JAMA Cardiology | Original Investigation | GLOBAL BURDEN OF DISEASE

Modifiable Risk Factors and Attributable Ischemic Heart Disease Mortality in US States, 1990-2023

A Systematic Analysis for the Global Burden of Disease Study 2023

Catherine P. Benziger, MD; Benjamin Stark, MA; Catherine O. Johnson, PhD; Gregory A. Roth, MD; and the GBD 2023 US IHD Collaborators

IMPORTANCE Ischemic heart disease (IHD), the leading cause of death in the US, is predominantly due to modifiable risk factors. Estimates of IHD mortality attributable to risk factors provide evidence for health policy decision-making.

OBJECTIVE To estimate the burden of IHD death attributable to risk factors in the US from 1990-2023.

DESIGN, SETTING, AND PARTICIPANTS The Global Burden of Disease Study 2023 (GBD 2023) used vital records and a broad set of epidemiologic data to estimate IHD death rates, risk factor exposure, and relative risk curves for risk-outcome pairs for 1990-2023 for the general population. Data analysis was performed from October 2024 to December 2025.

EXPOSURE Twelve metabolic, behavioral, and environmental risk factors.

MAIN OUTCOMES AND MEASURES The primary outcomes were IHD death rates per 100 000 persons, counts, and attributable risks from 1990-2023 by age, sex, and US state. Estimates include 95% uncertainty intervals (UI). IHD death rates were estimated using ensemble modeling methods. Risk exposures were estimated using bayesian meta-regression methods. Relative risks were estimated following the Burden of Proof framework.

RESULTS In 2023, there were 473 000 IHD deaths (95% UI, 414 000-510 000) in the US, a decrease of 58.7% (95% UI, 56.8%-61.0%) in age-standardized rate since 1990. Between 2010 and 2023, there was a 19.0% decrease (95% UI, 15.0%-22.9%) for males and a 24.5% decrease (95% UI, 20.3%-29.7%) for females in IHD death rates. High systolic blood pressure (SBP), dietary risks, and high low-density lipoprotein cholesterol (LDL-C) were the leading risk factors for IHD deaths in 2023, accounting for 47.2% (95% UI, 36.4%-57.0%), 38.6% (95% UI, 17.2%-56.8%), and 28.5% (95% UI, 19.3%-39.6%) of IHD deaths, respectively. Increased exposure to several risk factors substantially increased their attributable burden for IHD deaths in 2023, with high fasting plasma glucose (FPG) increasing 38.8% (95% UI, 11.5%-81.1%) and high body mass index (BMI) increasing 54.5% (95% UI, 41.8%-66.3%) since 1990. Smoking and particulate matter pollution had the greatest decrease in attributable IHD mortality since 1990, at 33.3% (95% UI, 23.6%-41.7%) and 74.9% (95% UI, 46.7%-88.8%), respectively.

CONCLUSION AND RELEVANCE Per the results of this systematic analysis of GBD 2023, a total of 88.7% (95% UI, 83.4%-92.5%) of IHD deaths were attributable to modifiable risk factors in the US in 2023, with high SBP, dietary risks, and high LDL-C being the greatest contributors. High BMI and high FPG showed the largest attribution increases, while exposure to other risks did not increase significantly for the population.

Editorial

Supplemental content

Author Affiliations: Heart and Vascular Center, Essentia Health, Duluth, Minnesota (Benziger); Institute for Health Metrics and Evaluation, University of Washington, Seattle (Stark, Johnson, Roth); Department of Health Metrics Sciences, School of Medicine, University of Washington, Seattle (Roth); Division of Cardiology, University of Washington, Seattle (Roth).

Group Information: The GBD 2023 US IHD Collaborators appear at the end of the article.

Corresponding Author: Gregory A. Roth, MD, Institute for Health Metrics and Evaluation, University of Washington, 3980 15th Ave NE, Box 351615, Seattle, WA 98195 (rothg@uw.edu).

JAMA Cardiol. doi:10.1001/jamacardio.2026.2435
Published online July 15, 2026.

In the US, ischemic heart disease (IHD) is the leading cause of death driven by modifiable metabolic, behavioral, and environmental risks.[1-3] High systolic blood pressure (SBP), low-density lipoprotein cholesterol (LDL-C), body mass index (BMI), diabetes, diet, sedentary lifestyle, and tobacco are targets for reducing IHD burden.[4,5] Environmental risks, including particulate matter pollution, lead exposure, and nonoptimal temperature also cause IHD.[6]

US IHD mortality declined between 1980 and 2010 due to improved prevention and treatment.[7] Since 2010, this trend has slowed or reversed in most states due to plateaus in risk factor improvements, shifting risk factor exposures, and fewer treatment advances. There is geographic variation and disparities in the US[8-11]—specifically, smoking has declined since 2000 but remains highly prevalent in certain populations, while obesity and diabetes have risen.[7]

To examine IHD and associated risk factor trends, we analyzed death records and all available data on population risk exposure and their causal associations with IHD as part of the Global Burden of Disease 2023 Study (GBD).[1,2,12,13] We estimated national and state-specific IHD mortality overall and attributable to 12 modifiable risks from 1990 to 2023 and used decomposition analysis to determine how population growth, population aging, and risk exposures drove IHD mortality trends. Our aim is to provide evidence that can guide public health interventions and health policy decision-making.

Key Points

Question How have the burden of ischemic heart disease (IHD) mortality in the US and the influence of its risk factors changed between 1990 and 2023?

Findings Per the results of this systematic analysis, there were an estimated 473 000 IHD deaths in the US in 2023, indicating the age-standardized mortality rate decreased by 58.7% since 1990. IHD deaths attributable to high body mass index (BMI) and high fasting plasma glucose (FPG) increased by 12.5% and 10.5% since 1990, respectively.

Meaning Modifiable risk factors are a major cause of IHD in the US, with increasing contributions attributable to high BMI and high FPG; addressing barriers to reducing risk exposure is essential to lessen IHD mortality.

Methods

Overview

GBD is a multinational study that provides mortality and disability estimates by country, age, and sex from 1990 to 2023; detailed methods were previously published.[14,15] We selected 1990, the inaugural and routinely updated GBD year, as the baseline. GBD 2023 included estimates for 376 diseases and 88 risk factors. GBD followed the Guidelines for Accurate and Transparent Health Estimate Reporting (GATHER) recommendations.[1] GBD used deidentified data, and a waiver of informed consent was reviewed and approved by the University of Washington institutional review board (study number 9060).

Mortality Estimation

IHD deaths were identified from the US National Vital Statistics System using *International Classification of Disease* (*ICD*) codes (*ICD-10*: I20-I25; *ICD-8* or *-9*: 410-414).[16] Death records coded to intermediate, implausible, or unspecified causes, including heart failure, were redistributed to valid underlying causes, including IHD. Redistribution used reclassification algorithms, differentiating our results from other national mortality databases.[17] An empirical bayesian noise reduction algorithm was applied to reduce random temporal stochasticity in mortality records.[17]

The cause of death ensemble modeling (CODEm) software estimated mortality by generating distinct statistical submodels with varying predictive covariates that weighted by out-of-sample predictive validity.[1] IHD mortality rates estimated by CODEm were scaled with all other causes to align with all-cause mortality estimates, including the effects of the COVID-19 pandemic in 2020-2022.[15,18]

Attributable Burden Estimation

IHD burden attributable to 12 risk factors was estimated using the GBD comparative risk assessment framework.[1] Risks were categorized into the following groups: (1) metabolic, including high SBP, high LDL-C, high BMI, high fasting plasma glucose (FPG), and kidney dysfunction; (2) behavioral, including diet, tobacco, physical activity, and alcohol consumption; and (3) environmental, including particulate matter pollution, temperature, and lead exposure. Estimating attributable burden required 5 entities: (1) the mean level and SD of risk exposure among the population modeled by age, sex, and year using regression and meta-regression methods; (2) the relative risk (RR) of IHD given exposure, estimated following the Burden of Proof meta-analysis method, accounting for between-study heterogeneity; (3) the theoretical minimum risk exposure level (TMREL), defined as the level of minimum health risk; (4) a risk mediation matrix specifying proportions of disease attributable to associated risks to account for nonindependence of specific biological or behavioral causal pathways; and (5) the population-attributable fraction (PAF) calculated for each risk, adjusted for mediation between nonindependent risks, and aggregated using the joint PAF formula to estimate combined impact of multiple risk factors.[1,19-21] PAFs are not fully mutually exclusive through mediation and thus may not sum to 100% of risk-attributable burden. Methodological details are in the eAppendices in Supplement 1 and eTable 1 in Supplement 2.

Decomposition Analysis

Decomposition analysis was performed using Das Gupta's method[22] to assess drivers of change in IHD mortality over time. Using counterfactual scenarios where the effect of 1 pathway was evaluated while holding all other pathways constant, deaths attributable to changes in population growth, population aging, risk exposure, and the remainder category of risk-deleted mortality were calculated. Risk-deleted mortality explained unmeasured change in IHD deaths assuming all other

Table 1. Ischemic Heart Disease (IHD) Death Rates (per 100 000), Percentage Change, and Counts by Age, Sex, and Year in the US

