

RESEARCH

Open Access



Global, regional, and national burden of opioid use disorder from 1990 to 2021: a statistical analysis of incidence, mortality, and disability-adjusted life years

Mingxing Fang¹, Qi Zhang¹, Jibin Peng¹, Wenwen Yao¹, Wenming Feng¹ and Xinan Wan^{1*}

Abstract

Background Opioid use disorder (OUD) present significant health challenges globally, especially among adolescents and young adults. This study leverages the Global Burden of Disease (GBD) Study 2021 to assess the burden of OUD from 1990 to 2021.

Methods The incidence, mortality, and disability-adjusted life years (DALYs) of OUD from 1990 to 2021 were extracted from the GBD Study 2021 website. The slope index of inequality (SII) and concentration index of inequality (CII) were used to quantify the inequality of OUD burden across countries. We employed frontier analysis to quantify the gap between a country's or territory's current burden and its potential minimum burden.

Results Globally, in 2021, the number of new cases, deaths, and the DALYs of OUD were 1942.52 thousand [95% uncertainty interval (UI): 1643.34, 2328.36], 99.55 thousand (95% UI: 92.94, 108.04), and 11,218.51 thousand (95% UI: 9188.65, 13,159.55), respectively. The age-standardized rates (ASRs) of incidence, mortality, and DALYs of OUD were 24.54 per 100,000 population (95% UI: 20.74, 29.48), 1.19 per 100,000 population (95% UI: 1.12, 1.29), and 137.15 per 100,000 population (95% UI: 112.29, 161.39), respectively. At the regional level, high-income North America had the most severe burden of OUD. The peak OUD incidence occurred in both males and females aged 20–24 years, and the peak OUD-related mortality occurred in males aged 30–44 years and females aged 30–59 years. Countries with higher SDIs have a heavier burden of OUD, and this trend continues to intensify. Countries with higher SDIs often have greater potential to reduce the burden of OUD.

Conclusion OUD remains an important contributor to the burden of disease and is concentrated mainly among young people, emphasizing the urgency of addressing this public health challenge.

Keywords Opioid use disorders, Global Burden of Diseases, Incidence, Mortality, Disability-adjusted life years, Inequality analysis, Frontier analysis

Introduction

Opioids are a class of analgesic drugs that can bind to opioid receptors in the central nervous system and are widely used for the treatment of moderate to severe pain [1]. Opioid use disorder (OUD), a chronic disorder with episodes of remission and recurrence, is characterized by loss of control of opioid use, compulsive use,

*Correspondence:

Xinan Wan
2263853630@qq.com

¹ The Second People's Hospital of Wuhu, Anhui Province, No.6 Duchun Road, Wuhu 241000, China



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

and continued use despite causes not just harm to those afflicted, but also to the individuals friends and family and to society in general in terms of crime associated with opioid use and lost ability to work [2]. OUD may develop as a consequence of the prescribed or nonmedical use of opioid pain medications or as a consequence of the use of illicitly manufactured synthetic opioids. The clinical course of OUD involves periods of exacerbation and remission, but the potential vulnerability will never disappear. OUD increases the risk of early death 20-fold, mainly due to accidental overdoses, trauma, suicide, and infectious diseases [3–7]. OUD remains a critical worldwide public health problem. Therefore, it is necessary to analyze the burden of OUD. Most studies reporting the burden of OUD are based on national/regional specialized databases, such as Centers for Disease Control and Prevention (CDC), with relatively few studies based on global databases and a lack of up-to-date data.

The Global Burden of Disease (GBD) Study 2021 included 371 diseases and injuries in 204 countries and territories [8, 9]. The present study aims to assess the global burden of OUD using data from the GBD Study 2021. Because the GBD database does not differentiate between different types of OUD, we focus on OUD in general, which would include both prescription opioids and illicit opioids. We describe the global epidemiological characteristics of OUD, including incidence, mortality, and disability-adjusted life years (DALYs), and show the variations in these characteristics according to several factors (sociodemographic index (SDI), age, sex, and region). We also analyzed significant inequalities in the OUD burden associated with SDI. Frontier analysis was conducted to explore the potential improvement space of the age-standardized incidence rate (ASIR) of OUD considering national and regional development levels. By describing and analyzing the burden of OUD, we aimed to promote the development of strategies to alleviate the burden caused by OUD at the global, regional, and national levels.

Methods

The incidence, mortality, and DALYs of OUD from 1990 to 2021 were extracted from the GBD Study 2021 website (<https://vizhub.healthdata.org/gbd-results/>). DALYs quantify disease burden by combining years of life lost to premature mortality (YLLs) and years lived with disability (YLDs). It serves as a core metric in the GBD study to compare health impacts across diseases, injuries, and risk factors. $YLLs = \text{Number of deaths} \times \text{Standard life expectancy at age of death}$ (Uses reference life tables, e.g., GBD 2021 uses 86.6 years as maximum lifespan). $YLDs = \text{Number of cases} \times \text{Disability weight} \times \text{Average duration}$ (Disability weights range 0–1, where 0 = perfect health

and 1 = equivalent to death). $DALYs = YLLs + YLDs$ (Represents total health gap between ideal and observed population health status). In the GBD Study, the world was divided into 21 GBD regions. Moreover, the 204 countries and territories were divided into five groups (low, low-medium, medium, high-medium, and high) according to their SDI values.

The slope index of inequality (SII) and concentration index of inequality (CII) quantify the inequality of the OUD burden across countries [10–12]. The SII is an absolute measure of socioeconomic inequality in health or other outcomes. It represents the linear regression-based difference in outcomes between the most and least advantaged ends of the socioeconomic spectrum. Formula: $SII = \beta_1 \times (\text{Top Socioeconomic Status Rank} - \text{Bottom Socioeconomic Status Rank})$, where: β_1 = regression coefficient of the outcome on socioeconomic rank, Socioeconomic Status Rank = relative position. The CII was calculated through a regression analysis relating each country's incidence rate to the relative position of its SDI, defined by the population's midpoint in a cumulative distribution ranked by SDI. The CII was calculated by numerically integrating the area under the Lorenz curve, which plots the cumulative proportion of incidence against the cumulative proportion of population ranked by SDI [13]. The range of the CII is from –1 to +1: A value of +1 indicates that the outcome is entirely concentrated in the most socioeconomically advantaged group, representing perfect inequality favoring the wealthy. A value of –1 indicates that the outcome is entirely concentrated in the most socioeconomically disadvantaged group, representing perfect inequality favoring the poor. A value of 0 indicates perfect equality, where the outcome is distributed proportionally across all socioeconomic status groups.

