

Global, regional, and national characteristics and incidence of sudden death from 1948 to 2022: a systematic review and modelling study

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Background Sudden death (SD) poses great health and social challenges worldwide. There are a few studies investigating the epidemiological characteristics and disease burden of SD globally. The study aimed to assess the epidemiological characteristics and global burden of SD in different population and regional groups, and to determine the incidence of SD and its influencing factors.

Methods We conducted a systematic review and spatiotemporal analysis to estimate global, regional, and national SD incidence. A comprehensive search was conducted across four databases, including PubMed, Embase, the Cochrane Library and Web of Science, between 1 July 2003 and 30 June 2023. The included studies reported the incidence of SD in the general population of a country or region, or provided data on which the incidence could be calculated. We utilised a Bayesian hierarchical linear mixed model to estimate global, regional, and national SD incidence and to describe the characteristics.

Results Our search identified 9797 records, with 108 studies meeting our inclusion criteria. The incidence of SD was significantly different among super-regions. South Asia was estimated to have the highest incidence for 4.01 cases (95% confidence interval (CI)=1.40, 7.51) per 100 000 person-years on a log-transformed basis, followed by South East Asia, East Asia, and Oceania. Among them, Guyana showed the highest estimated incidence of 5.06 cases (95% CI=2.78, 8.20) per 100 000 person-years, followed by India of 4.89 cases (95% CI=2.08, 7.76) per 100 000. Sub-Saharan Africa had the lowest estimated incidence, at 1.79 cases (95% CI=-1.83, 3.98) per 100 000 person-years. The temporal trends in SD incidence rates exhibited remarkable heterogeneity across regions. The downward trend was most pronounced in high-income countries, while Sub-Saharan Africa maintained a stable high incidence rate. Conversely, Latin America and the Caribbean exhibited continuous growth, with the Andean sub-region showing the most striking trend. Risk factors associated with SD include diabetes, hypertension, hyperlipidaemia, and heart disease.

Conclusions This study provides a comprehensive assessment of the global incidence of SD. The findings emphasise the need for targeted strategies to effectively reduce the burden of SD

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Sudden death (SD) is widely defined as an unexpected death occurring within one hour or within 24 hours in the absence of witnesses [1]. Generally, SD is categorised into traumatic and non-traumatic subtypes, with sudden cardiac death (SCD) representing the predominant aetiology of non-traumatic SD [2]. The World Health Organization (WHO) reported that cardiovascular diseases (CVD) remain a major threat to global health, accounting for approximately 17 million annual deaths world-

wide [3]. Contemporary research has quantified the SCD incidence across diverse populations in multinational studies. Notably, SCD accounts for 40–50% of CVD mortality, representing approximately 3.7 million deaths each year [4]. These findings not only reveal the current severity of SD but also underscore its significance as a critical global public health challenge.

In recent decades, there have been remarkable changes in the epidemiology and disease spectrum of CVD. From 1990 to 2019, global CVD cases increased significantly, with annual mortality rising from 12.1 million (95% uncertainty interval=11.4, 12.6 million) to 18.6 million deaths [4]. In contrast, another research demonstrated that the age-adjusted mortality rate of heart disease has declined in some developed regions, such as Japan, Australia, and New Zealand [5]. The burden of SCD is particularly pronounced in North America and Europe, affecting an estimated 50 to 1000 individuals per 100 000 annually. The epidemiological characteristics of SCD are strongly influenced by age, gender, genetic predisposition, and environmental factors [6,7]. For instance, studies have demonstrated the significant international variations in age-standardised mortality rates of CVD, particularly before the age 80–84 years, where the incidence and mortality rates among males are three times higher than those for females [8,9]. Although CVD mortality has declined in high-income countries and some middle-income countries, no clear changes have yet been observed in certain low- and middle-income regions. Limited healthcare resources and prevalent risk factors like hypertension, obesity, and smoking further exacerbate the burden of SD, leading to persistently high incidence rates [10,11]. This situation imposes substantial pressure on healthcare systems, which increases the financial burden on families and society as a whole [10]. Although existing studies have described the regional epidemiology and disease burden of SD, comprehensive investigations examining the full spectrum of SD and its global disease burden remain limited. Therefore, an in-depth investigation into the global epidemiology of SD and its impact on public health and socioeconomic factors is urgently warranted.

At present, epidemiological data on SD are mainly confined to specific countries and regions worldwide, lacking a systematic and comprehensive assessment. Although SD has received increasing attention, existing studies have mainly focused on regions such as Europe, South Asia, and the USA. Information on other regions, especially low- and middle-income countries, remains scarce [12]. Furthermore, existing studies are relatively scattered, which limits a comprehensive understanding of the global trends and characteristics of SD. There is an urgent need for further research into the global and regional epidemiology of SD to alleviate the social burden of premature mortality caused by the disease [12].

Therefore, we aimed to conduct a systematic assessment of the epidemiological characteristics and disease burden of SD across countries and regions worldwide. The main objective was to comprehensively investigate the demographic characteristics, spatiotemporal distribution, and temporal trends of SD, considering dimensions such as age, gender, economic status, and socio-cultural factors, and to conduct a multidimensional comparison of SD incidence and disease burden across population groups and regions. Overall, we aimed to provide scientific evidence for the effective formulation of public health policies and targeted preventive measures. We anticipate that this research will draw broader attention to the disease burden associated with SD and promote the implementation of effective interventions to reduce CVD mortality, thereby enhancing overall population health.

METHODS

Search strategy and selection criteria

We followed the PRISMA guidelines for conducting systematic reviews [13]. We conducted a comprehensive analysis to assess the epidemiology of SD and trends in disease burden at national, regional, and global levels. We systematically searched PubMed, Embase, Cochrane Library, and Web of Science, with the search period ranging from 1 July 2003 to 30 June 2023. The included lit-

erature was limited to English-language papers. We used free text keywords and thesaurus terms ‘sudden death,’ ‘epidemiology,’ ‘prevalence,’ ‘incidence,’ and ‘mortality’ to search for relevant literature (Table S1 in the [Online Supplementary Document](#)).

Two independent reviewers (CBX and SXL) applied the pre-established inclusion criteria to screen titles and abstracts, with any discrepancies resolved through discussion with a third researcher. Included studies were required to report SD cases, along with epidemiological and disease-burden data. Eligible study participants were required to meet the WHO definition of SD – death occurring within 24 hours of symptom onset [14]. We excluded non-human studies and those lacking specific SD population data.

We employed Rayyan (Rayyan Systems, Inc., Cambridge, Massachusetts, USA), a systematic review tool, to eliminate duplicate studies and to conduct a rigorous screening of titles and abstracts and full texts to ensure that only the most relevant studies were included [15]. Three authors (PSX, HXQ, and WXM) evaluated full texts. The eligible papers were evaluated strictly against the inclusion and exclusion criteria, and those that met them were selected for data extraction. Each step of the study selection process and the reasons for exclusion were documented. For studies with multiple publications or duplicates, only the most recent reports with comprehensive results were retained. This study was registered with the International Prospective Register of Systematic Reviews under registration number CRD42023432992 (Table S2 in the [Online Supplementary Document](#)).

Data extraction and quality assessment

Five authors (PSX, HXQ, WXM, CBX, and SXL) independently completed the data extraction using a pre-designed table. We extracted relevant information on demographic characteristics from the included studies, and study results were converted into a standardised data extraction format. The gathered data items encompassed general information (publication year, geographical location, lead author’s name, journal title, and the digital object identifier), characteristics of target population (sample size, age, gender, SD year, season, race, body mass index (BMI), marital status, occupation, and SD family history), disease incidence and outcomes (cause of SD, state before SD, and relevant risk factors). To minimise bias, our team resolved disagreements by discussing with senior researchers.

We assessed all included studies for risk of bias using three independent Joanna Briggs Institute critical appraisal tools tailored to cross-sectional, case-control, and cohort studies, respectively [16]. The studies were categorised as high, moderate, and low risk of bias based on the overall quality of study design, methodology, and reporting of results. The results of the systematic assessment did not involve pooling estimates through a meta-analysis. For incidence, target population characteristics, and outcome, we systematically combined qualitative and descriptive statistical analyses.

Data analysis

The primary outcome variable reported in this study was the incidence of SD, expressed as per 100 000 person-years. Descriptive summaries of the incidence rates of SD were either directly reported in the original studies or derived through our calculations. Specifically, we extracted the incidence rates and corresponding 95% confidence intervals (CIs) directly from the original studies, when available. For studies that did not report 95% CIs, we derived estimates using established statistical modelling techniques. Specifically, we constructed our estimates by utilising the available SD counts and corresponding person-years at risk. When data could not be extracted directly from the original studies, we utilised the WebPlotDigitizer tool (Automeris LLC, Austin, Texas, USA) to extract the relevant data points from the published graphs. The research results are stratified by country to facilitate detailed comparative assessments. Additionally, when the study data were available, we applied a random-effects model using the DerSimonian-Laird estimator for between-study variance, with variance correction implemented via the Hartung-Knapp-Sidik-

Jonkman method, to summarise the incidence rates across different periods for temporal trend analysis [17]. Therefore, based on the midpoint year of each case collection period, we divided the research into five time periods: 1971–1980, 1981–1990, 1991–2000, 2001–2010, and 2011–2022.