Sex	Age group, y	Mortality rate (95% UI)					Percentage change (95% UI), %		Mortality count (95% UI)	
		1990	2000	2010	2015	2023	1990-2023	2010-2023	1990	2023
Both sexes	All ages	234.8 (215.0 to 247.6)	206.1 (183.5 to 218.8)	150.6 (132.4 to 161.6)	146.5 (127.6 to 157.7)	140.9 (123.3 to 152.2)	−40.0 (−43.2 to −36.9)	−6.48 (−10.5 to −2.42)	597 000 (546 000 to 629 000)	473 000 (414 000 to 510 000)
	15-49	14.3 (13.7 to 14.9)	14.8 (14.1 to 15.7)	11.7 (11.1 to 12.4)	10.1 (9.3 to 10.9)	9.4 (8.5 to 10.3)	−34.2 (−41.5 to −27.0)	−19.4 (−26.5 to −11.3)	19 200 (18 400 to 20 100)	14 500 (13 100 to 15 900)
	50-69	325.6 (316.0 to 334.7)	215.6 (209.2 to 221.7)	143.8 (138.5 to 149.5)	141.3 (135.5 to 145.8)	141.4 (134.6 to 147.2)	−56.6 (−58.8 to −54.3)	−1.64 (−6.80 to 3.04)	139 000 (135 000 to 143 000)	116 000 (110 000 to 121 000)
	≥70	2073.3 (1837.6 to 2215.0)	1781.7 (1528.3 to 1914.4)	1261.7 (1059.3 to 1378.2)	1118.4 (934.5 to 1224.0)	856.0 (712.8 to 943.5)	−58.7 (−61.3 to −56.4)	−32.2 (−35.4 to −29.0)	438 000 (388 000 to 468 000)	342 000 (285 000 to 377 000)
	Age standardized	182.6 (167.1 to 192.6)	143.3 (128.9 to 151.6)	94.8 (84.5 to 101.3)	85.8 (75.8 to 91.9)	75.4 (66.7 to 81.2)	−58.7 (−61.0 to −56.8)	−20.5 (−23.9 to −17.4)	NA	NA
Female	All ages	222.2 (190.9 to 241.3)	202.4 (168.9 to 221.4)	139.7 (114.7 to 153.8)	130.7 (105.9 to 145.3)	117.4 (94.2 to 132.1)	−47.1 (−51.5 to −42.8)	−15.9 (−20.5 to −11.3)	289 000 (248 000 to 314 000)	199 000 (159 000 to 223 000)
	15-49	5.8 (5.3 to 6.4)	7.0 (6.3 to 7.6)	6.0 (5.6 to 6.5)	5.4 (4.9 to 6.0)	4.8 (4.2 to 5.5)	−17.3 (−31.3 to 1.70)	−19.3 (−28.9 to −7.74)	3900 (3560 to 4290)	3650 (3200 to 4170)
	50-69	187.8 (178.4 to 197.2)	128.2 (120.9 to 135.5)	79.8 (74.9 to 83.9)	79.1 (74.1 to 83.6)	80.0 (72.2 to 86.0)	−57.4 (−61.2 to −53.5)	0.25 (−7.68 to 7.53)	42 500 (40 400 to 44 600)	33 400 (30 200 to 36 000)
	≥70	1856.1 (1551.9 to 2027.7)	1644.7 (1333.9 to 1812.6)	1155.3 (912.5 to 1293.6)	1001.8 (780.1 to 1131.3)	722.7 (560.5 to 826.8)	−61.1 (−64.8 to −58.0)	−37.5 (−42.0 to −33.4)	242 000 (203 000 to 265 000)	162 000 (125 000 to 185 000)
	Age standardized	136.5 (118.5 to 147.7)	109.2 (93.5 to 118.3)	69.9 (58.8 to 76.1)	62.1 (52.1 to 68.2)	52.8 (43.3 to 58.7)	−61.3 (−64.6 to −58.4)	−24.5 (−29.7 to −20.3)	NA	NA
Male	All ages	248.1 (234.5 to 259.3)	209.8 (196.7 to 219.5)	162.0 (149.0 to 172.4)	162.6 (147.5 to 173.9)	164.7 (148.7 to 175.7)	−33.6 (−37.8 to −29.5)	1.72 (−3.364 to 6.80)	308 000 (291 000 to 322 000)	274 000 (247 000 to 292 000)
	15-49	22.8 (21.7 to 23.9)	22.6 (21.2 to 24.2)	17.4 (16.3 to 18.7)	14.6 (13.3 to 16.1)	13.9 (12.4 to 15.7)	−38.9 (−46.4 to −30.2)	−19.7 (−28.9 to −10.4)	15 300 (14 600 to 16 100)	10 900 (9670 to 12 200)
	50-69	480.7 (465.2 to 496.3)	310.1 (299.5 to 320.3)	212.1 (203.7 to 221.5)	207.0 (197.9 to 215.7)	205.4 (195.3 to 215.4)	−57.3 (−59.7 to −55.0)	−3.19 (−8.97 to 2.30)	96 600 (93 500 to 99 800)	82 500 (78 500 to 86 500)
	≥70	2424.4 (2249.3 to 2547.2)	1992.5 (1825.7 to 2099.9)	1411.6 (1251.9 to 1523.1)	1274.7 (1122.3 to 1389.4)	1025.2 (893.8 to 1108.7)	−57.7 (−61.0 to −54.9)	−27.4 (−31.7 to −23.3)	196 000 (182 000 to 206 000)	181 000 (157 000 to 195 000)
	Age standardized	246.6 (230.4 to 258.6)	189.1 (176.3 to 198.3)	126.8 (116.1 to 135.4)	115.6 (104.5 to 123.9)	102.7 (92.3 to 109.8)	−58.3 (−61.0 to −55.9)	−19.0 (−22.9 to −15.0)	NA	NA

Abbreviations: NA, not applicable; UI, uncertainty interval.

drivers of change remained constant. Analyses were performed for individual risk factors and aggregated by metabolic, behavioral, and environmental groups and all risk factors combined.

Statistical Analysis

Age standardization used the direct method with GBD standard population.[1] Uncertainty intervals (UI) reflected the 2.5th and 97.5th percentiles from 250 posterior distribution draws. Risks and outcomes were aggregated by their level in hierarchies developed by GBD to represent 4 levels of increasing granularity. To balance interpretability with sufficient granularity, level 3 (IHD) was used for causes of death and level 2 for risks. PAFs are reported as percentages with 95% UIs. Further details are provided in the eAppendices in Supplement 1 and on the Global Health Data Exchange. Software programs used were Python version 3.10.4 (Python Software Foundation), Stata version 13.1 (StataCorp), and R version 4.2.1 (R Foundation).

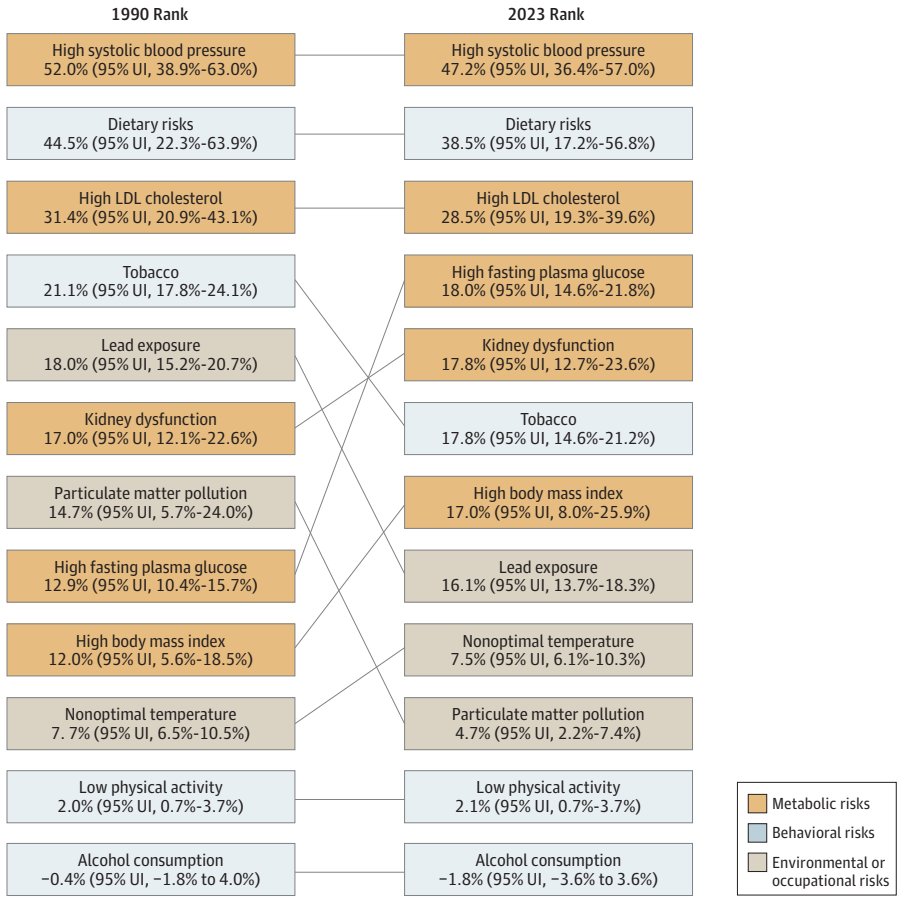
Results

National and State IHD Mortality Trends

In 2023, there were 473 000 (95% UI, 414 000-510 000) IHD deaths nationally, an age-standardized rate of 75.4 (95% UI, 66.7-81.2) per 100 000 (**Table 1**). From 1990 to 2023, the age-standardized mortality rate decreased 58.7% (95% UI, 56.8%-61.3%) nationally; the decline slowed after 2010, with a 20.5% (95% UI, 17.4%-23.9%) reduction through 2023.

Nationally, the IHD mortality rate decreased 58.3% (95% UI, 55.9%-61.0%) for males, from 246.6 (95% UI, 230.4-258.6) in 1990 to 102.8 (95% UI, 92.3-109.8) per 100 000 in 2023. In females, IHD mortality rates decreased 61.3% (95%

Figure 1. Arrow Diagram Showing Change in Percentage of Ischemic Heart Disease (IHD) Deaths Attributed to Risk Factors in the US



Change in percentage of IHD deaths attributable to 12 level 2 Global Burden of Disease (GBD) metabolic, behavioral, and environmental or occupational risk factors in the US from 1990 to 2023. Grouping risk factors by GBD hierarchy can be found in eTable 1 in Supplement 2. LDL indicates low-density lipoprotein; UI, uncertainty interval.

UI, 58.4%-64.6%), from 136.5 (95% UI, 118.5-147.7) per 100 000 in 1990 to 52.8 (95% UI, 43.3-58.7) in 2023. Between 2010 and 2023, there was a 19.0% decrease (95% UI, 15.0%-22.9%) for males and a 24.5% decrease (95% UI, 20.3%-29.7%) for females in IHD death rates.

In 2023, the highest IHD mortality rates per 100 000 ranged from 99.0 to 109.5 (in Kentucky, Tennessee, West Virginia, Mississippi, and Arkansas), while the lowest rates ranged from 53.5 to 58.0 (in Massachusetts, Oregon, Hawaii, Colorado, and Minnesota) (eTable 2 in Supplement 2). Massachusetts, New Jersey, and Minnesota led the reduction in age-standardized IHD mortality, achieving more than 63% reductions since 1990 (64.8%; 95% UI, 62.8%-66.9%; 64.5%; 95% UI, 62.4%-66.9%; and 63.5%; 95% UI, 61.3%-65.9%, respectively), while Arkansas, Montana, and New Mexico declined under 50% (42.2%; 95% UI, 38.8%-45.1%; 46.4%; 95% UI, 43.2%-49.6%; and 47.1%; 95% UI, 43.9%-50.4%, respectively).