We employed stochastic frontier analysis (SFA) to construct an ASIR-based efficiency frontier model, with the SDI as the development-level predictor. Frontier analysis is a regression-based technique originally developed for econometric efficiency estimation, adapted here to estimate the theoretical minimum achievable ASIR for each country or territory given its current SDI. The frontier represents the best-performing boundary defined by the lowest observed ASIR values across countries at similar development levels. Countries positioned on the frontier—those achieving the lowest ASIR values for their respective SDI levels—are considered to have attained optimal performance. In contrast, countries below the frontier exhibit measurable inefficiencies, represented by the absolute gap (vertical distance) between their observed 2021 ASIR and the minimum ASIR predicted by the frontier model [14–17].

All the statistical analyses and visualizations were conducted via the R statistical software program (version

4.4.2). A P value <0.05 was considered to indicate statistical significance.

Because the study was based on a publicly available dataset, this study was exempted by the ethics committee of the Second People's Hospital of Wuhu City.

Results

Global burden and temporal trend in OUD

Globally, in 2021, the number of new cases, deaths, and DALYs of OUD were 1942.52 thousand [95% uncertainty interval (UI): 1643.34, 2328.36], 99.55 thousand (95% UI: 92.94, 108.04), and 11,218.51 thousand (95% UI: 9188.65, 13,159.55), respectively. In addition, the age-standardized rates (ASRs) of incidence, mortality, and DALYs of OUD were 24.54 per 100,000 population (95% UI: 20.74, 29.48), 1.19 per 100,000 population (95% UI: 1.12, 1.29), and 137.15 per 100,000 population (95% UI: 112.29, 161.39), respectively. The estimated annual percentage changes (EAPCs) was employed to assess temporal trends, the EAPCs of the ASRs of incidence, mortality, and DALYs were -0.17 [95% confidence interval (CI): -0.34 , -0.00], 0.52 (95% CI95% CI: 0.25, 0.78), and 0.50 (95% CI95% CI: 0.30, 0.71), respectively (Table 1).

At the regional level, in 2021, high-income North America, South Asia, and North Africa and the Middle East were the three regions with the highest incidence rates, at 456.33 thousand (95% UI: 382.67, 549.88), 378.42 thousand (95% UI: 309.71, 466.04), and 245.27 thousand (95% UI: 203.63, 296.38) cases, respectively. High-income North America, Eastern Europe, and Australasia were the three regions with the highest ASIRs, at

144.24 per 100,000 people (95% UI: 120.13, 174.95), 73.32 per 100,000 people (95% UI: 61.90, 87.26), and 44.87 per 100,000 people (95% UI: 38.68, 51.99), respectively. Meanwhile, the three regions with the highest numbers of deaths from OUD were high-income North America, Western Europe, and South Asia, at 58.20 thousand (95% UI: 51.54, 65.87), 8.94 thousand (95% UI: 8.42, 9.04), and 8.06 thousand (95% UI: 6.70, 9.34), respectively. The three regions with the highest age-standardized mortality rates (ASMRs) were high-income North America, Eastern Europe, and Australasia, with 14.50 per 100,000 people (95% UI: 12.92, 16.30), 2.55 per 100,000 people (95% UI: 2.33, 2.81), and 1.74 per 100,000 people (95% UI: 1.51, 1.99), respectively. In addition, high-income North America, South Asia, and East Asia were the three regions with the highest numbers of DALYs associated with OUD, and high-income Asia-Pacific, Eastern Europe, and Australasia were the three regions with the highest age-standardized DALY rates (ASDRs) (Table 1 and Fig. 1).

Variation in OUD burden by SDI

In 2021, a higher SDI was associated with higher incidence, mortality, and DALYs of OUD, whether in cases or ASRs (Table 1).

From 1990 to 2021, the ASIR, ASMR, and ASDR remained stable in most regions and did not increase as the SDI increased. However, in high-income North America, the ASIR, ASMR, and ASDR increased with the SDI. In Eastern Europe and Australia, the burden of OUD

Table 1 Incidence, mortality, and DALYs of OUD in 2021 and their temporal trends from 1990 to 2021

