

Epidemiological Trends in Infant Mortality Related to Congenital Malformations of the Respiratory System between 1999-2023: A Comprehensive CDC WONDER Database Study

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Abstract

Background

Congenital malformations of the respiratory system are a major contributor of infant mortality in the United States (U.S.). However, long-term national trends and disparities to explain the increased infant mortality rates stratified by sex, race/ethnicity, and geography remain undercharacterized. This study aims to describe temporal trends in congenital respiratory malformation–related infant mortality from 1999 to 2023, with a focus on identifying demographic and structural inequities.

Methods

Data were extracted from the Centers for Disease Control and Prevention's Wide-ranging Online data for Epidemiologic Research (CDC WONDER), and trends in crude mortality rate (CMR) were analyzed for U.S. infants < 1 year of age from 1999 to 2023. Results were stratified according to sex, regional variations, race/ethnicity, and age. Trends were analyzed utilizing Joinpoint analysis software to estimate annual percentage change (APC) and average annual percent change (AAPC) with 95% confidence intervals (CI) for each demographic group.

Results

Overall, the CMR related to congenital malformations of the respiratory system declined over the study period. Mortality decreased during the study period for all geographic and demographic groups; however, male infants and Black or African American infants maintained the highest mortality rates despite the overall decline. All U.S. census regions demonstrated decreasing CMRs, with rural areas exhibiting persistently higher mortality than urban areas throughout the period.

Conclusion

Mortality within this population is driven by a complex interplay of clinical, demographic, and healthcare access factors, with notable disparities observed across both demographic and geographic groups. Although infant mortality attributable to congenital respiratory malformations has declined substantially over time, the persistently higher burden among male infants, Black or African American infants, and those residing in rural areas highlights ongoing inequities and underscores the need for targeted interventions, earlier diagnosis, and improved access to specialized perinatal and neonatal care services.

What is known

- Congenital malformations of the respiratory system are one of the leading causes of infant mortality in the United States.

What Is New

- This study identifies demographic and structural disparities across sex, race/ethnicity, and geographic subgroups for congenital respiratory malformations in the U.S.

Introduction

Congenital malformations of the respiratory system, including congenital diaphragmatic hernias and pulmonary hypoplasia, are a significant contributor to infant mortality. Congenital diaphragmatic hernias are estimated to occur in 1 out of every 3,000 live births and are associated with a 30–60% mortality rate (Politis et al., 2021). Congenital pulmonary hypoplasia is estimated to occur in roughly 9 to 11 per 10,000 live births but has an associated mortality rate between 71–95% (Hsu et al., 2012). Infants who survive into childhood encounter long-term consequences resulting in significant morbidities such as impairment in lung development, frequent infections, and reduced lung volumes. (Porcaro et al., 2025). While congenital malformations of the respiratory system encompass a wide range of conditions, these abnormalities collectively affect approximately 4 out of every 10,000 live births, with the most common presenting as airway abnormalities or solid masses that develop in utero (Johns Hopkins Medicine, n.d.).

Despite a recent increase in survival probability due to advances in prenatal care and ultrasound, the epidemiology of congenital pulmonary malformations remains underinvestigated (UpToDate, 2025; Bisht et al., 2026). Particularly, there is a lack of data regarding how demographic and structural factors shape outcomes. Existing studies on congenital lung malformations lack nationally representative data that is stratified based on race, ethnicity, and socioeconomic status. Despite this gap, there is a growing body of literature linking social determinants of health to higher risks of adverse perinatal and pediatric respiratory outcomes (Mutic et al., 2023). Therefore, the purpose of this study is to utilize the CDC WONDER database to examine temporal trends in infant mortality related to congenital pulmonary malformations in the U.S. from 1999 to 2023. Through providing crude mortality rates and stratifying outcomes by demographic and geographic characteristics, this analysis aims to address gaps in prior literature and generate epidemiologic insights that can inform efforts to improve early diagnosis, guide resource allocation, and ultimately enhance long-term health outcomes for infants with congenital respiratory malformations.