We implemented a Bayesian hierarchical linear mixed model to estimate the incidence of SD at the super-region, region, and country levels. The model enables clear descriptions of spatial patterns, time trends, and local trends for each country [18]. The spatial random effect term in the model captures regional variation through a conditional autoregressive prior and assesses spatial heterogeneity using comprehensive ecological data at the regional level, with disease risk factors incorporated as standardised spatial covariates [18]. In the Bayesian hierarchical model, the log-transformed incidence of SD was used as the outcome variable to satisfy the basic assumption of linearity. Following previous studies [19], we classified countries using the Global Burden of Disease classification system [20], grouping 185 countries into 21 regions, which were further grouped into seven super-regions (Table S4 in the [Online Supplementary Document](#)). The classification followed the spatial-geographic structure and income levels across countries and regions. Differences in the distribution across age groups, data sources, incidence estimates, diagnostic methods, and other factors may contribute to substantial heterogeneity in predictions of global SD incidence. Consequently, the Bayesian computational framework included four random effects (global, super-regional, regional, and national) and three fixed effects: age stratification (infant, children, adult and overall), population density, and whether all SD patients in a study underwent autopsies (yes or no) [19]. We obtained population density data for each country in 2020 from the WorldPop database (WorldPop, University of Southampton, Southampton, UK), with a spatial resolution of 1×1 km and treated them as a continuous variable.

With respect to the selection of studies, we intended to choose those with the latest data on the relevant variables and then select studies that provided the most comprehensive data on those variables. Specifically, studies with identical study areas, study periods, study populations, and age groups were included only once to avoid duplication of data sources. Geographic clustering of countries and regions was accounted for in our model to estimate the incidence of SD in countries with missing data. This suggests that the estimates of incidence depend on evidence borrowed from higher levels in this model. Briefly, when specific national data were unavailable, we utilised regional estimates; when corresponding regional data were unavailable, we resorted to super-regional estimates. Notably, both regional and super-regional incidence rates were estimated from national-level studies, indicating that no regional or super-regional studies were conducted. It should be noted that super-regional estimates differ from regional estimates within a super-region that encompasses only one region, as the super-regional estimates serve as the initial values for deriving regional estimates.

The statistical model employed to estimate the incidence of SD utilised Bayesian inference and sampled from the posterior distributions of the parameters using the Hamiltonian Markov Chain Monte Carlo framework [21]. The model was run with four chains, each undergoing 2000 iterations to ensure sampling robustness. We generated posterior predictions for each country-age group combination, uniformity of autopsy across study populations, and population density, providing incidence estimates expressed as proportions with 95% CIs [19]. To determine the national burden of individuals affected by SD, we multiplied the country-specific incidence estimates by the corresponding population sizes, using the demographic framework published by the United Nations in 2022. The adequacy of the model fit was rigorously appraised through an assessment of diagnostics pertinent to the effective sample size, autocorrelation, and trace plots, ensuring the reliability of our inferential process (Figures S4 and S5 in the [Online Supplementary Document](#)).

We performed all spatial analyses using ArcGIS, version 10.8 (Esri Inc, Redlands, California, USA). We conducted all statistical analyses using R, version 4.2.0 (R Core Team, Vienna, Austria) and the package ‘RStanArm’ (Stan Development Team, New York, New York, USA). Statistical tests were two-sided, with statistical significance defined as a P -value < 0.05 .

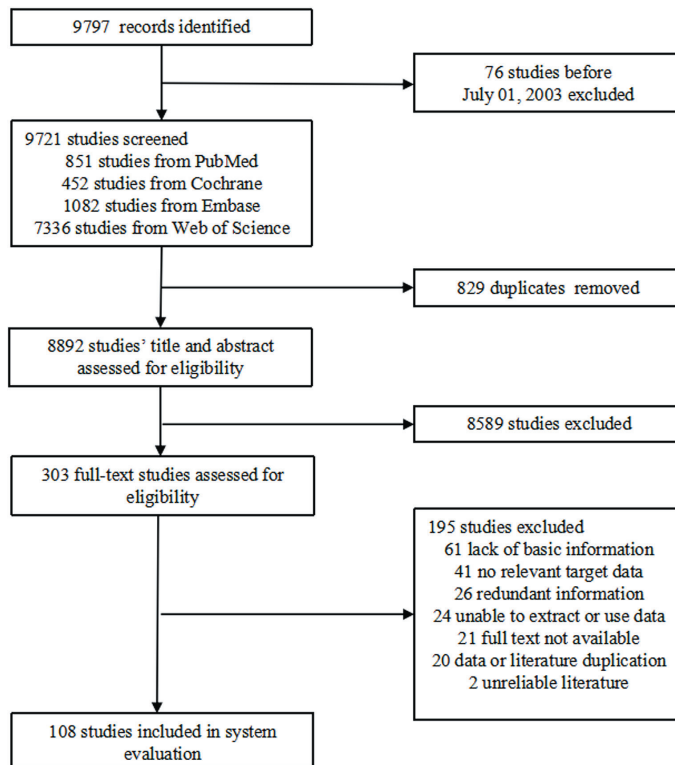


Figure 1. PRISMA diaphragm of study selection.

RESULTS

We identified 9797 potential studies after searching the four main databases regarding SD. Among these, we excluded 76 because of date-related reasons, and 829 were duplicate studies. According to the eligibility criteria, we further excluded 8589 studies. Subsequently, 195 studies failed to meet the inclusion and exclusion criteria for the following reasons, including: a lack of basic information ($n=61$), presenting all irrelevant data ($n=41$), redundant information ($n=26$), data unable to extract or use ($n=24$), unavailable full text ($n=21$), duplicated data or literature ($n=20$), and unreliable literature ($n=2$). Finally, we included 108 studies in evaluation (Figure 1).

We conducted a comprehensive analysis of 108 English-language literature sources published between 1 July 2003 and 30 June 2023. The majority of the included studies were categorised as having low to moderate risk of bias ($n/N=98/108$) (Table S8 in the [Online Supplementary Document](#)). The pooled data from these studies showed a total of approximately 201 549 cases of SD, with 61 341

cases attributed to SCD (Figure S1 and Table S10 in the [Online Supplementary Document](#)). The geographical distribution of these studies was widespread, encompassing 30 countries across six continents including Europe with 15 countries, Asia with seven, Africa with three, North America with two, Oceania with two, and South America with one, respectively. Notably, the majority of the studies originated from North America ($n=29$), followed by Australia ($n=9$), UK ($n=8$), China ($n=7$), and Spain ($n=6$) (Table S4 in the [Online Supplementary Document](#)). The temporal scope of the data extended from 1948 to 2022, with the majority of the studies conducted between the years 2000 and 2009 and carried out in high-income regions, which constituted 82.40% of the total, contrasting with a solitary study from a low-income region, Cameroon. In terms of study duration, more than half of the studies were of shorter duration, ranging from 0–14 years, with specific breakdowns as follows: 0–4 years ($n=26$; 24.07%), 5–9 years ($n=24$; 22.22%), and 10–14 years ($n=23$; 21.30%). Most of the studies were designed as cohort studies. The majority of the studies reviewed were published during the period from 2013 to 2017 ($n=46$; 42.59%), succeeded by research conducted between 2018 and 2023 ($n=33$; 30.56%) (Table S5 in the [Online Supplementary Document](#)).

Among the cases of SD reviewed, demographic features showed significant heterogeneity. Specifically, the proportion of SD was distinctly higher among whites (54.83%) and married individuals (50.70%). Moreover, in accordance with China's 2015 occupational classification, SD cases were disproportionately concentrated among professional technicians (20.52%) and manufacturing personnel (25.84%) (Table 1).

