Clinical research

Trends in pediatric sudden cardiac death-related mortality in the United States from 1999 to 2020: a nationwide CDC WONDER analysis

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Abstract

Introduction: Sudden cardiac death (SCD) in children is rare but devastating, often affecting previously healthy children. Unlike adults, pediatric SCD results from a wide spectrum of uncommon and heterogeneous conditions. Despite recent advancements in understanding and prevention strategies, national data on long-term mortality trends remain limited.

Material and methods: We analyzed death certificate data from the CDC WONDER database from 1999 to 2020 for SCD-related mortality in individuals aged 0 to 14 years. Age-adjusted mortality rates (AAMRs) per 100,000, with 95% confidence intervals (CIs) and annual percentage changes (APCs) with 95% CIs, were calculated, stratified by year, sex, race, state, urbanization, and census region.

Results: From 1999 until 2020, 30,675 pediatric SCD-related deaths occurred. The AAMR declined from 2.8 per 100,000 population in 1999 to 2.5 (APC = –6.0%, 95% CI: –10.8 to –0.9) in 2001 and further to 2.0 in 2020 (APC = –1.0%, 95% CI: –1.2 to –0.8). AAMRs were consistently higher in males than in females (1999: 3.2 vs. 2.4; 2020: 2.1 vs. 2.0). When stratified by race, non-Hispanic (NH) Black children had the highest AAMRs. Rates declined in all U.S. regions, with the highest rates observed in the Northeast (3.5 to 1.9) and the lowest in the Midwest (1.7 to 1.2). State-level rate disparities were marked, ranging from 4.9 in Mississippi to as low as 1.1 in Maine, Maryland, and Wisconsin.

Conclusions: Despite overall declines in SCD-related mortality, significant disparities persist across sex, race, region, and urbanization.

Key words: sociodemographic disparities, pediatric mortality, United States population health, epidemiology, state-level disparities.

Introduction

Death that occurs within one hour of the onset of symptoms is referred to as sudden cardiac death (SCD). A cardiovascular or unexplained

cause can lead to this condition. The interval between symptom onset and mortality is often very short, providing limited opportunity for resuscitation interventions [1]. While SCD is a leading cause of mortality in adults, with an incidence of 3.72 deaths per 1000 individuals, its prevalence in the pediatric population is low, approximately 0.49 deaths per 100,000 individuals [2, 3]. Despite the lower incidence compared to adults, SCD in children is a devastating event, and the trends in mortality and underlying mechanisms remain underexplored.

Ischemic heart disease is universally acknowledged as the leading cause of SCD in adults. However, the confounding factors influencing childhood SCD vary among anatomical, mechanical, and functional disorders. Congenital cardiac disease, inherited cardiomyopathies, myocarditis, and primary electrical disorders, such as long QT syndrome, catecholaminergic polymorphic ventricular tachycardia, and Brugada syndrome, constitute major underlying pathologies [4–6]. Despite progress in understanding the etiology, a significant number of cases remain unexplained due to the multifactorial nature of SCD in children and the lack of well-documented postmortem data [7, 8]. Although these studies have offered insights into the possible etiologies and risk factors, they are limited in epidemiological patterns and national mortality trends. Consequently, this is an important area for further research.

Furthermore, significant disparities in pediatric cardiovascular health outcomes influenced by factors such as sex, race/ethnicity, socioeconomic position, and geography are well documented. These disparities are clinically important as statistics demonstrate an elevated SCD risk among male children and certain racial/ethnic groups [9, 10]. Despite this evidence, no significant efforts have been made to understand the potential links between these disparities and current preventive measures. In light of these gaps, we assessed national trends in SCD-related mortality among the U.S. pediatric population from birth through 14 years of age between 1999 to 2020, using data from the Centers for Disease Control and Prevention Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER) database. This analysis examines demographic and temporal trends in this population, which could guide targeted preventive interventions and strategies.

