Global, Regional, and National Burden of Accidental Carbon Monoxide Poisoning, 1990–2019: A Systematic Analysis for the Global Burden of Disease Study 2019

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Research

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Abstract

Introduction

Health system planning requires careful assessment of accidental carbon monoxide poisoning (ACOP) epidemiology, but data of this disease are scarce or non-existent in many countries. This article investigates the global burden of ACOP based on the Global Burden of Disease Study 2019 (GBD 2019) and the World Bank database.

Materials and Methods

Numbers and age-standardized rates (ASR) of ACOP incidence, prevalence, deaths, Disability-Adjusted Life Years (DALYs), Years Lived with Disability (YLDs), and Years of Life Lost (YLLs) were analysed at global, regional, and national level. The estimated annual percentage change (EAPC) of age-standardized rates (ASR) was calculated by generalizing the linear model with a Gaussian distribution. Age, sex, and economics parameters are included to access their internal relevance.

Results

Globally, in 2019, there were approximately 0.97 million ACOP incidence cases (95% CI 0.66 million to 1.4 million), and 41,142 (95%UI 32957 to 45934) people died from it. Compared with 1990, the morbidity and mortality of ACOP in 2019 are on a downward trend. By sexes, from 1990 to 2019, females have a higher morbidity and lower mortality. This article also finds that the relevant parameters of ACOP are closely related to the economic parameters. This correlation enables us to evaluate the level and status of public health services in various countries.

Discussion

ACOP is the most common toxic disease in the world. In 2019, the number of patients who die from ACOP exceeded that of patients poisoned by all other means. In global health decision-making, especially in regions with high-middle and high SDI, more attention should be paid.

Conclusion

As the population ageing in areas with High-middle SDI and High SDI increases, the potential burden of ACOP is increasing, presenting the governments with an increasing demand for acute care, rehabilitation, and support services. The results of this study can be used by the health authorities to consider the burden of ACOP that could be addressed with preventive and therapeutic measures.

Introduction

Carbon monoxide (CO) results from the incomplete combustion of carbon-containing substances and is a colorless, odorless, and tasteless gas.[1] Exposure is most commonly from car exhaust (unleaded petrol cars produce about one-tenth the amount of CO of older cars), faulty heaters, fires, industrial accidents, and charcoal-burning suicide.[2] Moderate or serious ACOP can cause high-oxygen-demand organs injuring and disfunction, among which brain and cardiac effects dominate acute clinical features.[3, 4] Among them, more than 25% of patients will have the symptom of delayed neurologic sequelae (DNS) which is the most common sequela affecting the prognosis of patients.[5] Serious ACOP can affect the prognosis of patients and the quality of their life, meanwhile significantly increasing the burden on the family and society. In the past few years, based on several national studies, the burden of ACOP has been reported in several articles sporadically, such as the United Kingdom[6, 7], the United States of America[8, 9], New Zealand[10], and China[11]. Lippi and Mattiuzzi did a limited analysis of global ACOP data of "Global Burden of Disease Study 2017" (GBD 2017).[12] They studied the morbidity and mortality of ACOP based on age, sexes, and SDI. But detailed information has not been provided in all countries/regions.

To provide comprehensive, comparable, and up-to-date information on the burden of ACOP, this report introduces the modeled ACOP age-standardized incidence rate (ASIR), age-standardized prevalence rate (ASPR), age-standardized deaths rate (ASDR), the age-standardized rate of Disability-Adjusted Life Years (DALYs), the age-standardized rate of Years Lived with Disability (YLDs), and age-standardized rate of Years of Life Lost (YLLs) at the global, regional and national levels based on the "Global Burden of Disease Study 2019" (GBD 2019).[13] The influence of sexes, region, and economics parameters (e.g., sociodemographic index (SDI; the sum

of sociodemographic factors), consumer price index (CPI), Gross Domestic Product per capita (purchasing power parity) (GDP per capita (PPP)), Gross National Income per capita (purchasing power parity) (GNI per capita (PPP))) are also included in the article.

Materials And Methods

Data source

The age-standardized rate (ASR) of ACOP's incidence, prevalence, deaths, DALYs, YLDs, and YLLs were obtained from the website of GBD Results Tool (<http://ghdx.healthdata.org/gbd-results-tool>) – a catalog of global health and demographic data relied on GBD 2019. The GBD 2019 study conducted by the Institute for Health Metrics and Evaluation (IHME) is the largest and most comprehensive effort to measure the level and trend of global epidemiology. Since 1990, 204 countries and regions, 7 super regions, and 21 regions have been included in the GBD study. GBD 2019 systematically studies 369 diseases and injuries, 282 causes of deaths, and 87 risk factors. IHME's general approach to GBD 2019 and its major improvements over previous cycles have been explained in the previous publications [13, 14]. More information is access to <http://ghdx.healthdata.org/gbd-2019>.

