaction Sexual Orientation and Smoker	1.40 (1.06, 1.86)	*
Interaction Sexual Orientation and Insured	0.77 (0.52, 1.14)	

ABBREVIATIONS: NHW = non-Hispanic White, NHB = non-Hispanic Black

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

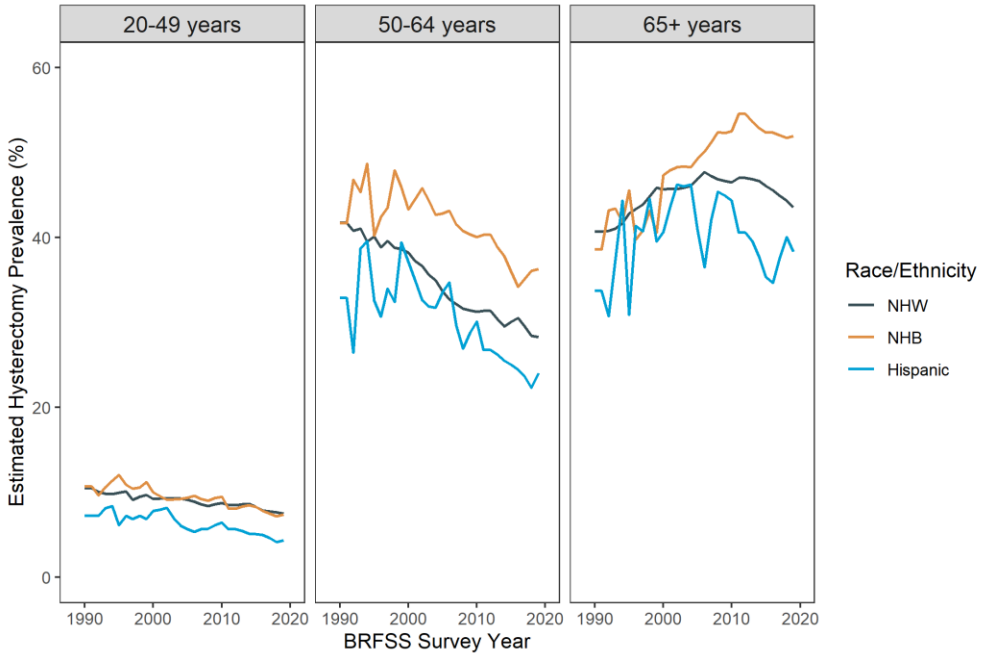
Table 5: Population characteristics by screening compliance status and age group (2014-2020)

		Screening Status			
		Not compliant		Compliant	
	Overall (% [95% CI])	Aged 21-29 (7.0 [6.6, 7.4])	Aged 30-65 (9.2 [9.0, 9.4])	Aged 21-29 (93.0 [92.6, 93.4])	Aged 30-65 (90.8 [90.6, 91.0]
Not Straight	8.1 (7.8, 8.3)	22.2 (18.0, 26.4)	7.3 (6.3, 8.4)	13.1 (12.2, 13.9)	5.9 (5.7, 6.2)
Age, year [mean (sd)]	41.65 (12.83)	25.86 (2.34)	49.98 (10.08)	25.28 (2.51)	45.93 (10.32)
Employment Status					
Unemployed	14.3 (14.0, 14.5)	15.1 (13.0, 17.2)	22.2 (21.3, 23.1)	11.9 (11.3, 12.5)	13.4 (13.1, 13.6)
Employed	63.3 (63.0, 63.6)	63.9 (61.1, 66.7)	54.2 (53.0, 55.3)	64.5 (63.7, 65.3)	65.7 (65.3, 66.0)
Student/homemaker/ retired	22.5 (22.2, 22.8)	21 (18.6, 23.4)	23.6 (22.6, 24.7)	23.6 (22.9, 24.3)	21.0 (20.6, 21.3)
Education					
High school graduate or less	34.0 (33.7, 34.3)	41.2 (38.3, 44.0)	45.9 (44.7, 47.0)	31.8 (31.0, 32.6)	31.8 (31.4, 32.1)
Some college	32.0 (31.7, 32.3)	37.6 (34.7, 40.4)	33.0 (32.0, 34.1)	36.8 (35.9, 37.6)	30.6 (30.3, 31.0)
College graduate	34.0 (33.8, 34.3)	21.3 (19.2, 23.3)	21.1 (20.3, 21.9)	31.4 (30.7, 32.1)	37.6 (37.2, 37.9)
Income category					
<$15,000	11.8 (11.6, 12.1)	16.2 (13.9, 18.5)	16.8 (15.9, 17.6)	14.1 (13.4, 14.7)	9.6 (9.4, 9.9)
$15,000 to <$50,000	38.2 (37.9, 38.5)	53.0 (49.9, 56.1)	45.4 (44.2, 46.6)	48.8 (47.9, 49.6)	33.4 (33.0, 33.8)
$50,000+	50.0 (49.7, 50.3)	30.8 (27.9, 38.1)	37.8 (36.6, 39.0)	37.2 (36.3, 38.1)	57.0 (56.6, 57.4)
Race/Ethnicity					
Non-Hispanic White	59.2 (58.8, 59.5)	60.1 (57.2, 63.1)	73.6 (72.4, 74.8)	55.5 (54.6, 56.3)	61.0 (60.6, 61.4)
Non-Hispanic Black	12.6 (12.4, 12.9)	10.7 (8.8, 12.6)	7.2 (6.5, 7.9)	15.1 (14.5, 15.7)	12.8 (12.5, 13.0)
Hispanic	19.2 (19.0, 19.5)	20.5 (18.1, 23.0)	13.3 (12.2, 14.3)	21.7 (20.9, 22.6)	18.4 (18.0, 18.7)
Other	9.0 (8.7, 9.2)	8.6 (6.8, 10.4)	5.9 (5.3, 6.5)	7.7 (7.2, 8.1)	7.9 (7.6, 8.1)
In a partnership	58.4 (58.1, 58.7)	41.7 (38.8, 44.5)	56.3 (55.2, 57.5)	40.1 (39.3, 40.9)	66.4 (66.1, 66.8)
Smoker	15.3 (15.1, 15.5)	27.5 (25.1, 30.0)	30.6 (29.6, 31.6)	15.9 (15.3, 16.4)	13.9 (13.7, 14.2)
Insured	86.2 (85.9, 86.4)	70.8 (68.2, 73.4)	74.1 (73.0, 75.2)	84.9 (84.2, 85.5)	89.6 (89.3, 89.8)