Methods

Data Collection

Infant mortality related to congenital respiratory defects from 1999 to 2023 was analyzed using the Centers for Disease Control Wide Ranging Online Data for Epidemiological Research (CDC WONDER) database, a publicly available database containing material relevant for in-depth public health analyses. Data was extracted from the CDC WONDER database using the congenital respiratory defect International Classification of Diseases (ICD), 10th revision code Q30-Q34. Stratification was performed

by sex, race, region, and urban/rural designation. The following races were analyzed: Non-Hispanic (NH) White, NH Black/African American, Hispanic, American Indian, and Asian or Pacific Islander. Census regions, defined by the Census Bureau classification, included the South, the West, the Midwest, and the Northeast. The Institutional Review Board (IRB) approval was not required for this study. This study was conducted in compliance with the ethical standards of the responsible institution on human subjects as well as with the Helsinki Declaration.

Data Analysis

Crude mortality rates (CMR) were calculated to describe the overall burden of deaths in the population without age standardization. Furthermore, CMRs were standardized to the 2000 U.S. standard population (Shah et al., 2019). Mortality trends over the study period were analyzed using the Joinpoint Regression Program (version 5.4.0.0) developed by the National Cancer Institute (National Cancer Institute, 2025a). This program uses segmented regression modeling to identify temporal changes, allowing for the estimation of Annual Percent Change (APC) and Average Annual Percent Change (AAPC). APCs, AAPCs, and their corresponding 95% confidence intervals (CIs) were calculated for each segment using the Monte Carlo permutation method, which determines the number and location of joinpoints. The number of joinpoints utilized for each analysis was selected by the Joinpoint program, utilizing the best-fit model approach. Missing data were excluded from the analysis to ensure the most accurate and reliable results. Any data that was deemed insufficient or unreliable by the CDC WONDER database, including estimates based on small case counts or those with high relative standard errors, was also excluded. Statistical significance was assessed using two-sided t-tests, with a threshold of $p < 0.05$ (National Cancer Institute, 2025b). Statistically significant values are indicated with an asterisk (*).

Results

1. Overall:

From 1999 to 2023, there were 23,190 infant deaths due to congenital respiratory defects in the U.S.

Overall crude mortality rates decreased during this period from 28.11 (95% CI, 26.42 to 29.8) in 1999 to 13.07 (95% CI, 11.9 to 14.25) in 2023, with an average annual percentage change (AAPC) of -3.59%* (95% CI, -4.34 to -3.10) (Table 1). The annual percentage change (APC) in mortality was -1.94* (95% CI, -4.16 to -1.36) from 1999–2014, which increased to 1.58 (95% CI, -0.83 to -7.03) in 2020, and then significantly decreased to -20.02* (95% CI, -26.93 to -14.07) by 2023 (Fig. 2). Overall, the lowest CMRs observed were during the year 2023

2. Demographic Differences:

2.1 Sex Stratified

From 1999 to 2023, congenital respiratory defects were associated with 13,630 (58.8%) deaths in infant males and 9,560 (41.2%) in infant females in the U.S. (Fig. 1, Table 1).

Among infant males, the crude mortality rate decreased from 32.52 (95% CI, 29.98 to 35.05) in 1999 to 13.41 (95% CI, 11.75 to 15.07) in 2023, with an AAPC of -3.96%* (95% CI, -5.29 to -3.26) (Table 1). The APC in mortality was -2.18%* (95% CI, -6.94 to -1.037) from 1999–2013, which then increased to +1.52% (95% CI, -1.11 to +8.48) from 2013 to 2020, and then sharply declined to -22.52%* (95% CI, -33.28 to -15.17) from 2020 to 2023 (Fig. 2).

The crude mortality for females decreased from 23.49 (95% CI, 21.28 to 25.69) in 1999 to 12.72 (95% CI, 11.07 to 14.38) in 2023, with an AAPC of -3.04%* (95% CI, -4.10 to -2.37) (Table 1). The APC was -1.30%* (95% CI, -1.74 to -0.76) from 1999 to 2021, and then declined significantly to -20.31%* (95% CI, -30.64 to -8.47) from 2021 to 2023 (Fig. 2).

2.2 Race Stratified

Although mortality declined across all racial groups, Black or African American infants consistently had the highest crude infant mortality rates throughout the study period, decreasing from 35.87 (95% CI, 30.95 to 40.79) in 1999 to 17.5 (95% CI, 14.09 to 21.49) in 2023, with an AAPC of -3.41%* (95% CI, -5.02 to -1.98) (Table 2). The APC declined by -1.07% (95% CI, -1.75 to -0.06) from 1999 to 2021 (Fig. 4).

