

A Retrospective Analysis of Mortality Due to Pulmonary Heart Disease and COPD in the United States From 1999 to 2020 Using the CDC WONDER Database

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Abstract

Introduction:

Pulmonary heart disease and chronic obstructive pulmonary disease remained major causes of mortality, particularly in older adults, often associated with factors such as aging, lifestyle, environment and occupation. The objective of this study is to investigate trends in mortality related to pulmonary heart disease and COPD among United States (US) adults aged ≥ 65 during the years 1999–2020.

Methods:

This retrospective study used death certificate data from the CDC WONDER database (1999–2020), focusing on pulmonary heart disease and diseases of pulmonary circulation and chronic lower respiratory disease (International Classification of Diseases-10: I26-I28 and J40-J47) as the underlying cause of death among US adults aged 65 and over. Age-adjusted mortality rates (AAMRs) were calculated and examined using Joinpoint regression analysis to estimate the Annual Per cent Change (APC), with 95% confidence intervals and a significance threshold of $P < 0.05$. Trends were analyzed across demographic factors including sex, race/ethnicity (Hispanic and non-Hispanic), and 2013 urbanization, as well as geographic variables such as US Census regions and states.

Results:

Pulmonary heart disease and Chronic obstructive pulmonary disease caused 182,397 deaths in adults aged ≥ 65 years between 1999 and 2020, with a mean age-adjusted mortality rate (AAMR) of 19.9 per 100,000 (95% CI: 19.4–20.3). Males and Females showed a comparable mean AAMR of 22.7 and 18.1, respectively. Since 1999, mortality has significantly increased among Blacks (APC: 3.25%, 95% CI: 2.39–4.48) meanwhile from 1999 to 2003, white individuals showed a significant decline in mortality (APC: -2.75; 95% CI: -5.28 to -0.14, $P < 0.05$), followed by a sharp increase from 2003 to 2018 (APC: 1.48; 95% CI: 1.02 to 1.94). Post-2004, a significant upward trend in mortality was observed in the CENS-R2:Midwest (APC: 0.68; 95% CI: 0.25 to 1.17), and CENS-R3 South exhibited significant increase from 2016 to 2020 (APC: 3.40; 95% CI: 1.58 to 5.26; $p < 0.05$). The West(CENS-R4) exhibited a significant decline from 1999 to 2005 (APC: -3.02 95% CI: -4.68 to -1.34; $p < 0.05$), followed by a significant increase from 2005 to 2018 (APC: 1.57; 95% CI: 1.01 to 2.15; $p < 0.05$). In the CENS-R1 Northeast, a significant decline was observed from 1999 to 2002 (APC: -5.25; 95% CI: -10.1 to -0.08; $p < 0.05$) followed by a prolonged non significant decline. State-level variation was also notable with the highest AAMRs observed in Colorado (42.9), while the lowest were reported in Louisiana (10.8).

Conclusion:

Mortality from Pulmonary heart disease and Chronic obstructive pulmonary disease has risen significantly across geographic and demographic groups since 2003, particularly census regions and Non hispanic origin, highlighting the need for targeted public health strategies.

Introduction

Chronic obstructive pulmonary disease (COPD) is a chronic respiratory disease that is marked by an irreversible airflow obstruction and permanent structural damage of the lungs leading to progressive impairment of breathing as the illness progresses [1]. COPD was the fifth leading cause of mortality in the United States in 2023, resulting in approx 141,734 deaths. The annual medical expenditure attributable to COPD is approximately 24 billion among adults aged 45 years and above [2]. Globally, COPD is the third major cause of mortality, after ischemic heart disease and stroke, representing between 3 million and almost 4.7 percent of all deaths across the world annually [3]. The main contributing factor of COPD in the United States is tobacco smoke, with other risk factors such as secondhand smoke, exposure to environmental or occupational risks, family history, and comorbid asthma [4]. Pulmonary heart disease (PHD) is characterized by alterations in structure and/or function of the right ventricle associated with abnormal respiratory function and is nearly always linked to pulmonary hypertension caused by lung diseases and/or hypoxemia, such as chronic obstructive pulmonary disease (COPD), interstitial lung diseases, and hypoventilatory disorders. Cor pulmonale is a classical term that is used to denote the hypertrophic remodelling of the right ventricle which may take place in the case of chronic respiratory disease. Pulmonary heart disease is a more contemporary term that encompasses both the structural alterations characteristic of cor pulmonale and functional dysfunction of the right ventricle that is caused by these respiratory disorders. In patients with COPD, cor pulmonale and right ventricular dysfunction develop due to increased pressure in the pulmonary artery. The effects of these changes include systemic venous congestion and are strongly linked to a significant reduction in life expectancy among affected patients [5, 6]. In fact, 10–30% percent of heart failure hospitalizations in the United States are linked to cor pulmonale, with the most widespread cause being COPD, accounting for up to 84 percent cases in one study [7].

It is important to examine mortality trends of COPD and pulmonary heart disease to inform evidence-based treatment strategies and effective health policy development. Although earlier studies have tended to analyze the burden of these conditions separately, few studies have conducted

a comprehensive evaluation of their combined impact on mortality among older adults. To fill this gap, the current study analyzes U.S. national mortality data from 1999 onwards through the CDC WONDER database and focuses on the age-standardized mortality rates within the population aged 65 years and above. The stratification of mortality was based on gender, racial/ethnic groups geographic area, and urban or rural residence. By examining the demographic and geographic patterns of mortality through the decades, this study will be able to identify the high-risk populations and highlight evolving trends in changing patterns of mortality rates due to COPD and PHD. The results may facilitate the development of focused interventions and health policies intended to reduce disparities and improve patient outcomes.

Materials and Methods

Study Design and Data Sources

The study followed an observational design and used United States death-certificate data available in the Wide-Ranging Online Data to Epidemiologic Research (CDC-WONDER) system of Centers for Disease Control and Prevention. The database includes mortality records reported by all states in the United States. Thus, the dataset gives a detailed, nationwide map of the causes of death from 1999 to 2020. Since the data are in the public domain and completely anonymous, the study did not require approval from an Institutional Review Board. The analysis was conducted and reported according to the STROBE guidelines to ensure methodological transparency and detailed presentation of findings.