Location	Incidence			Mortality			DALYs		
	No. $\times 10^3$ (95% UI)	ASRs per 100,000 (95% UI)	EAPC (95% CI)	No. $\times 10^3$ (95% UI)	ASRs per 100,000 (95% UI)	EAPC (95% CI)	No. $\times 10^3$ (95% UI)	ASRs per 100,000 (95% UI)	EAPC (95% CI)
Global	1942.52(1643.34,2328.36)	24.54(20.74,29.48)	-0.17(-0.34,-0.00)	99.55(92.94,108.04)	1.19(1.12,1.29)	0.52(0.25,0.78)	11218.51(9188.65,13159.55)	137.15(112.29,161.39)	0.50(0.30,0.71)
Region									
Andean Latin America	12.37(9.82,15.47)	17.39(13.80,21.67)	0.14(0.06,0.22)	0.07(0.06,0.10)	0.12(0.09,0.16)	1.73(1.35,2.11)	32.55(22.89,43.83)	46.21(32.59,61.99)	0.28(0.18,0.39)
Australasia	12.97(11.08,15.00)	44.87(38.68,51.99)	-0.34(-0.76,0.07)	0.58(0.50,0.66)	1.74(1.51,1.99)	-1.02(-1.88,-0.15)	65.32(53.56,76.29)	205.48(168.06,240.26)	-0.58(-1.02,-0.15)
Caribbean	7.62(6.09,9.43)	15.61(12.48,19.26)	-0.59(-0.67,-0.51)	0.04(0.03,0.05)	0.09(0.07,0.11)	-2.69(-4.23,-1.12)	20.23(14.01,26.53)	40.77(28.15,53.52)	-1.20(-1.50,-0.89)
Central Asia	35.07(29.58,41.82)	36.68(30.96,43.70)	-0.07(-0.22,0.09)	0.60(0.49,0.70)	0.63(0.52,0.74)	1.73(0.71,2.76)	117.88(89.53,144.81)	117.72(89.49,144.38)	0.35(-0.08,0.78)
Central Europe	16.49(14.14,19.42)	16.10(13.62,18.96)	0.55(0.42,0.67)	0.77(0.71,0.84)	0.56(0.52,0.61)	0.35(0.11,0.59)	74.95(62.01,87.47)	64.41(53.16,75.80)	0.49(0.40,0.58)
Central Latin America	40.99(32.75,50.72)	15.25(12.19,18.85)	-0.17(-0.26,-0.07)	0.23(0.20,0.27)	0.09(0.08,0.10)	-0.85(-1.11,-0.57)	108.44(75.53,142.29)	40.33(28.12,52.90)	-0.25(-0.33,-0.17)
Central Sub-Saharan Africa	16.04(12.74,20.23)	12.49(10.24,15.37)	0.38(0.35,0.42)	0.36(0.20,0.54)	0.35(0.20,0.53)	0.58(0.36,0.80)	52.14(37.99,67.99)	45.14(32.46,58.02)	0.52(0.44,0.61)
East Asia	244.99(202.87,293.57)	16.71(13.88,20.27)	-2.82(-3.17,-2.47)	6.01(4.80,7.35)	0.33(0.26,0.40)	-6.98(-7.80,-6.15)	887.51(681.70,1086.67)	54.37(40.97,67.47)	-4.63(-5.11,-4.15)
Eastern Europe	129.17(110.16,153.54)	73.32(61.90,87.26)	-0.57(-1.22,0.07)	6.01(5.46,6.59)	2.55(2.33,2.81)	0.32(-0.74,1.40)	657.68(555.40,766.23)	311.15(259.01,365.83)	-0.01(-0.88,0.88)
Eastern Sub-Saharan Africa	42.75(34.33,53.62)	10.77(8.94,12.99)	-0.05(-0.09,-0.02)	1.78(1.21,2.30)	0.62(0.43,0.79)	0.21(0.13,0.29)	177.70(136.84,219.97)	51.62(40.64,62.98)	0.29(0.27,0.31)
High-income Asia Pacific	23.88(19.43,28.71)	14.92(12.05,18.42)	-0.02(-0.13,0.08)	0.29(0.27,0.31)	0.12(0.11,0.13)	0.76(-0.13,1.65)	78.89(55.97,100.98)	43.74(30.90,57.08)	-0.01(-0.21,0.19)
High-income North America	456.33(382.67,549.88)	144.24(120.13,174.95)	5.72(5.10,6.34)	58.20(51.54,65.87)	14.50(12.92,16.30)	7.98(7.73,8.23)	5570.17(4605.34,6442.01)	1502.44(1235.96,1740.10)	7.06(6.80,7.32)
North Africa and Middle East	245.27(203.63,296.38)	37.82(31.50,45.62)	0.30(0.14,0.47)	4.90(4.14,5.66)	0.81(0.68,0.93)	0.08(-0.14,0.30)	842.16(650.32,1031.71)	128.78(99.59,157.46)	0.34(0.13,0.55)
Oceania	1.73(1.40,2.15)	12.49(10.20,15.23)	0.11(0.01,0.12)	0.01(0.01,0.02)	0.13(0.09,0.17)	-1.64(-1.93,-1.34)	4.60(3.26,6.10)	34.29(24.39,44.64)	-0.27(-0.31,-0.22)
South Asia	378.42(309.71,466.04)	18.90(15.73,23.12)	0.13(-0.10,0.36)	8.06(6.70,9.34)	0.48(0.40,0.55)	-0.27(-0.48,-0.06)	1190.53(891.41,1478.43)	61.71(46.98,75.92)	0.03(-0.18,0.24)
Southeast Asia	68.52(56.76,82.42)	9.36(7.79,11.23)	-0.08(-0.16,0.01)	1.68(1.37,2.07)	0.25(0.20,0.30)	0.41(0.30,0.51)	244.55(187.10,300.79)	32.90(23.23,40.51)	0.09(-0.01,0.19)
Southern Latin America	12.38(9.94,15.25)	17.75(14.11,22.10)	-0.12(-0.20,-0.03)	0.10(0.09,0.12)	0.14(0.12,0.16)	4.50(3.87,5.14)	37.40(26.19,48.81)	51.70(36.07,67.75)	0.02(-0.07,0.11)
Southern Sub-Saharan Africa	19.23(16.06,23.40)	23.31(19.68,28.10)	-1.44(-1.77,-1.10)	0.61(0.54,0.70)	0.88(0.78,0.99)	-0.22(-0.66,0.22)	71.74(57.88,85.22)	88.95(71.72,105.11)	-1.32(-1.72,-0.92)
Tropical Latin America	37.57(29.89,46.84)	15.82(12.43,19.74)	-0.22(-0.34,-0.10)	0.08(0.07,0.09)	0.03(0.03,0.04)	5.08(4.31,5.86)	95.39(63.99,126.54)	38.51(25.72,51.57)	-0.15(-0.27,-0.04)
Western Europe	90.78(78.90,104.67)	24.07(20.69,28.09)	-0.27(-0.59,0.05)	8.94(8.42,9.40)	1.67(1.59,1.74)	0.73(0.45,1.01)	778.89(657.86,897.77)	178.12(149.99,207.30)	0.25(-0.01,0.52)
Western Sub-Saharan Africa	49.84(39.45,63.15)	10.88(8.95,13.31)	-0.03(-0.07,0.01)	0.11(0.07,0.15)	0.05(0.04,0.07)	-0.62(-1.27,0.04)	109.72(72.68,147.98)	26.84(18.22,35.30)	-0.03(-0.07,0.02)
Socio-demographic Index(SDI)									
High SDI	609.68(518.56,721.84)	68.52(57.67,82.33)	3.66(3.23,4.10)	67.68(61.16,75.43)	5.47(4.97,6.06)	5.80(5.64,5.97)	6548.59(5421.92,7567.17)	587.41(484.84,680.69)	4.98(4.72,5.24)
High-middle SDI	335.80(284.83,398.89)	27.16(23.02,32.63)	-1.36(-1.78,-0.95)	10.28(9.48,10.98)	0.67(0.62,0.71)	-2.42(-2.91,-1.92)	1377.43(1108.11,1649.45)	98.70(78.06,119.48)	-1.75(-2.21,-1.29)
Middle SDI	469.92(393.63,562.64)	18.82(15.81,22.76)	-1.25(-1.43,-1.08)	11.21(9.70,12.66)	0.42(0.36,0.47)	-4.30(-4.83,-3.77)	1667.04(1293.20,2026.94)	63.60(49.05,77.63)	-2.50(-2.76,-2.24)
Low-middle SDI	370.91(305.80,455.79)	18.22(15.29,22.17)	0.09(-0.01,0.18)	7.09(6.03,8.16)	0.42(0.36,0.48)	0.05(-0.10,0.19)	1140.80(861.82,1406.31)	58.69(44.52,71.94)	0.11(0.01,0.21)
Low SDI	155.16(124.66,194.32)	14.35(11.93,17.42)	0.10(0.06,0.14)	3.23(2.47,3.94)	0.43(0.34,0.51)	0.20(0.11,0.29)	480.61(364.31,591.72)	50.81(39.15,61.76)	0.21(0.16,0.27)