ABBREVIATIONS: sd = standard deviation

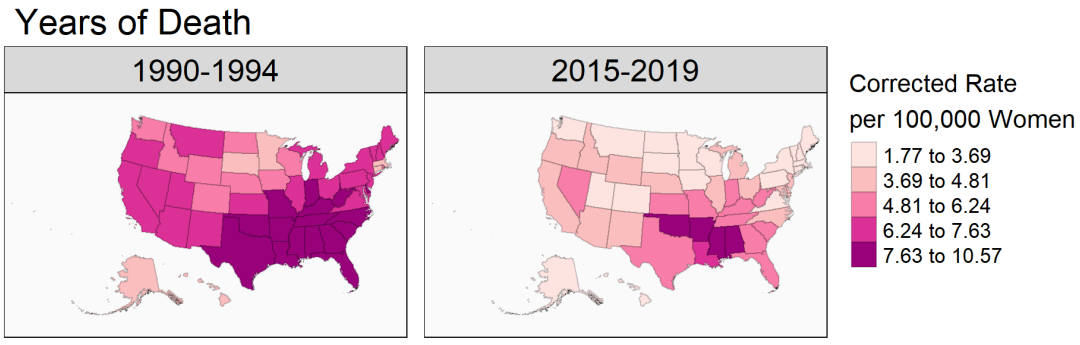
FIGURES

Figure 1: Hysterectomy prevalence estimates by race/ethnicity and age (1990-2019)



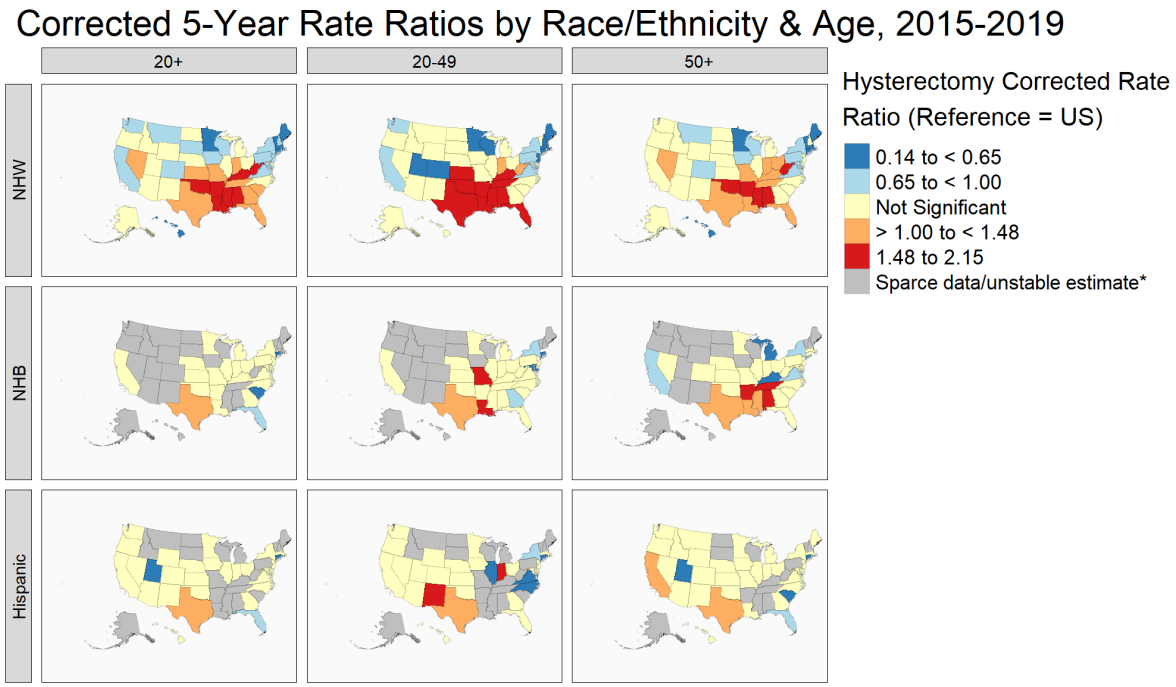
ABBREVIATIONS: NHW = non-Hispanic White, NHB = non-Hispanic Black, BRFSS = Behavioral Risk Factor Surveillance System