Study Population

The study comprised adults who were 65 years or older who died in the United States during 1999–2020, and who had chronic obstructive pulmonary disease (COPD) along with pulmonary heart disease (PHD) mentioned on their death certificates.[8] We identified COPD cases using the International classification of disease (ICD 10) codes J40–J47, cases of COPD and PHD cases using the ICD-10 code I27. Codes for pulmonary heart disease were included to account for right heart complications, which are often associated with COPD [9].

Inclusion Criteria

Individuals aged 65 years or older, who were residents of the United States at the time of death.

Deaths that occurred between 1999 and 2020 and were registered in state vital statistics and subsequently reported to the CDC WONDER database.

Deaths for which COPD or pulmonary heart disease was listed as either the primary cause or a contributing factor to the death certificate.

Exclusion Criteria

Death records that were not filled with or included in state registries.

Individuals who died before 65 years.

Data Extraction

The dataset included population size, year of death, geographic region, and demographic variables such as age and race/ethnicity. Race and ethnicity were classified as Hispanic or non-Hispanic, with further divisions for non-Hispanic individuals into White, Black/African American, American Indian/Alaska Native, and Asian/Pacific Islander. Place of death was categorized as outpatient setting, emergency department, inpatient facility, home, hospice, nursing home, or long-term care facility. For clearing of urban and rural residency, the 2013 National Center for Health Statistics Urban-Rural Classification Scheme was the source for classification. Areas are divided into metropolitan (large central metro, large fringe metro, medium metro, and small metro) and nonmetropolitan (micropolitan and noncore) categories with this scheme. Geographic regions were delineated based on the U.S. Census Bureau's classification into four major divisions of Northeast, Midwest, South, and West. The demographic classification enabled a more accurate analysis of mortality trends across different population groups [10, 11].

Statistical Analysis

We computed both crude mortality rates and age-adjusted mortality rates (AAMRs) per 100,000 population at the national level for each year, standardizing AAMRs with reference to the 2000 U.S. standard population. Additionally, the calculated confidence intervals (CIs) for the rates were calculated at 95%. The trends across the years were analyzed using the Joinpoint Regression Program (version 4.9.0.0, National Cancer Institute), which gives annual percent change (APC) and average annual percent change (AAPC) with the corresponding confidence intervals [12]. Analyses were further stratified by age groups (65–74, 75–84, 85+), gender, race/ethnicity, geographic region, and urban versus rural residence to assess differences in mortality trends and identity disparities. The statistical significance was defined as p-value below 0.05 [13, 14].

Results

182,397 deaths were reported in patients with PHD and COPD (Supplementary Table 1). Most of the deaths were seen in medical facilities (48.60%), followed by decedents' homes (26.70%), nursing homes (16.70%), hospice facilities (4.60%), and others (3.30%). (Supplementary Table 2) A higher proportion of deaths were observed in females (53.6%). (Supplementary Table 1).

Overall annual trends in patients with concurrent PHD and COPD:

The overall age-adjusted mortality rate (AAMR) decreased significantly from 21.5 in 1999 to 19.1 in 2002 (APC: -3.79; 95% CI: -0.15 to -2.23; $p < 0.05$) and then increased to 20.5 in 2018 (APC: 0.42; 95% CI: 0.09 to 0.76; $p < 0.05$). From 2018 to 2020, a non-significant increase was observed (APC: 5.68; 95% CI: -1.53 to 13.43). Figure 1, Supplementary Table 3, Supplementary Table 4

Trends stratified by gender:

Males exhibited a higher AAMR than Females across the study period (22.7 vs 18.1). In males, a significant decline in mortality was seen from 1999 to 2004 (APC: -4.08; 95% CI: -5.87 to -2.26; $p < 0.05$), followed by a gradual non-significant decline from 2004 to 2018 (APC: -0.05; 95% CI: -0.45 to 0.34) and a non-significant rise from 2018 to 2020 (APC: 5.39; 95% CI: -0.91 to 12.10). In females, the mortality increased significantly from 1999 to 2018 (APC: 0.72; 95% CI: 0.42 to 1.01; $p < 0.05$), followed by non-significant rise from 2018 to 2020 (APC: 6.22; 95% CI: -2.35 to 15.57). Figure 2, Supplementary Table 3, Supplementary Table 4

Trends stratified by Race:

Most of the deaths were observed in Non-Hispanic (NH) White individuals (90%), followed by NH Blacks (8.39%), NH Asians (1.1%), and NH American Indians (0.9%). The Hispanic or Latino accounted for 2.6% of the deaths.

Among Hispanics, a non-significant decline was noted from 1999 to 2017 (APC: -0.54; 95% CI: -1.49 to 0.41), followed by a non-significant increase from 2017 to 2020 (APC: 10.08; 95% CI: -0.97 to 22.37). Among NH American Indians, a non-significant rise was seen from 2007 to 2020 (APC: 1.41; 95% CI: -0.35 to 3.22). A non-significant decrease was observed among NH Asians from 1999 to 2020 (APC: -0.31; 95% CI: -1.21 to 0.59). Among NH Blacks, mortality increased significantly from 1999 to 2020 (APC: 1.48; 95% CI: 1.02 to 1.94; $p < 0.05$). Among NH White individuals, a significant decrease was observed from 1999 to 2003 (APC: -2.75; 95% CI: -5.28 to -0.14; $p < 0.05$), followed by a significant increase from 2003 to 2018 (APC: 0.54; 95% CI: 0.21 to 0.87; $p < 0.05$) and a non-significant increase from 2018 to 2020 (APC: 5.50; 95% CI: -0.77 to 12.18). Figure 3, Supplementary Table 3, Supplementary Table 5

Trends stratified by Geography:

The highest AAMR was observed in Midwest (23.3), followed by West (21.6), South (18.6), and Northeast (16.9). Non-metropolitan areas maintained a higher AAMR than metropolitan areas (23.6 vs 19.1).