Material and methods

Population and study setting

This descriptive study analyzed death certificate records from 1999 to 2020, obtained by utilizing the CDC WONDER database [11]. The study population included individuals aged 14 years and younger, with underlying or multiple causes of death attributed to SCD. SCD was identified using International Classification of Diseases, Tenth Revision (ICD-10) codes I46.0 (Cardiac arrest with successful resuscitation), I46.1 (Sudden cardiac death, so described), and I46.9 (Cardiac arrest, unspecified). These codes have been employed in prior studies using the CDC WONDER database to reliably capture SCD-related mortality [12]. Mortality data included all 50 U.S. states and the District of Columbia. As the dataset is publicly available and de-identified, institutional review board (IRB) approval was not required. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [13].

Data abstraction

Mortality data stratified by year of death, age, sex, race, state of residence, census region, and urbanization status, as well as place of death (medical facility, home, hospice, nursing home/long-term care, or other), were extracted. Race/ethnicity was categorized as non-Hispanic (NH) White, NH Black or African American, NH Asian, NH Pacific Islander, NH American Indian or Alaska Native, and Hispanic or Latino. Urbanization status was classified according to the 2013 National Center for Health Statistics (NCHS) Urban-Rural Classification Scheme, with areas classified into metropolitan areas (large central metropolitan, large fringe metropolitan, medium metropolitan, and small metropolitan) and nonmetropolitan areas (micropolitan and noncore) [14]. Geographic regions were categorized into Northeast, Midwest, South, and West, in accordance with U.S. Census Bureau definitions [15].

Statistical analysis

Age-adjusted mortality rates (AAMRs) per 100,000 population were calculated for the period 1999-2020. Rates were derived using the direct method of standardization to the 2000 U.S. standard population to account for differences in age distribution over time. AAMRs were stratified by sex, race/ethnicity, census region, urbanization, and place of death with corresponding 95% confidence intervals (CIs). Annual percentage changes (APCs) and their 95% CIs were computed using the Joinpoint Regression Program (version 5.0.2; National Cancer Institute) to assess temporal trends in AAMRs [16]. Log-linear regression models with joinpoints were applied to identify statistically significant changes in trends over time. APCs were classified as increasing or decreasing based on

whether the slope significantly differed from zero, determined by a 2-tailed *t*-test, and a *p*-value of ≤ 0.05 was considered significant.

Results

From 1999 to 2020, a total of 30,675 sudden cardiac arrest-related deaths were recorded among the U.S. pediatric population (birth to 14 years of age), of which 16,778 (54.7%) were male and 13,897 (45.3%) were female. By race/ethnicity, NH Whites accounted for 20,838 deaths, 7,726 in NH Blacks or African Americans, 1,648 among NH Asian or Pacific Islanders, 463 among NH American Indian or Alaska Natives, and Hispanic/Latinos accounted for 7,619 deaths (Table I). The location of death was available for 30,055 individuals. The majority of deaths occurred in medical facilities (85.94%), with 74.66% being inpatients, 23.52% outpatients or emergency room cases, and 1.80% dead on arrival. This was followed by 12.75% of deaths occurring at home, 0.97% in nursing homes, and 0.34% in hospice care.

Annual trends for pediatric sudden cardiac arrest-associated AAMR

The AAMR for sudden cardiac arrest-associated deaths declined from 2.8 per 100,000 population in 1999 to 2.0 in 2020. From 1999 to 2001, the AAMR declined significantly from 2.8 to 2.5 (APC = –6.0; 95% CI: –10.8 to –0.9). This was followed by another significant decrease from 2001 to 2020, with the AAMR reaching 2.0 (APC = –1.0; 95% CI: –1.2 to –0.8) (Table II).