Conversely, Asian or Pacific Islander infants consistently had the lowest mortality rates, declining from 20.7 (95% CI, 14.04 to 29.33) in 1999 to 10.52 (95% CI, 6.51 to 16.1) in 2021, with an AAPC of -1.59% (95% CI, -3.37 to +0.15) (Table 2).

Among other racial and ethnic groups, mortality among White infants decreased from 26.8 (95% CI, 24.6 to 28.9) in 1999 to 13.0 (95% CI, 11.3 to 14.8) in 2023. The AAPC was -3.45%* (95% CI, -4.46 to -2.82) with an APC of -1.40%* (95% CI, -1.82 to -0.96) from 1999–2021 and -23.37* (95% CI, -32.7 to -11.6) from 2021–2023. Similarly, mortality among Hispanic infants declined from 26.5 (95% CI, 22.8 to 30.1) in 1999 to 12.9 (95% CI, 10.6 to 15.1) in 2023, with an AAPC of -3.41%* (95% CI, 04.86 to -2.50) and an APC of -1.21%* (95% CI, -1.76 to -0.45) from 1999 to 2021 and -24.6% (95% CI, -37.52 to -8.55) from 2021 to 2023. (Table 2, Fig. 4).

3 Regional variation

3.1 Census region

Between 1999 and 2023, the Northeast (AAPC: -4.43%*, 95% CI, -6.23 to -3.15), Midwest (AAPC: -4.26%*, 95% CI, -5.74 to -3.38), South (AAPC: -3.53%*, 95% CI, -4.87 to -2.62), and West (AAPC: -3.83%*, 95% CI, -5.06 to -2.68) regions all demonstrated decreases in crude mortality rates (Fig. 3).

Between 1999 and 2021, patients in the Northeast region experienced a decrease in CMR, from 21.8 in 1999 to 17.36 in 2021 (APC: -1.46%*, 95% CI, -2.22 to -0.50), followed by another decrease to 9.24 in 2023 (APC: -31.81%*, 95% CI, -46.2 to -10.9). Between 1999 and 2021, patients in the Midwest region demonstrated a decrease in crude mortality rates, from 30.57 in 1999 to 23.3 in 2020 (APC: -1.63%*, 95%

CI, -2.24 to - 0.96), which then decreased to 12.78 in 2023 (APC: -20.81%*, 95% CI, -37.33 to - 10.58). Between 1999 and 2021, patients in the South region showed a decrease in crude mortality rates, from 29.64 in 1999 to 27.65 in 2021 (APC: -0.69%*, 95% CI, -1.26 to -0.03), which then decreased to 14.92 in 2023 (APC: -29.95%*, 95% CI, -41.21 to -14.70). Between 1999 and 2021, patients in the West region experienced a decrease in crude mortality rates, from 28.06 in 1999 to 17.74 in 2020 (APC: -2.55%*, 95% CI, -3.09 to -0.45), which then decreased to 12.74 in 2023 (APC: -12.35%*, 95% CI, -27.06 to - 3.36).

3.2 Rural vs Urban

When comparing rural versus urban areas, crude mortality rates were consistently highest in rural areas compared to metropolitan (urban) regions. Rural zones displayed crude mortality rates change from 39.6 (95% CI, 38.9 to 40.3) in 1999 to 23.5 (95% CI, 23 to 24) in 2020, with a consistent AAPC of -2.5% (95% CI, -3.1 to -2.0) (Table 6, Fig. 4). Similarly, urban zones saw crude mortality rates change from 28.13 (95% CI, 26.3 to 29.95) in 1999 to 22.38 (95% CI, 20.75 to 24) in 2020, with an AAPC of - 1.04% (95% CI, - 1.52 to - 0.64). (Table 6, Fig. 4).

Table 1
Congenital respiratory malformation-
related crude mortality rate per
100,000 infants; overall and stratified
by sex, 1999–2023.