In the Northeast, a significant decline was observed from 1999 to 2002 (APC: -5.25; 95% CI: -10.1 to -0.08; $p < 0.05$), followed by non-significant increase from 2002 to 2011 (APC: 1.07; 95% CI: -0.18 to 2.35), a non-significant decline from 2011 to 2018 (APC: -1.12; 95% CI: -2.80 to 0.57) and a non-significant increase from 2018 to 2020 (APC: 7.53; 95% CI: -1.17 to 17.01). In the Midwest, a non-significant decline was observed from 1999 to 2004 (APC: -2.25; 95% CI: -4.82 to 0.38), followed by a significant increase from 2004 to 2020 (APC: 0.68; 95% CI: 0.25 to 1.17; $p < 0.05$). The South exhibited a non-significant decline from 1999 to 2016 (APC: -0.15; 95% CI: -0.40 to 0.09), followed by a significant increase from 2016 to 2020 (APC: 3.40; 95% CI: 1.58 to 5.26; $p < 0.05$). The West exhibited a significant decline from 1999 to 2005 (APC: -3.02 95% CI: -4.68 to -1.34; $p < 0.05$), followed by a significant increase from 2005 to 2018 (APC: 1.57; 95% CI: 1.01 to 2.15; $p < 0.05$) and a non-significant increase from 2018 to 2020 (APC: 6.19; 95% CI: -1.88 to 14.92). Figure 4, Supplementary Table 3, Supplementary Table 7

The metropolitan areas exhibited a non-significant decline from 1999 to 2003 (APC: -3.46; 95% CI: -7.71 to 0.97), followed by a significant rise from 2003 to 2020 (APC: 0.80; 95% CI: 0.47 to 1.14; $p < 0.05$). The non-metropolitan areas exhibited similar trends; a non-significant decline from 1999 to 2016 (APC: -0.03; 95% CI: -0.31 to 0.24), followed by a significant increase from 2016 to 2020 (APC: 4.78; 95% CI: 2.50 to 7.10; $p < 0.05$). Figure 5, Supplementary Table 3, Supplementary Table 8

Significant disparities were also observed across different U.S. states. AAMR was as high as 42.9 in Colorado and as low as 10.8 in Louisiana. States falling within top 90th percentile include Colorado (42.9), Vermont (41.3), Wyoming (41.2), Montana (34.0), Oregon (30.4), and the states falling within lowest 10th percentile include Louisiana (10.8), Hawaii 12.1, New York (13.0), Georgia (13.8), Arkansas (14.2). Figure 6, Supplementary Table 6

Figure 7 is a central illustration showing a summary of our findings

Discussion

This retrospective study analysed concurrent pulmonary heart disease and COPD mortality data obtained from CDC wonder database to assess changing trends in demographic factors between 1999 and 2020. COPD is a common persistent respiratory infection associated with a high mortality. According to WHO, it is the fourth most common cause of death worldwide [15], expected to cause 4.5 million deaths in 2030 [16]. The prognosis of COPD is significantly influenced by its comorbidities including pulmonary heart disease or cor pulmonale.

Recent literature shows the COPD is the leading cause of chronic PHD, responsible for about 87% of the cases [17]. Our study revealed that 182,397 deaths resulted from this comorbid condition from 1999 to 2000. The overall AAMR showed an initial significant decline from 21.5 in 1999 to 19.1 in 2002, which was followed by a gradual uptrend through 2018 and a non-significant rise until 2020. The overall age-adjusted mortality rate (AAMR) initially declined significantly from 21.5 in 1999 to 19.1 in 2002, followed by a gradual increase through 2018 and a non-significant rise from 2018 to 2020. The early decline can be attributed to the adoption of better diagnostic and treatment procedures, including long acting vasodilators and oxygen therapy [18], leading to better survival outcomes. Long term oxygen therapy is considered the only acceptable intervention to improve survival in hypoxemic COPD [19] and additionally, may help slow the progression of pulmonary hypertension, a major contributing factor to PHD [20]. The subsequent upward trend in mortality suggests that these benefits were short-lived and not maintained over time. Factors such as changing population dynamics with increasing proportion of aging population and chronic disease burden, along with disparities in healthcare access and quality of care [21], may have influenced this mortality trend. The treatment for PHD in COPD has been mainly symptomatic with no disease modification, leading to poor prognosis later [22] and hence, the upward trend in mortality. The modest increase in mortality observed towards the end of study period may partially reflect the impact of COVID-19 pandemic on individuals with underlying COPD and PHD, although causal inference is limited.

Gender stratification reported males having consistently higher AAMRs than females. Despite this, women showed a steeper and more significant uptrend over time, suggesting a growing burden in this population. Several factors may contribute to these disparities. Historically, COPD has been more common among men, but smoking patterns among women have risen recently with trends among women following the male pattern after a delay of almost a century [23]. Women may be more susceptible to tobacco-related lung injury [24] and may develop pulmonary vascular involvement at lower levels of exposure [25]. Additionally, COPD and its complications are often underdiagnosed in women and often mis-diagnosed as asthma [26], which delays the recognition of PHD. This rising mortality in women highlights the need for earlier cardiopulmonary evaluation among the population.

Disparities in mortality among different racial and ethnic groups were evident. Although non-hispanic white individuals comprised the majority of deaths (90%), NH black individuals went through a significant increase in mortality throughout the study period (APC = 1.48). This is in line with previous literature that demonstrates worse clinical outcomes in patients with COPD

among NH blacks. Black individuals, despite similar levels of tobacco exposure, exhibit worse functional status and increased frequency of COPD-related exacerbations [27, 28]. In Hispanics, the mortality associated with PHD in COPD remained relatively stable, which may be due to decreased cumulative exposure to tobacco smoke [29]. These differences likely result from different patterns of risk factor prevalence across different populations. Disparities in healthcare access along with structural and social disadvantage to certain groups are also likely to affect outcomes.