National Trends in Attributable Burden and Drivers of Change

In 2023, modifiable risks caused 419 000 (95% UI, 363 000-462 000) US IHD deaths, comprising 88.7% (95% UI, 83.4%-92.5%) of all IHD deaths, varying by risk factor (**Figure 1**, **Table 2**; eTable 3 in Supplement 2). In 1990, the number of IHD deaths attributable to risk factors was 546 000 (95% UI, 494 000-585 000), a decrease of 127 000 deaths (95% UI, 104 000-154 000), or 23.3% (95% UI, 19.1%-28.2%). The decomposition analysis (**Figure 2**) revealed the competing drivers behind this national trend. Since 1990, reduced exposure across IHD risk factors decreased IHD deaths by 180 000 (95% UI, 50 700-313 000), a 32.9% (95% UI, 9.5%-55.2%) decline in risk-attributable IHD mortality (eTable 4 in Supplement 2). Improvements in risk-deleted mortality, which represent the underlying decline in deaths after removing the effects of population changes and risk exposures, mitigated 313 000 IHD deaths (95% UI, 199 000-431 000), a 57.3% (95% UI, 35.4%-80.0%) decline. Population growth and aging added 175 000 (95% UI, 152 000-190 000) and 191 000 (95% UI, 162 000-213 000) IHD deaths, respectively.

There were 365 000 IHD deaths (95% UI, 317 000-411 000) attributable to metabolic risk factors in 2023, representing 77.3% (95% UI, 70.7%-83.1%) of IHD deaths (eTable 3 in Supplement 2). The leading metabolic risks for IHD were high SBP and high LDL-C, for which 47.2% (95% UI, 36.4%-57.0%) and 28.5% (95% UI, 19.3%-39.6%) of IHD deaths were attributable, respectively. Changed exposure to high SBP and high LDL-C led to nonsignificant change in IHD-attributable deaths. Since 1990, IHD deaths attributable to high FPG increased from

Table 2. Risk-Attributable Ischemic Heart Disease (IHD) Deaths and Age-Standardized Mortality Rates in the US, 1990-2023[a]

Risk	No. of deaths			Age-standardized mortality rate (95% UI)		
	1990, No. (95% UI)	2023, No. (95% UI)	Percentage change, %	1990	2023	Percentage change, %
All risk factors	546 000 (494 000 to 585 000)	419 000 (363 000 to 462 000)	−23.3 (−28.2 to −19.1)	168 (152 to 180)	67.1 (58.8 to 73.8)	−60 (−62.3 to −57.8)
Metabolic risks	466 000 (410 000 to 515 000)	365 000 (316 000 to 411 000)	−21.6 (−27.3 to −15.5)	143 (126 to 158)	58.4 (50.9 to 65.7)	−59.2 (−62 to −56)
High systolic blood pressure	310 000 (233 000 to 375 000)	223 000 (167 000 to 272 000)	−28.1 (−37.6 to −13.7)	94 (70.1 to 114)	34.9 (26.5 to 42.8)	−62.8 (−67.9 to −55.2)
High LDL cholesterol	187 000 (127 000 to 255 000)	135 000 (92 100 to 187 000)	−28.1 (−38.8 to −16.8)	59.3 (40.7 to 79.8)	22.8 (16 to 31.2)	−61.5 (−67.2 to −55.5)
Kidney dysfunction	102 000 (69 200 to 138 000)	84 200 (58 800 to 115 000)	−17.1 (−22.5 to −11.6)	30.8 (21 to 41.9)	12.8 (8.97 to 17.5)	−58.4 (−60.9 to −55.8)
High fasting plasma glucose	77 100 (61 700 to 94 500)	85 200 (67 100 to 106 000)	10.5 (−8.64 to 37.6)	23.3 (18.6 to 28.5)	13.3 (10.5 to 16.6)	−42.9 (−52.7 to −28.9)
High body mass index	71 400 (32 900 to 112 000)	80 300 (37 200 to 126 000)	12.5 (3.81 to 22.8)	22.4 (10.4 to 35.2)	13.5 (6.31 to 20.9)	−39.7 (−44.3 to −34.2)
Behavioral risks	334 000 (225 000 to 441 000)	232 000 (145 000 to 311 000)	−30.6 (−41.4 to −22.1)	104 (70.3 to 136)	38.3 (24.5 to 50.7)	−63.1 (−68.5 to −58.6)
Dietary risks	265 000 (136 000 to 394 000)	182 000 (78 100 to 277 000)	−31.4 (−47.9 to −18.1)	82.7 (43.1 to 122)	30.2 (13.4 to 45.3)	−63.4 (−71.8 to −56.2)
Tobacco	126 000 (107 000 to 147 000)	83 900 (69 800 to 101 000)	−33.3 (−41.7 to −23.6)	40 (34.3 to 46.4)	14.5 (12.1 to 17.4)	−63.7 (−68.1 to −58.8)
Low physical activity	11 800 (4320 to 21 900)	9880 (3530 to 17 900)	−16.5 (−57.3 to 61.9)	3.56 (1.29 to 6.63)	1.5 (0.54 to 2.7)	−57.9 (−78.2 to −17.5)
Alcohol consumption	−2610 (−11 000 to 24 400)	−8510 (−16 600 to 17 300)	226 (−1180 to 1690)	−1.07 (−3.75 to 7.63)	−1.64 (−3.17 to 2.9)	52.4 (−826 to 572)
Environmental or occupational risks	211 000 (159 000 to 257 000)	123 000 (99 600 to 144 000)	−42 (−51.5 to −29.3)	64.5 (48.5 to 78.7)	19.2 (15.7 to 22.7)	−70.2 (−75.1 to −63.7)
Lead exposure	107 000 (89 200 to 127 000)	75 900 (60 900 to 90 300)	−29.3 (−34.2 to −25)	32.7 (27.2 to 38.6)	11.7 (9.48 to 14)	−64.1 (−66.4 to −61.9)
Particulate matter pollution	87 600 (33 400 to 144 000)	22 000 (10 200 to 36 300)	−74.9 (−88.8 to −46.7)	26.8 (10.2 to 44.2)	3.51 (1.63 to 5.76)	−86.9 (−94.2 to −72.4)
Nonoptimal temperature	45 800 (37 800 to 63 000)	35 300 (27 700 to 48 400)	−23 (−30 to −18.3)	14 (11.6 to 19.3)	5.63 (4.45 to 7.72)	−59.8 (−63.4 to −57.6)

Abbreviations: LDL, low-density lipoprotein; UI, uncertainty interval.

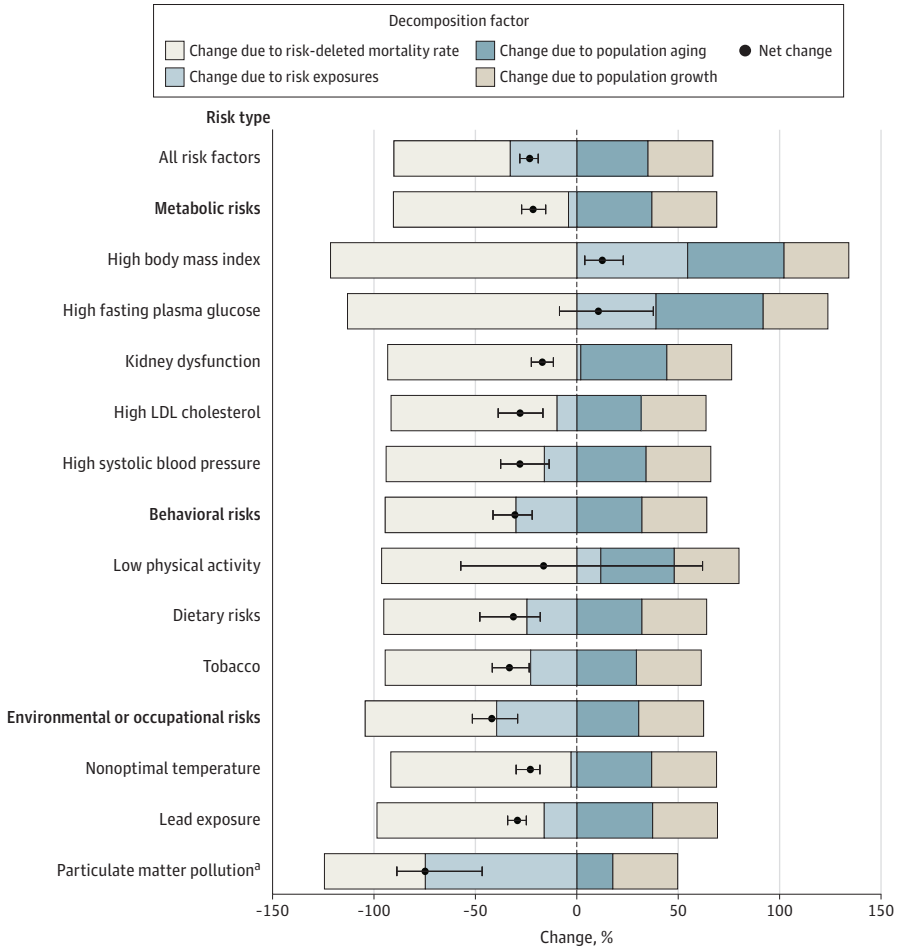
[a] Percentage change of IHD deaths attributable to risk factors given from 1990 to 2023. Counts, rates, and percentages were rounded to 3 significant figures.

77 100 (95% UI, 61 700-94 500) to 85 200 (95% UI, 67 100-106 000) in 2023. Population growth, aging, and increased high FPG exposure resulted in 24 700 (95% UI, 19 400-30 700), 40 700 (95% UI, 31 900-51 500), and 29 900 (95% UI, 9850-60 100) additional IHD deaths, respectively, which represented increases of 32% (95% UI, 29.5%-33.5%), 52.8% (95% UI, 44.5%-65.3%), and 38.8% (95% UI, 11.5%-81.1%) of high FPG-attributable IHD deaths since 1990; risk-deleted mortality did not offset these (Figure 2). IHD deaths attributable to high BMI increased by 8900 (95% UI, 2700-16 300), or 12.5% (95% UI, 3.8%-22.8%), since 1990. Increased high BMI exposure added 38 900 (95% UI, 17 000-64 800) IHD deaths, a 54.5% (95% UI, 41.8%-66.3%) increase in high BMI-attributable IHD deaths since 1990, which, alongside impacts of population growth and aging, was not offset by improved risk-deleted mortality.