Figure 2: Five-year cervical cancer mortality rate by state over time



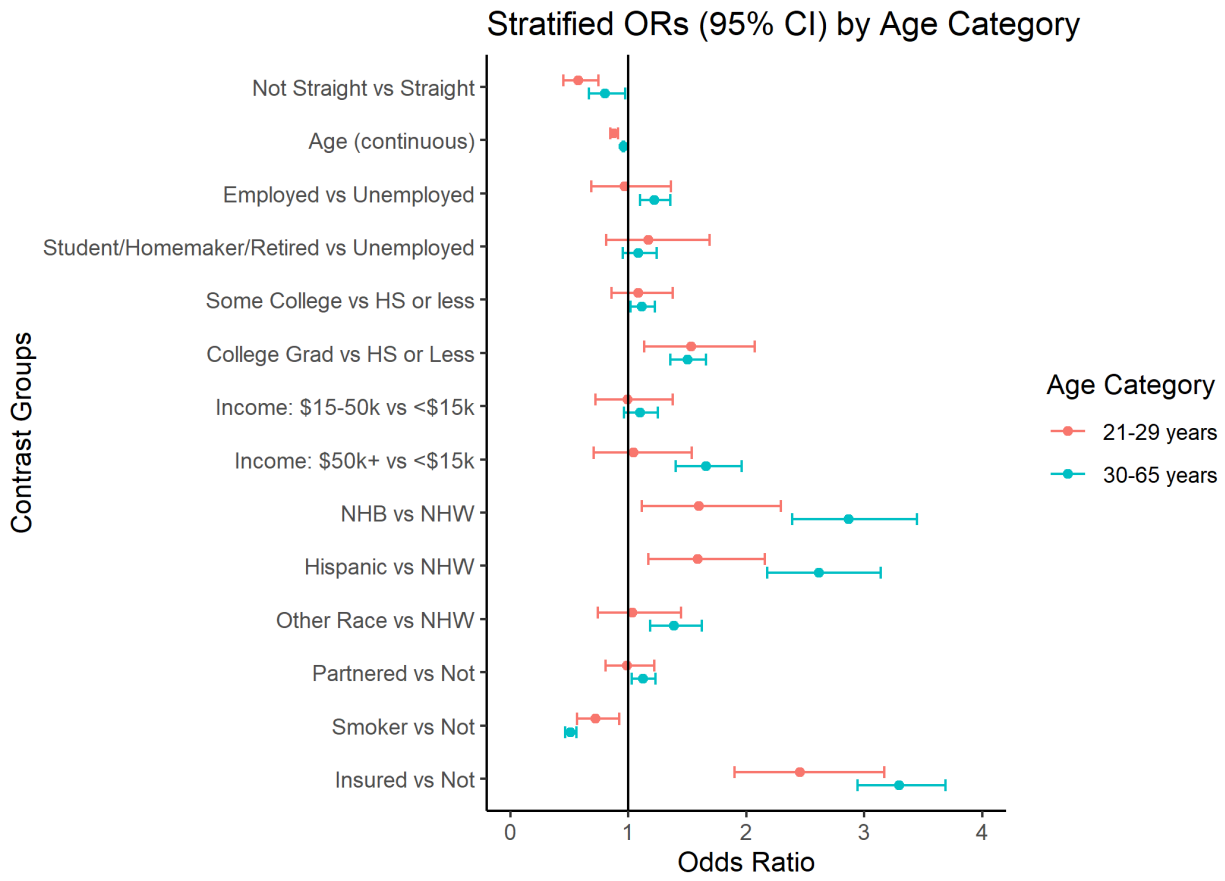
NOTE: Age-adjusted to the US 2000 standard population

Figure 3: Five-year cervical cancer mortality rate ratios by race/ethnicity, age, and US State (2015-2019)



*Hysterectomy estimates considered unstable if BRFSS response count < 50 or relative standard error > 0.30

Figure 4: Odds ratios of screening compliance estimated from stratified logistic regression models (2014-2020)



ABBREVIATIONS: HS = high school, NHW = non-Hispanic White, NHB = non-Hispanic Black, $k = $1,000

APPENDIX

Supplemental Table 1. Trends in corrected cervical cancer mortality rates by age and state (1990-2019)

State & Age (years)	Trend 1		Trend 2		Trend 3		Trend 4		Trend 5		AAPC		
	Years	APC	Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
Alabama	1990-1999	-3.5 *	1999-2019	0.3							0.3	0.3	0.3
20-49	1990-2004	-0.3									-0.3	-0.3	-0.3
50-64	1990-1996	-11.0 *	1996-2019	0.6							0.6	0.6	0.6
65+	1990-2019	-0.5									-0.5	-0.5	-0.5
Alaska	1990-2019	-0.8									-0.8	-0.8	-0.8
20-49	-	-									-	-	-
50-64	-	-									-	-	-
65+	-	-									-	-	-
Arizona	1990-1998	-5.5 *	1998-2001	9.8	2001-2008	-7.4 *	2008-2013	6.3	2013-2019	-4.0 *	3.6	-4.0*	-0.7
20-49	1990-2019	-1.6 *									-1.6*	-1.6*	-1.6*
50-64	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
65+	1990-2019	-1.6 *									-1.6*	-1.6*	-1.6*
Arkansas	1990-2019	-0.5 *									-0.5*	-0.5*	-0.5*
20-49	1990-2019	-0.6									-0.6	-0.6	-0.6
50-64	1990-2019	-0.1									-0.1	-0.1	-0.1
65+	1990-2019	-1.0 *									-1.0*	-1.0*	-1.0*
California	1990-2000	-1.6 *	2000-2003	-7.3	2003-2019	-1.1 *					-1.1*	-1.1*	-1.1*
20-49	1990-2019	-0.9 *									-0.9*	-0.9*	-0.9*
50-64	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
65+	1990-2006	-2.0 *									-2.0*	-2.0*	-2.0*
Colorado	1990-2019	-2.7 *									-2.7*	-2.7*	-2.7*
20-49	1990-2019	-1.5 *									-1.5*	-1.5*	-1.5*
50-64	1990-2019	-2.9 *									-2.9*	-2.9*	-2.9*
65+	1990-2019	-3.3 *									-3.3*	-3.3*	-3.3*
Connecticut	1990-2019	-2.6 *									-2.6*	-2.6*	-2.6*
20-49	1990-2019	-3.2 *									-3.2*	-3.2*	-3.2*
50-64	1990-2019	-3.6 *									-3.6*	-3.6*	-3.6*
65+	1990-2019	-1.5 *									-1.5*	-1.5*	-1.5*