Pediatric sudden cardiac arrest-associated AAMR stratified by sex

Among males, the AAMR declined significantly from 3.2 in 1999 to 2.6 in 2001 (APC = –7.5; 95% CI: –13.5 to –1.2). This was followed by a further significant decline from 2001 to 2020, with the AAMR reaching as low as 2.1 (APC = –1.2; 95% CI: –1.4 to –0.9) (Table II). Among females, the AAMR demonstrated a significant decline from 2.4 in 1999 to 1.9 in 2012 (APC = –1.1; 95% CI:

Table I. Sudden cardiac arrest-related deaths, stratified by sex and race, in the pediatric population (0-14 years) in the United States, 1999 to 2020

Year	Death	Female	Male	NH White	NH Black or African American	NH Asian or Pacific Island er	NH Amencan Indian or Alaska Native	Hispanic or Latino	Population
1999	1672	699	973	1179	399	75	19	339	59955368
2000	1518	670	848	1070	372	64	12	323	60253375
2001	1505	692	813	1062	330	84	29	332	60450257
2002	1526	654	872	1060	381	68	17	326	60563030
2003	1480	672	808	1039	354	67	20	401	60628650
2004	1480	690	790	1019	350	87	24	368	60651802
2005	1437	629	808	1019	323	74	21	362	60519046
2006	1426	625	801	982	349	79	16	378	60516709
2007	1445	638	807	976	384	71	14	344	60681615
2008	1422	626	796	964	359	76	23	375	60907384
2009	1440	703	737	981	355	77	27	379	61087581
2010	1356	587	769	918	347	63	28	354	61227213
2011	1371	617	754	962	313	72	24	365	61201106
2012	1304	585	719	904	306	70	24	367	61144098
2013	1381	632	749	920	346	93	22	341	61089123
2014	1279	585	694	834	356	70	19	322	61067955
2015	1313	595	718	873	337	87	16	338	61016787
2016	1319	632	687	862	354	76	27	324	60975069
2017	1273	595	678	828	338	83	24	325	61021552
2018	1266	608	658	801	372	77	16	322	60885444
2019	1266	607	659	808	364	72	22	315	60570846
2020	1196	556	640	777	337	63	19	319	60293426
Total	30675	13897	16778	20838	7726	1648	463	7619	1336707436

NH – non Hispanic.

Table II. Overall and sex-stratified sudden cardiac arrest–related age-adjusted mortality rates per 10,000 in pediatric population in the United States, 1999 to 2020

Year	Age-adjusted rate (95% CI)		
	Men	Women	Overall
1999	12 (3–3.4)	2.4 (2.2–2.5)	2.8 (2.6–2.9)
2000	2.7 (2.6–2.9)	2.3 (2.1–2.5)	2.6 (2.4–2.7)
2001	2.6 (2.4–2.8)	2.3 (2.1–2.4)	2.5 (2.3–2.6)
2002	2.8 (2.6 – 3)	2.2 (2–2.4)	2.5 (2.4–2.6)
2003	2.6 (2.4–2.8)	2.2 (2.1–2.4)	2.4 (2.3–2.6)
2004	2.5 (2.3–2.7)	2.3 (2.1–2.5)	2.4 (2.3–2.5)
2005	2.6 (2.4–2.8)	2.1 (1.9–2.2)	2.3 (2.2–2.4)
2006	2.5 (2.4–2.7)	2.1 (1.9–2.3)	2.3 (2.2–2.4)
2007	2.5 (2.4–2.7)	2.1 (1.9–2.2)	2.3 (2.2–2.4)
2008	2.5 (2.3–2.7)	2 (1.9–2.2)	2.3 (22–2.4)
2009	2.3 (2.1–2.5)	2.3 (2.2–2.5)	2.3 (2.2–2.4)
2010	2.4 (2.3–2.6)	2 (1.8–2.2)	2.2 (2.1–2.3)
2011	2.4 (2.2–2.6)	2 (1.9–2.2)	2.2 (2.1–2.3)
2012	2.3 (2.2–2.5)	1.9 (1.8–2.1)	2.1 (2–2.2)
2013	2.4 (2.2–2.6)	2.1 (2–2.3)	2.2 (2.1–2.3)
2014	2.2 (2.1–2.4)	2 (1.8–2.1)	2.1 (2–2.2)
2015	2.3 (2.1–2.4)	2 (1.8–2.2)	2.2 (2–2.3)
2016	2.2 (2–2.4)	2.1 (2–2.3)	2.1 (2–2.2)
2017	2.2 (2–2.3)	2 (1.9–2.2)	2.1 (2–2.2)
2018	2.2 (2–2.3)	2 (1.9–2.2)	2 (1.9–2.2)
2019	2.1 (2–2.3)	2.1 (1.9–2.2)	2.1 (2–2.2)
2020	2.1 (1.9–2.3)	1.9 (1.7–2.1)	2 (1.9–2.1)