In 2023, 232 000 IHD deaths (95% UI, 145 000-311 000) were attributable to behavioral risks nationally, representing 49.1% (95% UI, 30.3%-63.9%) of IHD deaths. Diet was the leading behavioral risk, comprising 38.6% (95% UI, 17.2%-56.8%) of IHD deaths. Tobacco caused 83 900 (95% UI, 69 800-101 000) IHD deaths in 2023, a decrease of 41 900 (95% UI, 29 700-52 500) since 1990, which represented a 33.3% (95% UI, 23.6%-41.7%) reduction in tobacco-attributable IHD deaths. Decomposition analysis showed that changed exposure across behavioral risks drove a 30.0% (95% UI, 4.9%-52.7%) decrease in attributable deaths since 1990 (Figure 2). This progress was driven by reduced tobacco exposure, which alone yielded a 22.8% (95% UI, 7.7%-34.5%) drop in IHD deaths attributable to tobacco. Changed diet and physical activity exposure showed no significant effects.

In 2023, environmental risks caused 123 000 (95% UI, 99 600-144 000) US IHD deaths, comprising 25.9% (95% UI, 22.4%-29.8%) of IHD deaths. Lead exposure, the leading environmental risk, caused 75 900 (95% UI, 60 900-90 300) IHD deaths in 2023, or 16.1% (95% UI, 13.7%-18.3%) of IHD deaths. Additionally, nonoptimal temperature and particulate matter pollution led to 35 300 (95% UI, 27 700-48 400) and 22 000 (95% UI, 10 200-36 300) IHD deaths in 2023, respectively. For particulate matter pollution, this corresponded to a 74.9% (95% UI, 46.7%-88.8%) reduction in the number of attributable IHD deaths since 1990 (Table 2). Since 1990, IHD deaths attributable to environmental risks decreased by 42.0% (95% UI, 29.3%-51.6%). The decline was driven primarily by reduced particulate matter pollution exposure, which resulted in a decrease of 65 400 (95% UI, 13 300-126 000), or 74.7% (95% UI, 37.5%-94.6%), attributable IHD deaths (Figure 2).

Figure 2. Bar Plot Showing Decomposition Analysis: Percentage Change in Attributable Risk Factors to Ischemic Heart Disease (IHD) Deaths Due to Population Growth, Population Aging, Risk Exposure, and Risk-Deleted Mortality: US, 1990-2023



Decomposition of change in all ages, all sexes combined IHD deaths attributable to risk factors from 1990 to 2023 due to population growth, population aging, risk exposure, and risk-deleted deaths in the US. Risk-deleted deaths are the number of deaths left after removing the effect of risk factors, population growth, and population aging on overall deaths. They were calculated as the overall IHD death count multiplied by 1 minus the population-attributable fraction for each risk. The dot and error bar represent the net change and 95% uncertainty interval in percentage change in number of deaths attributable to the risk from 1990 to 2023.

[a]Aggregate of ambient particulate matter air pollution and household air pollution due to solid fuels.

US State–Level Variation in Attributable Burden

In all states, high SBP, high LDL-C, and diet were the leading risk factors for IHD deaths (**Figures 3** and **4**). In 2023, the percentage of IHD deaths attributable to high BMI ranged from 13.7% (95% UI, 6.4%-20.7%) in Hawaii to 19.2% (95% UI, 9.2%-28.7%) in Mississippi; its rank decreased in only 1 state (Colorado). Kidney dysfunction contributed most to IHD deaths in Massachusetts at 19.5% (95% UI, 13.6%-26.1%) and least in Texas at 14.7% (95% UI, 10.5%-19.5%).

The percentage of IHD deaths attributable to dietary risks ranged from 35.4% (95% UI, 15.6%-52.7%) in New Jersey to 42.6% (95% UI, 19.4%-61.4%) in Mississippi. Tobacco's contribution ranged from 11.2% (95% UI, 9.0%-13.5%) in Utah to 23.5% (95% UI, 19.4%-27.8%) in Alaska. In over half of states, tobacco ranked the fourth- or fifth-highest risk for IHD deaths. Low physical activity was ranked the 11th-highest contributor in all but 1 state (Hawaii).

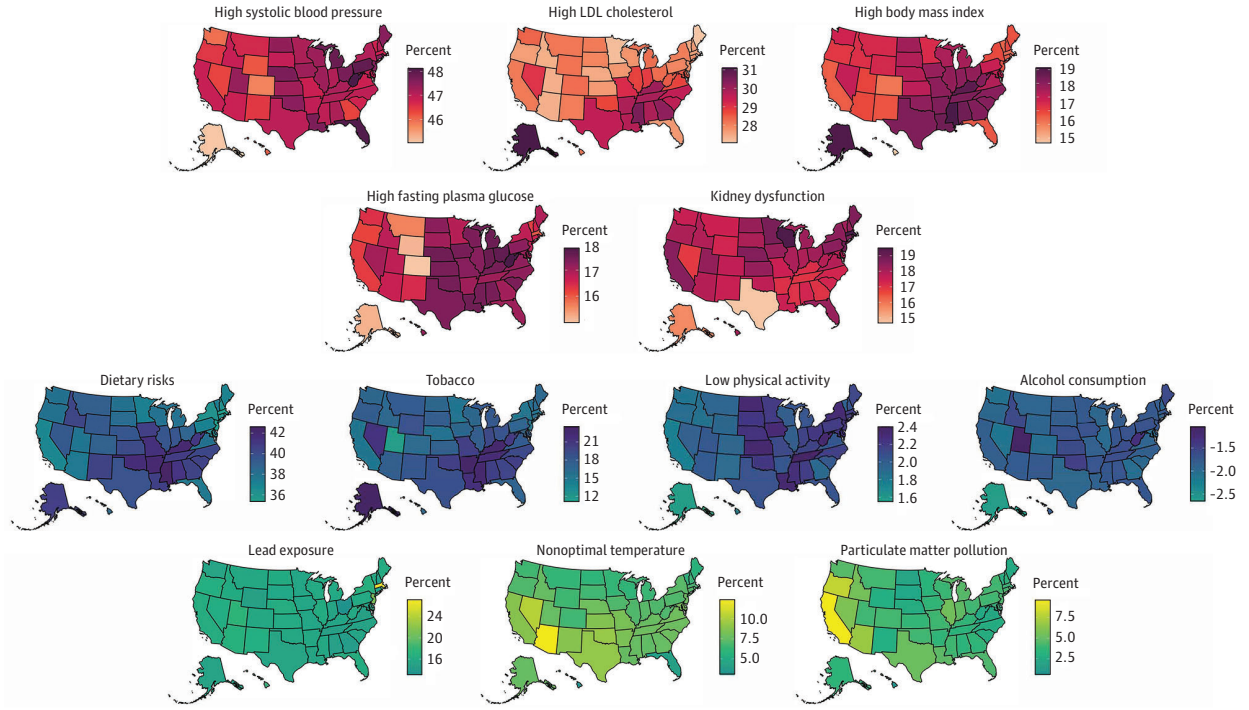
The percentage of IHD deaths attributable to nonoptimal temperature was highest in Arizona at 12.3% (95% UI, 6.1%-19.8%) and lowest in Hawaii at 3.0% (95% UI, 2.8%-3.4%). Nonoptimal temperature was the eighth-ranked risk nationally, and it increased rank in all but 5 states (Arizona, California, Florida, Hawaii, and Oregon).

Discussion

Main Findings

Since 1990, population growth and aging caused 365 000 additional IHD deaths, while modifiable risk factor changes prevented 180 000 deaths. High SBP, poor diet, and high LDL-C were the leading IHD mortality risk factors, with no significant decrease from changed exposures. Increased high BMI and high FPG added 38 900 and 29 900 IHD deaths, respectively, as reduced risk-deleted mortality did not offset their impact. Reduced tobacco exposure, lead, and air pollution have prevented 28 700, 17 300, and 65 400 IHD deaths nationally, respectively. This study highlights the importance of public health policies targeting modifiable risk factors, especially high BMI and high FPG, to reduce IHD mortality by addressing their role in accelerating atherosclerosis and counterbalancing population growth and aging.

Figure 3. Heatmap Showing Percentage of Ischemic Heart Disease (IHD) Deaths Attributable to Risk Factors in the US by State, 2023



Percentage of IHD deaths attributable to 12 level 2 Global Burden of Disease (GBD) risk factors in 2023 by state. Grouped by metabolic, behavioral, and environmental or occupational risks. Grouping risk factors by GBD hierarchy can be found in eTable 1 in Supplement 2. LDL indicates low-density lipoprotein.