Year	Overall	Male	Female
1999	28.11	32.52	23.49
2000	30.45	35.15	25.53
2001	26.72	31.03	22.21
2002	27.21	31.01	23.23
2003	27.26	31.62	22.7
2004	27.48	31.58	23.19
2005	26.65	31.6	21.46
2006	26.6	31.37	21.61
2007	24.49	28.48	20.32
2008	23.74	26.83	20.52
2009	23.6	26.12	20.98
2010	24.85	29.54	19.95
2011	22.49	25.69	19.15
2012	21.89	24.25	19.42
2013	22.55	24.79	20.21
2014	21.15	23.34	18.86
2015	22.4	26.39	18.22
2016	23.7	28.37	18.82
2017	22.8	26.85	18.55
2018	23.15	27.23	18.89
2019	23.55	27.54	19.37
2020	22.95	25.68	20.09
2021	21.49	24.27	18.59
2022	12.71	14.66	10.67
2023	13.07	13.41	12.72

Table 2
Congenital respiratory malformation-related crude mortality rate per 100,000 infants;
overall and stratified by race, 1999–2023.

Year	Asian or Pacific Islander	Black or African American	White	Hispanic
1999	20.66	35.87	26.78	26.46
2000	22.79	39.52	28.6	30.09
2001	14.96	35.84	25.59	25.58
2002	18.34	36.76	25.64	26.41
2003	24.29	34.29	26.28	25.2
2004	12.95	38.4	25.7	26.5
2005	22.98	35.74	23.69	27.4
2006	15.25	35.49	25.69	24.18
2007	15.07	31.19	23.7	23.79
2008	16.8	27.28	23.54	23.01
2009	14.53	29.26	23.29	21.7
2010	13.28	32.77	23.86	23.71
2011	9.52	30.15	21.22	22.68
2012	15.25	28.43	20.78	20.4
2013	9.34	28.84	22.23	21.28
2014	16.47	26.97	20.08	20.43
2015	15.46	28.78	20.6	22.75
2016	10.12	37.53	22.01	21.07
2017	14.87	31.52	20.87	22.51
2018	15.73	29.4	21.21	24.02
2019	23.52	33.25	20.99	22.17
2020	13.08	28.65	22.59	22.16
2021	10.52	30.8	20.68	21.54
2022	unreliable	17.84	11.77	12.93
2023	unreliable	17.5	13.04	12.85

Table 6
Congenital respiratory
malformation-related
crude mortality rate per
100,000 infants; stratified
by urban versus rural
areas, 1999–2020.

Year	Urban	Rural
1999	26.3	23.58
2000	27.6	31.26
2001	24.6	24.71
2002	24.86	26.32
2003	24.51	28.81
2004	24.89	28.03
2005	24.14	26.91
2006	24.63	23.81
2007	22.48	22.72
2008	21.71	22.21
2009	21.69	21.25
2010	23.27	20.14
2011	20.28	22.32
2012	19.35	23.77
2013	19.86	25.22
2014	18.84	21.9
2015	20.04	23.13
2016	21.28	24.48
2017	21.02	19.78
2018	21.01	22.12
2019	21.09	24.25
2020	20.75	22.12

Discussion

This study identified key epidemiologic trends in mortality rates relating to congenital malformations of the respiratory tract during 1999 to 2023. Congenital respiratory defects contributed to an overall greater infant mortality rate for males when compared to females; however, males experienced a steeper decline in CMRs in comparison to females. When examining the racial differences, congenital respiratory tract anomalies revealed substantial disparities in mortality outcomes. Black or African American infants experienced the highest rates of mortality compared to other racial categories throughout this study period. Whereas Asian or Pacific Islander infants had the lowest rates. Regional analysis revealed minimal differences in mortality rates overall, despite the Northeast region showing the greatest decline from 1999 to 2023. Similarly, both rural and urban mortality rates resulted in an overall decrease in mortality. However, rural areas exhibited higher mortality rates across all years, with the rate of decline occurring more rapidly than in urban areas. Collectively, these findings highlight persistent inequities in healthcare access, quality of neonatal care, and availability of specialized medical resources across populations—factors that may contribute to the observed disparities in outcomes.

Previous literature demonstrates male infants having a higher mortality rate related to congenital respiratory system malformations when compared to female infants (Townsel et al., 2017). One proposed explanation of this is the protective effect of estrogen on pulmonary maturation (Adamson et al., 1990). Consistent with these findings, our study observed that a greater proportion of male infants died due to congenital respiratory defects in comparison to female infants (58.8% vs. 41.2%, respectively). Our research expands upon evidence with the inclusion of more recent years, identifying notable declines in APC from 2020 to 2023 (-22.28% in male infants and -16.77% in female infants). This substantial decline can be explained by several different factors, including advancements in prenatal screenings and improved “Golden Hour” management—the critical first 60 minutes after birth where immediate stabilization, airway management, and respiratory support are provided (Lamray et al., 2023). Recent advancements, such as the use of neonatal transport teams and improved ventilation strategies, likely contributed to the improved survival outcomes observed (Wild et al., 2025).