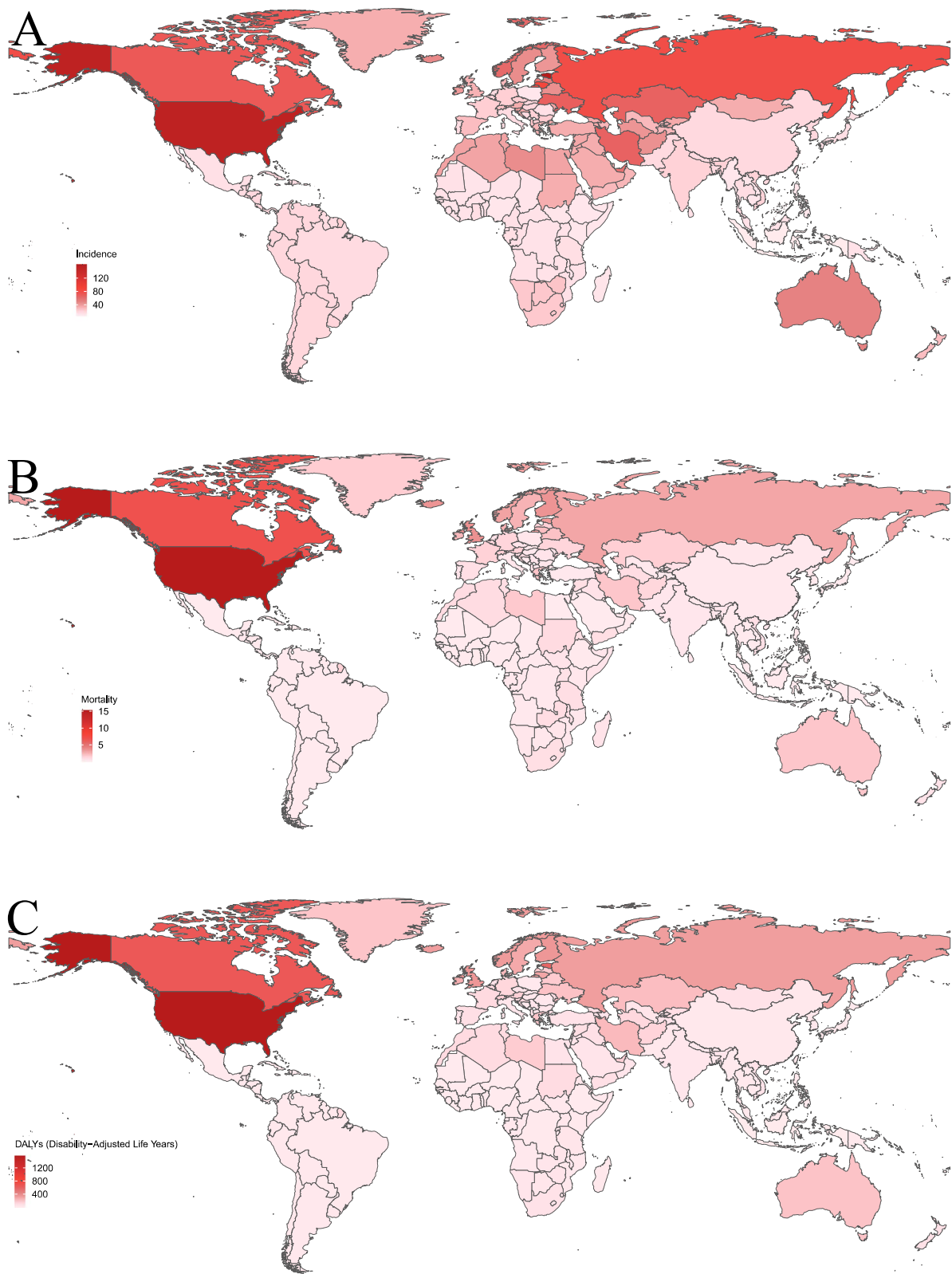


Fig.1 The global burden of OUD in 204 countries and territories in 2021. (A) ASIR. (B) ASMR. (C) ASDR

first increased and then decreased with increasing SDI (Fig. 2).

Variation in OUD burden by sex and five-year age group

Overall, the incidence, mortality, and DALYs of OUD were higher in males than in females in 2021, especially mortality and DALYs. However, as age increased, the gap in the burden of OUD narrowed, and in some older age groups, the burden on females even exceeded that on males.

The incidence peaked in the age group of 20–24 years for both sexes. Moreover, the highest peak OUD mortality occurred at ages 30–44 years in males and 30–59 years in females. The highest peak in DALYs occurred at ages 25–34 years in males and 25–34 years in females in 2021 (Fig. 3).

Analysis of inequalities among countries

The study revealed significant absolute and relative inequalities in OUD burden associated with SDI. A higher ASIR was observed to disproportionately concentrate in countries with higher SDIs. The slope index of inequality indicated an increase in the ASIR gap between the countries with the highest and lowest SDIs, with the gap widening from 9.74 (95% CI: 6.53, 12.96) in 1990 to 13.65 (95% CI: 10.07, 17.23) in 2021. The concentration index of inequality changed from 0.12 (95% CI: 0.08, 0.16) in 1990 to 0.19 (95% CI: 0.13, 0.25) by 2021, suggesting increased inequalities (Fig. 4).

Frontier analysis

With the ASIR and SDI as the variables of interest, frontier analysis was conducted using data from 1990 to 2021 to explore the potential improvement space of the ASIR of OUD considering national and regional development levels. In 2021, the 15 countries and territories with the most significant actual potential for improvement (effective difference range: 156.75–41.19) were Estonia, the United States of America, Lithuania, the Russian Federation, Canada, Ukraine, Kazakhstan, the Islamic Republic of Iran, Norway, the United Arab Emirates, Latvia, Australia, Iceland, Lebanon, and Sweden (Fig. 5).

Discussion

In 2021, the number of new cases, deaths, and DALYs of OUD worldwide reached 1942.52 thousand, 99.55 thousand, and 11,218.51 thousand, respectively. At the regional level, high-income North America had the most severe burden of OUD, and the numbers of incident cases, deaths, and DALYs of OUD reached 456.33 thousand, 58.20 thousand, and 5570.17 thousand, respectively, accounting for almost half of the global total. The causes of the current opioid crisis in the United States

include increased demand for opioids as chronic pain medications, overprescription of opioids, massive diversion into illicit markets, lack of research on nonopioid pain management, ethical lapses by corporations, and failure to promote evidence-based treatment for opioid addiction [18]. Also a part of the current United States crisis is due to the introduction of ever stronger opioids into the market such as fentanyl, nizatenes [19, 20]. Research has shown that the prevalence of OUD in some parts of the United States is close to 1 in 20 [21]. In 2022, 81,806 opioid-involved overdose deaths were reported in the United States. A total of 3.7% of US adults need treatment for OUD, and only 25.1% of them receive medication treatment [22]. We found that a higher SDI was associated with a greater burden of OUD, especially in high-SDI regions, which may be due to the greater burden of OUD in the United States.