Significant geographic variation was seen with higher AAMRs in the Midwest and West. These results are backed by previous studies that show similar geographic trends in individuals with coexisting COPD and heart failure [30]. These differences may be attributed to disparities in healthcare infrastructure, unequal distribution of resources and demographic characteristics of the population [31]. Consistently higher AAMR was reported in rural settings (23.6) as compared to large urban areas (19.1). Rural populations face multiple challenges which may lead patients presenting with a more advanced disease. These factors include higher rates of smoking, greater occupational risk exposures and limited availability of specialty care services. [32]. This mortality might have further worsened due to the increasing hospital shutdowns in rural regions. A scoping review of previous literature reports that from 1990 to 2020, around 334 rural hospitals in the United States closed, and since 2011 the number of hospital closures have surpassed new openings [33]. This emphasizes the need for directing healthcare investments towards non-metropolitan areas [34].

At state levels, mortality rates varied widely, with highest AAMRs observed in Colorado, Wyoming and Vermont, and lowest rates in states including Louisiana and Hawaii. High altitude states may experience hypoxic vasoconstriction which can exacerbate pulmonary hypertension and thus PHD [35]. At high altitudes, systolic pulmonary artery pressure is significantly greater than that described at lower altitudes [36]. Therefore, it is plausible to expect a higher risk for the development of PHD in these populations. Differences in population demographics and access to advanced care also contribute to these trends.

Nearly half of the deaths (48.60%) occurred in medical facilities, with a substantial proportion occurring at home (26.70%) and nursing facilities (16.70%). This distribution suggests a high burden of advanced disease which requires medical care. It also indicates that many patients may be dying outside specialized medical settings due to limited access to palliative care and structural end-of-life planning.

The observations of this analysis carry important implications for clinical practice and public health. Bridging gaps in healthcare access, implementing early diagnostic and preventive initiatives, in addition to development of improved therapeutic interventions are necessary steps

for the reduction of mortality among individuals with COPD related PHD. Clinicians should maintain a high index of suspicion for worsening pulmonary hypertension and pulmonary heart disease in COPD patients with worsening functional status or persistent hypoxemia. Targeted cardiopulmonary evaluation of high-risk groups may facilitate improvements in mortality trends. We may identify a need for standardized protocols for the early detection in all hospital settings. Additionally, clinical trials evaluating targeted therapies are needed. The disparities in mortality rates by sex, race and geography show the impact of structural and social determinants of health on survival outcomes. Reducing the burden of this disease requires addressing these inequities and improving access to specialized care. Policies must address the infrastructure of rural healthcare, including ambulances rapid transport protocols for remote monitoring. Sustained efforts towards smoking cessation and reduction of environmental exposures are also necessary.

Limitations:

Our study had multiple strengths including using 25 years of national mortality data, stratification across various groups and the use of joinpoint regression which enhances the detection of significant inflection points through the calculation of APC and average APC. We also acknowledge the limitations of our study. Relying on death certificate records introduces the possibility of misclassification of COPD and PHD. Although ICD-10 codes are standardized, different clinicians may apply these codes differently, producing inconsistencies..

The assessment of individual level factors including clinical and socioeconomic factors along with medication adherence data cannot be assessed, limiting causal inference and introducing bias.

Abbreviations

AAPC:
Average Annual Percent Change
APC:
Annual Percent Change
AAMR:
Age-Adjusted Mortality Rate
CDC:
Centers for Disease Control and Prevention
CI:
Confidence Interval
CMR:
Crude Mortality Rate
CVD:
Cardiovascular Disease
HTN:
Hypertension
ICD-10:
International Classification of Diseases, 10th Revision

NCHS:
National Center for Health Statistics
NH:
Non-Hispanic
STROBE:
Strengthening the Reporting of Observational Studies in Epidemiology
US:
United States
WONDER:
Wide-Ranging Online Data for Epidemiologic Research

Declarations

Author contributions:

SS and AK contributed equally to this work. SS and AK were involved in conceptualization, data analysis, and manuscript drafting. SAH, AKS, AF and LHS contributed to methodology, data curation, and visualisation. SC and UAS assisted with data collection and initial drafting. SK, HHS, SP, and MA contributed to data interpretation and critical revision of the manuscript. MTA reviewed and approved the final version. All authors approved the final manuscript.

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Conflicts of interest:

The authors report no relationships that could be construed as a conflict of interest

Ethics approval and consent to participate:

Ethics approval is deemed unnecessary according to national regulations as our study did not involve any human/animal test subject. The need for consent to participate is deemed unnecessary according to national regulations as our study did not involve any human/animal test subject and the data used in this study is de-identified and publicly available, thus no institutional review board approval was required. We ensured adherence to the ethical principles outlined in the Declaration of Helsinki.

Study Participants:

The research is based on de-identified human death certificate data from the CDC WONDER database. <https://wonder.cdc.gov/mcd.html>.

Declaration of Generative AI in Scientific Writing:

The authors report no AI usage to facilitate this manuscript.

Consent for publication:

Not applicable

Consent and Ethics Approval:

The research is based on de-identified data and does not require the consent of the participants or ethics approval.

Availability of data and materials:

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

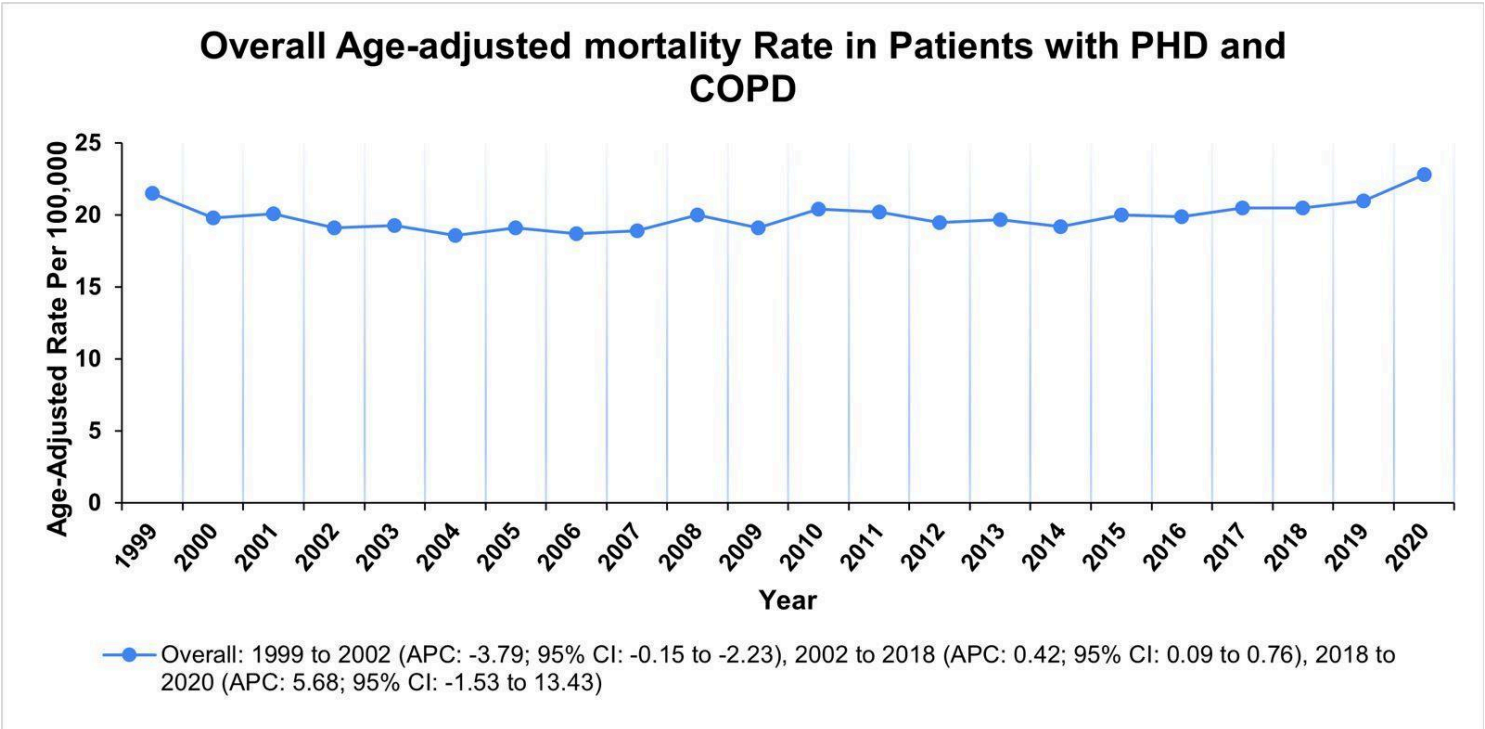


Figure 1

Overall pulmonary heart disease and COPD related AAMRs per 100,000 in the United States, 1999 to 2020.

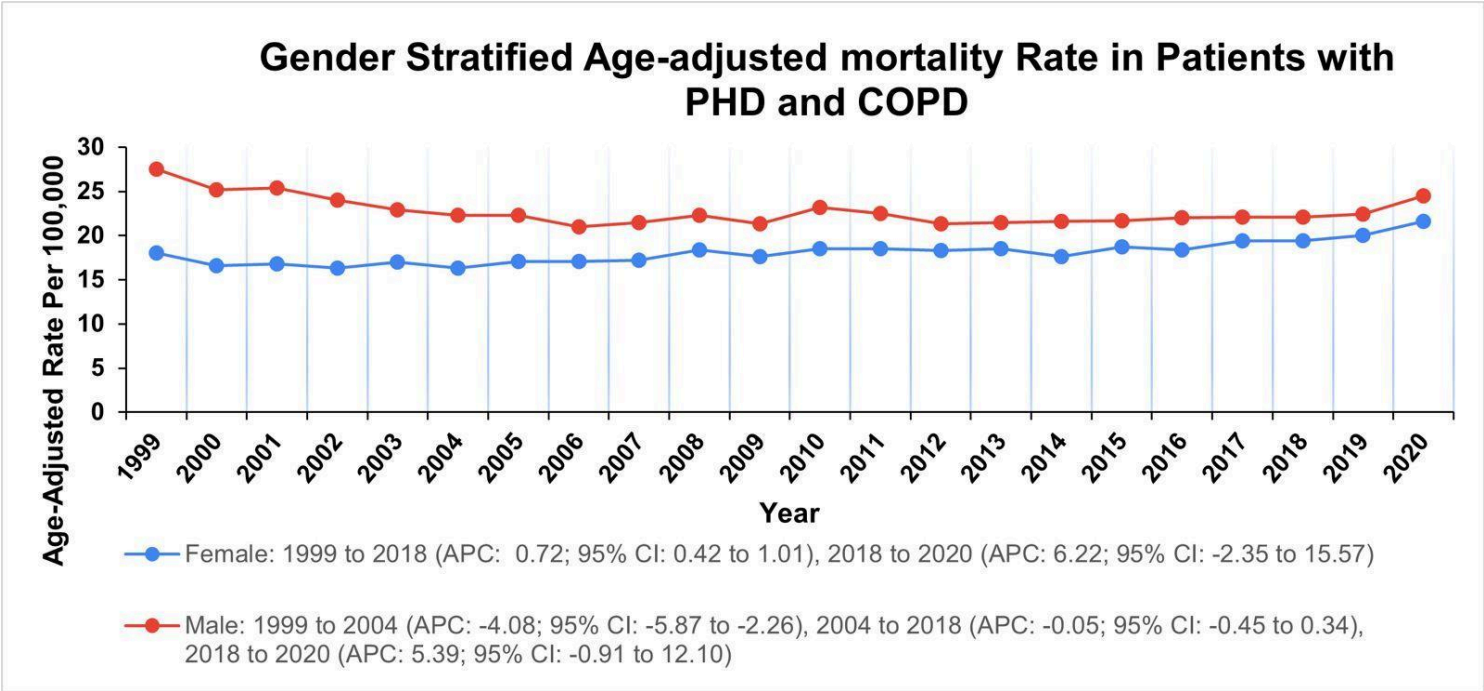


Figure 2

Gender-stratified pulmonary heart disease and COPD related AAMRs per 100,000 in the United States, 1999 to 2020.