The impact of racial disparities on health outcomes, particularly in Black or African American patients, has been reported in existing research (Tsoi et al., 2025). Our data reinforces this pattern, showing that Black or African American infants experienced the highest CMR throughout the study period. It is important to acknowledge, however, that mortality rates for these patients are declining by -1.07 APC from 1999 to 2021. These findings likely reflect structural inequities. Differences in access to high-quality prenatal care, earlier detection of congenital anomalies through advanced imaging, maternal comorbidities, insurance status, delivery at lower-resource hospitals, and limited access to subspecialty neonatal surgical teams may all contribute to the observed mortality gap. Additionally, systemic factors, such as implicit bias and geographic clustering of high-level perinatal centers, may further exacerbate these disparities. Notably, our study demonstrated that Asian or Pacific Islander infants had the lowest mortality rates consistently throughout the study period. By examining congenital pulmonary malformations from an epidemiological perspective, this study offers an opportunity for further investigation into potential causes for the lower mortality rates observed in the Asian or Pacific Islander race.

The effect of geographic variability (rural vs urban) on mortality rates of infants with congenital malformations of the respiratory tract has not yet been clearly elucidated in the literature. Our research demonstrates that mortality rates are declining in both rural and urban zones during the study period. Furthermore, infants in rural areas experienced higher mortality rates compared to urban regions, which aligns with overall infant mortality rate trends from 2021–2023 (Ely, 2025). This may reflect limited access to maternal–fetal medicine specialists, neonatologists, pediatric surgeons, and advanced respiratory support technologies in rural hospitals. Longer transport times to tertiary care centers, delayed surgical intervention, and fewer high-level NICUs in rural regions may also directly impact outcomes in infants with congenital respiratory tract anomalies. Additionally, lifestyle and social factors may contribute to rural areas' higher infant mortality rates. Higher rates of maternal smoking, limited access to consistent prenatal care, transportation barriers to specialty services, lower socioeconomic status, reduced insurance coverage, and environmental exposures such as agricultural pollutants may increase both the incidence and severity of congenital respiratory conditions. Further research could be done to establish or improve community programs to reduce the effects of social determinants of health on infant mortality rates.

Conclusions

Infant mortality related to congenital malformations of the respiratory system in the United States declined substantially between the period of 1999 and 2023. The mortality rates were found to be disproportionately higher for male infants, Black or African American infants, and those living in rural areas—despite downward trends across all subgroups. Regional analyses showed broadly similar declines in mortality in all four Census regions. These findings suggest that advances in perinatal and neonatal care, as well as prenatal screening, have resulted in improved survival. However, these advances have benefits that are unequally distributed across demographic and geographic subgroups. Targeted efforts to enhance access to specialized perinatal services, address structural and social determinants of health, and improve care delivery in high-risk communities are needed to further reduce mortality and narrow persistent inequities in outcomes for infants with congenital respiratory malformations.

Limitations

This study is subject to several limitations due to the use of a large, administrative mortality database. First, reliance on ICD-10 codes may lead to misclassification or underreporting of congenital respiratory malformations, particularly when conditions are complex, overlapping, or incompletely documented. Second, CDC mortality data may underrepresent contributing causes of death, as death certificates often list a single underlying cause and may omit important comorbidities, which can bias interpretation of cause-specific mortality patterns. Finally, as a retrospective analysis, this study cannot establish causal relationships or fully adjust for individual-level clinical factors, socioeconomic status, or healthcare access.

Declarations

Author Contribution

J.P and S.B. wrote the main manuscript text and prepared each figure and table. L.P., V.M., and A.T. edited the manuscript. All authors reviewed the manuscript.

Data Availability

The data utilized in this study originated from the publicly available CDC WONDER database.