Our findings reveal that the current peak in incidence is focused on the age group of 20–24 years for both sexes. This is a very young age group, which is a serious issue worth noting. Young adults experience higher fatal overdose rates than older age groups, partly due to polydrug use (e.g., opioids combined with benzodiazepines or stimulants), which exacerbates respiratory depression [23]. Early-onset opioid use is associated with more severe OUD trajectories due to the heightened neurodevelopmental plasticity of young brains, accelerating the progression to dependence [24]. In addition, young adults with OUD face decades of disability-adjusted life years. The age groups associated with OUD-related mortality were also very young, with peaks in males aged 30–44 years and females aged 30–59 years. The burden of OUD on males is greater than that on females, especially in terms of mortality and DALYs. In some elderly populations, the burden of OUD on females may even exceed that on men, possibly due to the larger population of elderly females.

In the inequality analysis, we found that countries with higher SDIs have a more severe burden of OUD, and this trend is still worsening. This may be due to the greater availability and insufficient management of opioids in high-SDI countries.

Through frontier analysis, we found that countries with higher SDIs often have greater potential to reduce the burden of OUD. The countries and regions with the greatest potential for actual improvement include, among others, Estonia, the United States of America, Lithuania, the Russian Federation, and Canada. Higher-SDI countries typically have better-funded healthcare systems, which facilitate broader access to medication-assisted treatment [25]. These nations often have advanced monitoring systems to track OUD trends and allocate resources efficiently. Higher-SDI countries can invest in

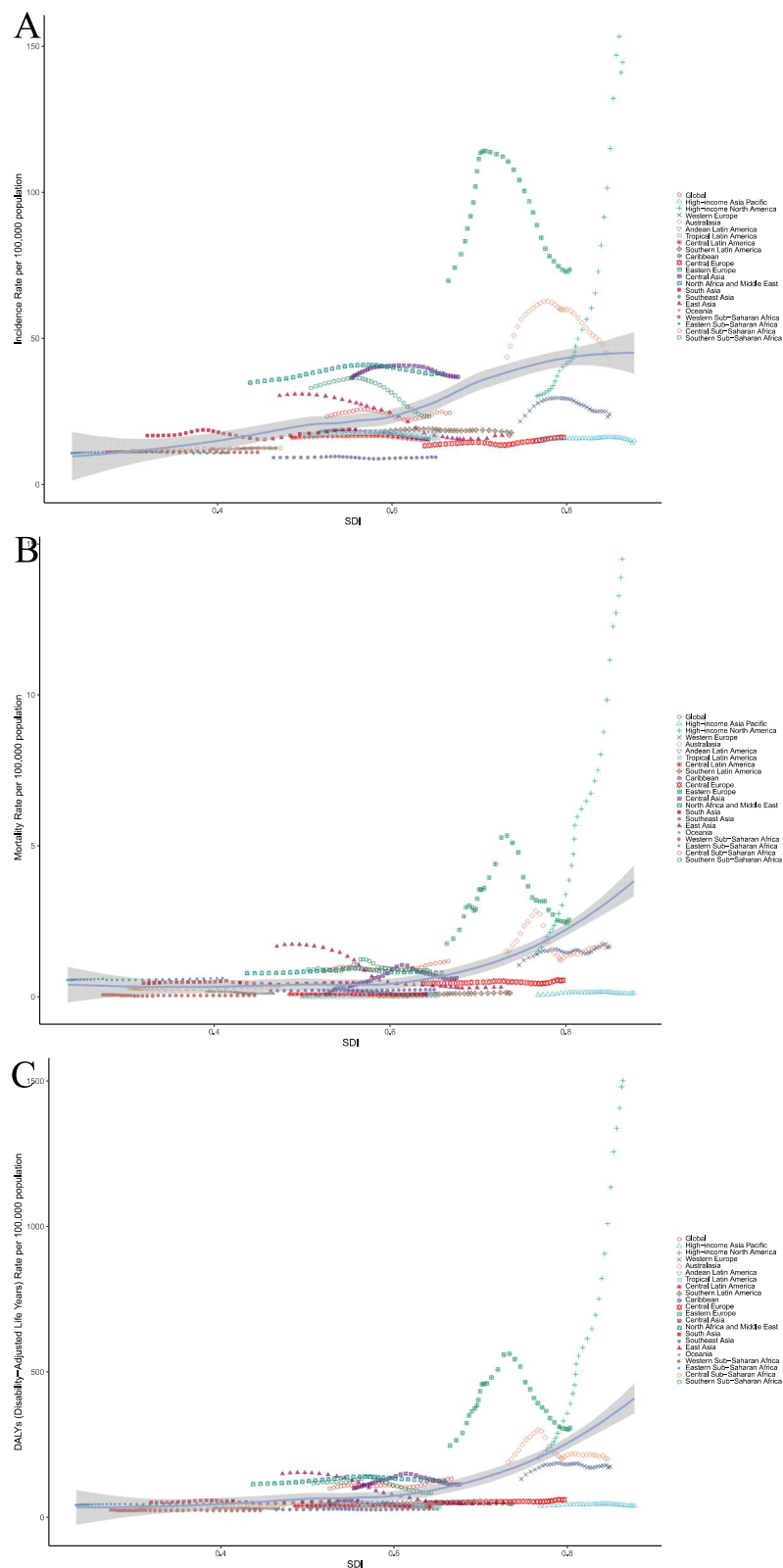


Fig.2 ASIR (A), ASMR (B), and ASDR (C) of OUD globally and for 21 GBD regions by SDI from 1990 to 2021