State & Age (years)	Trend 1		Trend 2		Trend 3		Trend 4		Trend 5		AAPC		
	Years	APC	Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
Delaware	1990-2019	-3.2 *									-3.2*	-3.2*	-3.2*
20-49	-	-									-	-	-
50-64	1990-2019	-4.0 *									-4.0*	-4.0*	-4.0*
65+	1990-2019	-3.0 *									-3.0*	-3.0*	-3.0*
Florida	1990-2019	-0.6									-0.6	-0.6	-0.6
20-49	1990-2019	-1.9 *									-1.9*	-1.9*	-1.9*
50-64	1990-2019	-2.2 *									-2.2*	-2.2*	-2.2*
65+	1990-2019	-1.3 *									-1.3*	-1.3*	-1.3*
Georgia	1990-2019	-1.6 *									-1.6*	-1.6*	-1.6*
20-49	1990-2019	-1.1 *									-1.1*	-1.1*	-1.1*
50-64	1990-2019	-2.2 *									-2.2*	-2.2*	-2.2*
65+	1990-2019	-1.5 *									-1.5*	-1.5*	-1.5*
Hawaii	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
20-49	1990-2019	-2.0 *									-2.0*	-2.0*	-2.0*
50-64	1990-2019	-0.4									-0.4	-0.4	-0.4
65+	-	-									-	-	-
Idaho	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
20-49	-	-									-	-	-
50-64	1990-2019	-2.4 *									-2.4*	-2.4*	-2.4*
65+	1990-2019	-1.9 *									-1.9*	-1.9*	-1.9*
Illinois	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
20-49	1990-2019	-2.7 *									-2.7*	-2.7*	-2.7*
50-64	1990-2019	-2.8 *									-2.8*	-2.8*	-2.8*
65+	1990-2019	-1.6 *									-1.6*	-1.6*	-1.6*
Indiana	1990-2008	-3 *	2008-2019	1.0							1.0	1.0	1.0
20-49	1990-2009	-2.8 *	2009-2019	4.9 *							4.9*	4.9*	4.9*
50-64	1990-2019	-1.4 *									-1.4*	-1.4*	-1.4*
65+	1990-2019	-2.8 *									-2.8*	-2.8*	-2.8*
Iowa	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
20-49	1990-2019	-1.5 *									-1.5*	-1.5*	-1.5*
50-64	1990-2019	-1.9 *									-1.9*	-1.9*	-1.9*
65+	1990-2019	-2.1 *									-2.1*	-2.1*	-2.1*

State & Age (years)	Trend 1		Trend 2		Trend 3		Trend 4		Trend 5		AAPC		
	Years	APC	Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
Kansas	1990-2019	-1.4 *									-1.4*	-1.4*	-1.4*
20-49	1990-1999	-6.8 *	1999-2019	2.0							2.0	2.0	2.0
50-64	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
65+	1990-2019	-1.5 *									-1.5*	-1.5*	-1.5*
Kentucky	1990-2019	-2.4 *									-2.4*	-2.4*	-2.4*
20-49	1990-2019	-1.2 *									-1.2*	-1.2*	-1.2*
50-64	1990-2019	-2.4 *									-2.4*	-2.4*	-2.4*
65+	1990-2019	-3.0 *									-3.0*	-3.0*	-3.0*
Louisiana	1990-1996	2.9	1996-2000	-9.6	2000-2019	-0.1					-0.1	-0.1	-0.1
20-49	1990-2019	-1.0 *									-1.0*	-1.0*	-1.0*
50-64	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
65+	1990-2019	-1.3 *									-1.3*	-1.3*	-1.3*
Maine	1990-1994	11.0	1994-2000	-11.3 *	2000-2019	-2.4 *					-2.4*	-2.4*	-2.4*
20-49	-	-									-	-	-
50-64	1990-2019	-4.0 *									-4.0*	-4.0*	-4.0*
65+	1990-2019	-3.6 *									-3.6*	-3.6*	-3.6*
Maryland	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
20-49	1990-2019	-2.0 *									-2.0*	-2.0*	-2.0*
50-64	1990-2019	-2.7 *									-2.7*	-2.7*	-2.7*
65+	1990-2019	-2.1 *									-2.1*	-2.1*	-2.1*
Massachusetts	1990-2019	-3.7 *									-3.7*	-3.7*	-3.7*
20-49	1990-2019	-3.5 *									-3.5*	-3.5*	-3.5*
50-64	1990-2016	-4.6 *	2016-2019	19.2							-4.6*	12.7	2.7
65+	1990-2019	-3.6 *									-3.6*	-3.6*	-3.6*
Michigan	1990-2006	-3.5 *	2006-2019	-0.4							-0.4	-0.4	-0.4
20-49	1990-2003	-4.1 *	2003-2019	0.5							0.5	0.5	0.5
50-64	1990-2006	-4.3 *	2006-2019	-0.1							-0.1	-0.1	-0.1
65+	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
Minnesota	1990-2019	-2.1 *									-2.1*	-2.1*	-2.1*
20-49	1990-2019	-0.9									-0.9	-0.9	-0.9
50-64	1990-2019	-2.5 *									-2.5*	-2.5*	-2.5*
65+	1990-2019	-2.5 *									-2.5*	-2.5*	-2.5*

State & Age (years)	Trend 1		Trend 2		Trend 3		Trend 4		Trend 5		AAPC		
	Years	APC	Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
Mississippi	1990-2019	-0.8 *									-0.8*	-0.8*	-0.8*
20-49	1990-2019	-1.0									-1.0	-1.0	-1.0
50-64	1990-2019	-1.5 *									-1.5*	-1.5*	-1.5*
65+	1990-2019	-0.2									-0.2	-0.2	-0.2
Missouri	1990-2001	-3.9 *	2001-2019	-0.5							-0.5	-0.5	-0.5
20-49	1990-2019	-1.3 *									-1.3*	-1.3*	-1.3*
50-64	1990-2019	-1.5 *									-1.5*	-1.5*	-1.5*
65+	1990-2019	-2.0 *									-2.0*	-2.0*	-2.0*
Montana	1990-2019	-2.6 *									-2.6*	-2.6*	-2.6*
20-49	-	-									-	-	-
50-64	-	-									-	-	-
65+	1990-2019	-4.1 *									-4.1*	-4.1*	-4.1*
Nebraska	1990-2019	-1.0									-1.0	-1.0	-1.0
20-49	1990-2019	-0.5									-0.5	-0.5	-0.5
50-64	1990-2019	-0.3									-0.3	-0.3	-0.3
65+	1990-2019	-1.9 *									-1.9*	-1.9*	-1.9*
Nevada	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
20-49	1990-2019	-2.0 *									-2.0*	-2.0*	-2.0*
50-64	1990-2019	-1.3 *									-1.3*	-1.3*	-1.3*
65+	1990-2019	-2.4 *									-2.4*	-2.4*	-2.4*
New Hampshire	1990-2019	-3.7 *									-3.7*	-3.7*	-3.7*
20-49	1990-2019	-3.7 *									-3.7*	-3.7*	-3.7*
50-64	1990-2019	-4.3 *									-4.3*	-4.3*	-4.3*
65+	1990-2019	-3.7 *									-3.7*	-3.7*	-3.7*
New Jersey	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
20-49	1990-2019	-3.1 *									-3.1*	-3.1*	-3.1*
50-64	1990-2019	-2.8 *									-2.8*	-2.8*	-2.8*
65+	1990-2019	-1.3 *									-1.3*	-1.3*	-1.3*
New Mexico	1990-2019	-1.9 *									-1.9*	-1.9*	-1.9*
20-49	1990-2019	0.6									0.6	0.6	0.6
50-64	1990-2019	-2.2 *									-2.2*	-2.2*	-2.2*