Metabolic Risks

Our findings of rising high FPG and high BMI increasing US IHD deaths align with analyses documenting increased diabetes prevalence since 1990, while 10% of cases remain undiagnosed.[23-26] Current guidelines recommend screening at age 35 years and sooner if overweight or obesity is present, yet less than half of eligible US adults report glucose testing, potentially due to issues including health care access, clinician guideline familiarity, or patient care-seeking practices.[27] Glycemic and BP control among US patients with diabetes declined from the late 2000s onwards after a decade of progress in the late 1990s to early 2000s.[28] Our findings regarding high FPG lend further evidence to studies describing the resurgence of diabetes complications, including IHD, in the US.[29] Our results reflect the well-described US obesity epidemic, with 172 million adults overweight or obese as of 2021 and numbers projected to increase.[30] Multifaceted interventions, including medical management and surgical and lifestyle approaches focusing on improved nutrition, health education, and physical activity, show effectiveness in reducing obesity rates.[31,32]

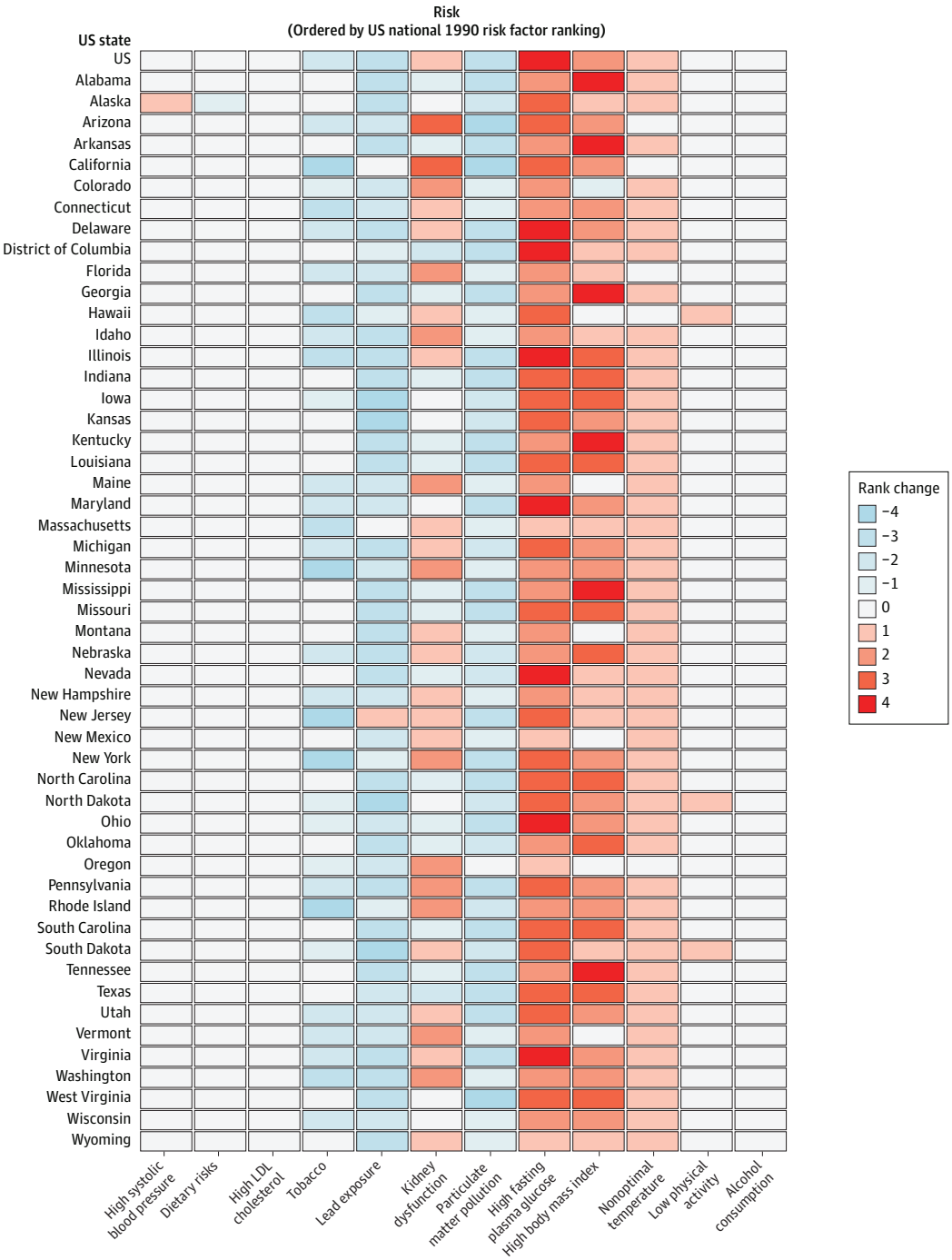
IHD deaths attributable to high SBP and high LDL-C declined slightly since 1990, predominantly due to reductions in risk-deleted mortality, not risk exposure. This likely reflects improved primary and secondary cardiovascular risk prevention rather than large differences in risk exposure control, including increased antihypertensive and lipid-lowering therapies.[33,34] However, high SBP and high LDL-C prevalence remains high.[34,35] Our findings align with national studies showing slight decreases in mean SBP since 1990.[35] National Health and Nutrition Examination Survey (NHANES) data indicate SBP control in hypertensive individuals improved from 1990 to 2010 but declined slightly since 2013.[36,37] Regarding LDL-C, our results align with NHANES analysis finding that US mean total cholesterol decreased but the proportion of people with controlled cholesterol did remain unchanged from the late 2000s to the early 2010s.[38]

Behavioral Risks

Dietary risks were the leading behavioral risk for IHD deaths. Although NHANES data show fewer adults meeting dietary guidelines since the early 2000s, our results found a slight reduction in IHD deaths attributable to dietary risks since 1990, partially due to banning trans fats in the late 2010s.[39,40] GBD does not measure total energy (calories) or high glycemic food consumption as risk factors, so our estimate of IHD trends attributable to diet reflects meal composition rather than quantity eaten (eg, dietary drivers of obesity).

Our findings show decreased IHD deaths from tobacco use nationally, primarily due to decreased exposure.[41] US tobacco prevention and control programs have shown success in reducing smoking prevalence. Our study found that states that experienced the lowest smoking PAF had implemented statewide programs (Utah, New Jersey, California).[42,43] Cohort and case-control studies show low and moderate levels of alcohol consumption decreases IHD risk compared with no or high consumption levels, although recent mendelian randomization studies have not shown this protective effect.[44,45]

Figure 4. Heatmap of Change in Rank of Ischemic Heart Disease (IHD) Deaths Attributable to Risks From 1990 to 2023 in the US



Heatmap of change in rank in IHD deaths attributable to 12 level 2 Global Burden of Disease (GBD) risk factors from 1990 to 2023 at the national and state level. White boxes represent no change in rank from 1990 to 2023. Red boxes indicate an increase in risk factor ranking, and blue boxes indicate a decrease. LDL indicates low-density lipoprotein.

We used all available evidence when we estimated a J-shaped risk curve for IHD attributable to alcohol use and therefore used a TMREL that accounted for the possibility of protective effects at low consumption levels. This resulted in a conservative approach, with IHD risk increasing for alcohol consumption above 60 g per day. However, low levels of alcohol consumption increase risk for other outcomes, including cancers, cirrhosis, and atrial fibrillation, and thus alcohol consumption should not be considered as a strategy to reduce IHD mortality.[46]

Environmental Risks

Lead exposure was the top environmental contributor to IHD deaths. NHANES and prospective cohort studies support the harmful association between lead and IHD in the US.[47] Our study showed a small decrease in IHD deaths attributable to lead since 1990, consistent with findings of decreased lead exposure nationally.[48] Recent US Environmental Protection Agency messaging is aimed at continuing the decreasing US lead exposure trend, specifically targeting high-risk communities.[49] IHD deaths attributable to particulate matter pollution decreased nationally. Unlike many global regions, household air pollution from the use of solid fuels for cooking contributed little to US IHD deaths, likely due to air quality management, regulation, and enforcement.[50] Since 2016, wildfire-driven ambient particulate matter increases have been detected in nearly two-thirds of states and are unregulated by the Clean Air Act.[51] Notably, the 2 states (California and Oregon) in which air pollution accounted for the most IHD deaths experienced high levels of wildfire air pollution historically.[52] Air pollution is associated with an increase in IHD in Utah, but longer-term trends are needed.[53] The proportion of IHD deaths attributed to nonoptimal temperature remained consistent since 1990 nationally but increased in states with extreme temperatures, such as Arizona and Alaska.

Trends, Disparities, and Policy

Since 1990, the US has significantly reduced age-standardized IHD death rates, largely from better preventative medications and health care system and public health interventions. However, since 2010, this progress has stalled or reversed with some demographics. While exposure changes for high SBP and high LDL-C are not decreasing IHD deaths, increased high FPG and BMI are increasing US IHD risk. This finding in the US coincides with global findings showing that high FPG and high BMI are increasingly contributors to IHD burden.[54] Health policies aimed to reduce these modifiable risk factors include improving health care access, providing affordable medications to treat risk factors, and addressing health disparities and social determinants of health.[7,55-57] Recent recommendations emphasize a shift toward targeting underlying IHD mechanisms, with a particular focus on early detection and treatment of atherosclerosis.[58,59] Studies from the US and Sweden show that even those at low risk of IHD may have subclinical atherosclerosis, particularly at younger ages.[60,61] Viewing atherosclerosis and IHD as a lifetime continuum and targeting modifiable risk factors via early detection provides opportunity to delay or reverse early atherosclerosis and subsequent IHD manifestations.

Limitations

Data availability limitations impacted both risk and mortality estimates. For geographic or temporal gaps in input data for risk exposures, covariates and statistical modeling were used to generate estimates. For example, input data for LDL and SBP exposures were only available through the end of 2021 (eTable 5 in Supplement 2). Similarly, lags in data availability from government sources meant that 2023 vital registration data were not accessible to investigators outside the government. The 2023 estimates relied on covariates related to IHD based on vital registration data from 1990 to 2022, potentially impacting short-term trend analysis.

This study focused on population-level modifiable risk factors that captured the majority of US IHD burden. Future studies incorporating emerging risks not currently estimated in GBD, such as lipoprotein(a), inflammation-related markers, sleep, and psychosocial factors, may provide a more comprehensive cardiovascular risk assessment but were not included either due to limited data availability, unclear causal pathways, or limited exposure data standardization. Polygenic risk scores were not included, as they represent inherited genetic susceptibility and are not currently considered modifiable.

Conclusions

Per the results of this systematic review of GBD 2023, the top 3 US modifiable risk factors for IHD were high SBP, diet, and high LDL-C. The largest increasing risk factors for IHD deaths were high BMI and high FPG, driven by increased risk exposure and population aging and growth. Reduced national exposure decreased tobacco and air pollution's contribution to IHD deaths, although tobacco remains a leading risk in most states. Reductions in IHD mortality in the US have slowed, especially in younger populations. Past declines in IHD mortality in the US are unlikely to resume without further reduction of these leading risk factors.

ARTICLE INFORMATION

Accepted for Publication: May 14, 2026.