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Figures

Sex Crude Rate of Infant Mortality Related to Congenital Malformations of the Respiratory System

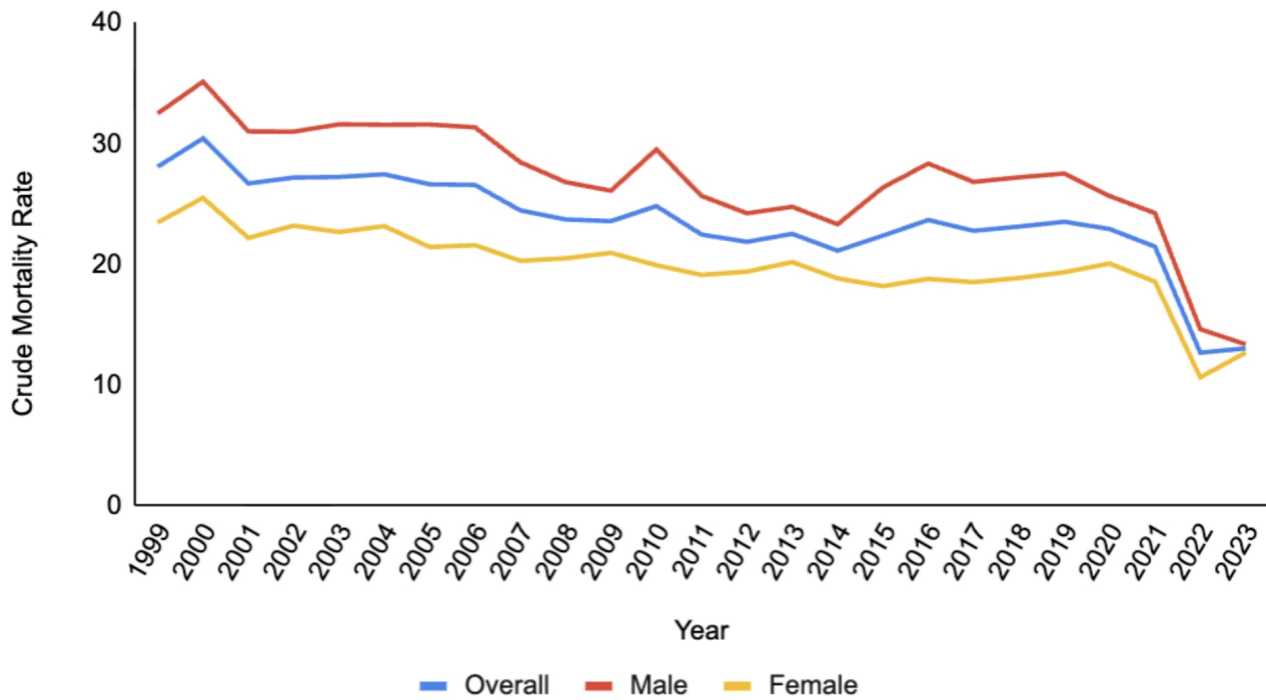


Figure 1

Congenital respiratory malformation-related crude mortality rate per 100,000 infants; overall and stratified by sex, 1999-2023.