State & Age (years)	Trend 1		Trend 2		Trend 3		Trend 4		Trend 5		AAPC		
	Years	APC	Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
65+	1990-2019	-3.4 *									-3.4*	-3.4*	-3.4*
New York	1990-2019	-2.4 *									-2.4*	-2.4*	-2.4*
20-49	1990-2006	-3.8 *	2006-2019	-1.0							-1.0	-1.0	-1.0
50-64	1990-2019	-3.3 *									-3.3*	-3.3*	-3.3*
65+	1990-2019	-1.5 *									-1.5*	-1.5*	-1.5*
North Carolina	1900-2019	-2.7 *									-2.7*	-2.7*	-2.7*
20-49	1990-2019	-2.7 *									-2.7*	-2.7*	-2.7*
50-64	1990-2019	-2.7 *									-2.7*	-2.7*	-2.7*
65+	1990-2019	-2.8 *									-2.8*	-2.8*	-2.8*
Ohio	1990-2003	-3.2 *	2003-2019	-0.9							-0.9	-0.9	-0.9
20-49	1990-2019	-1.3 *									-1.3*	-1.3*	-1.3*
50-64	1990-2004	-4.1 *	2004-2019	0.1							0.1	0.1	0.1
65+	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
Oklahoma	1990-2004	-3.6 *	2004-2019	1.4							1.4	1.4	1.4
20-49	1990-2019	-0.4									-0.4	-0.4	-0.4
50-64	1990-2019	-0.4									-0.4	-0.4	-0.4
65+	1990-1997	1.6	1997-2004	-13.5 *	2004-2007	38.2	2007-2013	-11.4 *	2013-2019	6.3	-7.3	6.3	0.1
Oregon	1990-2019	-2.0 *									-2.0*	-2.0*	-2.0*
20-49	1990-2019	-1.0 *									-1.0*	-1.0*	-1.0*
50-64	1990-2019	-2.1 *									-2.1*	-2.1*	-2.1*
65+	1990-2019	-2.5 *									-2.5*	-2.5*	-2.5*
Pennsylvania	1990-2019	-2.6 *									-2.6*	-2.6*	-2.6*
20-49	1990-2019	-2.2 *									-2.2*	-2.2*	-2.2*
50-64	1990-2019	-3.2 *									-3.2*	-3.2*	-3.2*
65+	1990-2019	-2.4 *									-2.4*	-2.4*	-2.4*
Rhode Island	1990-2019	-4.0 *									-4.0*	-4.0*	-4.0*
20-49	-	-									-	-	-
50-64	1990-2019	-4.4 *									-4.4*	-4.4*	-4.4*
65+	-	-									-	-	-
South Carolina	1990-2019	-2.6 *									-2.6*	-2.6*	-2.6*
20-49	1990-1998	4.0	1998-2003	-16.4 *	2003-2006	20.5	2006-2019	-2.6 *			-2.6*	-2.6*	-2.6*

State & Age (years)	Trend 1		Trend 2		Trend 3		Trend 4		Trend 5		AAPC		
	Years	APC	Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
50-64	1990-2019	-3.1 *									-3.1*	-3.1*	-3.1*
65+	1990-2019	-2.6 *									-2.6*	-2.6*	-2.6*
Tennessee	1990-2019	-1.9 *									-1.9*	-1.9*	-1.9*
20-49	1990-2019	-1.3 *									-1.3*	-1.3*	-1.3*
50-64	1990-2019	-2.5 *									-2.5*	-2.5*	-2.5*
65+	1990-2019	-1.7 *									-1.7*	-1.7*	-1.7*
Texas	1990-1995	-2.1 *									-2.1*	-2.1*	-2.1*
20-49	1990-2011	-1.9 *	2011-2019	1.8							0.8	1.8	1.4
50-64	1990-2019	-2.5 *									-2.5*	-2.5*	-2.5*
65+	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
Utah	1990-2019	-2.2 *									-2.2*	-2.2*	-2.2*
20-49	-	-									-	-	-
50-64	1990-2019	-3.2 *									-3.2*	-3.2*	-3.2*
65+	1990-2019	-0.9									-0.9	-0.9	-0.9
Vermont	1990-2019	-2.5 *									-2.5*	-2.5*	-2.5*
20-49	-	-									-	-	-
50-64	1990-2019	-2.8 *									-2.8*	-2.8*	-2.8*
65+	1990-2019	-2.0									-2.0	-2.0	-2.0
Virginia	1990-2019	-2.8 *									-2.8*	-2.8*	-2.8*
20-49	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
50-64	1990-2019	-2.6 *									-2.6*	-2.6*	-2.6*
65+	1990-2019	-3.0 *									-3.0*	-3.0*	-3.0*
Washington	1990-2019	-2.0 *									-2.0*	-2.0*	-2.0*
20-49	1990-2019	-2.1 *									-2.1*	-2.1*	-2.1*
50-64	1990-2019	-1.9 *									-1.9*	-1.9*	-1.9*
65+	1990-2019	-2.1 *									-2.1*	-2.1*	-2.1*
West Virginia	1990-2019	-1.7 *									-1.7*	-1.7*	-1.7*
20-49	1990-2019	-1.0									-1.0	-1.0	-1.0
50-64	1990-2019	-1.7 *									-1.7*	-1.7*	-1.7*
65+	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
Wisconsin	1990-2002	-4.9 *	2002-2019	-1.2							-1.2	-1.2	-1.2
20-49	1990-2019	-3.3 *									-3.3*	-3.3*	-3.3*