–1.7 to v0.5). This was followed by a steady but nonsignificant AAMR from 2012 to 2020, with minor fluctuations over the years but ultimately returning to 1.9 in 2020 (APC = 0.05; 95% CI: –1.3 to 1.4) (Table II).

Pediatric sudden cardiac arrest-associated AAMR stratified by race

Among NH White individuals, the AAMR for SCD-associated deaths decreased nonsignificantly from 2.5 in 1999 to 2.2 in 2001 (APC = –5.1; 95% CI: –11.3 to 1.5). This was followed by a significant decline from 2001 to 2020, reaching 1.8 (APC = –1.2; 95% CI: –1.4 to –0.9). Among NH Blacks or African Americans, the AAMR declined significantly from 4.1 in 1999 to 2.9 in 2012 (APC = –1.5%; 95% CI: –2.3 to –0.6). This was followed by a non-significant decrease from 2012 to 2020, with the AAMR reaching 3.3 (APC = 1.1; 95% CI: –0.8 to 3.1). Among Hispanics or Latinos, the AAMR declined significantly from 3.1 in 1999 to 2.0 in 2018 (APC = –2.0; 95% CI: –2.4 to –1.5). This was followed by a non–significant increase from 2018 to 2020, with the AAMR rising slightly to 2.1 (APC = 1.2; 95% CI: –12.7 to 17.4). Among NH American Indian or Alaska Native individuals, the AAMR declined slightly from 2.5 in 1999 to 1.7 in 2006 (APC = –3.3; 95% CI: –11.7 to 6.0), though this change was not statistically significant. From 2006 to 2020, the AAMR decreased to 1.6, but this decline was also not significant (APC = –0.6; 95% CI: –3.5 to 2.3). Among NH Asian or Pacific Islanders, the AAMR decreased from 3 in 1999 to 2 in 2018 (APC = –1.7; 95% CI: –2.6 to –0.8). A subsequent decrease was observed from 2018 to 2020, with the AAMR reaching 1.5; however, the change remained non-significant (APC = –9.6; 95% CI: –36.6 to 28.8).

Pediatric sudden cardiac arrest associated AAMR stratified by geographic region

State

Age-adjusted mortality rate varied across the states from 1999 to 2020, ranging from as low as 1.1 in Maine (95% CI: 0.9–1.5), Maryland (95% CI: 1–1.3) and Wisconsin (95% CI: 0.9–1.2), to a high of 4.9 (95% CI: 4.5–5.3) in Mississippi. States in the top 90th percentile include Mississippi (4.9), Alabama (4.2), New York (3.9), California (3.6), and Georgia (3.5), with rates nearly three times high-

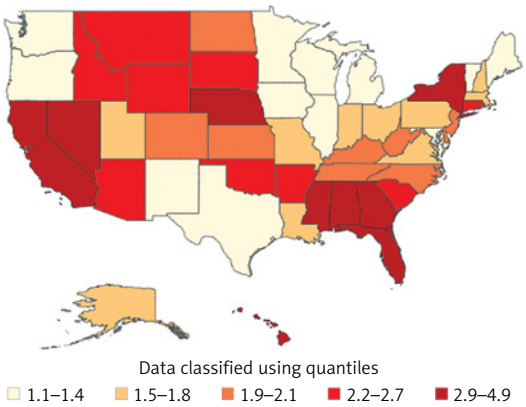

Figure 1. Sudden cardiac death-related AAMRs per 100,000 stratified by state in the pediatric population in the United States, 1999 to 2020