Cardiovascular system diseases account for the majority of SD cases, with a higher proportion of 93.6%. Additionally, respiratory system diseases also account for a substantial proportion of SD cases. The main contributor of SCD was coronary artery disease, which accounted for more than half of the cases. Subsequent causes included cardiomyopathies and arrhythmias, with comparable proportions. A considerable proportion of individuals experience SD during sleep or exercise. Discrepancies in age and gender were also apparent, with individuals aged 50–59 years and males representing a larger proportion of cases, contrasting with the relatively smaller proportion observed in the 4–14 years age group. Diabetes, hypertension, hyperlipidaemia, and

Table 1. Summary of demographic characteristics of sudden death (SD) included in the systematic assessment*

Demographic characteristics	n (%)	Demographic characteristics	n (%)
Sex (n=103 362)		<i>Third</i>	354 (12.81)
<i>Male</i>	56 191 (54.36)	<i>Fourth</i>	395 (14.30)
<i>Female</i>	47 171 (45.64)	<i>Fifth</i>	0
Age group in years (n=108)		<i>Sixth</i>	714 (25.84)
<i>0–3</i>	23 (21.30)	<i>Seventh</i>	200 (7.24)
<i>4–14</i>	25 (23.15)	<i>Eighth</i>	407 (14.73)
<i>15–49</i>	47 (43.52)	State before death (n=8550)	
<i>50–59</i>	4 (3.70)	<i>Sleeping</i>	2224 (26.01)
<i>60–69</i>	5 (4.63)	<i>Working</i>	263 (3.08)
<i>≥70</i>	1 (0.93)	<i>Exercise</i>	1981 (23.17)
<i>Not sure</i>	3 (2.78)	<i>Rage</i>	528 (6.18)
Race (n=49 284)		<i>Daily activities</i>	675 (7.89)
<i>White</i>	27 021 (54.83)	<i>Relax</i>	708 (8.28)
<i>Yellow</i>	9703 (19.69)	<i>Drinking</i>	43 (0.50)
<i>Black</i>	7465 (15.15)	<i>Medical treatment</i>	91 (1.06)
<i>Others</i>	5095 (10.34)	<i>Driving</i>	45 (0.53)
BMI in kg/m ² (n=2366)		<i>Others</i>	1992 (23.30)
<i>>25.0 (overweight)</i>	1685 (71.22)	Season (n=11 915)	
<i>>30.0 (obesity)</i>	681 (28.78)	<i>Spring</i>	2666 (22.38)
Marital status (n=71)		<i>Summer</i>	2304 (19.34)
<i>Married</i>	36 (50.70)	<i>Autumn</i>	2869 (24.08)
<i>Single</i>	17 (23.94)	<i>Winter</i>	4076 (34.21)
<i>Others</i>	18 (25.35)	Family history of SD (n=667)	
Occupation category (n=2763)†		<i>Yes</i>	551 (82.61)
<i>First</i>	126 (4.56)	<i>No</i>	24 (3.60)
<i>Second</i>	567 (20.52)	<i>Not sure</i>	92 (13.79)

BMI – body mass index, SD – sudden death

*The total number of SD cases included in the systematic assessment was 201 549.

†Occupational classification standard: The first category encompasses public service and administrative personnel. The second category comprises professional and technical personnel. The third category pertains to clerical and administrative support workers, who provide organisational support. The fourth category involves service workers. The fifth category consists of agricultural, forestry, and fishing workers. The sixth category includes manufacturing and production workers. The seventh category is military personnel. The eighth category comprises other workers who do not fit neatly into the aforementioned classifications.

heart disease were important risk factors in the majority of SD cases, with hypertension being particularly prevalent, affecting nearly one-third of the cases. Concurrently, the results showed that obesity and smoking were also major factors contributing to SD (**Figure 2**; **Figure S2** in the **Online Supplementary Document**).

Based on the extracted incidence rate data of SD in 21 regions worldwide, we stratified the SD rates by time period based on the midpoint of each study cycle. The results showed substantial fluctuations in global SD incidence. The incidence of SD peaked at 233.8 cases (95% CI=210.74, 258.04) per 100 000 person-years during 1971–1980, then sharply declined to 4.83 (95% CI=4.61, 5.04) per 100 000 person-years during 1981–1990. From 1991 to 2010, global SD incidence rates stabilised at 20.57 (1991–2000) and 18.39 (2001–2010) before dropping to the lowest recorded level in 2011–2020 with 7.39 (95% CI=2.19, 15.63) per 100 000 person-years (**Figure S3** and **Table S6** in the **Online Supplementary Document**). According to Havmoeller [22], the incidence rate among the USA population was 58.00 cases (95% CI=54.75, 61.44) per 100 000 person-years from 2002 to 2005. Two studies investigated incidence rate of SD in children population aged between two and 17 years reported at 0.3 cases (95% CI=0.20, 0.50) per 100 000 person-years from 1986 to 2011 [23], while the incidence rate from 2007 to 2013 exhibited a rise, reaching 0.99 cases (95% CI=0.78, 1.26) per 100 000 person-years [24]. Conversely, the incidence of SD noted 13.00 cases (95% CI=10.90, 15.50) per 100 000 person-years from 1977 to 2001 in adult [25], escalating to 15.44 cases (95% CI=13.86, 17.21) per 100 000 person-years from 2011 to 2013

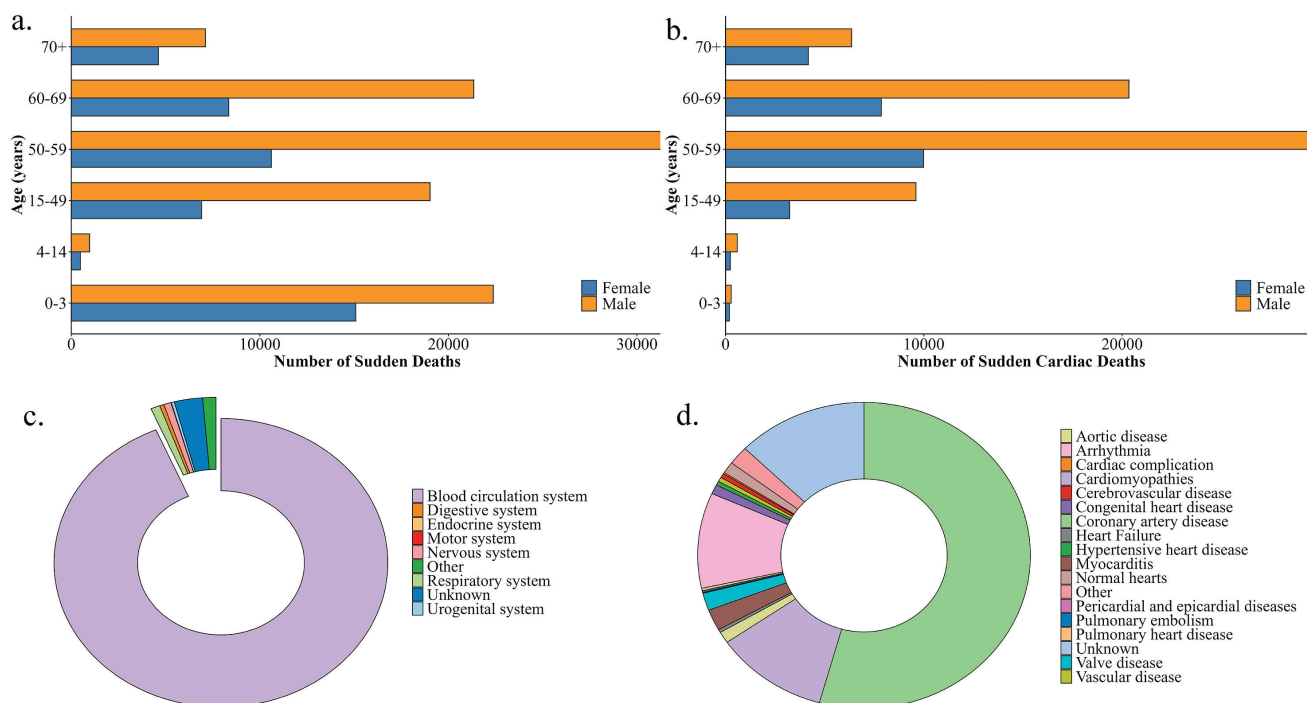


Figure 2. Distribution and causes of sudden death (SD) stratified by age, sex, disease category. **Panel A.** SD quantitative distribution by age and gender. **Panel B.** Sudden cardiac deaths (SCD) quantitative distribution by age and gender. **Panel C.** Causes of SD stratified by organ systems. **Panel D.** Causes of SCD stratified by specific disease.

[26]. In addition, a compelling study undertaken in Denmark highlighted that the incidence among children from 2000 to 2006 was reported at 1.47 cases (95% CI=1.21, 1.77) per 100 000 person-years [27], (Table 2) whereas the total population incidence reached 8.60 cases (95% CI=8.00, 9.20) per 100 000 person-years from 2000 to 2009 [36], thereby indicating a rising trend in overall incidence rates within the general population, with adult incidence rates surpassing those of their younger counterparts. Moreover, it is particularly that Rao's research indicated the incidence rate of total population in India soared to 761.31 cases (95% CI=654.28, 885.3) per 100 000 person-years in 2010 [37], while concurrently, Germany was reported 81.00 cases (95% CI=76.54, 85.72) per 100 000 person-years from 2002 to 2009 [40], which further underscores the alarming incidence of SD across various global contexts (Table 2; Table S9 in the Online Supplementary Document).

In 108 included studies, we identified a subset of 10 studies specifically addressing sudden infant death syndrome (SIDS), which accounted for 69 096 cases. The majority of these studies were conducted in Europe and the Americas, highlighting the regional focus within the research landscape. It was noteworthy that the proportion of SIDS appears to be evenly distributed among males and females, with the majority of cases occurring within zero to one years (Table 3). The recorded incidence rates of SIDS vary significantly across regions. Chang *et al.* reported the population incidence was recorded 71.22 cases (95% CI=69.48, 73.00) per 100 000 person-years from 1989 to 2008 in the USA [52], which was broadly comparable with the reports of Hakeem *et al.* (64.45 cases per 100 000 person-years) [56] and Bartick *et al.* (91.31 cases per 100 000 person-years) [60]. However, this was in stark contrast to the incidence of SIDS reported by Malloy *et al.* (43.56 cases per 100 000 person-years) [54] and Drake *et al.* (106.18 cases per 100 000 person-years) [58]. The incidence of SIDS varied over time within the same country. Unexpectedly, the incidence of SIDS in France from 2000 to 2017 was 12.75 cases (95% CI=10.69, 15.19) per 100 000 person-years, as reported by Tuchtan *et al.* [57]. Based on incidence data extracted from the literature, the difference in SIDS incidence between male and female infants in the United States is not statistically significant (Table S12 in the Online Supplementary Document).