State & Age (years)	Trend 1		Trend 2		Trend 3		Trend 4		Trend 5		AAPC		
	Years	APC	Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
50-64	1990-2019	-3.3 *									-3.3*	-3.3*	-3.3*
65+	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
Wyoming	1990-2019	-0.4									-0.4	-0.4	-0.4
20-49	-	-									-	-	-
50-64	-	-									-	-	-
65+	-	-									-	-	-

ABBREVIATIONS: APC = annual percent change, AAPC = average annual percent change

*Statistically significant ($p < 0.05$)

- Could not be calculated due to sparce data

Supplemental Table 2. Trends in non-Hispanic White corrected cervical cancer mortality rates by age and state (1990-2019)

	Trend 1		Trend 2		Trend 3		Trend 4		Trend 4		AAPC		
	Years	APC	Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
Alabama	1990-2003	-1.9	2003-2019	1.9 *							1.9*	1.9*	1.9*
20-49	1990-2019	0.8									0.8	0.8	0.8
50-64	1990-2005	-13.6	2005-2019	1.6 *							1.6*	1.6*	1.6*
65+	1990-2019	0.1									0.1	0.1	0.1
Alaska	1990-2019	-0.1									-0.1	-0.1	-0.1
20-49	-	-									-	-	-
50-64	-	-									-	-	-
65+	-	-									-	-	-
Arizona	1990-1998	-5.2 *	1998-2001	9.2	2001-2006	-9.6	2006-2019	1.8			1.8	1.8	1.8
20-49	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
50-64	1990-2019	-2.0 *									-2.0*	-2.0*	-2.0*
65+	1990-2019	-1.0									-1.0	-1.0	-1.0
Arkansas	1990-2019	-0.1									-0.1	-0.1	-0.1
20-49	1990-2019	0.0									0.0	0.0	0.0
50-64	1990-2019	0.3									0.3	0.3	0.3
65+	1990-2019	-0.9 *									-0.9*	-0.9*	-0.9*
California	1990-2004	-3.3 *	2004-2019	-0.7							-0.7	-0.7	-0.7
20-49	1990-2019	-1.7 *									-1.7*	-1.7*	-1.7*
50-64	1990-2004	-4.3 *	2004-2019	-0.6							-0.6	-0.6	-0.6
65+	1990-2019	-1.8 *									-1.8*	-1.8*	-1.8*
Colorado	1990-2019	-2.5 *									-2.5*	-2.5*	-2.5*
20-49	1990-2019	-1.1									-1.1	-1.1	-1.1
50-64	1990-2019	-2.3 *									-2.3*	-2.3*	-2.3*
65+	1990-2019	-3.4 *									-3.4*	-3.4*	-3.4*
Connecticut	1990-2019	-2.5 *									-2.5*	-2.5*	-2.5*
20-49	1990-2019	-3.1 *									-3.1*	-3.1*	-3.1*
50-64	1990-2019	-3.8 *									-3.8*	-3.8*	-3.8*
65+	1990-2019	-1.4 *									-1.4*	-1.4*	-1.4*
Delaware	1990-2019	-2.4 *									-2.4*	-2.4*	-2.4*
20-49	-	-									-	-	-
50-64	-	-									-	-	-

	Trend 1			Trend 2			Trend 3			Trend 4			Trend 4			AAPC		
	Years	APC		Years	APC		Years	APC		Years	APC		Years	APC		2010-2014	2015-2019	2010-2019
65+	1990-2019	-2.4	*													-2.4*	-2.4*	-2.4*
Florida	1990-2003	-3.0	*	2003-2019	-0.2											-0.2	-0.2	-0.2
20-49	1990-2004	-1.0	*													-1.0*	-1.0*	-1.0*
50-64	1990-2019	-1.9	*													-1.9*	-1.9*	-1.9*
65+	1990-2019	-1.3	*													-1.3*	-1.3*	-1.3*
Georgia	1990-2019	-1.1	*													-1.1*	-1.1*	-1.1*
20-49	1990-2019	0.1														0.1	0.1	0.1
50-64	1990-2019	-1.1														-1.1	-1.1	-1.1
65+	1990-2019	-1.8	*													-1.8*	-1.8*	-1.8*
Hawaii	1990-2019	-3.4	*													-3.4*	-3.4*	-3.4*
20-49	-	-														-	-	-
50-64	-	-														-	-	-
65+	-	-														-	-	-
Idaho	1990-2019	-1.6	*													-1.6*	-1.6*	-1.6*
20-49	-	-														-	-	-
50-64	1990-2019	-2.3														-2.3	-2.3	-2.3
65+	1990-2019	-2.0	*													-2.0*	-2.0*	-2.0*
Illinois	1990-2019	-1.8	*													-1.8*	-1.8*	-1.8*
20-49	1990-1993	7.1		1993-1997	6.0		1997-2012	-4.5	*	2012-2015	18.9		2015-2019	-7.9		6.6	-7.9	1.1
50-64	1990-2019	-2.5	*													-2.5*	-2.5*	-2.5*
65+	1990-2019	-1.3	*													-1.3*	-1.3*	-1.3*
Indiana	1990-2008	-2.8	*	2008-2019	0.9											0.9	0.9	0.9
20-49	1990-2008	-0.7														-0.7	-0.7	-0.7
50-64	1990-2019	-1.3	*													-1.3*	-1.3*	-1.3*
65+	1990-2019	-2.6	*													-2.6*	-2.6*	-2.6*
Iowa	1990-2019	-1.8	*													-1.8*	-1.8*	-1.8*
20-49	1990-2019	-1.4	*													-1.4*	-1.4*	-1.4*
50-64	1990-2019	-2.0	*													-2.0*	-2.0*	-2.0*
65+	1990-2019	-2.0	*													-2.0*	-2.0*	-2.0*
Kansas	1990-2019	-0.9	*													-0.9*	-0.9*	-0.9*
20-49	1990-1996	-10.9		1996-2019	2.2	*										2.2*	2.2*	2.2*
50-64	1990-2019	-2.1	*													-2.1*	-2.1*	-2.1*
65+	1990-2019	-1.2														-1.2	-1.2	-1.2