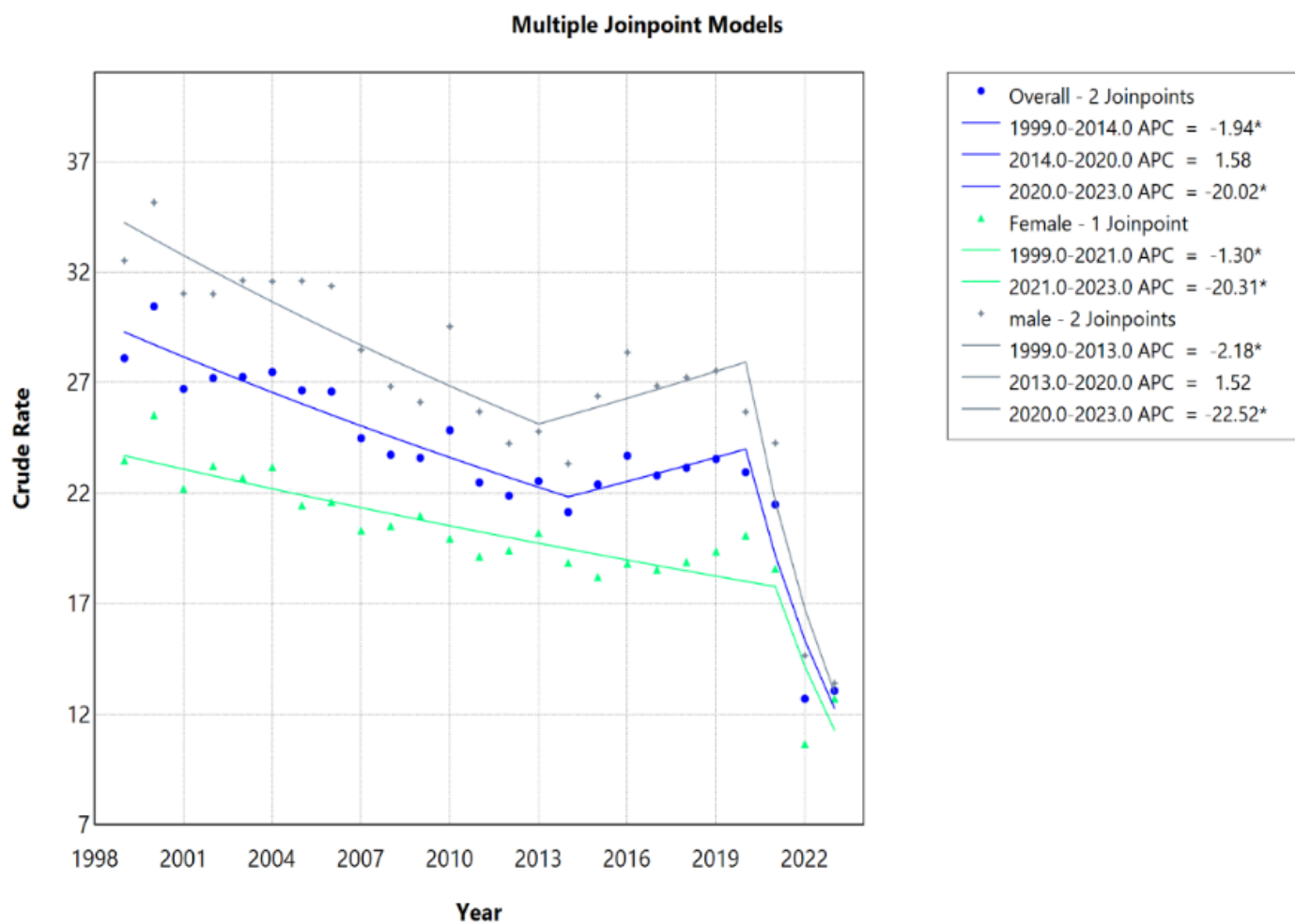


Figure 2

Congenital respiratory malformation-related crude mortality rate per 100,000 infants overall and stratified by sex, 1999-2023 (*indicates the APC is statistically significant).