The data of Socio-demographic index (SDI) was downloaded from <http://ghdx.healthdata.org/record/ihme-data/gbd-2019-socio-demographic-index-sdi-1950-2019>, which is developed by GBD researchers and used to help produce these estimates (Additional file 1). SDI is a composite indicator of development status strongly correlated with health outcomes. It is the geometric mean of 0 to 1 indices of total fertility rate under the age of 25 (TFU25), mean education for those ages 15 and older (EDU15+), and lag distributed income (LDI) per capita. As a composite, a location with an SDI of 0 would have a theoretical minimum level of development relevant to health, while a location with an SDI of 1 would have a theoretical maximum level.

The coal mines of countries are referred to Wikipedia (<https://www.wikipedia.org>) and the website of the Ministry of Foreign Affairs of the People's Republic of China (<https://www.fmprc.gov.cn/web/>). The data of consumer price index (CPI), annual Australia coal price, Gross Domestic Product per capita (purchasing power parity) (GDP per capita (PPP)) and Gross National Income per capita (purchasing power parity) (GNI per capita (PPP)) were downloaded from <https://data.worldbank.org>. CPI measures changes in the weighted average market basket price level of consumer goods and services purchased by households. The annual percentage change in CPI is used to measure inflation. Over the past 30 years, Australia has been one of the world's leading coal exporters [15]. Australia's annual coal price was used to represent changes in coal price over the past 30 years. GDP per capita (PPP) is a monetary measure of the market value of all final goods and services produced in a specific period. Per capita, gross national income (PPP) refers to the total domestic and foreign output claimed by residents of a country, including gross domestic product (GDP) plus factor income earned by foreign residents, minus income earned by non-residents in the domestic economy. These two parameters are used to describe the state of the national economy and average purchasing power. These economic parameters are widely used in the evaluation and prediction of national economic development. [16–19]

Case definition

According to GBD 2019 Diseases and Injuries Collaborators, the definition of ACOP is based on the International Classification of Diseases and Injuries-10 (ICD-10). The “poisoning by carbon monoxide” includes accidental poisoning by and exposure to carbon monoxide from combustion engine exhaust, utility gas, other domestic fuels, other sources, and unspecified sources, and accidental poisoning by and exposure to other specified gases or vapors and unspecified gases or vapors. Notably, exposure to carbon monoxide by self-poisoning or undetermined intent are not included.

Data calculation and adjustment

According to GBD 2019[13], the Cause of Deaths Ensemble model (CODEm) is used to estimate mortality while DisMod-MR 2.1, a Bayesian meta-regression tool, was used to evaluate prevalence and DALYs of accidental poisoning by carbon monoxide. All estimates are expressed as counts, and the 95% uncertainty interval (95% user interface) is based on the average of 1000 extractions, determined by 97.5% and 2.5% of the extracted distribution.

The estimated annual percentage change (EAPC) of age-standardized rates (ASR) was calculated by generalizing the linear model with a Gaussian distribution by R 4.0.2. The whole process includes two steps: 1. Linear regression of 30 years' data; i.e., $y = \alpha + \beta x + \epsilon$, where $x = \text{year}$ and $y = \ln(\text{rate})$; 2. Calculation of linear regression parameters. $\text{EAPC} = 100 \times (e^{\beta} - 1)$.

All the data analysis was performed by R 4.0.2. The missing data of CPI were modelled by the 'mice' package (method: Predictive mean matching). CPI-adjusted was calculated by cumulative multiplication of completed CPI to represent the relative level of price. All null values in GDP per capita (PPP) and GNI per capita (PPP) were removed before calculation to ensure the accuracy and authenticity of the data.

Results

Global level

In 2019, there were approximately 0.97 million ACOP incidence cases (95% UI 0.66 million to 1.4 million). In 2019, the age-standardized incidence rate (ASIR) was 13.05/100,000 (95% UI 8.84 to 18.69), and the EAPC was -0.53% (95%CI -0.67% to -0.40% , $p < 0.01$) between 1990 and 2019 (table 1 and Fig. 1). There were approximately 0.92 million prevalence cases (95% UI 0.74 million to 1.17 million) of ACOP, and the age-standardized prevalence rate (ASPR) per 100,000 population was 11.50 (95% UI 9.23 to 14.64). The EAPC of ASPR from 1990 to 2019 is estimated to be -0.35% (95% UI -0.55% to -0.15% , $p < 0.01$). Over the past 30 years, the ASR YLDs of ACOP (-0.41% , 95% UI -0.65% to -0.17%) has remained steady, while the age-standardized rate of deaths, prevalence, DALYs and YLLs had significantly decreased, with their EAPC respectively to be -1.95% (95% CI -2.26% to -1.64% , $p < 0.01$), -0.35% (95% CI -0.55% to -0.15% , $p < 0.01$), -2.24% (95% CI to -2.52% to -1.96% , $p < 0.01$), -2.30% (95% CI -2.60% to -2.01% , $p < 0.01$).