Table 2. Comparative incidence rates and characteristics of sudden death (SD) across children, adults, and overall populations in the included studies

Study	Study period and country	Age of the population in years	SD	Incidence rate per 100 000 person-years (95% CI)		
				Total	Male	Female
Children						
Maron et al., 2012 [23]	1986–2011, USA	12–18	17	0.30 (0.20, 0.50)*	0.50 (0.30, 0.90)*	0
Winkel et al., 2013 [27]	2000–2006, Denmark	1–18	87	1.47 (1.21, 1.77)*†	NA	NA
Harmon et al., 2016 [24]	2007–2013, USA	14–18	69	0.99 (0.78, 1.26)*†	1.45 (1.12, 1.89)*†	0.32 (0.15, 0.62)*†
Adult						
Eckart et al., 2004 [25]	1977–2001, USA	NA	126	13.00 (10.90, 15.50)*	13.30 (11.00, 16.00)*	11.50 (7.00, 18.90)*
Niemeijer et al., 2015 [28]	1990–2010, Netherlands	≥45	583	422.64 (389.41, 458.65)*†	513.43 (455.87, 578.1)*†	363.61 (324.47, 407.39)*†
Kim et al., 2016 [26]	2011–2013, USA	≥18	336	15.44 (13.86, 17.21)*†	21 (18.43, 23.92)*†	9.66 (7.92, 11.77)*†
Feng et al., 2016 [29]	1997–2010, Australia	35–84	8077	58.45 (57.19, 59.74)*†	82.67 (80.54, 84.85)*†	34.44 (33.08, 35.86)*†
Bonny et al., 2017 [30]	2013, Cameroon	≥18	135	1.63 (1.37, 1.92)*	1.87 (1.57, 2.21)*	0.30 (0.51, 1.00)*
Shuvy et al., 2019 [31]	2003–2014, Canada	35–74	36 334	49.11 (48.61, 49.62)*†	75.27 (74.38, 76.17)*†	23.98 (23.49, 24.48)*†
Park et al., 2020 [32]	2002–2015, USA	≥20	197	39.86 (37.77, 42.06)*†	47.54 (44.39, 50.92)*†	31.59 (28.94, 34.48)*†
Overall						
Tabib et al., 2003 [33]	1980–1999, France	1–65	200	4.82 (4.61, 5.05)*†	NA	NA
Moore et al., 2005 [34]	2003–2004, UK	NA	300	19.88 (17.73, 22.30)*†	NA	NA
Byrne et al., 2008 [35]	2005, Ireland	0–80	212	51.17 (44.62, 58.67)*†	76.42 (65.24, 89.47)*†	25.38 (19.14, 33.55)*†
Fragkouli et al., 2010 [36]	1998–2008, Greece	1–80	688	32.22 (30.47, 34.07)*†	NA	NA
Rao et al., 2010 [37]	2010, India	≤90	173	761.31 (654.28, 885.3)*†	NA	NA
Havmoeller et al., 2012 [22]	2002–2005, USA	0–85	1175	58.00 (54.75, 61.44)*†	70.00 (65.00, 75.37)*†	45.00 (41.03, 49.35)*†
Pilmer et al., 2013 [38]	2005–2009, Canada	1–19	116	0.78 (0.64, 0.93)*	1.01 (0.8, 1.27)*†	0.54 (0.39, 0.75)*†
Hofer et al., 2014 [39]	2000–2007, Switzerland	5–39	40	1.71*‡	2.73*‡	0.69*‡
Martens et al., 2014 [40]	2002–2009, Germany	0–90	1212	81.00 (76.54, 85.72)*†	55 (51.37, 58.89)*†	25 (22.56, 27.70)
Braggion-Santos et al., 2015 [41]	2006–2010, Brazil	10–80	899	29.97 (28.05, 32.01)*†	NA	NA
Zheng et al., 2015 [8]	2007–2013, China	0–111	879	1.26 (1.18, 1.34)*	14.83*	1.26*
Zhao et al., 2016 [42]	1997–2012, Seychelles	0–97	484	32.88 (30.05, 35.98)*†	NA	NA
Bagnall et al., 2016 [43]	2010–2012, Australia	1–35	490	1.30 (1.20, 1.40)*†	1.80 (1.62, 2.00)*†	0.70 (0.59, 0.83)*†
Risgaard et al., 2016 [44]	2000–2009, Denmark	1–49	1575	8.60 (8.00, 9.20)*	NA	NA
Ifteni et al., 2017 [45]	2001–2015, Romania	0–89	1085	18.08 (17.03, 19.20)*†	NA	NA
Wisten et al., 2016 [46]	2000–2010, Sweden	1–35	552	1.29 (1.18, 1.40)*†	NA	NA
Belhaj et al., 2023 [47]	2010–2019, Tunisia	NA	2385	2.15 (2.06, 2.24)*†	NA	NA
Frontera et al., 2022 [48]	2010–2015, Italy	1–35	301	0.24 (0.13, 0.45)*	0.40*‡	0.10*‡
Růcklová et al., 2022 [49]	2014–2019, Czech Republic	1–40	245	2.44 (2.15, 2.77)*†	3.20*‡	0.80*‡
Işın et al., 2021 [50]	2011–2019, Turkey	10–59	118	0.41*‡	NA	NA
Ripoll-Vera et al., 2021 [51]	2015–2019, Spain	0–50	123	5.8*‡	10.10*‡	1.60*

CI – confidence interval, NA – not available, SD – sudden death

*Value reported from the study.

†CI estimated and added by the authors as it was not present in the original study.

‡It was not possible to calculate the confidence interval due to a lack of raw data.

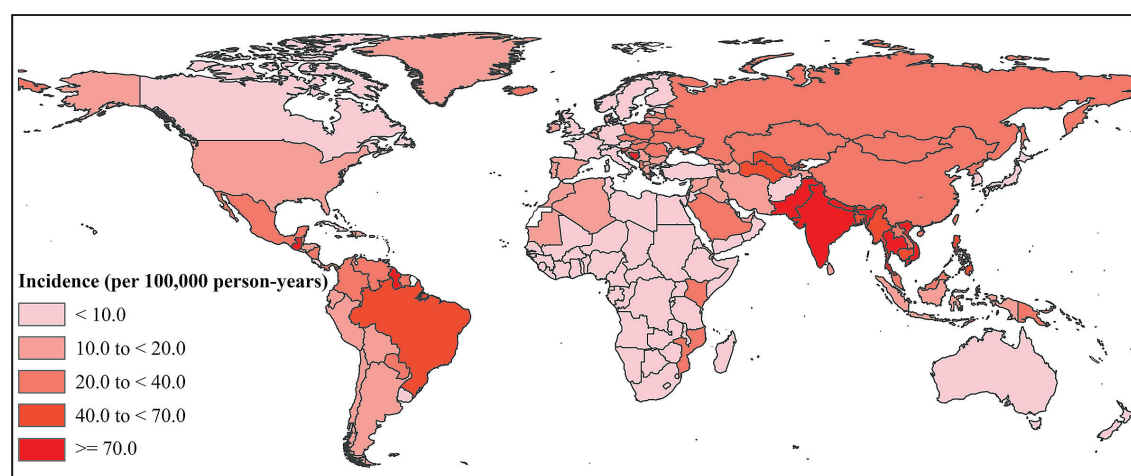
Table 3. The characteristics and epidemiological data of sudden infant death syndrome (SIDS) in the studies included

Study	Study period	Continent	Country	Incidence rate (per 100 000 person-years)	Age in years	Male, n (%)	Race, n				Total cases, n*
							White	Yellow	Black	Other	
Chang <i>et al.</i> , 2008 [52]	1998–2004	North America	USA	71.22	0–1	3872 (61.43)	4626	454	1222	0	6303
Liebrechts <i>et al.</i> , 2013 [53]	1984–2005	Europe	Netherlands	18.00	0–1	110 (58.82)	NR	NR	NR	NR	187
Malloy <i>et al.</i> , 2013 [54]	2005–2007	North America	USA	43.56	2–3.5	3111 (59.79)	2856	932	1415	0	5203
Evans <i>et al.</i> , 2013 [55]	2000–2010	Oceania	Australia	NR	0–1	138 (61.06)	NR	NR	NR	NR	226
Hakeem <i>et al.</i> , 2015 [56]	1995–2004	North America	USA	64.45	0–1	14 300 (59.33)	NR	NR	NR	NR	24 101
Tuchtan <i>et al.</i> , 2019 [57]	2000–2017	Europe	France	12.75	0–2	80 (61.54)	NR	NR	NR	NR	130
Drake <i>et al.</i> , 2019 [58]	2004–2013	North America	USA	106.18	0–1	421 (57.51)	403	19	310	0	732
Mitchell <i>et al.</i> , 2023 [59]	2012–2018	Oceania	New Zealand	63.87	0–1	137 (51.31)	0	267	0	0	267
Bartick <i>et al.</i> , 2022 [60]	2015–2018	North America	USA	91.31	0–1	NR	7656	416	3870	0	11 942
Anderson <i>et al.</i> , 2022 [61]	2006–2015	North America	USA	NR	0–1	NR	7134	NR	NR	5010	20 005

NR – not reported

*Number of SIDS cases included in the study.