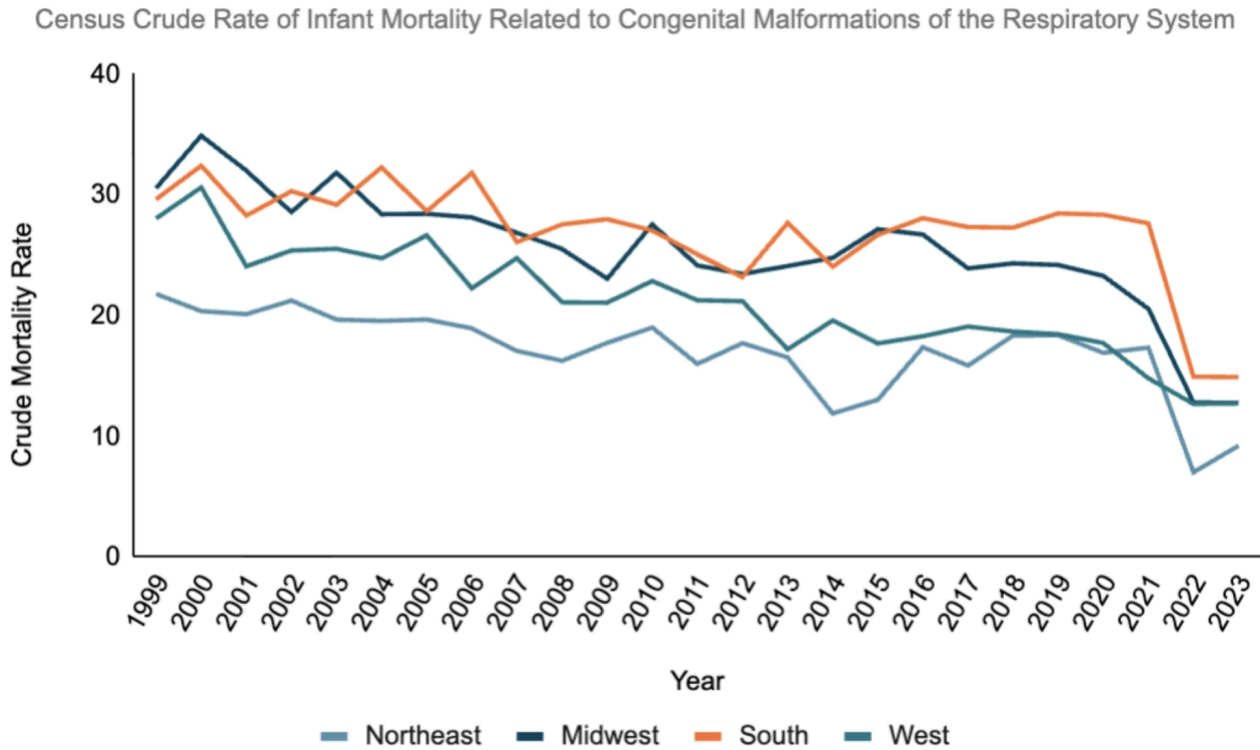


Figure 3

Congenital respiratory malformations-related crude mortality rate per 100,000 infants; overall and stratified by census region, 1999-2023.

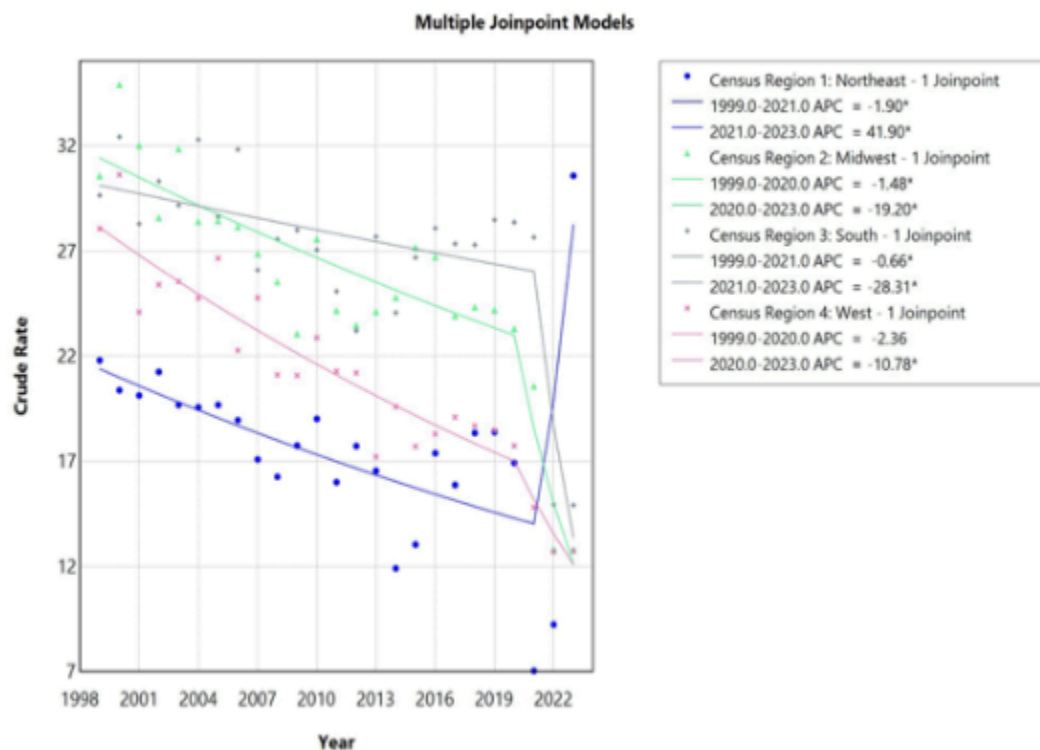


Figure 4

Congenital respiratory malformation-related crude mortality rate per 100,000 infants stratified by census region, 1999-2023 (*indicates the APC is statistically significant).