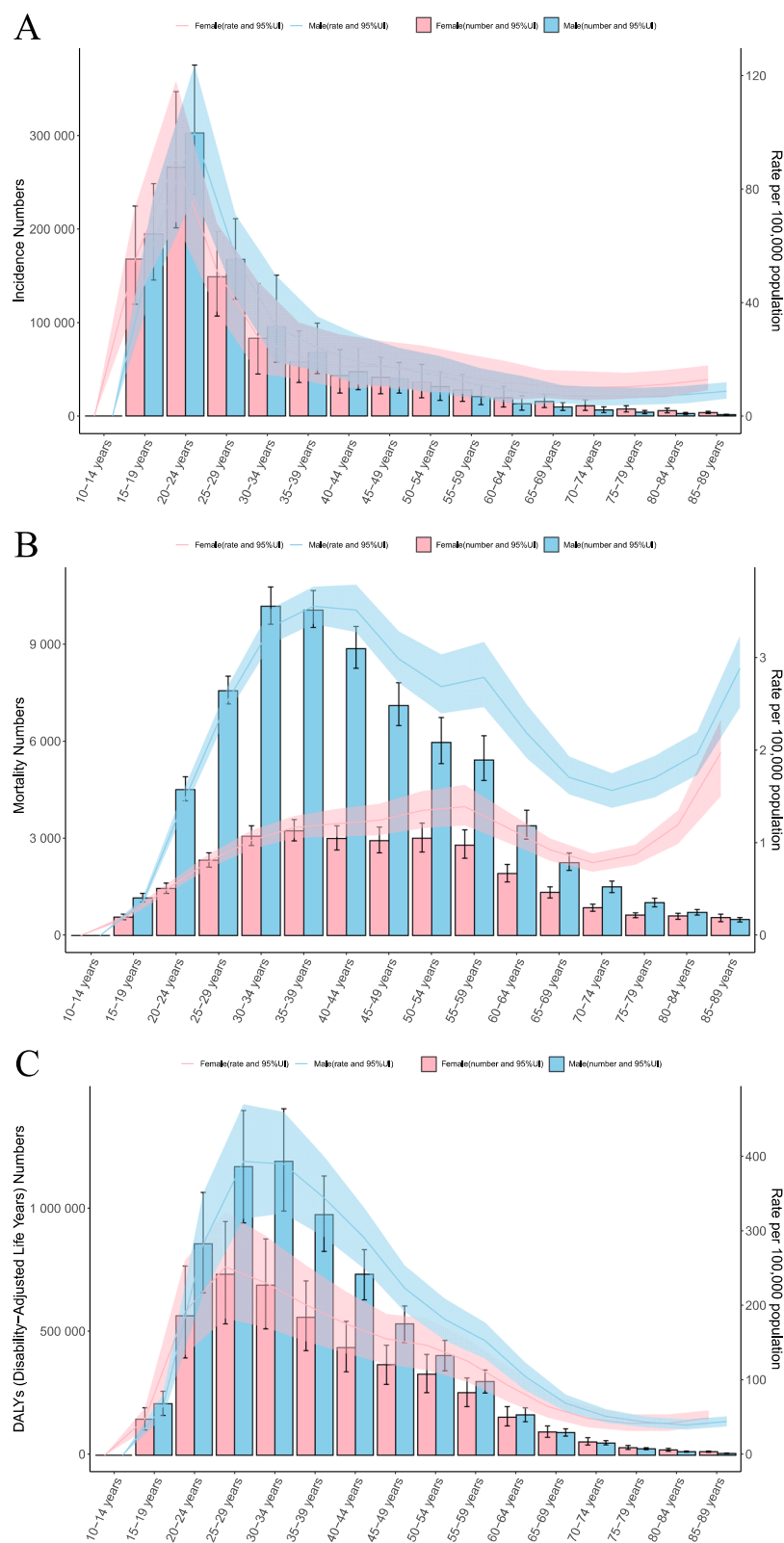


Fig.3 Sex-specific age patterns in the total numbers of cases, deaths, and DALYs and the ASIR (A), ASMR (B), and ASDR (C) due to OUD at the global level in 2021

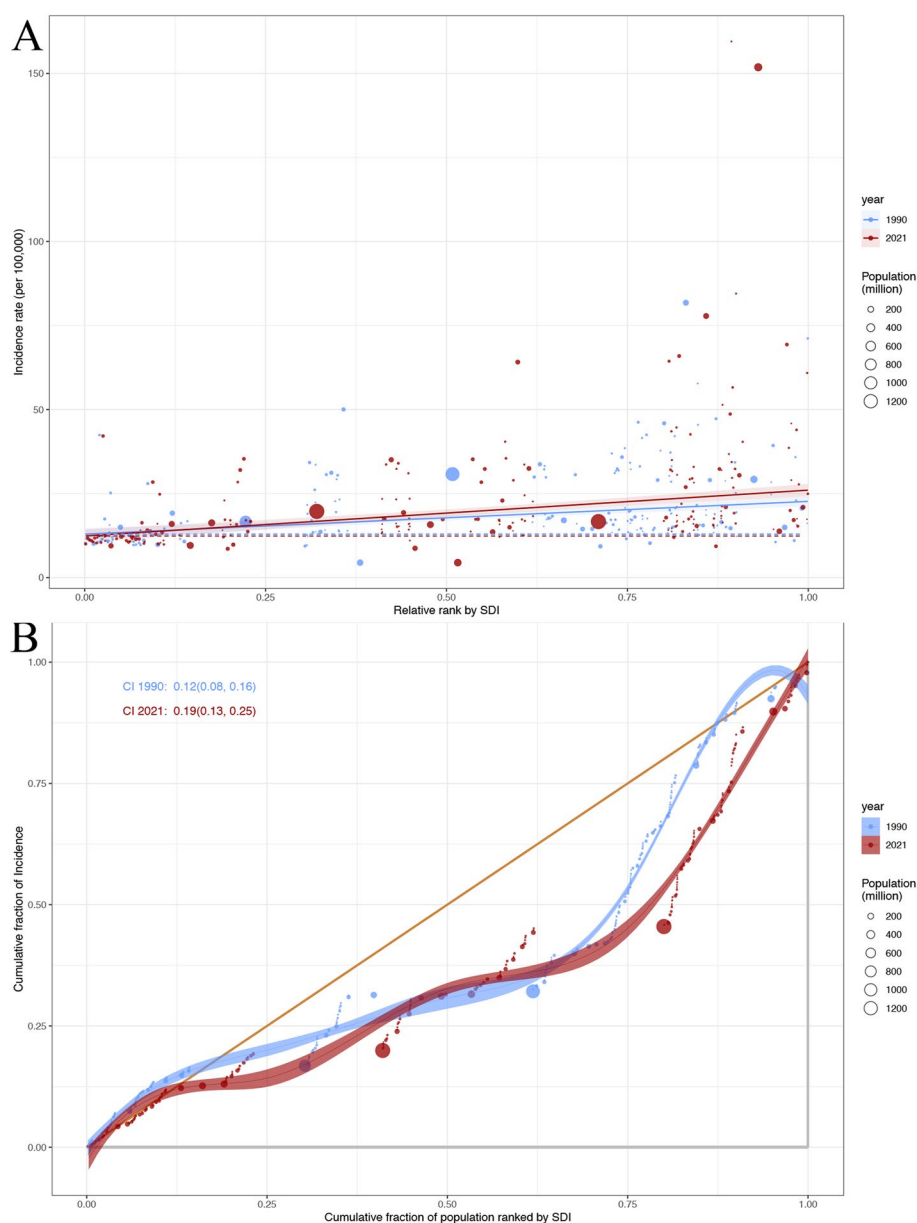


Fig.4 Slope index of inequality (A) and concentration index of inequality (B) for the ASIR of OUD from 1990 to 2021 across the worldwide

preventive education and long-term rehabilitation programs. Countries such as Sweden and the United States are at the forefront of developing innovative therapies for OUD, including extended-release medications and digital health interventions [26–29].