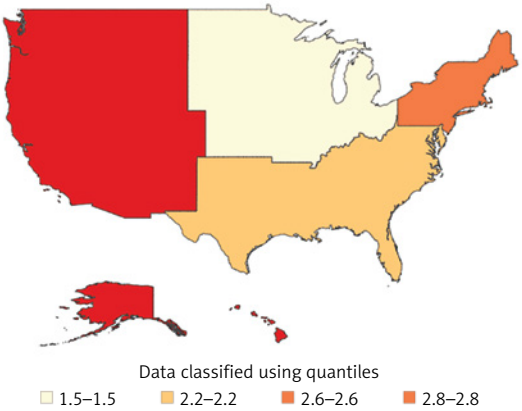

Figure 2. Sudden cardiac death-related AAMRs per 100,000 stratified by census region in the pediatric population in the United States, 1999 to 2020

er than states in the 10th percentile Maine (1.1), Maryland (1.1), Wisconsin (1.1), Michigan (1.2), Vermont (1.2) (Figure 1).

Census region

Pediatric populations across U.S. census regions exhibited distinct patterns in age–adjusted mortality rates due to SCD from 1999 to 2020. In the Northeast, the AAMR declined from 3.5 (95% CI: 3.1–3.8) in 1999 to 2.1 (95% CI: 1.8–2.4) in 2020. In the Midwest, the AAMR remained unchanged at 1.7 (95% CI: 1.5–1.9) from 1999 to 2020, despite minor fluctuations observed in the intervening years. The South showed a reduction from 2.7 (95% CI: 2.5–2.9) in 1999 to 2 (95% CI: 1.8–2.2) in 2020. In the West, the AAMR fell from 3.4 (95% CI: 3.1–3.7) in 1999 to 2.3 (95% CI: 2–2.5) in 2020 (Figure 2, Table I).

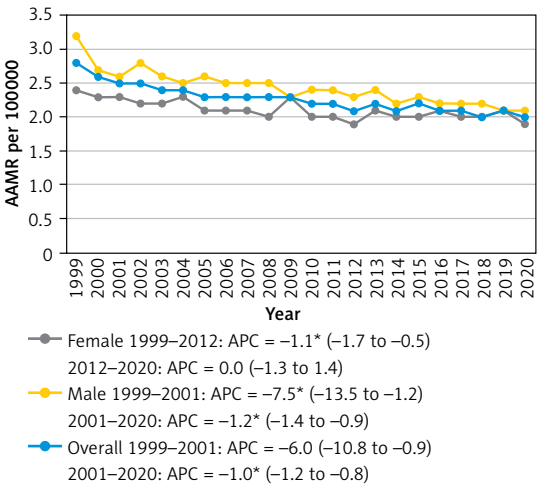

Figure 3. Overall and sex-stratified sudden cardiac death-related AAMRs per 100,000 in the pediatric population in the United States, 1999 to 2020.

Urban–rural status

Among micropolitan areas, the AAMR for SCD-associated deaths decreased from 2.8 in 1999 to 2.2 in 2001 (APC = –7.0; 95% CI: –26.0 to 16.9), which was not statistically significant. From 2001 to 2020, the AAMR further declined to 2.0 (APC = –0.5; 95% CI: –1.3 to 0.2), indicating a slight but statistically non-significant decrease over time. Non-core rural areas experienced a significant decline in AAMR from 3.5 in 1999 to 2.3 in 2003 (APC = –7.2; 95% CI: –13.6 to –0.3). This was followed by a decline to 2.1 in 2020 (APC = –0.08; 95% CI:–1.0 to 0.9), suggesting a meaningful reduction in mortality, but this was not statistically significant.