Published Online: July 15, 2026. doi:10.1001/jamacardio.2026.2435

The GBD 2023 US IHD Collaborators: Catherine P. Benziger, MD; Benjamin A. Stark, MA; Catherine O. Johnson, PhD; Shady Abohashem, MPH; Syed Anees Ahmed, PhD; Ziyad Al-Aly, MD; Mohammed A. Alsabri, MD; Catherine M. Antony, MA; Aleksandr Y. Aravkin, PhD; Demelash Areda, PhD; Michelle L. Bell, PhD; Michael Brauer, DSc; Gerald Chi, MD; Michael H. Criqui, MD; Xiaochen Dai, PhD; Ojas Prakashbhai Doshi, MS; Rajkumar Prakashbhai Doshi, MD; Abdel Rahman E'mar, MD; Muhammed Elhadi, MD; Laszlo Göbölös, PhD; Demewoz Haile, PhD; Jeffrey J. Hebert, PhD; Mehdi Hemmati, MD; Ramzi Ibrahim, MD; Samuel Berchi Kankam, MD; Rami S. Kantar, MD; Jagdish Khubchandani, PhD; Min Seo Kim, MD; Ruth W. Kimokoti, MD; Adnan Kisa, PhD; Michail Kokkorakis, MD; Ashish Kumar, MD; Xuefeng Liu, PhD; Lei Lv, PhD; Morteza Mahmoudi, PhD; Yosef Manla, MD; Ramon Martinez-Piedra, BSc; Sammer Marzouk, MA; George A. Mensah, MD; Tomislav Mestrovic, PhD; Ted R. Miller, PhD; Ali H. Mokdad, PhD; Vincent Mougin, BA; Ahmad Mustafa, MD; Mahmoud Nassar, PhD; Zuhair S. Natto, DrPH; Fred Nugen, PhD; Romil R. Parikh, MD; Maja Pasovic, Med; Shankargouda Patil, PhD; Jagadeesh Puvvula, PhD; Shakthi Kumaran Ramasamy, MD; Ahmed Mustafa Rashid, MD; Kevin T. Root, BS; Monika Sawhney, PhD; Art Schuermans, BSc; Mariam Shariff, MD; Kerem Shuval, PhD; Gizeaddis Lamesgin Simegn, PhD; Rohit Singh, MD; Lauryn K. Stafford, MS; Jabeen Taiba, PhD; Manoj Tanwar, MD; Masayuki Teramoto, MD; Sathish Thirunavukkarasu, PhD; Thang Huu Tran, MD; Dipan Uppal, MD; Manish Vinayak, MD; Deniz Yuce, MD; Christopher J. L. Murray, DPhil; Andrew E. Moran, MD; Gregory A. Roth, MD.

Affiliations of The GBD 2023 US IHD Collaborators: Heart and Vascular Center, Essentia Health, Duluth, Minnesota (Benziger); Institute for Health Metrics and Evaluation, University of

Washington, Seattle (Stark, Johnson, Antony, Aravkin, Brauer, Dai, Haile, Mestrovic, Mokdad, Mougin, Pasovic, Stafford, Murray, Roth); Department of Health Metrics Sciences, School of Medicine, University of Washington, Seattle (Aravkin, Dai, Mokdad, Murray, Roth); Division of Cardiology, University of Washington, Seattle (Roth); Cardiovascular Research Center, Massachusetts General Hospital, Boston (Abohashem); Department of Radiology, Harvard University, Boston, Massachusetts (Abohashem); Brody School of Medicine, East Carolina University, Greenville, North Carolina (Ahmed); Department of Research and Development, Washington University in St Louis, St Louis, Missouri (Al-Aly); Clinical Epidemiology Center, US Department of Veterans Affairs, St Louis, Missouri (Al-Aly); Department of Emergency Medicine, Sana'a University, Sanaa, Yemen (Alsabri); Pediatric Emergency Medicine Department, Drexel University, Philadelphia, Pennsylvania (Alsabri); Department of Applied Mathematics, University of Washington, Seattle (Aravkin); College of Art and Science, Ottawa University, Surprise, Arizona (Areda); School of the Environment, Yale University, New Haven, Connecticut (Bell); School of Health Policy and Management, Korea University, Seoul, South Korea (Bell); School of Population and Public Health, University of British Columbia, Vancouver, British Columbia, Canada (Brauer); Division of Cardiovascular Medicine, Harvard University, Boston, Massachusetts (Chi); Department of Family Medicine and Public Health, University of California, San Diego, La Jolla (Criqui); Independent Consultant, Bridgewater, New Jersey (O. P. Doshi); Department of Cardiology, Hackettstown Medical Center, Hackettstown, New Jersey (R. P. Doshi); Newton Medical Center, Sparta, New Jersey (R. P. Doshi); Department of Pediatrics, Cleveland Clinic, Cleveland, Ohio (E'mar); College of Medicine, Korea University, Seoul, South Korea (Elhadi); Houston Methodist Hospital, Houston, Texas (Elhadi); Department of Cardiac Surgery, Cleveland Clinic Abu Dhabi, Abu Dhabi, United Arab Emirates (Göbölös); Lerner College of Medicine, Case Western Reserve University, Cleveland, Ohio (Göbölös); Faculty of Kinesiology, University of New Brunswick, Fredericton, New Brunswick, Canada (Hebert); School of Allied Health, Murdoch University, Murdoch, Western Australia, Australia (Hebert); Department of Medicine, MedStar Health, Washington, DC (Hemmati); Department of Medicine, Georgetown University, Washington, DC (Hemmati); Department of Cardiovascular Medicine, Mayo Clinic, Phoenix, Arizona (Ibrahim); T. H. Chan School of Public Health, Harvard University, Boston, Massachusetts (Kankam); The Hansjörg Wyss Department of Plastic and Reconstructive Surgery, New York University, New York (Kantar); Department of Public Health, New Mexico State University, Las Cruces (Khubchandani); Cardiovascular Disease Initiative, Broad Institute of MIT and Harvard, Cambridge, Massachusetts (Kim); Massachusetts General Hospital, Boston (Kim); Health and Healing Research, Education, and Service, Boston, Massachusetts (Kimokoti); Millennium Prevention, Westwood, Massachusetts (Kimokoti); School of Health Sciences, Kristiania University College, Oslo, Norway (Kisa); Department of International Health and Sustainable Development, Tulane University, New Orleans, Louisiana (Kisa); Department of Medicine, Harvard University, Boston, Massachusetts (Kokkorakis); Department of Cardiovascular Medicine, Mayo Clinic, Rochester, Minnesota (Kumar); Lerner Research Institute, Cleveland Clinic, Cleveland, Ohio (Liu); Department of Quantitative Health Science, Case Western Reserve University, Cleveland, Ohio (Liu); Department of Clinical Data Science and Evidence, Novo Nordisk, Plainsboro, New Jersey (Lv); Radiology and Precision Health Program, Michigan State University, East Lansing (Mahmoudi); Department of Internal Medicine, Eisenhower Health, Palm Desert, California (Manla); Department of Noncommunicable Diseases and Mental Health, Pan American Health Organization, Washington, DC (Martinez-Piedra); Medical Scientist Training Program, Northwestern University, Chicago, Illinois (Marzouk); Center for Translation Research and Implementation Science, US National Institutes of Health, Bethesda, Maryland (Mensah); Department of Medicine, University of Cape Town, Cape Town, South Africa (Mensah); University Centre Varazdin, University North, Varazdin, Croatia (Mestrovic); College of Human Medicine, Michigan State University, Flint (Miller); Department of Cardiology, Northwell Health, Staten Island, New York (Mustafa); Division of Endocrinology and Diabetes, University of Vermont, South Burlington (Nassar); Department of Dental Public Health, King Abdulaziz University, Jeddah, Saudi Arabia (Natto); Department of Radiology, Mayo Clinic, Rochester, Minnesota (Nugen); School of Information, University of California, Berkeley (Nugen); Division of Health Policy and Management, University of Minnesota, Minneapolis (Parikh); College of Dental Medicine, Roseman University of Health Sciences, South Jordan, Utah (Patil); Department of Biostatistics, Epidemiology, and Informatics, University of Pennsylvania, Philadelphia (Puvvula); Department of Radiology, Stanford University, Stanford, California (Ramasamy); Department of Research, Baylor Scott and White Research Institute, Dallas, Texas (Rashid); Baylor University, Dallas, Texas (Rashid); College of Medicine, University of Florida, Gainesville (Root); Department of Public Health Sciences, University of North Carolina at Charlotte (Sawhney); Faculty of Medicine, Katholieke Universiteit Leuven, Leuven, Belgium (Schuermans); Department of Cardiovascular Sciences, Katholieke Universiteit Leuven, Leuven, Belgium (Schuermans); Department of General Surgery, Mayo Clinic Foundation for Medical Education and Research, Rochester, Minnesota (Shariff); Kenneth H. Cooper Institute, Texas Tech University Health Sciences Center, Dallas (Shuval); Department of Radiology and Radiological Science, Johns Hopkins University, Baltimore, Maryland (Simegn); Division of Hematology and Oncology, University of Vermont, Burlington (Singh); Department of Environmental, Agricultural and Occupational Health, University of Nebraska Medical Center, Omaha (Taiba); Department of Radiology, University of Alabama at Birmingham (Tanwar); Department of Preventive Medicine, Northwestern University, Chicago, Illinois (Teramoto); Department of Family and Preventive Medicine, Emory University, Atlanta, Georgia (Thirunavukkarasu); Department of Internal Medicine, University of Medicine and Pharmacy at Ho Chi Minh City, Ho Chi Minh City, Vietnam (Tran); Department of Business Analytics, University of Massachusetts Dartmouth (Tran); Section of Advanced Heart Failure and Transplant, Northwell Health/North Shore University Hospital, Manhasset, New York (Uppal); Department of Cardiology, Icahn School of Medicine at Mount Sinai, New York, New York (Vinayak); Cancer Institute, Hacettepe University, Ankara, Türkiye (Yuce); Department of Medicine, Columbia University Medical Center, New York, New York (Moran); Global Hypertension Control, Resolve to Save Lives, New York, New York (Moran).