Based on our models, the estimates of SD incidence revealed substantial geographic and temporal heterogeneity across general and age-stratified populations. Among seven super-regions, South Asia had the highest incidence rate at 4.01 cases (95% CI=1.40, 7.51) per 100 000 person-years on a log-transformed basis, followed by South East Asia, east Asia, and Oceania for 3.38 (95% CI=1.69, 5.29) and Latin America and Caribbean for 3.36 (95% CI=1.16, 6.39) per 100 000 person-years, respectively. Sub-Saharan Africa demonstrated the lowest incidence for 1.79 cases (95% CI=–1.83, 3.98) per 100 000 person-years (**Figure 3**; Table S11 in the **Online Supplementary Document**). For different regions, Asia South had the highest incidence rate at 4.51 cases (95% CI=1.85, 7.74) per 100 000 person-years, and a high-incidence cluster had formed in the Latin America region and the Caribbean region, with a rate of 3.28 to 3.64 cases per 100 000 person-years. East Asia (3.47) and Southeast Asia (3.62) are close to the level in Andean Latin America (3.44). The results of the age-stratified analysis showed that children had a significantly lower incidence than adults and

**Figure 3.** Geographical distribution of estimated incidence of sudden death (SD) by country. The estimated national incidence of SD was estimated using Bayesian hierarchical linear mixed models. Details about countries with observed or extrapolated data are given in the appendix.

infants, with South Asia consistently showing peak rates across age strata. Infants were estimated the highest incidence rate at 5.74 cases (95%CI=3.28, 9.85) per 100 000 person-years, following adults with 5.72 cases (95%CI=2.72, 9.39) per 100 000 person-years and children demonstrated the lowest incidence for 2.39 cases (95% CI=-0.95, 6.22) per 100 000 person-years. Besides, Latin America and the Caribbean constitute a persistently high-burden cluster (Figure S6–8 in the [Online Supplementary Document](#)). Nationally, Guyana was estimated to have the highest incidence of 5.06 cases (95% CI=2.78, 8.20) per 100 000 person-years, followed by India for 4.89 cases (95% CI=2.08, 7.76) per 100 000 person-years and Saint Vincent and the Grenadines for 4.76 cases (95% CI=2.46, 7.74) per 100 000 person-years (Table S11 in the [Online Supplementary Document](#)). The results from the generalised linear mixed models indicate that the global overall decline has significant super-regional heterogeneity. High-income countries were estimated to have the largest declines despite the greatest dispersion, and Sub-Saharan Africa maintained a stable high rate. Southeast Asia, East Asia and Oceania demonstrated nonlinear progress since 2005. Latin America and the Caribbean continued to grow, with the Andes region being the most notable (Figure S3 in the [Online Supplementary Document](#)).

DISCUSSION

We provided a comprehensive description of the global incidence and disease burden of SD, quantifying substantial global heterogeneity among SD cases across varying demographic characteristics. South Asia exhibited the highest incidence of SD, which could be attributed to racial differences, a lack of overall medical resources and awareness, and underlying disease factors [62]. Consistent with research on sudden cardiac arrest, Blacks are more prone to congestive heart failure and left ventricular hypertrophy, and they also have a longer corrected QT interval [62]. In India, low out-of-hospital cardiac arrest survival rates are linked to deficient cardiac arrest recognition [63–65], low bystander cardiopulmonary resuscitation (CPR) rates [66,67], legal and social concerns regarding CPR provision [68], and limited emergency medical services [69].

Sub-Saharan Africa (especially western regions) showed the lowest SD incidence, aligning with advances in reducing HIV-related CVD through improved testing/diagnosis/treatment [70] and younger demographics (64.2% aged <25years) [69]. Nevertheless, inadequate reporting partially underestimates incidence [71].

Country-level variations were significant, with Guatemala in Latin America, in particular, exhibiting the highest incidence rate of SD due to Chagas disease [72] and poor adherence to implantable cardioverter defibrillator [73]. Comparatively, countries in Southern Latin America, such as Argentina, Chile, and Uruguay, reported considerably lower incidence rates of SD (Figure S7 in the [Online Supplementary Document](#)). This disparity aligns with findings associated with higher total health expenditure and a more developed healthcare infrastructure [74].

Demographically, most SCD cases occur in adults [74], with incidence increasing with age [73]. Our study indicates that SIDS also constitutes a notable proportion of such fatalities in the infant population. We identified 50–59 years as high-risk due to excessive stress. Females show lower SD incidence with protective factors involving oestrogen, pregnancy, and cellular electrophysiology [75,76]. White ethnicity and higher socioeconomic status are associated with reduced incidence [77], and the discrepancy in the incidence of SD among whites may be explained by the population sizes of the different races included in our review.

Cardiac causes predominate, with coronary artery disease being responsible for more than half of deaths related to the circulatory system (Figure 2). Comprehensive risk reduction requires multi-factorial interventions; established predictors include hypertension, diabetes, dyslipidaemia, smoking, and obesity [3,4,10]. Genetic factors such as pathogenic/likely pathogenic variants [78] and Myosin Heavy Chain seven mutations [79] support existing evidence. Moreover, women are underrepresented in cardiovascular trials and face barriers to medical access [10], necessi-

tating gender-specific prevention strategies [80]. The true SD incidence remains controversial due to data source and collection biases [81].

Global SD incidence peaked at 233.8 cases per 100 000 person-years during 1971–1980, then declined. However, it is worthy of particular attention that only one piece of literature was included for both periods of 1971–1980, and we need to interpret this analysis. Our research results showed that the global incidence rate was generally declining. This reduction aligns with synergistic improvements in: medical technology (>80% coverage of percutaneous coronary intervention/coronary artery bypass grafting/automated external defibrillator enhancing emergency care), public health policies (Australia's tobacco taxation increasing hypertension control from 32% to 54%), and localised interventions (China's chest pain networks reducing ST-segment elevation myocardial infarction mortality by 28%) [11]. The mortality rate of SD for the zero to three year age group deviated from the overall age-incidence trend, with an overall increase mainly attributed to SIDS, which remains the leading cause of death between one to 12 months despite a >50% decline over 20 years [82]. Cultural practices correlate with SIDS incidence [82]. Given that three mechanisms of SIDS have been widely identified-preterm or exposed to maternal smoking, exogenous stressor and immature cardio-respiratory control-recommendations for the prevention of SIDS have been proposed [83]. These included sleeping in a safe environment, breastfeeding on demand, and abstaining from tobacco, alcohol, and illicit drugs during pregnancy and postpartum by parents [84].

Lifestyle and environmental factors influence SD occurrence – manufacturing and production workers [85] and blue-collar occupations show a higher risk, potentially due to physical and mental stress, which may be related to long-term exposure [86]. Seasonal variations (higher incidence in autumn and winter) may be related to cold-induced physiological stress or increased exposure during these seasons [87].

Our study has several strengths. Principally, this study represented the first systematic assessment and review of relevant literature on SD cases spanning 60 years globally, contributing valuable academic insights to the medical field. Additionally, our research was innovative in employing a comprehensive and systematic methodology to investigate and analyse a multi-centre, large-sample database. Elucidating epidemiological characteristics and occurrence patterns guides mitigating disease burden and reducing the incidence of SD.

There are also some limitations to note. First, due to variations in the sample sizes of the studies included across the seven continents, with a predominant focus on Europe, Asia, and South America, there may be differences in the accuracy of estimates of global incidence rates. One possible reason for this bias is that our study only includes English-language literature. Therefore, among the 108 included studies, 61.11% focused on SCD, vs. 20.37% on other systemic SD. Although the majority of included primary studies were judged to have a low to moderate risk of bias, their inherent limitations may still lead to overestimation or underestimation of the results. Finally, the inclusion of studies with small sample sizes or retrospective designs may negatively affect the validity and reliability of the evidence.

CONCLUSIONS

Overall, the incidence of SD has been systematically assessed, revealing notable national and regional variance, accompanied by discrepancies in demographic characteristics, primarily within the domains of age, gender, occupation, race, and income level, with particular emphasis on SIDS. Throughout this 60-year review, the circulatory system has predominantly been implicated in the origin of SD. Taking the existing limitations into consideration, a more valid and reliable assessment is encouraged for future studies.

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Ethics statement: Ethical approval was not required because the study was based on published literature and publicly available summary-level data.