Regional level

Regionally, the highest ASIR of ACOP per 100,000 people in 2019 occurred in Eastern Europe (52.24 (95%UI 35.30 to 72.05)), Central Europe (48.04 (95%UI 30.81 to 70.20)) and Central Asia (34.28 (95%UI 22.88 to 49.55)). The lowest is Central sub-Africa (4.71 (95%UI 3.05 to 6.98)), Tropical Latin America 5.26 (95%UI 2.22 to 9.44), and Western Sub-Africa (5.48 (95%UI 3.51 to 8.03)).

From 1990 to 2019, The ASIR EAPC of East Asia was the highest, 1.37% (95%CI 1.13% - 1.60% , $p < 0.01$). The ASPR EAPC of Southern Latin America was the highest, 1.13% (95%CI 0.98% - 1.28% , $p < 0.01$), while Tropical Latin America had the lowest ASPR EAPC. It was -1.76% (95%CI 2.58% to -0.93% , $p < 0.01$). From 1990 to 2019, EAPC in ASIR and ASPR indicated a downward trend in most regions (Table 1, Fig. 2).

In general, in the past 30 years, every 100,000 population in the most regions of ASDR DALY ratio decreased, and Central Europe (-4.51% (95% CI, -4.71% to -4.31% , $p < 0.01$)) had the biggest drop, while Andean Latin America has risen trend (1.15% (95% CI 0.75% – 1.55% , $p < 0.01$)). For the EAPC of DALY, Andean Latin America remains the highest (0.92% (95% CI 0.54% – 1.3% , $p < 0.01$)), while Central Europe is the lowest (-4.45% (95%CI -4.66% to -4.23% , $p < 0.01$)) (Table 2).

For EAPC of ASR YLDs, Southern Latin America was the highest (1.13% (95%CI 0.97% – 1.29% , $p < 0.01$)) and Tropical Latin America was the lowest (-1.89% (95%CI -2.71% – -1.07% , $p < 0.01$)). For EAPC of ASR YLLs, Andean Latin America was the highest (0.96% (95%CI 0.52% – 1.41% , $p < 0.01$)) and Central Europe was the lowest (-4.79% (95%CI -5.02% – -4.55% , $p < 0.01$)) (Table 3).

Table 3

The number, age-standardized rate (ASR), and estimated annual percentage change (EAPC) of accidental carbon monoxide poisoning YLDs and YLLs in 2019.