Author Contributions: Mr Stark and Dr Roth had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Dr Benziger and Mr Stark contributed equally as co–first authors.
Concept and design: Roth, Benziger, Stark, Johnson, Abohashem, Areda, Bell, Brauer, O. Doshi, Elhadi, Göbölös, Ibrahim, Kantar, Kisa, Kokkorakis, Manla, Marzouk, Mokdad, Mustafa, Natto, Root, Taiba, Yuce.
Acquisition, analysis, or interpretation of data: Roth, Benziger, Stark, Johnson, Abohashem, Ahmed, Al-Aly, Alsabri, Antony, Aravkin, Brauer, Chi, Criqui, Dai, O. Doshi, R. Doshi, E'mar, Elhadi, Göbölös, Haile, Hebert, Hemmati, Ibrahim, Kankam, Kantar, Khubchandani, Kim, Kimokoti, Kisa, Kokkorakis, Kumar, Liu, Lv, Mahmoudi, Martinez-Piedra, Marzouk, Mensah, Mestrovic, Miller, Mougin, Nassar, Natto, Nugen, Parikh, Pasovic, Patil, Puvvula, Ramasamy, Rashid, Sawhney, Schuermans, Shariff, Shuval, Simegn, Singh, Stafford, Taiba, Tanwar, Teramoto, Thirunavukkarasu, Tran, Uppal, Vinayak, Yuce, Murray, Moran.
Drafting of the manuscript: Benziger, Stark, E'mar, Elhadi, Göbölös, Ibrahim, Kantar, Khubchandani, Kisa, Kokkorakis, Marzouk, Patil, Rashid, Root, Tanwar.
Critical review of the manuscript for important intellectual content: Roth, Benziger, Johnson, Abohashem, Ahmed, Al-Aly, Alsabri, Antony, Aravkin, Areda, Bell, Brauer, Chi, Criqui, Dai, O. Doshi, R. Doshi, E'mar, Elhadi, Göbölös, Haile, Hebert, Hemmati, Ibrahim, Kankam, Kantar, Khubchandani, Kim, Kimokoti, Kisa, Kumar, Liu, Lv, Mahmoudi, Manla, Martinez-Piedra, Marzouk, Mensah, Mestrovic, Miller, Mokdad, Mougin, Mustafa, Nassar, Natto, Nugen, Parikh, Pasovic, Patil, Puvvula, Ramasamy, Rashid, Root, Sawhney, Schuermans, Shariff, Shuval, Simegn, Singh, Stafford, Taiba, Tanwar, Teramoto, Thirunavukkarasu, Tran, Uppal, Vinayak, Yuce, Murray, Moran.
Statistical analysis: Benziger, Stark, Johnson, Abohashem, Alsabri, Aravkin, Brauer, Dai, Göbölös, Haile, Ibrahim, Kisa, Liu, Martinez-Piedra, Marzouk, Mokdad, Nassar, Natto, Ramasamy, Sawhney, Simegn, Stafford.
Obtained funding: Mokdad.
Administrative, technical, or material support: Stark, Abohashem, Ahmed, Antony, Dai, O. Doshi, Elhadi, Göbölös, Hebert, Ibrahim, Kantar, Kokkorakis, Mokdad, Mustafa, Parikh, Pasovic, Shuval, Tanwar, Yuce, Murray.
Supervision: Roth, Benziger, Johnson, Brauer, Criqui, Göbölös, Ibrahim, Kantar, Mokdad, Mustafa, Natto, Patil, Puvvula, Rashid, Root, Singh, Tanwar, Murray.

Conflict of Interest Disclosures: Dr Benziger reported being a consultant for Novartis for the V1P study (a lipid trial) and serving as a site principal investigator (PI) of various studies funded by the US National Institutes of Health (NIH), the Patient-Centered Outcomes Research Institute, and

industry sponsors not related to this manuscript outside the submitted work. Drs Stark, Antony, Root, and Stafford reported grants from the Gates Foundation during the conduct of the study. Dr Bell reported grants paid to her university from the NIH and the Wellcome Trust; honorarium from Korea University; honorarium for grant review from the Fund for Scientific Research; travel reimbursement and honorarium from the Community Modeling and Analysis System Conference (CMAS) and the Colorado School of Public Health; travel reimbursement from the *American Journal of Public Health*, Columbia University, Harvard, Health Effects Institute, MIT, and the University of Connecticut; consulting fees from ToxiMap; honoraria for grant reviews and a mock grant review from NIH, Hong Kong, and the United Arab Emirates and from the University of Texas, respectively; honorarium for editorial duties from Institute of Physics; and honorarium for committee membership from the Environmental Protection Agency outside the submitted work. Dr Brauer reported grants from the Gates Foundation to his institution during the conduct of the study. Dr Hebert reported grants from ResearchNB in the form of salary and project support during the conduct of the study. Dr Mahmoudi reported being a cofounder and director of the Academic Parity Movement (a nonprofit organization dedicated to addressing academic discrimination, violence, and incivility) and a cofounder of Targets Tip, AlbuDerm, and XProteome Inc and receiving royalties and honoraria for his published books, plenary lectures, and licensed patents. Dr Tanwar reported grants from the University of Alabama at Birmingham Health Service Foundation outside the submitted work. No other disclosures were reported.

Funding/Support: This research was supported by the Gates Foundation.

Role of the Funder/Sponsor: The Gates Foundation had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Data Sharing Statement: See Supplement 3.

Additional Information: Members of the core Institute for Health Metrics and Evaluation (IHME) research team had full access to the underlying data used to generate estimates presented in this article. All other authors had access to and reviewed estimates as part of the Global Burden of Disease (GBD) Study and research evaluation process, which includes additional stages of internal IHME and external formal collaborator review. This article was developed as part of the GBD Collaborator Network and GBD Protocol with support from the GBD Secretariat, IHME, and the GBD Collaborator Network under the IHME identifier 5513.

REFERENCES

1. GBD 2023 Disease and Injury and Risk Factor Collaborators. Burden of 375 diseases and injuries, risk-attributable burden of 88 risk factors, and healthy life expectancy in 204 countries and territories, including 660 subnational locations, 1990-2023: a systematic analysis for the Global Burden of Disease Study 2023. *Lancet*. 2025;406 (10513):1873-1922. doi:10.1016/S0140-6736(25) 01637-X

2. Roth GA, Johnson CO, Abate KH, et al; Global Burden of Cardiovascular Diseases Collaboration. The burden of cardiovascular diseases among US states, 1990-2016. *JAMA Cardiol*. 2018;3(5):375-389. doi:10.1001/jamacardio.2018.0385

3. Roth GA, Dwyer-Lindgren L, Bertozzi-Villa A, et al. Trends and patterns of geographic variation in cardiovascular mortality among US counties, 1980-2014. *JAMA*. 2017;317(19):1976-1992. doi:10.1001/jama.2017.4150

4. Lloyd-Jones DM, Hong Y, Labarthe D, et al; American Heart Association Strategic Planning Task Force and Statistics Committee. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic impact goal through 2020 and beyond. *Circulation*. 2010;121(4):586-613. doi:10.1161/CIRCULATIONAHA.109.192703

5. Lloyd-Jones DM, Elkind M, Albert MA. American Heart Association's 2024 impact goal: every person deserves the opportunity for a full, healthy life. *Circulation*. 2021;144(18):e277-e279. doi:10.1161/ CIRCULATIONAHA.121.057617

6. Bhatnagar A. Environmental determinants of cardiovascular disease. *Circ Res*. 2017;121(2):162-180. doi:10.1161/CIRCRESAHA.117.306458

7. Tsao CW, Aday AW, Almarzooq ZI, et al; American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics-2023 update: a report from the American Heart Association. *Circulation*. 2023;147 (8):e93-e621. doi:10.1161/CIR.0000000000001123

8. Mensah GA, Wei GS, Sorlie PD, et al. Decline in cardiovascular mortality: possible causes and implications. *Circ Res*. 2017;120(2):366-380. doi:10.1161/CIRCRESAHA.116.309115

9. Ritchey MD, Wall HK, Owens PL, Wright JS. Vital signs: state-level variation in nonfatal and fatal cardiovascular events targeted for prevention by Million Hearts 2022. *MMWR Morb Mortal Wkly Rep*. 2018;67(35):974-982. doi:10.15585/mmwr. mm6735a3

10. Johnson CO, DeCleene NK, Blacker BF, et al. State-level cardiovascular mortality rates among Hispanic, non-Hispanic Black, and non-Hispanic White populations, 1990 to 2019. *JAMA Cardiol*. 2023;8(5):429-442. doi:10.1001/jamacardio.2023. 0112

11. GBD US Health Disparities Collaborators. Cause-specific mortality by county, race, and ethnicity in the USA, 2000-19: a systematic analysis of health disparities. *Lancet*. 2023;402(10407): 1065-1082. doi:10.1016/S0140-6736(23)01088-7

12. Vaduganathan M, Mensah GA, Turco JV, Fuster V, Roth GA. The global burden of cardiovascular diseases and risk: a compass for future health. *J Am Coll Cardiol*. 2022;80(25):2361-2371. doi:10.1016/ j.jacc.2022.11.005

13. Roth GA, Mensah GA, Johnson CO, 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(25):2982-3021. doi:10.1016/ j.jacc.2020.11.010

14. Institute for Health Metrics and Evaluation (IHME). GBD Compare. University of Washington. Accessed March 10, 2026. http://vizhub.healthdata.org/gbd-compare.

15. GBD 2023 Causes of Death Collaborators. Global burden of 292 causes of death in 204 countries and territories and 660 subnational locations, 1990-2023: a systematic analysis for the Global Burden of Disease Study 2023. *Lancet*. 2025;406(10513):1811-1872. doi:10.1016/S0140-6736 (25)01917-8

16. Data release policy for vital statistics micro-data files. National Vital Statistics System, Centers for Disease Control and Prevention. Accessed March 10, 2026. https://www.cdc.gov/nchs/nvss/dvs_ data_release.htm

17. Johnson SC, Cunningham M, Dippenaar IN, et al; GBD Cause of Death Collaborators. Public health utility of cause of death data: applying empirical algorithms to improve data quality. *BMC Med Inform Decis Mak*. 2021;21(1):175. doi:10.1186/ s12911-021-01501-1

18. COVID-19 Excess Mortality Collaborators. Estimating excess mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19-related mortality, 2020-21. *Lancet*. 2022; 399(10334):1513-1536. doi:10.1016/S0140-6736(21) 02796-3

19. Zheng P, Barber R, Sorensen RJ, Murray CJ, Aravkin AY. Trimmed constrained mixed effects models: formulations and algorithms. *J Comput Graph Stat*. 2021;30(3):1-13. https://doi.org/ 10.1080/10618600.2020.1868303

20. Zheng P, Afshin A, Biryukov S, et al. The Burden of Proof studies: assessing the evidence of risk. *Nat Med*. 2022;28(10):2038-2044. doi:10.1038/s41591-022-01973-2

21. Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration. Cardiovascular disease, chronic kidney disease, and diabetes mortality burden of cardiometabolic risk factors from 1980 to 2010: a comparative risk assessment. *Lancet Diabetes Endocrinol*. 2014;2(8):634-647. doi:10.1016/S2213-8587(14)70102-0

22. Das Gupta P. *Standardization and Decomposition of Rates: A User's Manual*. US Bureau of the Census; 1993.

23. Wang L, Li X, Wang Z, et al. Trends in prevalence of diabetes and control of risk factors in diabetes among US adults, 1999-2018. *JAMA*. 2021; 326(8):1-13. doi:10.1001/jama.2021.9883

24. GBD 2021 Diabetes Collaborators. Global, regional, and national burden of diabetes from 1990 to 2021, with projections of prevalence to 2050: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet*. 2023;402(10397): 203-234. doi:10.1016/S0140-6736(23)01301-6

25. Menke A, Casagrande S, Geiss L, Cowie CC. Prevalence of and trends in diabetes among adults in the United States, 1988-2012. *JAMA*. 2015;314 (10):1021-1029. doi:10.1001/jama.2015.10029

26. Fang M, Wang D, Coresh J, Selvin E. Undiagnosed diabetes in U.S. adults: prevalence and trends. *Diabetes Care*. 2022;45(9):1994-2002. doi:10.2337/dc22-0242

27. Ali MK, Imperatore G, Benoit SR, et al. Impact of changes in diabetes screening guidelines on testing eligibility and potential yield among adults without diagnosed diabetes in the United States. *Diabetes Res Clin Pract*. 2023;197:110572. doi:10.1016/j.diabres.2023.110572

28. Fang M, Wang D, Coresh J, Selvin E. Trends in diabetes treatment and control in U.S. adults, 1999-2018. *N Engl J Med*. 2021;384(23):2219-2228. doi:10.1056/NEJMsa2032271

29. Gregg EW, Hora I, Benoit SR. Resurgence in diabetes-related complications. *JAMA*. 2019;321 (19):1867-1868. doi:10.1001/jama.2019.3471

30. GBD 2021 US Obesity Forecasting Collaborators. National-level and state-level prevalence of overweight and obesity among children, adolescents, and adults in the USA, 1990-2021, and forecasts up to 2050. *Lancet*. 2024;404(10469):2278-2298. doi:10.1016/S0140-6736(24)01548-4

31. Finn EB, Whang C, Hong PH, Costa SA, Callahan EA, Huang TT. Strategies to improve the implementation of intensive lifestyle interventions for obesity. *Front Public Health*. 2023;11:1202545. doi:10.3389/fpubh.2023.1202545

32. Temple NJ. A proposed strategy against obesity: how government policy can counter the obesogenic environment. *Nutrients*. 2023;15(13): 2910. doi:10.3390/nu15132910

33. Scholcoff C, Kay C, Nickoloff S, Jackson JL. Trends in systolic blood pressure control and management in the USA, 2007 to 2016. *J Gen Intern Med*. 2020;35(8):2510-2512. doi:10.1007/s11606-020-05812-3

34. Gao Y, Shah LM, Ding J, Martin SS. US trends in cholesterol screening, lipid levels, and lipid-lowering medication use in US adults, 1999 to 2018. *J Am Heart Assoc*. 2023;12(3):e028205. doi:10.1161/JAHA.122.028205

35. Forouzanfar MH, Liu P, Roth GA, et al. Global burden of hypertension and systolic blood pressure of at least 110 to 115 mm Hg, 1990-2015. *JAMA*. 2017;317(2):165-182. doi:10.1001/jama.2016.19043

36. Fields LE, Burt VL, Cutler JA, Hughes J, Roccella EJ, Sorlie P. The burden of adult hypertension in the United States 1999 to 2000: a rising tide. *Hypertension*. 2004;44(4):398-404. doi:10.1161/01.HYP.0000142248.54761.56

37. Hardy ST, Jaeger BC, Foti K, Ghazi L, Wozniak G, Muntner P. Trends in blood pressure control among US adults with hypertension, 2013-2014 to 2021-2023. *Am J Hypertens*. 2025;38(2):120-128. doi:10.1093/ajh/hpae141

38. Aggarwal R, Bhatt DL, Rodriguez F, Yeh RW, Wadhera RK. Trends in lipid concentrations and lipid control among US adults, 2007-2018. *JAMA*. 2022;328(8):737-745. doi:10.1001/jama.2022.12567

39. Long T, Zhang K, Chen Y, Wu C. Trends in diet quality among older US adults from 2001 to 2018. *JAMA Netw Open*. 2022;5(3):e221880. doi:10.1001/jamanetworkopen.2022.1880

40. Downs SM, Bloem MZ, Zheng M, et al. The impact of policies to reduce trans fat consumption: a systematic review of the evidence. *Curr Dev Nutr*. 2017;1(12):cdn.117.000778. doi:10.3945/cdn.117.000778

41. Leas EC, Trinidad DR, Pierce JP, McMenamin SB, Messer K. Trends in cigarette consumption across the United States, with projections to 2035. *PLoS One*. 2023;18(3):e0282893. doi:10.1371/journal.pone.0282893

42. Dilley JA, Harris JR, Boysun MJ, Reid TR. Program, policy, and price interventions for tobacco control: quantifying the return on investment of a state tobacco control program. *Am J Public Health*. 2012;102(2):e22-e28. doi:10.2105/AJPH.2011.300506

43. Kilgore EA, Mandel-Ricci J, Johns M, et al. Making it harder to smoke and easier to quit: the effect of 10 years of tobacco control in New York City. *Am J Public Health*. 2014;104(6):e5-e8. doi:10.2105/AJPH.2014.301940

44. Carr S, Bryazka D, McLaughlin SA, et al. A burden of proof study on alcohol consumption and ischemic heart disease. *Nat Commun*. 2024;15 (1):4082. doi:10.1038/s41467-024-47632-7

45. Piano MR, Marcus GM, Aycock DM, et al; on behalf the American Heart Association Council on Lifestyle and Cardiometabolic Health; Council on Cardiovascular and Stroke Nursing; Council on Clinical Cardiology; and Stroke Council. Alcohol use and cardiovascular disease: a scientific statement from the American Heart Association. *Circulation*. 2025;152(1):e7-e21. doi:10.1161/CIR.0000000000001341

46. Levesque C, Sanger N, Edalati H, et al. A systematic review of relative risks for the relationship between chronic alcohol use and the occurrence of disease. *Alcohol Clin Exp Res (Hoboken)*. 2023;47(7):1238-1255. doi:10.1111/acer.15121

47. Lamas GA, Ujueta F, Navas-Acien A. Lead and cadmium as cardiovascular risk factors: the burden of proof has been met. *J Am Heart Assoc*. 2021;10 (10):e018692. doi:10.1161/JAHA.120.018692

48. Wang T, Zhou YP, Sun Y, Zheng YX. Trends in blood lead levels in the U.S. from 1999 to 2016. *Am J Prev Med*. 2021;60(4):e179-e187. doi:10.1016/j.amepre.2020.10.024

49. Actions to reduce potential lead exposure. US Environmental Protection Agency. Accessed November 4, 2025. https://www.epa.gov/lead/actions-reduce-potential-lead-exposure

50. Bennett JE, Tamura-Wicks H, Parks RM, et al. Particulate matter air pollution and national and county life expectancy loss in the USA: a spatiotemporal analysis. *PLoS Med*. 2019;16(7): e1002856. doi:10.1371/journal.pmed.1002856

51. Clean Air Act. GovInfo. Accessed March 10, 2026. https://www.govinfo.gov/app/details/COMPS-8160

52. Hadley MB, Henderson SB, Brauer M, Vedanthan R. Protecting cardiovascular health from wildfire smoke. *Circulation*. 2022;146(10):788-801. doi:10.1161/CIRCULATIONAHA.121.058058

53. Pope CA, Muhlestein JB, Anderson JL, et al. Short-term exposure to fine particulate matter air pollution is preferentially associated with the risk of ST-segment elevation acute coronary events. *J Am Heart Assoc*. 2015;4(12):e002506. doi:10.1161/JAHA.115.002506

54. Global Burden of Cardiovascular Diseases and Risks 2023 Collaborators. Global, regional, and national burden of cardiovascular diseases and risk factors in 204 countries and territories, 1990-2023. *J Am Coll Cardiol*. 2025;86(22):2167-2243. doi:10.1016/j.jacc.2025.08.015

55. Jaeger BC, Chen L, Foti K, et al. Hypertension statistics for US adults: an open-source web application for analysis and visualization of National Health and Nutrition Examination survey data. *Hypertension*. 2023;80(6):1311-1320. doi:10.1161/HYPERTENSIONAHA.123.20900

56. Bolnick HJ, Bui AL, Bulchis A, et al. Health-care spending attributable to modifiable risk factors in the USA: an economic attribution analysis. *Lancet Public Health*. 2020;5(10):e525-e535. doi:10.1016/S2468-2667(20)30203-6

57. Raisi-Estabragh Z, Kobo O, Mieres JH, et al. Racial disparities in obesity-related cardiovascular mortality in the United States: temporal trends from 1999 to 2020. *J Am Heart Assoc*. 2023;12(18): e028409. doi:10.1161/JAHA.122.028409

58. Zaman S, Wasfy JH, Kapil V, et al. The Lancet Commission on rethinking coronary artery disease: moving from ischaemia to atheroma. *Lancet*. 2025;405(10486):1264-1312. doi:10.1016/S0140-6736(25)00055-8

59. Blumenthal RS, Morris PB, Gaudino M, et al; Writing Committee Members. 2026 ACC/AHA/AACVPR/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA/PCNA Guideline on the Management of Dyslipidemia: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation*. 2026;153(17):e1154-e1276. doi:10.1161/CIR.0000000000001423

60. Berry JD, Liu K, Folsom AR, et al. Prevalence and progression of subclinical atherosclerosis in younger adults with low short-term but high lifetime estimated risk for cardiovascular disease: the Coronary Artery Risk Development in Young Adults study and Multi-Ethnic Study of Atherosclerosis. *Circulation*. 2009;119(3):382-389. doi:10.1161/CIRCULATIONAHA.108.800235

61. Bergström G, Persson M, Adiels M, et al. Prevalence of subclinical coronary artery atherosclerosis in the general population. *Circulation*. 2021;144(12):916-929. doi:10.1161/CIRCULATIONAHA.121.055340