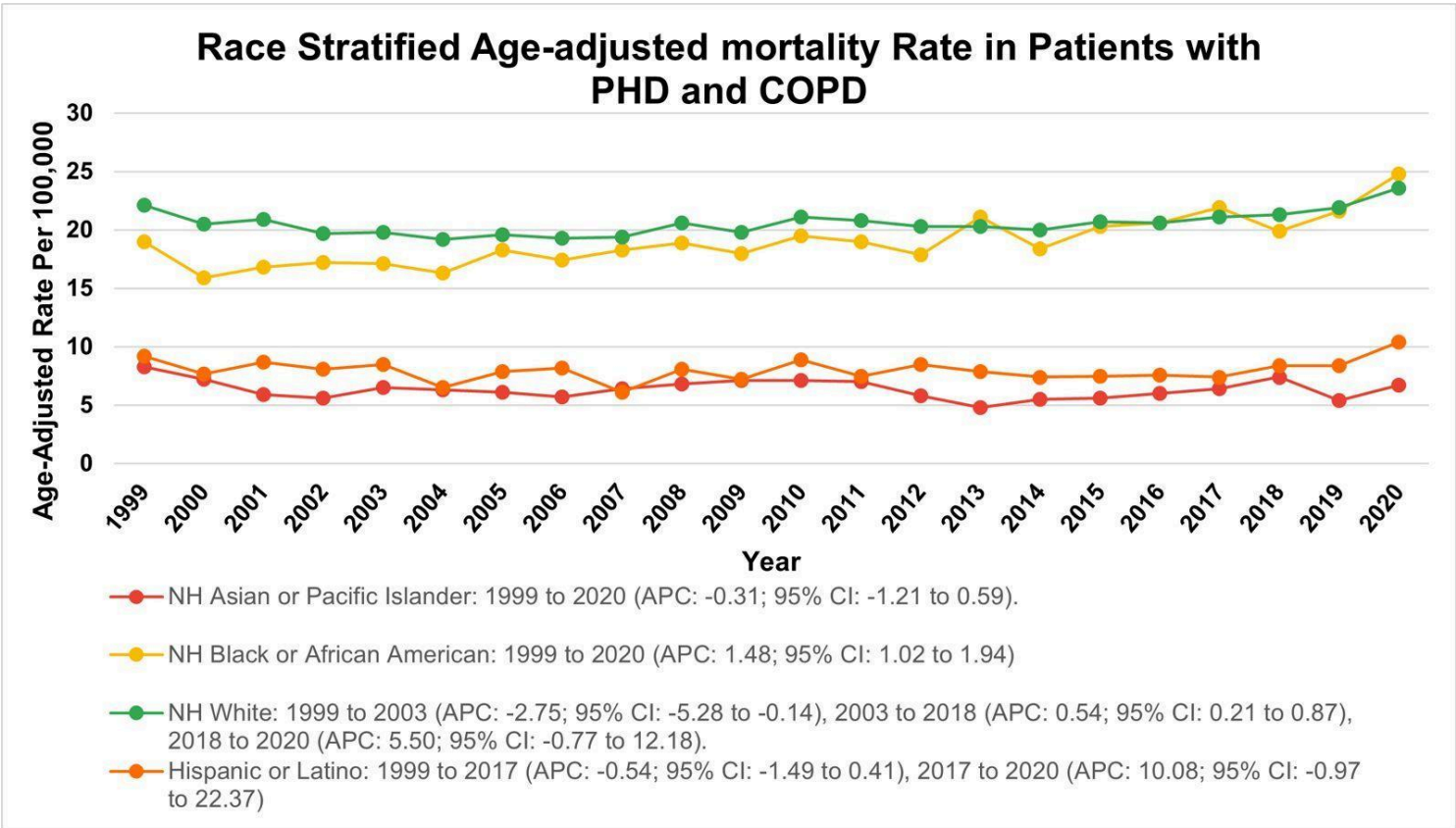


Figure 3

Race-stratified pulmonary heart disease and COPD related AAMRs per 100,000 in the United States, 1999 to 2020.