In large central metropolitan areas, the AAMR decreased non-significantly from 3.3 in 1999 to 2.9 in 2001 (APC = –5.8; 95% CI: –15.0 to 4.2). Between 2001 and 2004, the AAMR rose to 3.1, but the increase was not statistically significant (APC = 0.7; 95% CI: –9.4 to 12.1). However, after 2004, the AAMR showed a significant downward trend, declining to 2.1 in 2020 (APC = –1.9; 95% CI: –2.4 to –1.4). Large fringe metropolitan areas saw a steady non–significant decline in AAMR from 2.1 in 1999 to 1.7 in 2004 (APC = –3.3; 95% CI: –6.8 to 0.1). A reversal was observed from 2004 to 2008, with the rate increasing to 2.1 (APC = 1.7; 95% CI: –6.7 to 11.0). However, the rise was not statistically significant. From 2008 to 2020, there was a significant downward trend, with the AAMR reaching 1.6 in 2020 (APC = –1.2; 95% CI: –2.3 to –0.2). In medium metro areas, the AAMR declined from 2.9 in 1999 to 2.0 in 2015 (APC = –1.5; 95% CI: –2.3 to –0.7), which was statistically significant. From 2015 to 2020, a non–significant increase was observed (APC = 2.2; 95% CI: –2.1 to 6.8), with the AAMR reaching 2.2. Small metropolitan areas saw a nonsignificant decline in AAMR from 2.1 in 1999 to 1.8 in 2002 (APC = –6.2; 95% CI: –16.8 to 5.7),

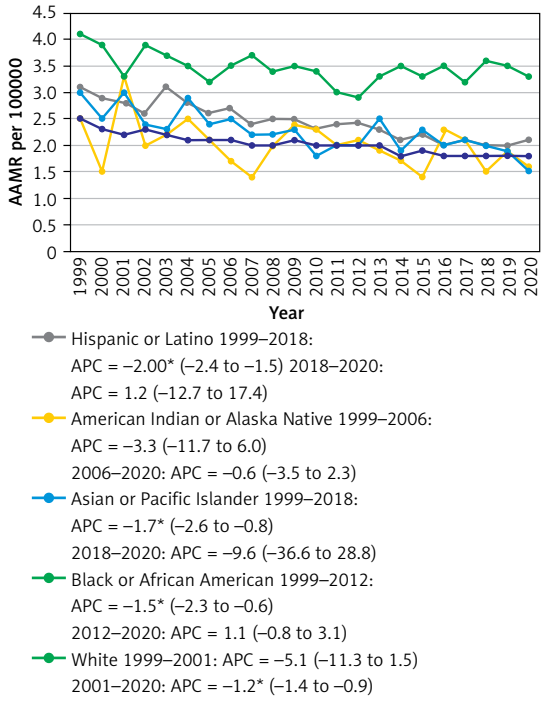

Figure 4. Sudden cardiac death-related AAMRs per 100,000 stratified by race in the pediatric population in the AAMR per 100000

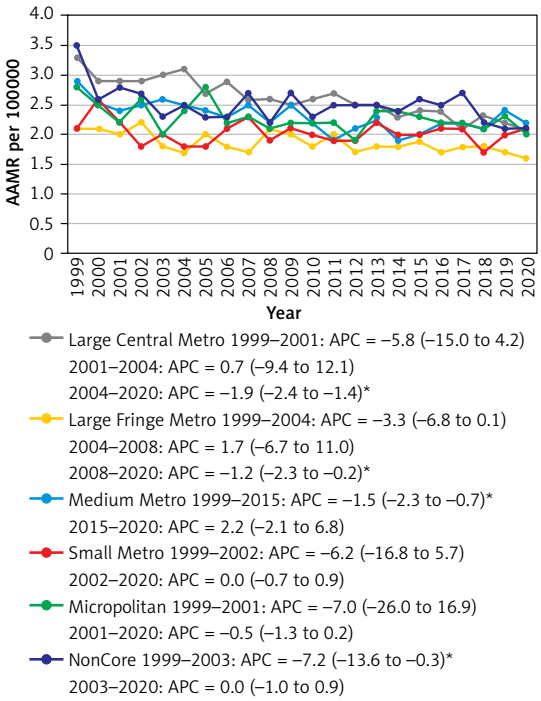

Figure 5. Sudden cardiac death-related AAMRs per 100,000 stratified by urbanization in the pediatric population in the United States, 1999 to 2020