	Trend 1			Trend 2			Trend 3			Trend 4			Trend 4			AAPC		
	Years	APC		Years	APC		Years	APC		Years	APC		Years	APC		2010-2014	2015-2019	2010-2019
Kentucky	1990-2019	-2.0	*													-2.0*	-2.0*	-2.0*
20-49	1990-2019	-0.6														-0.6	-0.6	-0.6
50-64	1990-2019	-2.1	*													-2.1*	-2.1*	-2.1*
65+	1990-2019	-2.8	*													-2.8*	-2.8*	-2.8*
Louisiana	1991-2019	-0.6														-0.6	-0.6	-0.6
20-49	1991-2019	0.6														0.6	0.6	0.6
50-64	1991-2019	-1.0														-1	-1	-0.9
65+	1991-2019	-1.2														-1.2	-1.2	-1.2
Maine	1990-1994	12.9		1994-2000	-10.7	*	2000-2019	-2.8	*							-2.8*	-2.8*	-2.8*
20-49	-	-														-	-	-
50-64	1990-2019	-4.3	*													-4.3*	-4.3*	-4.3*
65+	1990-2019	-3.4	*													-3.4*	-3.4*	-3.4*
Maryland	1990-2019	-2.3	*													-2.3*	-2.3*	-2.3*
20-49	1990-2019	-0.8														-0.8	-0.8	-0.8
50-64	1990-2019	-2.8	*													-2.8*	-2.8*	-2.8*
65+	1990-2019	-2.7	*													-2.7*	-2.7*	-2.7*
Massachusetts	1990-2019	-3.9	*													-3.9*	-3.9*	-3.9*
20-49	1990-2019	-3.6	*													-3.6*	-3.6*	-3.6*
50-64	1990-2016	-4.8	*	2016-2019	20.9											-4.8*	13.9	3.1
65+	1990-2019	-4.5	*													-4.5*	-4.5*	-4.5*
Michigan	1990-2007	-3.7	*	2007-2019	1.2											1.2	1.2	1.2
20-49	1990-2005	-1.2	*													-1.2*	-1.2*	-1.2*
50-64	1990-2007	-5.1	*	2007-2019	2.3											2.3	2.3	2.3
65+	1990-2019	-2.2	*													-2.2*	-2.2*	-2.2*
Minnesota	1990-2019	-2.4	*													-2.4*	-2.4*	-2.4*
20-49	1990-2019	-1.2														-1.2	-1.2	-1.2
50-64	1990-2019	-2.7	*													-2.7*	-2.7*	-2.7*
65+	1990-2019	-2.8	*													-2.8*	-2.8*	-2.8*
Mississippi	1990-2019	0.1														0.1	0.1	0.1
20-49	1990-2019	-0.1														-0.1	-0.1	-0.1
50-64	1990-2019	-0.1														-0.1	-0.1	-0.1
65+	1990-2019	0.4														0.4	0.4	0.4
Missouri	1990-2001	-3.6	*	2001-2019	-0.3											-0.3	-0.3	-0.3

	Trend 1			Trend 2		Trend 3		Trend 4		Trend 4		AAPC		
	Years	APC		Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
20-49	1990-2019	-0.9										-0.9	-0.9	-0.9
50-64	1990-2019	-1.0	*									-1.0*	-1.0*	-1.0*
65+	1990-2019	-2.0	*									-2.0*	-2.0*	-2.0*
Montana	1990-2019	-2.9	*									-2.9*	-2.9*	-2.9*
20-49	-	-										-	-	-
50-64	-	-										-	-	-
65+	1990-2019	-4.1	*									-4.1*	-4.1*	-4.1*
Nebraska	1990-2019	-0.8										-0.8	-0.8	-0.8
20-49	1990-2019	-0.7										-0.7	-0.7	-0.7
50-64	1990-2019	0.4										0.4	0.4	0.4
65+	1990-2019	-2.0	*									-2.0*	-2.0*	-2.0*
Nevada	1990-2019	-1.2	*									-1.2*	-1.2*	-1.2*
20-49	1990-2019	-1.3										-1.3	-1.3	-1.3
50-64	1990-2019	-0.6										-0.6	-0.6	-0.6
65+	1990-2019	-2.2	*									-2.2*	-2.2*	-2.2*
New Hampshire	1993-2019	-3.3	*									-3.3*	-3.3*	-3.3*
20-49	1993-2019	-3.8	*									-3.8*	-3.8*	-3.8*
50-64	1993-2019	-4.0	*									-4.0*	-4.0*	-4.0*
65+	1993-2019	-2.9	*									-2.9*	-2.9*	-2.9*
New Jersey	1990-2019	-1.9	*									-1.9*	-1.9*	-1.9*
20-49	1990-2019	-2.6	*									-2.6*	-2.6*	-2.6*
50-64	1990-2019	-2.3	*									-2.3*	-2.3*	-2.3*
65+	1990-2019	-1.1	*									-1.1*	-1.1*	-1.1*
New Mexico	1990-2019	-2.5	*									-2.5*	-2.5*	-2.5*
20-49	-	-										-1.7*	-1.7*	-1.7*
50-64	-	-										-	-	-
65+	1990-2019	-3.4	*									-3.4*	-3.4*	-3.4*
New York	1990-2019	-1.9	*									-1.9*	-1.9*	-1.9*
20-49	1990-2019	-1.9	*									-1.9*	-1.9*	-1.9*
50-64	1990-2019	-2.8	*									-2.8*	-2.8*	-2.8*
65+	1990-2019	-1.3	*									-1.3*	-1.3*	-1.3*
North Carolina	1990-2019	-2.1	*									-2.1*	-2.1*	-2.1*
20-49	1990-2019	-1.4	*									-1.4*	-1.4*	-1.4*