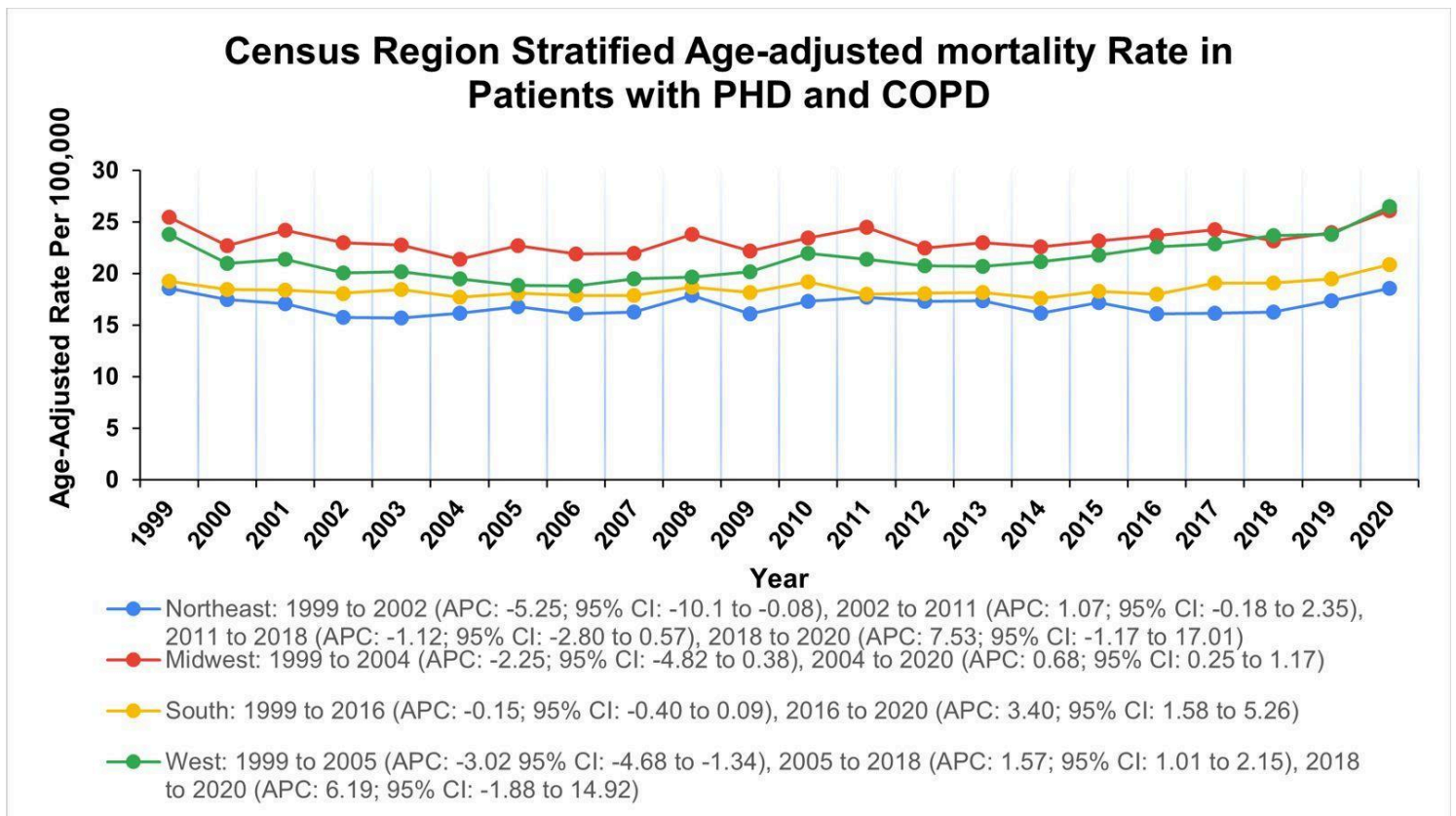


Figure 4

Pulmonary heart disease and COPD related AAMRs per 100,000 stratified by regions in the United States, 1999 to 2020.

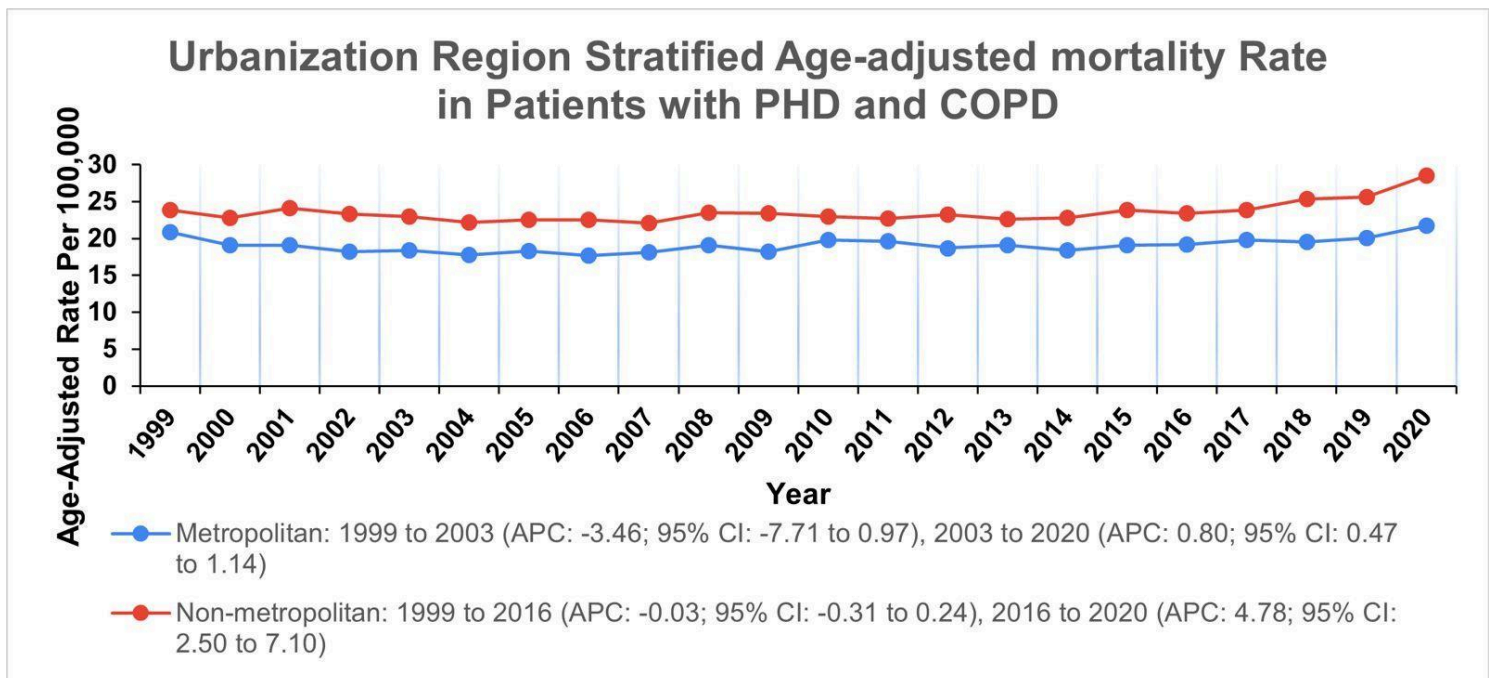


Figure 5

Pulmonary heart disease and COPD related AAMRs per 100,000 stratified by urbanization in the United States, 1999 to 2020.