followed by a non–significant increase to 2.1 in 2020 (APC = 0.07; 95% CI: –0.7 to 0.9) (Table I).

Discussion

Our analysis of SCD-related mortality in children aged 14 and younger showed that AAMR declined by approximately 29% from 1999 to 2020. This decline was observed across strata defined by sex, race, and urbanization, although several interesting epidemiological trends were observed (Figures 3–5).

SCD-related mortality was 9.4% higher in males than in females, with a significant decline in AAMR among males (a 34% reduction) compared to a 20% reduction among females over the study period. Notably, the AAMR among females did not change significantly after 2012. Previous studies have explored the incidence and etiology of SCD in broader age categories, such as 1 to 35 or 15 to 35 years, and have defined these as "younger" populations [7, 17]. Specific studies in the pediatric age group of infancy to 14 years are sparse, and the precise cardiac pathologies contributing to death are not well characterized. However, available population-based studies suggest that congenital heart disease predominates in infants, while cardiomyopathies and arrhythmia syndromes are more prominent in older children [4, 18]. A population-based analysis by Chugh *et al.* showed that 76% of sudden cardiac arrests (SCA) occurred in children aged < 1 year, with at least 90% of these deaths also meeting the criteria for sudden infant death syndrome (SIDS) [4]. Autopsies performed on infants with sudden death either met SIDS criteria or identified congenital heart defects, such as an interrupted aortic arch, aortic stenosis, or a ventricular septal defect. The study also showed that in children > 1 year old, autopsies revealed pre-existing structural or congenital cardiac abnormalities, such as Ebstein anomaly with Wolff-Parkinson-White syndrome and hypertrophic cardiomyopathy [4].

Another Denmark-based retrospective study showed that 49% of the autopsied sudden death cases in the pediatric population had potentially inherited cardiac disorders, with myocarditis accounting for 13% of all autopsied SCD cases [18]. These data suggest that structural anomalies may be among the potential underlying causes of SCD in our study population. Furthermore, a retrospective study done in Canada also offered interesting insights into another possible underlying etiology. A large number of autopsies in children of this age group were negative for any structural heart disease, which raised the possibility of inherited arrhythmia syndromes, particularly channelopathies [19]. Indeed, a study conducted by Kanter *et al.* at Duke University Medical Center showed that infants who presented with ventricular arrhythmias and had no structural cardiac pathologies had either a sodium channel or a calcium channel mu-

tation [20]. Moreover, a molecular autopsy-based study of autopsy-negative SCD cases by Tester *et al.* discovered mutations causing heart rhythm disorders in children less than 5 years of age [21]. These studies support an association between channelopathies and SCD in children.

An interesting trend was noted in our analysis when stratified by race. The highest number of SCD-related deaths was recorded in the NH White population. This trend contrasts with the well-documented higher burden of SIDS and out-of-hospital cardiac arrests (OHCAs) reported among NH Black children in prior studies [9, 22]. These studies show that Black children have a higher incidence of OHCAs than White children (15.5 vs. 3.8 per 100,000) as well as consistently higher rates of sudden unexplained infant deaths (SUIDs). The contrasting trend in our analysis likely reflects our specific case definition, which included only deaths assigned a cardiac cause code (ICD-10 I46) and excluded SUID/SIDS and other ill-defined causes. While our dataset focuses on cardiac-coded pediatric deaths, the literature indicates that sudden deaths in Black infants are disproportionately classified under SUID/SIDS or undetermined codes. For instance, Black infants have SUID/SIDS rates more than twice those of NH White infants [23]. In one local study, African American infants had significantly higher rates of undetermined causes of death compared to non-African American infants [24]. These disparities may reflect differences in classification practices, which may contribute to under-identification of underlying cardiac causes in death-certificate data. In addition, the larger underlying U.S. pediatric NH White population may contribute to higher absolute numbers of deaths, despite potentially similar or higher race-specific incidence in other groups [25].