However, our study had several limitations. First, the analysis heavily relied on the GBD database. OUD diagnosis and reporting systems may not be sufficient in some underdeveloped countries and regions, leading to an underestimation of the true burden of OUD. Second, the GBD data extend only up to 2021 and cannot fully

reflect the current global burden of OUD. Third, the GBD database does not differentiate between prescription OUD and heroin/illicit OUD, despite significant differences between these populations.

Conclusion

In 2021, the numbers of incident cases, deaths, and DALYs of OUD worldwide reached 1942.52 thousand, 99.55 thousand, and 11,218.51 thousand, respectively. At the regional level, high-income North America had the most severe burden of OUD. The burden of OUD

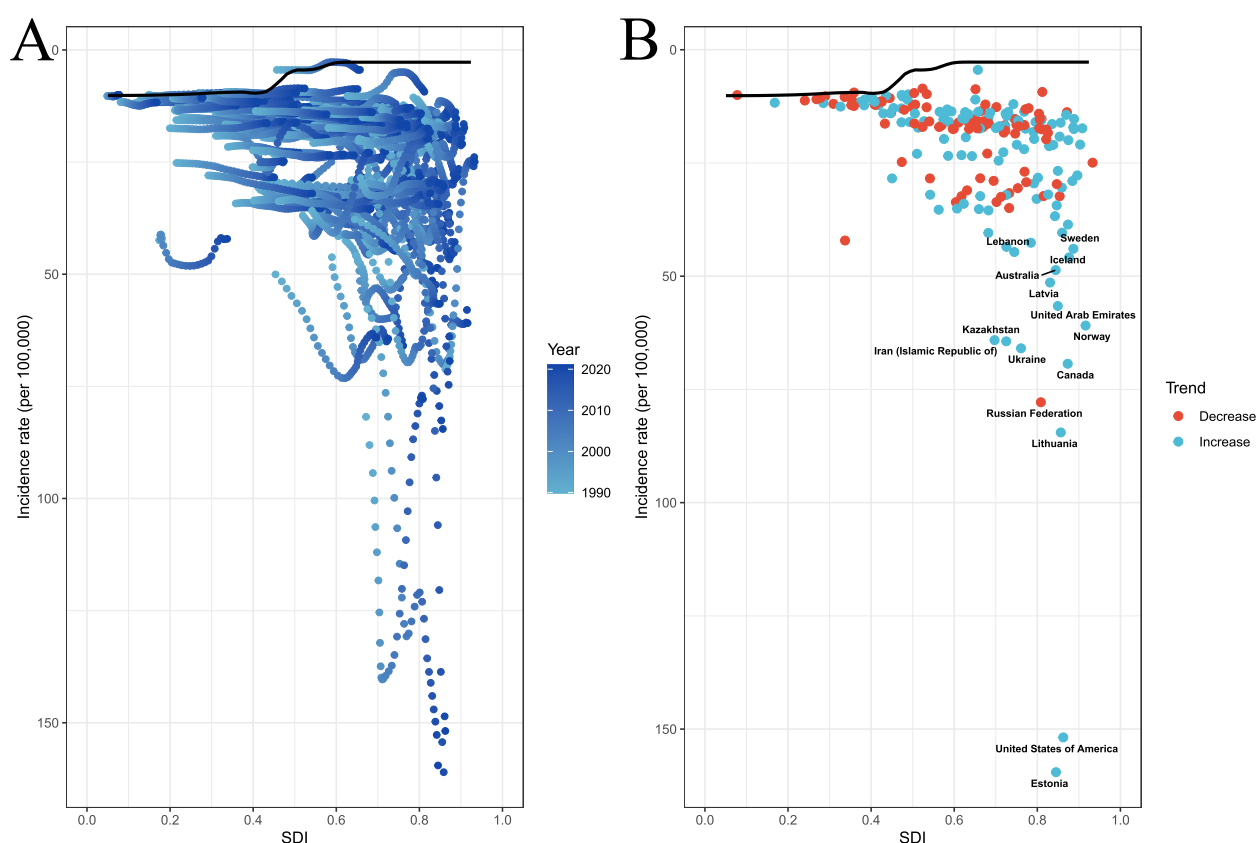


Fig. 5 Frontier analysis exploring the relationship between the SDI and the ASIR of OUD in 204 countries and territories; the frontier line is shown in black. The color change from light blue (1990) to dark blue (2021) represents the change in years (**A**). Each point represents a specific country or territory in 2021, and the top 15 countries and territories with the largest differences from the frontier are marked (**B**)

is mainly concentrated among young people. The peak OUD incidence was concentrated in the age group of 20–24 years for both sexes, and OUD-related mortality peaked in males aged 30–44 years and females aged 30–59 years. Countries with higher SDIs have a heavier burden of OUD, and this trend continues to intensify. Countries with higher SDIs often have greater potential to reduce the burden of OUD.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12889-025-23283-1>.

Supplementary Material 1.

Authors' contributions

M.F. and X.W. accessed and acquired the raw data, conducted the data analysis, and created tables and figures. Q.Z. and J.P. contributed to the interpretation of the data and provided important comments on the manuscript. W.Y. and W.F. drafted the manuscript. All authors reviewed and approved the final manuscript.

Funding

This work was supported by Clinical Medical Research Transformation Project of Anhui Province of China (202204295107020064).

Data availability

The datasets generated and/or analyzed during the current study are available on the GBD Study 2021 website (<https://vizhub.healthdata.org/gbd-results/>).