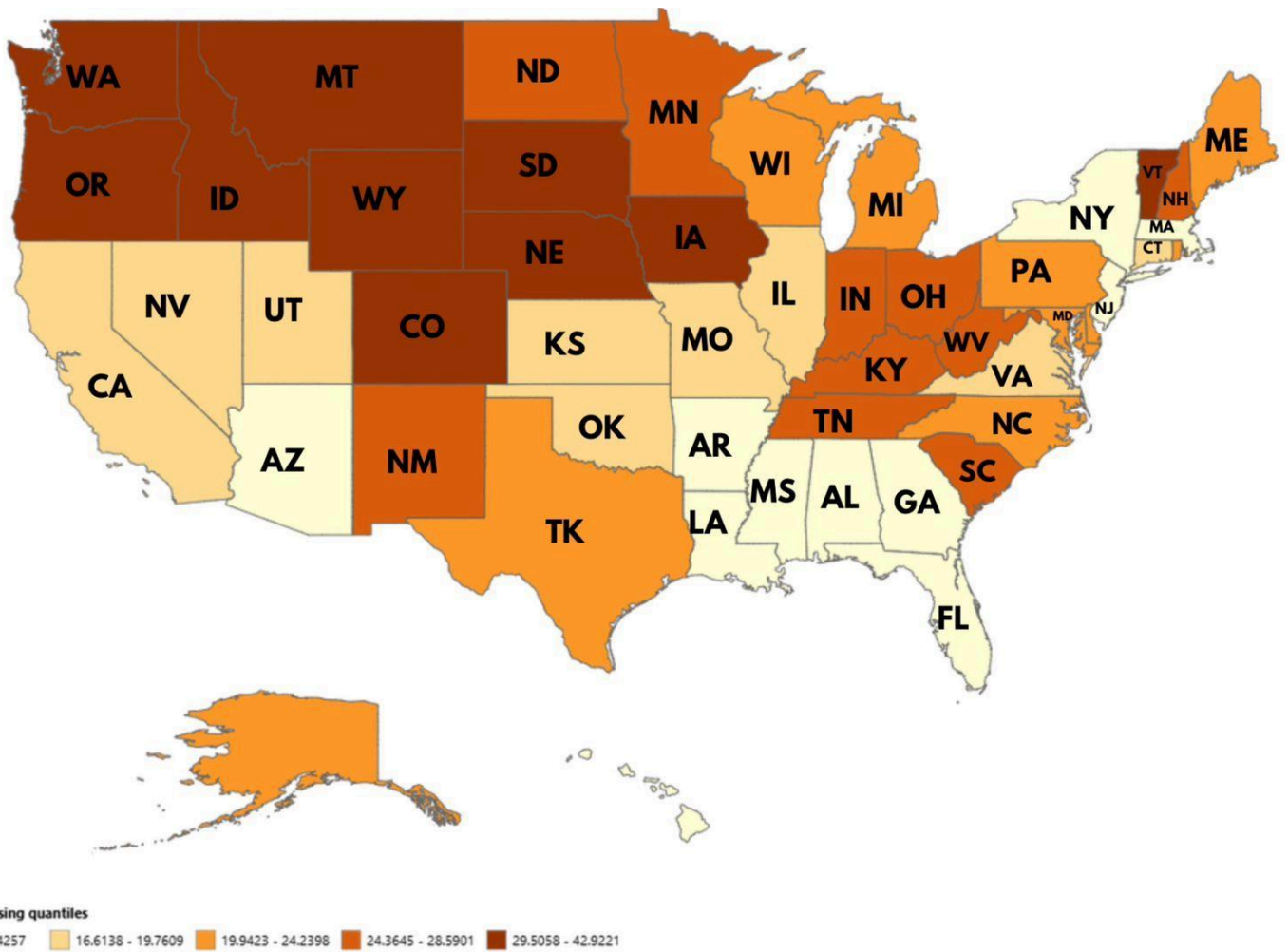


Figure 6

Pulmonary heart disease and COPD related AAMRs per 100,000 stratified by States, 1999 to 2020. Heat map



MORTALITY TRENDS IN COPD AND PULMONARY HEART DISEASE AMONG OLDER ADULTS IN USA

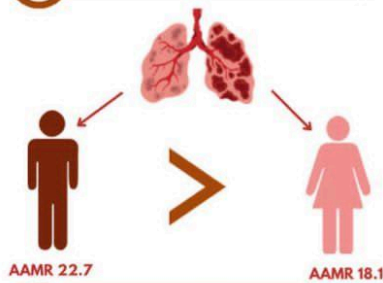


A RETROSPECTIVE ANALYSIS OF CDC WONDER DATABASE



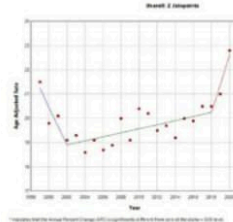
From 1999 to 2020, 182,397 deaths were reported in patients with concurrent COPD and PHD.

GENDER DISPARITIES



ANNUAL AAMR TRENDS

(AAMR PER 100,000 POPULATION)

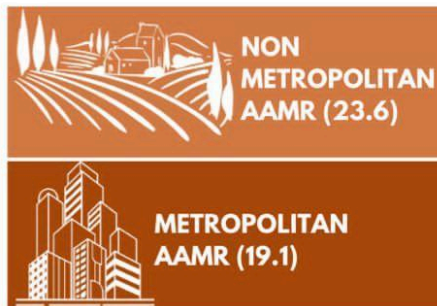
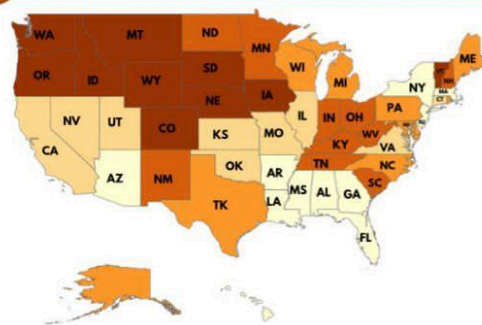


The overall age-adjusted mortality rate (AAMR) decreased significantly from 21.5 in 1999 to 19.1 in 2002 and then increased to 20.5 in 2018. From 2018 to 2020, a non-significant increase was observed.

RACIAL DISPARITIES (AAMR PER 100,000 POPULATION)



GEOGRAPHICAL DISPARITIES (AAMR PER 100,000 POPULATION)



The highest AAMR was observed in Midwest (233), followed by West (216), South (186), and Northeast (169).

Figure 7

Central illustration. Mortality trends in Pulmonary heart disease and COPD in the United States from 1999 to 2020, with a further illustration of racial and geographical disparities.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryfilesCOPDandPHD.docx](#)