When stratified by urbanization, pediatric SCD mortality was higher in urban areas (large central metro) compared to rural areas. Urban-rural differences in SCD among children have not been extensively studied, but a few studies have shed light on possible explanations for these disparities. As discussed earlier, the classification of death in infants as SCD is based on autopsy findings and postmortem genetic testing. Prior literature indicates that rural jurisdictions have significantly lower autopsy and molecular testing rates, which can hinder accurate classification of cardiac causes [26]. Conversely, urban areas benefit from more thorough death investigation methods, which may lead to more accurate classification of causes of death and may partly explain the higher SCD reported in these areas [27]. Additionally, variable socioeconomic conditions and disparities in certifier training contribute to under-classification of SCD in rural regions, with death certificates more likely to use ill-defined or nonspecific codes in those settings [28].

This study has several limitations inherent to the use of the CDC WONDER database. First, the reliance on death certificates and ICD-10 coding may result in misclassification or underreporting of SCD in the pediatric population. Sudden cardiac events may be inaccurately classified as broader or nonspecific causes such as "cardiac arrest" or "unknown etiology", potentially obscuring the true burden of SCD. Second, the database lacks access to clinical details that are critical in determining the exact cause of death, including autopsy findings, family history of inherited cardiac conditions, electrocardiographic abnormalities, or structural heart defects noted in imaging. This can limit our ability to distinguish between various etiologies of pediatric SCD, such as channelopathies, cardiomyopathies, or congenital heart disease. Third, CDC WONDER does not differentiate between witnessed and unwitnessed deaths, nor does it provide data on the circumstances surrounding the event (e.g., exertion, sleep, or trauma), which may be relevant to the classification and interpretation of sudden cardiac deaths. In addition, comorbid conditions that may contribute to mortality, such as epilepsy, substance use, or respiratory disorders, are not always reliably documented or linked to the primary cause of death. This limitation affects the ability to control for confounding variables in trend analyses. Lastly, while the study period includes a few years affected by the coronavirus disease 2019 (COVID-19) pandemic, the data do not allow for accurate quantification of its specific impact on pediatric SCD rates. This is due to the absence of direct indicators of COVID-19 infection status or its cardiac complications in individual death records. Despite these limitations, the study's strength lies in its use of a large, national population-based dataset via the CDC WONDER database and a prolonged observation period, which provides valuable context for understanding the evolving epidemiology of SCD.

In conclusion, despite a decline in pediatric SCD mortality from 1999 to 2020, disparities across sex, race, and urbanization persist. The highest AAMRs were observed in males and NH Black individuals. By level of urbanization, large central metropolitan areas exhibited higher mortality rates than rural areas. These disparities highlight the need for increased use of molecular testing in sudden death cases to support more standardized classification of causes of death across the country. Improved classification and death certification may facilitate a better understanding of the epidemiology of pediatric SCD and inform future approaches to risk stratification, early detection, and targeted interventions in this population.

Availability of data and materials

The data that support the findings of this study are openly available in the CDC WONDER database at https://wonder.cdc.gov/. Supplementary Tables SI-SVIII and Supplementary Figure S1 are available as Supplementary Tables and Figures.

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Ethical approval

This study was based on a secondary analysis of publicly available, de-identified data from the CDC WONDER database. As such, it did not involve human subjects research as defined by federal regulations and did not require review or approval by an Institutional Review Board (IRB). The analysis was conducted in accordance with all applicable guidelines and regulations.

Conflict of interest

The authors declare no conflict of interest.

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