Data availability: The raw data and all illustrative materials collected during this systematic assessment are available in the supplementary appendix. Additionally, the analytical code used for the study is accessible upon request. Interested researchers should direct their inquiries to the corresponding author at pguo@stu.edu.cn, ensuring compliance with data privacy and protection policies.

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Additional material

Online Supplementary Document

REFERENCES

- 1 Bayés de Luna A, Elosua R. Sudden death. *Rev Esp Cardiol (Engl Ed)*. 2012;65:1039–52. **Medline:22959179**
- 2 Murakoshi N, Aonuma K. Epidemiology of arrhythmias and sudden cardiac death in Asia. *Circ J*. 2013;77:2419–31. **Medline:24067274 doi:10.1253/circj.CJ-13-1129**
- 3 Wong CX, Brown A, Lau DH, Chugh SS, Albert CM, Kalman JM, et al. Epidemiology of Sudden Cardiac Death: Global and Regional Perspectives. *Heart Lung Circ*. 2019;28:6–14. **Medline:30482683 doi:10.1016/j.hlc.2018.08.026**
- 4 Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, et al; GBD-NHLBI-JACC Global Burden of Cardiovascular Diseases Writing Group. Global Burden of Cardiovascular Diseases and Risk Factors, 1990-2019: Update From the GBD 2019 Study. *J Am Coll Cardiol*. 2020;76:2982–3021. **Medline:33309175 doi:10.1016/j.jacc.2020.11.010**
- 5 Mensah GA, Wei GS, Sorlie PD, Fine LJ, Rosenberg Y, Kaufmann PG, et al. Decline in Cardiovascular Mortality: Possible Causes and Implications. *Circ Res*. 2017;120:366–80. **Medline:28104770 doi:10.1161/CIRCRESAHA.116.309115**
- 6 Chugh SS, Jui J, Gunson K, Stecker EC, John BT, Thompson B, et al. Current burden of sudden cardiac death: multiple source surveillance versus retrospective death certificate-based review in a large U.S. community. *J Am Coll Cardiol*. 2004;44:1268–75. **Medline:15364331 doi:10.1016/j.jacc.2004.06.029**
- 7 Mehra R. Global public health problem of sudden cardiac death. *J Electrocardiol*. 2007;40:S118–22. **Medline:17993308 doi:10.1016/j.jelectrocard.2007.06.023**
- 8 Zheng J, Lv C, Zheng W, Zhang G, Tan H, Ma Y, et al. Incidence, process of care, and outcomes of out-of-hospital cardiac arrest in China: a prospective study of the BASIC-OHCA registry. *Lancet Public Health*. 2023;8:e923–32. **Medline:37722403 doi:10.1016/S2468-2667(23)00173-1**
- 9 Roth GA, Johnson C, Abajobir A, Abd-Allah F, Abera SF, Abyu G, et al. Global, Regional, and National Burden of Cardiovascular Diseases for 10 Causes, 1990 to 2015. *J Am Coll Cardiol*. 2017;70:1–25. **Medline:28527533 doi:10.1016/j.jacc.2017.04.052**
- 10 Vogel B, Acevedo M, Appelman Y, Bairey Merz CN, Chieffo A, Figtree GA, et al. The Lancet women and cardiovascular disease Commission: reducing the global burden by 2030. *Lancet*. 2021;397:2385–438. **Medline:34010613 doi:10.1016/S0140-6736(21)00684-X**
- 11 Danaei G, Finucane MM, Lu Y, Singh GM, Cowan MJ, Paciorek CJ, et al. National, regional, and global trends in fasting plasma glucose and diabetes prevalence since 1980: systematic analysis of health examination surveys and epidemiological studies with 370 country-years and 2·7 million participants. *Lancet*. 2011;378:31–40. **Medline:21705069 doi:10.1016/S0140-6736(11)60679-X**
- 12 Go AS, Mozaffarian D, Roger VL, Benjamin EJ, Berry JD, Blaha MJ, et al. Heart disease and stroke statistics–2014 update: a report from the American Heart Association. *Circulation*. 2014;129:e28–92. **Medline:24352519 doi:10.1161/01.cir.0000441139.02102.80**

- 13 Moher D, Liberati A, Tetzlaff J, Altman DG. PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement. *Open Med*. 2009;3:e123–30. **Medline:21603045**
- 14 Naneix AL, Périer MC, Beganton F, Jouven X, Lorin de la Grandmaison G. Sudden adult death: an autopsy series of 534 cases with gender and control comparison. *J Forensic Leg Med*. 2015;32:10–5. **Medline:25882142 doi:10.1016/j.jflm.2015.02.005**
- 15 Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. *Syst Rev*. 2016;5:210. **Medline:27919275 doi:10.1186/s13643-016-0384-4**
- 16 Moola S, Munn Z, Tufanaru C, Aromataris E, Sears K, Sfetcu R, et al. Systematic reviews of etiology and risk. In: Aromataris E, Lockwood C, Porritt K, Pilla B, Jordan Z, editors. *JBIManual for Evidence Synthesis*. Adelaide, South Australia, Australia: JBI; 2024. Available: <https://synthesismanual.jbi.global>. Accessed: 20 May 2024.
- 17 Li Y, Choi H, Leung K, Jiang F, Graham DY, Leung WK. Global prevalence of *Helicobacter pylori* infection between 1980 and 2022: a systematic review and meta-analysis. *Lancet Gastroenterol Hepatol*. 2023;8:553–64. **Medline:37086739 doi:10.1016/S2468-1253(23)00070-5**
- 18 Abellan JJ, Richardson S, Best N. Use of space-time models to investigate the stability of patterns of disease. *Environ Health Perspect*. 2008;116:1111–9. **Medline:18709143 doi:10.1289/ehp.10814**
- 19 Li G, Haining R, Richardson S, Best N. Space-time variability in burglary risk: A Bayesian spatio-temporal modelling approach. *Spatial Statistics*. 2014;9:180–191. **doi:10.1016/j.spasta.2014.03.006**
- 20 Institute for Health Metrics and Evaluation (IHME). GBD Results. 2020. Available: <https://vizhub.healthdata.org/gbd-results/>. Accessed: 24 May 2024.
- 21 Wang S, Ren Z, Liu X. Spatiotemporal trends in neonatal, infant, and child mortality (1990–2019) based on Bayesian spatiotemporal modeling. *Front Public Health*. 2023;11:996694. **Medline:36844832 doi:10.3389/fpubh.2023.996694**
- 22 Havmoeller R, Reinier K, Teodorescu C, Uy-Evanado A, Mariani R, Gunson K, et al. Low rate of secondary prevention ICDs in the general population: multiple-year multiple-source surveillance of sudden cardiac death in the Oregon Sudden Unexpected Death Study. *J Cardiovasc Electrophysiol*. 2013;24:60–5. **Medline:22860692 doi:10.1111/j.1540-8167.2012.02407.x**
- 23 Maron BJ, Haas TS, Ahluwalia A, Rutten-Ramos SC. Incidence of cardiovascular sudden deaths in Minnesota high school athletes. *Heart Rhythm*. 2013;10:374–7. **Medline:23207138 doi:10.1016/j.hrthm.2012.11.024**
- 24 Harmon KG, Asif IM, Maleszewski JJ, Owens DS, Prutkin JM, Salerno JC, et al. Incidence and Etiology of Sudden Cardiac Arrest and Death in High School Athletes in the United States. *Mayo Clin Proc*. 2016;91:1493–502. **Medline:27692971 doi:10.1016/j.mayocp.2016.07.021**
- 25 Eckart RE, Scoville SL, Campbell CL, Shry EA, Stajduhar KC, Potter RN, et al. Sudden death in young adults: a 25-year review of autopsies in military recruits. *Ann Intern Med*. 2004;141:829–34. **Medline:15583223 doi:10.7326/0003-4819-141-11-200412070-00005**
- 26 Kim AS, Moffatt E, Ursell PC, Devinsky O, Olgin J, Tseng ZH. Sudden neurologic death masquerading as out-of-hospital sudden cardiac death. *Neurology*. 2016;87:1669–73. **Medline:27638923 doi:10.1212/WNL.0000000000003238**
- 27 Winkel BG, Risgaard B, Sadjadieh G, Bundgaard H, Haunsø S, Tfelt-Hansen J. Sudden cardiac death in children (1–18 years): symptoms and causes of death in a nationwide setting. *Eur Heart J*. 2014;35:868–75. **Medline:24344190 doi:10.1093/eurheartj/ehf509**
- 28 Niemeijer MN, van den Berg ME, Leening MJ, Hofman A, Franco OH, Deckers JW, et al. Declining incidence of sudden cardiac death from 1990–2010 in a general middle-aged and elderly population: The Rotterdam Study. *Heart Rhythm*. 2015;12:123–9. **Medline:25277989 doi:10.1016/j.hrthm.2014.09.054**
- 29 Feng JL, Nedkoff L, Knuiman M, Semsarian C, Ingles J, Briffa T, et al. Temporal Trends in Sudden Cardiac Death From 1997 to 2010: A Data Linkage Study. *Heart Lung Circ*. 2017;26:808–16. **Medline:28190759 doi:10.1016/j.hlc.2016.11.021**
- 30 Bonny A, Tibazarwa K, Mbouh S, Wa J, Fonga R, Saka C, et al. Epidemiology of sudden cardiac death in Cameroon: the first population-based cohort survey in sub-Saharan Africa. *Int J Epidemiol*. 2017;46:1230–8. **Medline:28453817 doi:10.1093/ije/dyx043**
- 31 Shuvy M, Qiu F, Lau G, Koh M, Dorian P, Geri G, et al. Temporal trends in sudden cardiac death in Ontario, Canada. *Resuscitation*. 2019;136:1–7. **Medline:30650337 doi:10.1016/j.resuscitation.2019.01.010**
- 32 Park YM, Moon J, Hwang IC, Lim H, Cho B. Short stature is associated with incident sudden cardiac death in a large Asian cohort. *Heart Rhythm*. 2020;17:931–6. **Medline:32028046 doi:10.1016/j.hrthm.2020.01.026**
- 33 Tabib A, Loire R, Chalabreysse L, Meyronnet D, Miras A, Malicier D, et al. Circumstances of death and gross and microscopic observations in a series of 200 cases of sudden death associated with arrhythmogenic right ventricular cardiomyopathy and/or dysplasia. *Circulation*. 2003;108:3000–5. **Medline:14662701 doi:10.1161/01.CIR.0000108396.65446.21**