Declarations

Ethics approval and consent to participate

Because the study was based on a publicly available dataset, this study was exempted by the ethics committee of the Second People's Hospital of Wuhu City.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 8 March 2025 Accepted: 22 May 2025

Published online: 29 May 2025

References

- Lyden J, Binswanger IA. The United States opioid epidemic. *Semin Perinatol*. 2019;43(3):123–31.
- Falisse AM, Li Z, Huggins-Manley AC, Lopez-Quintero C, Cottler LB, Striley CW. Age-related Psychometric Dimensionality Using the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition Opioid Use Disorder Diagnostic Criteria. *J Addict Med*. 2024;18(6):675–82.
- Degenhardt L, Larney S, Kimber J, Farrell M, Hall W. Excess mortality among opioid-using patients treated with oral naltrexone in Australia. *Drug Alcohol Rev*. 2015;34(1):90–6.
- Evans E, Li L, Min J, Huang D, Urada D, Liu L, et al. Mortality among individuals accessing pharmacological treatment for opioid dependence in California, 2006–10. *Addiction*. 2015;110(6):996–1005.
- Teesson M, Marel C, Darke S, Ross J, Slade T, Burns L, et al. Long-term mortality, remission, criminality and psychiatric comorbidity of heroin dependence: 11-year findings from the Australian Treatment Outcome Study. *Addiction*. 2015;110(6):986–93.
- Centers for Disease Control and Prevention (CDC). HIV infection and HIV-associated behaviors among injecting drug users - 20 cities, United States, 2009. *MMWR Morb Mortal Wkly Rep*. 2012;61(8):133–8.
- Degenhardt L, Larney S, Kimber J, Gisev N, Farrell M, Dobbins T, et al. The impact of opioid substitution therapy on mortality post-release from prison: retrospective data linkage study. *Addiction*. 2014;109(8):1306–17.
- GBD 2021 Diseases and Injuries Collaborators. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet*. 2024;403(10440):2133–61.
- GBD 2021 Causes of Death Collaborators. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet*. 2024;403(10440):2100–32.
- Hosseinpoor AR, Bergen N, Schlottheuber A. Promoting health equity: WHO health inequality monitoring at global and national levels. *Glob Health Action*. 2015;8:29034.
- Jiang CY, Han K, Yang F, Yin SY, Zhang L, Liang BY, et al. Global, regional, and national prevalence of hearing loss from 1990 to 2019: A trend and health inequality analyses based on the Global Burden of Disease Study 2019. *Ageing Res Rev*. 2023;92: 102124.
- Guan SY, Zheng JX, Feng XY, Zhang SX, Xu SZ, Wang P, et al. Global burden due to modifiable risk factors for autoimmune diseases, 1990–2021: Temporal trends and socio-demographic inequalities. *Autoimmun Rev*. 2024;23(12): 103674.
- Ordunez P, Martinez R, Soliz P, Giraldo G, Mujica OJ, Nordet P. Rheumatic heart disease burden, trends, and inequalities in the Americas, 1990–2017: a population-based study. *Lancet Glob Health*. 2019;7(10):e1388–97.
- Bai ZH, Han JR, An J, Wang H, Du XY, Yang ZC, et al. The global, regional, and national patterns of change in the burden of congenital birth defects, 1990–2021: an analysis of the global burden of disease study 2021 and forecast to 2040. *EClinicalMedicine*. 2024;77: 102873.
- Wang F, Ma B, Ma Q, Liu X. Global, regional, and national burden of inguinal, femoral, and abdominal hernias: a systematic analysis of prevalence, incidence, deaths, and DALYs with projections to 2030. *Int J Surg*. 2024;110(4):1951–67.
- Ruan R, Liu X, Zhang Y, Tang M, He B, Zhang QW, et al. Global, Regional, and National Advances Toward the Management of Rheumatic Heart Disease Based on the Global Burden of Disease Study 2019. *J Am Heart Assoc*. 2023;12(13): e028921.
- Bai ZH, Wang H, Shen C, An J, Yang ZC, Mo XM. The global, regional, and national patterns of change in the burden of non-malignant upper gastrointestinal diseases from 1990 to 2019 and the forecast for the next decade. *Int J Surg*. 2024;111(1):80–92.
- Heimer R, Hawk K, Vermund SH. Prevalent Misconceptions About Opioid Use Disorders in the United States Produce Failed Policy and Public Health Responses. *Clin Infect Dis*. 2019;69(3):546–51.
- Ciccarone D. The rise of illicit fentanyl, stimulants and the fourth wave of the opioid overdose crisis. *Curr Opin Psychiatry*. 2021;34(4):344–50.
- Marks C, Abramovitz D, Donnelly CA, Carrasco-Escobar G, Carrasco-Hernández R, Ciccarone D, et al. Identifying counties at risk of high overdose mortality burden during the emerging fentanyl epidemic in the USA: a predictive statistical modelling study. *Lancet Public Health*. 2021;6(10):e720–8.
- Barocas JA, White LF, Wang JN, Walley AY, LaRochelle MR, Bernson D, et al. Estimated Prevalence of Opioid Use Disorder in Massachusetts, 2011–2015: A Capture-Recapture Analysis. *Am J Public Health*. 2018;108(12):1675–81.
- Dowell D, Brown S, Gyawali S, Hoenig J, Ko J, Mikosz C, et al. Treatment for Opioid Use Disorder: Population Estimates—United States, 2022. *MMWR Morb Mortal Wkly Rep*. 2024;73(25):567–74.
- Lim JK, Earlywine JJ, Bagley SM, Marshall BDL, Hadland SE. Polysubstance Involvement in Opioid Overdose Deaths in Adolescents and Young Adults, 1999–2018. *JAMA Pediatr*. 2021;175(2):194–6.
- Chambers RA, Taylor JR, Potenza MN. Developmental neurocircuitry of motivation in adolescence: a critical period of addiction vulnerability. *Am J Psychiatry*. 2003;160(6):1041–52.
- Carter M, Boyd J, Bennett T, Baus A. Medication Assisted Treatment Program Policies: Opinions of People in Treatment. *J Prim Care Community Health*. 2023;14:21501319231195610.
- Mitchell SG, Monico LB, Gryczynski J, Fishman MJ, O'Grady KE, Schwartz RP. Extended-release naltrexone for youth with opioid use disorder. *J Subst Abuse Treat*. 2021;130: 108407.
- Wenzel K, Selby V, Wildberger J, Lavorato L, Thomas J, Fishman M. Choice of extended release medication for OUD in young adults (buprenorphine or naltrexone): A pilot enhancement of the Youth Opioid Recovery Support (YORS) intervention. *J Subst Abuse Treat*. 2021;125: 108306.
- Nunes EV, Comer SD, Lofwall MR, Walsh SL, Peterson S, Tiberg F, et al. Extended-Release Injection vs Sublingual Buprenorphine for Opioid Use Disorder With Fentanyl Use: A Post Hoc Analysis of a Randomized Clinical Trial. *JAMA Netw Open*. 2024;7(6): e2417377.
- Ward MK, Guille C, Jafry A, Gwanzura T, Pryce K, Lewis P, et al. Digital health interventions to support women with opioid use disorder: A scoping review. *Drug Alcohol Depend*. 2024;261: 111352.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.