	Trend 1			Trend 2		Trend 3		Trend 4		Trend 4		AAPC		
	Years	APC		Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
50-64	1990-2019	-2.1	*									-2.1*	-2.1*	-2.1*
65+	1990-2019	-2.5	*									-2.5*	-2.5*	-2.5*
North Dakota	1990-2019	-3.0	*									-3.0*	-3.0*	-3.0*
20-49	-	-										-	-	-
50-64	-	-										-	-	-
65+	-	-										-	-	-
Ohio	1990-2019	-1.7	*									-1.7*	-1.7*	-1.7*
20-49	1990-2019	-1.0	*									-1.0*	-1.0*	-1.0*
50-64	1990-2019	-1.7	*									-1.7*	-1.7*	-1.7*
65+	1990-2019	-2.2	*									-2.2*	-2.2*	-2.2*
Oklahoma	1997-2019	0.3										0.3	0.3	0.3
20-49	1997-2019	0.6										0.6	0.6	0.6
50-64	1997-2019	1.7										1.7	1.7	1.7
65+	1997-2004	-12.0	*	2004-2007	39.1	2007-2011	-19.0	2011-2019	4.6			-1.9	4.6	1.6
Oregon	1990-2019	-1.9	*									-1.9*	-1.9*	-1.9*
20-49	1990-2019	-0.6										-0.6	-0.6	-0.6
50-64	1990-2019	-2.2	*									-2.2*	-2.2*	-2.2*
65+	1990-2019	-2.4	*									-2.4*	-2.4*	-2.4*
Pennsylvania	1990-2019	-2.5	*									-2.5*	-2.5*	-2.5*
20-49	1990-2019	-2.0	*									-2.0*	-2.0*	-2.0*
50-64	1990-2019	-2.9	*									-2.9*	-2.9*	-2.9*
65+	1990-2019	-2.4	*									-2.4*	-2.4*	-2.4*
Rhode Island	1990-2019	-3.7	*									-3.7*	-3.7*	-3.7*
20-49	-	-										-	-	-
50-64	1990-2019	-4.3	*									-4.3*	-4.3*	-4.3*
65+	-	-										-	-	-
South Carolina	1990-2019	-1.7	*									-1.7*	-1.7*	-1.7*
20-49	1990-1998	6.7	*	1998-2001	-19.0	2001-2019	1.4					1.4	1.4	1.4
50-64	1990-2019	-2.3	*									-2.3*	-2.3*	-2.3*
65+	1990-2019	-2.0	*									-2.0*	-2.0*	-2.0*
South Dakota	1990-2019	-0.9										-0.9	-0.9	-0.9
20-49	-	-										-	-	-
50-64	-	-										-	-	-

	Trend 1			Trend 2		Trend 3		Trend 4		Trend 4		AAPC		
	Years	APC		Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
65+	-	-										-	-	-
Tennessee	1990-2019	-1.6	*									-1.6*	-1.6*	-1.6*
20-49	1990-2019	-0.5										-0.5	-0.5	-0.5
50-64	1990-2019	-2.6	*									-2.6*	-2.6*	-2.6*
65+	1990-2019	-1.6	*									-1.6*	-1.6*	-1.6*
Texas	1990-2019	-1.4	*									-1.4*	-1.4*	-1.4*
20-49	1990-2019	0.2										0.2	0.2	0.2
50-64	1990-2019	-1.8	*									-1.8*	-1.8*	-1.8*
65+	1990-2019	-2.3	*									-2.3*	-2.3*	-2.3*
Utah	1990-2019	-2.0	*									-2.0*	-2.0*	-2.0*
20-49	-	-										-	-	-
50-64	1990-2019	-2.8	*									-2.8*	-2.8*	-2.8*
65+	1990-2019	-0.6										-0.6	-0.6	-0.6
Vermont	1990-2019	-5.6	*									-5.6*	-5.6*	-5.6*
20-49	-	-										-	-	-
50-64	-	-										-	-	-
65+	-	-										-	-	-
Virginia	1990-2019	-2.3	*									-2.3*	-2.3*	-2.3*
20-49	1990-2019	-1.8	*									-1.8*	-1.8*	-1.8*
50-64	1990-2019	-1.9	*									-1.9*	-1.9*	-1.9*
65+	1990-2019	-2.8	*									-2.8*	-2.8*	-2.8*
Washington	1990-2019	-1.7	*									-1.7*	-1.7*	-1.7*
20-49	1990-2019	-1.7	*									-1.7*	-1.7*	-1.7*
50-64	1990-2019	-1.4	*									-1.4*	-1.4*	-1.4*
65+	1990-2019	-2.0	*									-2.0*	-2.0*	-2.0*
West Virginia	1990-2019	-1.5	*									-1.5*	-1.5*	-1.5*
20-49	1990-2019	-0.9										-0.9	-0.9	-0.9
50-64	1990-2019	-1.4	*									-1.4*	-1.4*	-1.4*
65+	1990-2019	-2.2	*									-2.2*	-2.2*	-2.2*
Wisconsin	1990-2009	-4.1	*	2009-2019	1.4							1.4	1.4	1.4
20-49	1990-2019	-3.3	*									-3.3*	-3.3*	-3.3*
50-64	1990-2019	-3.0	*									-3.0*	-3.0*	-3.0*
65+	1990-2019	-2.0	*									-2.0*	-2.0*	-2.0*

	Trend 1		Trend 2		Trend 3		Trend 4		Trend 4		AAPC		
	Years	APC	Years	APC	Years	APC	Years	APC	Years	APC	2010-2014	2015-2019	2010-2019
Wyoming	1990-2019	-0.3									-0.3	-0.3	-0.3
20-49	-	-									-	-	-
50-64	-	-									-	-	-
65+	-	-									-	-	-

ABBREVIATIONS: APC = annual percent change, AAPC = average annual percent change

*Statistically significant ($p < 0.05$)

- Could not be calculated due to sparce data