- 34 Moore MJ, Glover BM, McCann CJ, Cromie NA, Ferguson P, Catney DC, et al. Demographic and temporal trends in out of hospital sudden cardiac death in Belfast. *Heart*. 2006;92:311–5. **Medline:15939727 doi:10.1136/hrt.2004.059857**
- 35 Byrne R, Constant O, Smyth Y, Callagy G, Nash P, Daly K, et al. Multiple source surveillance incidence and aetiology of out-of-hospital sudden cardiac death in a rural population in the West of Ireland. *Eur Heart J*. 2008;29:1418–23. **Medline:18424446 doi:10.1093/eurheartj/ehn155**
- 36 Fragkouli K, Vougiouklakis T. Sudden cardiac death: an 11-year postmortem analysis in the region of Epirus, Greece. *Pathol Res Pract*. 2010;206:690–4. **Medline:20932458 doi:10.1016/j.prp.2010.05.005**
- 37 Rao BH, Sastry BK, Chugh SS, Kalavakolanu S, Christopher J, Shangula D, et al. Contribution of sudden cardiac death to total mortality in India - a population based study. *Int J Cardiol*. 2012;154:163–7. **Medline:20888652 doi:10.1016/j.ijcard.2010.09.016**
- 38 Pilmer CM, Kirsh JA, Hildebrandt D, Krahn AD, Gow RM. Sudden cardiac death in children and adolescents between 1 and 19 years of age. *Heart Rhythm*. 2014;11:239–45. **Medline:24239636 doi:10.1016/j.hrthm.2013.11.006**
- 39 Hofer F, Fellmann F, Schläpfer J, Michaud K. Sudden cardiac death in the young (5-39 years) in the canton of Vaud, Switzerland. *BMC Cardiovasc Disord*. 2014;14:140. **Medline:25291980 doi:10.1186/1471-2261-14-140**
- 40 Martens E, Sinner MF, Siebermair J, Raufhake C, Beckmann BM, Veith S, et al. Incidence of sudden cardiac death in Germany: results from an emergency medical service registry in Lower Saxony. *Europace*. 2014;16:1752–8. **Medline:25061228 doi:10.1093/europace/euu153**
- 41 Braggion-Santos MF, Volpe GJ, Pazin-Filho A, Maciel BC, Marin-Neto JA, Schmidt A. Sudden cardiac death in Brazil: a community-based autopsy series (2006-2010). *Arq Bras Cardiol*. 2015;104:120–7. **Medline:25424162**
- 42 Zhao P, Wang JG, Gao P, Li X, Brewer R. Sudden unexpected death from natural diseases: Fifteen years' experience with 484 cases in Seychelles. *J Forensic Leg Med*. 2016;37:33–8. **Medline:26580722 doi:10.1016/j.jflm.2015.10.004**
- 43 Bagnall RD, Weintraub RG, Ingles J, Duflou J, Yeates L, Lam L, et al. A Prospective Study of Sudden Cardiac Death among Children and Young Adults. *N Engl J Med*. 2016;374:2441–52. **Medline:27332903 doi:10.1056/NEJMoa1510687**
- 44 Risgaard B, Lynge TH, Wissenberg M, Jabbari R, Glinge C, Gislason GH, et al. Risk factors and causes of sudden noncardiac death: A nationwide cohort study in Denmark. *Heart Rhythm*. 2015;12:968–74. **Medline:25614248 doi:10.1016/j.hrthm.2015.01.024**
- 45 Ifteni P, Barabas B, Gavris C, Moga M, Burtea V, Dracea L. Sudden Cardiac Death: Autopsy Findings in 7200 Cases Between 2001 and 2015. *Am J Forensic Med Pathol*. 2017;38:49–53. **Medline:27973393 doi:10.1097/PAF.0000000000000274**
- 46 Wisten A, Krantz P, Stattin EL. Sudden cardiac death among the young in Sweden from 2000 to 2010: an autopsy-based study. *Europace*. 2017;19:1327–34. **Medline:28873959**
- 47 Belhaj A, Shimi M, Kort I, Zaara MA, Hamdoun M, Ben Khelil M. Risk factors of sudden cardiac death in women: A 10 years study in Tunisia. *J Forensic Leg Med*. 2023;96:102517. **Medline:37004373 doi:10.1016/j.jflm.2023.102517**
- 48 Frontera A, Anselmino M, Matta M, Baccelli A, Vlachos K, Bonsignore A, et al. Ante-mortem characterization of sudden deaths as first-manifestation in Italy. *J Interv Card Electrophysiol*. 2022;63:267–74. **Medline:33638776 doi:10.1007/s10840-021-00949-5**
- 49 Rücklová K, Dobiáš M, Bílek M, Pohlová Kučerová Š, Kulvajtová M, Tavačová T, et al. Burden of sudden cardiac death in persons aged 1-40 years in the Czech Republic. *Cent Eur J Public Health*. 2022;30:58–64. **Medline:35421300 doi:10.21101/cejph.a6793**
- 50 Işın A, Turgut A, Peden AE. Epidemiology of Football-Related Sudden Cardiac Death in Turkey. *Medicina (Kaunas)*. 2021;57:1105. **Medline:34684142 doi:10.3390/medicina57101105**
- 51 Ripoll-Vera T, Pérez Luengo C, Borondo Alcázar JC, García Ruiz AB, Sánchez Del Valle N, Barceló Martín B, et al. Sudden cardiac death in persons aged 50 years or younger: diagnostic yield of a regional molecular autopsy program using massive sequencing. *Rev Esp Cardiol (Engl Ed)*. 2021;74:402–13. **Medline:32917565 doi:10.1016/j.recsp.2020.03.001**
- 52 Chang RK, Keens TG, Rodriguez S, Chen AY. Sudden infant death syndrome: changing epidemiologic patterns in California 1989-2004. *J Pediatr*. 2008;153:498–502. **Medline:18534214 doi:10.1016/j.jpeds.2008.04.022**
- 53 Liebrechts-Akkerman G, Bovee JV, Wijnaendts LC, Maes A, Nikkels PG, de Krijger RR. Histological findings in unclassified sudden infant death, including sudden infant death syndrome. *Pediatr Dev Pathol*. 2013;16:168–76. **Medline:23331080 doi:10.2350/12-10-1262-OA.1**

- 54 Malloy MH. Prematurity and sudden infant death syndrome: United States 2005-2007. *J Perinatol.* 2013;33:470–5. [Medline:23288251](#) [doi:10.1038/jp.2012.158](#)
- 55 Evans A, Bagnall RD, Duflo J, Semsarian C. Postmortem review and genetic analysis in sudden infant death syndrome: an 11-year review. *Hum Pathol.* 2013;44:1730–6. [Medline:23623143](#) [doi:10.1016/j.humpath.2013.01.024](#)
- 56 Hakeem GF, Oddy L, Holcroft CA, Abenham HA. Incidence and determinants of sudden infant death syndrome: a population-based study on 37 million births. *World J Pediatr.* 2015;11:41–7. [Medline:25447630](#) [doi:10.1007/s12519-014-0530-9](#)
- 57 Tuchtan L, Delteil C, Levrat F, Bacquet J, Garcia P, Fayol L, et al. Sudden unexpected infant death characteristics in the French region of West Provence-Alpes-Côte d'Azur. *Paediatr Int Child Health.* 2019;39:104–10. [Medline:30382004](#) [doi:10.1080/20469047.2018.1533734](#)
- 58 Drake SA, Wolf DA, Yang Y, Harper S, Ross J, Reynolds T, et al. A Descriptive and Geospatial Analysis of Environmental Factors Attributing to Sudden Unexpected Infant Death. *Am J Forensic Med Pathol.* 2019;40:108–16. [Medline:30570520](#) [doi:10.1097/PAF.0000000000000455](#)
- 59 Mitchell EA, Taylor BJ, Milne BJ. Regional variation in sudden unexpected death in infancy in New Zealand. *J Paediatr Child Health.* 2023;59:319–27. [Medline:36511387](#) [doi:10.1111/jpc.16293](#)
- 60 Bartick M, Barr AW, Feldman-Winter L, Guxens M, Tiemeier H. The Role of Breastfeeding in Racial and Ethnic Disparities in Sudden Unexpected Infant Death: A Population-Based Study of 13 Million Infants in the United States. *Am J Epidemiol.* 2022;191:1190–201. [Medline:35292797](#) [doi:10.1093/aje/kwac050](#)
- 61 Anderson TM, Allen K, Ramirez JM, Mitchell EA. Circadian variation in sudden unexpected infant death in the United States. *Acta Paediatr.* 2021;110:1498–504. [Medline:33251652](#) [doi:10.1111/apa.15695](#)
- 62 Reinier K, Nichols GA, Huertas-Vazquez A, Uy-Evanado A, Teodorescu C, Stecker EC, et al. Distinctive Clinical Profile of Blacks Versus Whites Presenting With Sudden Cardiac Arrest. *Circulation.* 2015;132:380–7. [Medline:26240262](#) [doi:10.1161/CIRCULATIONAHA.115.015673](#)
- 63 Krishna CK, Showkat HI, Taktani M, Khatri V. Out of hospital cardiac arrest resuscitation outcome in North India - CARO study. *World J Emerg Med.* 2017;8:200–5. [Medline:28680517](#) [doi:10.5847/wjem.j.1920-8642.2017.03.007](#)
- 64 Aroor AR, Saya RP, Attar NR, Saya GK, Ravinanthanan M. Awareness about basic life support and emergency medical services and its associated factors among students in a tertiary care hospital in South India. *J Emerg Trauma Shock.* 2014;7:166–9. [Medline:25114425](#) [doi:10.4103/0974-2700.136857](#)
- 65 Joseph N, Narayanan T, Bin Zakaria S, Nair AV, Belayutham L, Subramanian AM, et al. Awareness, attitudes and practices of first aid among school teachers in Mangalore, south India. *J Prim Health Care.* 2015;7:274–81. [Medline:26668832](#) [doi:10.1071/HC15274](#)
- 66 Bhat R, Ravindra P, Sahu AK, Mathew R, Wilson W. Study of pre-hospital care of out of hospital cardiac arrest victims and their outcome in a tertiary care hospital in India. *Indian Heart J.* 2021;73:446–50. [Medline:34474756](#) [doi:10.1016/j.ihj.2021.02.004](#)
- 67 Kronick SL, Kurz MC, Lin S, Edelson DP, Berg RA, Billi JE, et al. Part 4: Systems of Care and Continuous Quality Improvement: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation.* 2015;132:S397–413. [Medline:26472992](#) [doi:10.1161/CIR.0000000000000258](#)
- 68 Patel H, Mahtani AU, Mehta LS, Kalra A, Prabhakaran D, Yadav R, et al. Outcomes of out of hospital sudden cardiac arrest in India: A review and proposed reforms. *Indian Heart J.* 2023;75:321–6. [Medline:37657626](#) [doi:10.1016/j.ihj.2023.08.005](#)
- 69 Lindquist BD, Koval KW, Acker PC, Bills CB, Khan A, Zachariah S, et al. Continuing Education for Prehospital Healthcare Providers in India - A Novel Course and Concept. *Open Access Emerg Med.* 2020;12:201–10. [Medline:32982494](#) [doi:10.2147/OAEM.S249447](#)
- 70 Syed FF, Sani MU. Recent advances in HIV-associated cardiovascular diseases in Africa. *Heart.* 2013;99:1146–53. [Medline:23680889](#) [doi:10.1136/heartjnl-2012-303177](#)
- 71 Bonny A, Tibazarwa K, Mbouh S, Wa J, Fonga R, Saka C, et al. Epidemiology of sudden cardiac death in Cameroon: the first population-based cohort survey in sub-Saharan Africa. *Int J Epidemiol.* 2017;46:1230–8. [Medline:28453817](#) [doi:10.1093/ije/dyx043](#)
- 72 Carbajales J, Krishnan D, Principato M, Tomatti A, Paolucci A, Yoo HS, et al. Prevalence of Cardiac Arrhythmias and Distal Conduction Disorders in Patients With Chronic Chagas' Disease and Elevated Autoantibodies Against M2 Muscarinic Acetylcholine Receptors. *Curr Probl Cardiol.* 2021;46:100820. [Medline:33743434](#) [doi:10.1016/j.cpcardiol.2021.100820](#)
- 73 Gonzalez-Zuelgaray J, Pellizon O, Muratore CA, Oropeza ES, Rabinovich R, Ramos JL, et al. Lack of current implantable cardioverter defibrillator guidelines application for primary prevention of sudden cardiac death in

- Latin American patients with heart failure: a cross-sectional study. *Europace*. 2013;15:236–42. **Medline:22968848 doi:10.1093/europace/eus253**
- 74 Atun R, de Andrade LO, Almeida G, Cotlear D, Dmytraczenko T, Frenz P, et al. Health-system reform and universal health coverage in Latin America. *Lancet*. 2015;385:1230–47. **Medline:25458725 doi:10.1016/S0140-6736(14)61646-9**
- 75 Hayashi M, Shimizu W, Albert CM. The spectrum of epidemiology underlying sudden cardiac death. *Circ Res*. 2015;116:1887–906. **Medline:26044246 doi:10.1161/CIRCRESAHA.116.304521**
- 76 Martínez-Solano J, Martínez-Sellés M. Sudden Death in Men Versus Women with Heart Failure. *Curr Heart Fail Rep*. 2023;20:129–37. **Medline:36881322 doi:10.1007/s11897-023-00596-z**
- 77 Reinier K, Rusinaru C, Chugh SS. Race, ethnicity, and the risk of sudden death. *Trends Cardiovasc Med*. 2019;29:120–6. **Medline:30029848 doi:10.1016/j.tcm.2018.07.001**
- 78 Guo L, Torii S, Fernandez R, Braumann RE, Fuller DT, Paek KH, et al. Genetic Variants Associated With Unexplained Sudden Cardiac Death in Adult White and African American Individuals. *JAMA Cardiol*. 2021;6:1013–22. **Medline:34076677 doi:10.1001/jamacardio.2021.1573**
- 79 Ripoll-Vera T, Pérez Luengo C, Borondo Alcázar JC, García Ruiz AB, Sánchez Del Valle N, Barceló Martín B, et al. Sudden cardiac death in persons aged 50 years or younger: diagnostic yield of a regional molecular autopsy program using massive sequencing. *Rev Esp Cardiol (Engl Ed)*. 2021;74:402–13. **Medline:32917565 doi:10.1016/j.recresp.2020.03.001**
- 80 Feng JL, Nedkoff L, Knuiman M, Semsarian C, Ingles J, Briffa T, et al. Temporal Trends in Sudden Cardiac Death From 1997 to 2010: A Data Linkage Study. *Heart Lung Circ*. 2017;26:808–16. **Medline:28190759 doi:10.1016/j.hlc.2016.11.021**
- 81 Emery MS, Kovacs RJ. Sudden Cardiac Death in Athletes. *JACC Heart Fail*. 2018;6:30–40. **Medline:29284578 doi:10.1016/j.jchf.2017.07.014**
- 82 Adams SM, Ward CE, Garcia KL. Sudden infant death syndrome. *Am Fam Physician*. 2015;91:778–83. **Medline:26034855**
- 83 Horne RSC. Sudden infant death syndrome: current perspectives. *Intern Med J*. 2019;49:433–8. **Medline:30957377 doi:10.1111/imj.14248**
- 84 Jullien S. Sudden infant death syndrome prevention. *BMC Pediatr*. 2021;21:320. **Medline:34496779 doi:10.1186/s12887-021-02536-z**
- 85 Kivimäki M, Singh-Manoux A, Pentti J, Sabia S, Nyberg ST, Alfredsson L, et al. Physical inactivity, cardiometabolic disease, and risk of dementia: an individual-participant meta-analysis. *BMJ*. 2019;365:l1495. **Medline:30995986 doi:10.1136/bmj.l1495**
- 86 Amantea C, Pilia E, Rossi MF, Corona VF, Amato G, Ciccu C, et al. Sudden cardiac death among workers: a systematic review and meta-analysis. *Syst Rev*. 2024;13:84. **Medline:38461297 doi:10.1186/s13643-024-02504-5**
- 87 Rytö NRI, Mäkitö EMS, Antikainen H, Hookana E, Junttila MJ, Ikäheimo TM, et al. Risk of sudden cardiac death in relation to season-specific cold spells: a case-crossover study in Finland. *BMJ Open*. 2017;7:e017398. **Medline:29127226 doi:10.1136/bmjopen-2017-017398**