	Prevalence				Incidence			
	Number,2019	ASR/10000	EAPC(%)	p	Number,2019	ASR/10000	EAPC(%)	p
	(95%UI)	2019(95%UI)	(95%CI)		(95%UI)	2019(95%UI)	(95%CI)	
Global	922323·64 (742036·25 to 1170319·04)	11·5 (9·23 to 14·64)	-0·35 (-0·55 to -0·15)	< 0·01	973600·97 (664806·26 to 1398273·55)	13·05 (8·84 to 18·69)	-0·53 (-0·67 to -0·4)	< 0·01
Sex								
Males	462665·81 (375240·17 to 579780·13)	11·64 (9·43 to 14·6)	-0·21 (-0·39 to -0·03)	< 0·01	462046·48 (317765·85 to 653759·31)	12·19 (8·33 to 17·27)	-0·58 (-0·67 to -0·49)	< 0·01
Females	459657·83 (368937·21 to 589512·88)	11·34 (9·08 to 14·6)	-0·47 (-0·7 to -0·25)	< 0·01	511554·49 (345044·53 to 740756·12)	13·93 (9·38 to 20·16)	-0·49 (-0·67 to -0·31)	< 0·01
Social-demographic index								
Low SDI	56441·03 (42476·34 to 76471·07)	5·52 (4·22 to 7·4)	0·06 (-0·15 to 0·26)	0·818335	74998·84 (45881·55 to 114061·69)	5·09 (3·27 to 7·57)	0·14 (-0·07 to 0·35)	0·533126
Low-middle SDI	129622·66 (101301·08 to 172020·03)	7·5 (5·87 to 9·92)	0·22 (-0·05 to 0·48)	0·345423	145342·43 (91206·58 to 219097·84)	7·72 (4·94 to 11·5)	0·18 (-0·08 to 0·44)	0·50128
Middle SDI	254783·04 (203469·91 to 325467·88)	10·08 (8·04 to 12·92)	0·07 (-0·15 to 0·29)	0·728868	257925·31 (171880·61 to 374220·63)	11·68 (7·72 to 16·96)	0·31 (0·1 to 0·52)	0·062847
High-middle SDI	281024·46 (231221·76 to 347442·08)	16·98 (13·86 to 21·38)	-0·47 (-0·6 to -0·34)	< 0·01	284561·96 (194703·97 to 390357·35)	23·78 (16·18 to 33·39)	-0·64 (-0·72 to -0·57)	< 0·01
High SDI	200045·38 (162484·83 to 246866·26)	16·71 (13·45 to 21·09)	-0·05 (-0·45 to 0·36)	0·364601	193993·19 (129477·46 to 280161·92)	24·39 (15·75 to 36·34)	0·05 (-0·39 to 0·48)	0·620337
Region								
Central Asia	23164·5 (18267·2 to 30072·68)	25·15 (19·88 to 32·56)	0·67 (0·48 to 0·86)	< 0·01	32765·52 (21923·76 to 46985·2)	34·28 (22·88 to 49·55)	0·33 (0·19 to 0·48)	0·031405
Central Europe	41254·86 (33405·76 to 52526·77)	30·88 (24·74 to 39·97)	0·35 (0·1 to 0·6)	0·143983	38551·08 (25716·24 to 54472·4)	48·04 (30·81 to 70·2)	0·17 (-0·04 to 0·39)	0·90581
Eastern Europe	71121·4 (58918·33 to 85056·55)	27·94 (23·08 to 33·84)	-1·1 (-1·35 to -0·84)	< 0·01	91658·53 (63871·52 to 122143·29)	52·24 (35·3 to 72·05)	-1·32 (-1·71 to -0·92)	< 0·01
Australasia	3382·79 (2760·64 to 4166·04)	10·1 (8·13 to 12·63)	-0·01 (-0·16 to 0·14)	0·111542	4104·83 (2774·19 to 5960·68)	16·84 (11·02 to 24·72)	0·02 (-0·11 to 0·15)	0·065405
High-income Asia Pacific	50746·4 (40753·69 to 64622·61)	22·64 (17·88 to 29·48)	-0·39 (-0·69 to -0·09)	< 0·01	36807·88 (24718·69 to 52984·87)	30·84 (19·67 to 46·18)	-0·3 (-0·61 to 0·02)	< 0·01
High-income North America	68451·36 (55810·12 to 83211·6)	16·15 (13·08 to 19·86)	0·04 (-0·92 to 1)	0·847404	80268·54 (51276·39 to 117876·33)	25·93 (16·18 to 39·22)	0·49 (-0·44 to 1·43)	0·463889

	Prevalence				Incidence			
	Number,2019	ASR/10000	EAPC(%)	p	Number,2019	ASR/10000	EAPC(%)	p
	(95%UI)	2019(95%UI)	(95%CI)		(95%UI)	2019(95%UI)	(95%CI)	
Southern Latin America	11430.57 (9158.96 to 14559.89)	16.17 (12.89 to 20.7)	1.13 (0.98 to 1.28)	< 0.01	14061.36 (9039.23 to 20785.28)	23.47 (15.01 to 34.4)	0.99 (0.86 to 1.12)	< 0.01
Western Europe	67968.41 (55474.8 to 84013.25)	13.08 (10.49 to 16.54)	-0.06 (-0.22 to 0.09)	0.017371	66669.19 (45352.1 to 95423.42)	19.89 (12.86 to 29.47)	-0.08 (-0.25 to 0.1)	0.01312
Andean latin america	3963.26 (3069.1 to 5224.04)	6.28 (4.87 to 8.26)	0.88 (0.79 to 0.98)	< 0.01	5335.13 (3251.31 to 8168.51)	8.23 (5.02 to 12.62)	1.14 (1.03 to 1.25)	< 0.01
Caribbean	5816.57 (4550.81 to 7552.64)	11.96 (9.35 to 15.57)	0.72 (0.61 to 0.84)	< 0.01	5518.68 (3530.06 to 8211.54)	12.5 (7.92 to 18.71)	0.61 (0.49 to 0.73)	< 0.01
Central Latin America	25938.39 (19776.33 to 34741.82)	10.22 (7.8 to 13.69)	-0.09 (-0.28 to 0.09)	0.032122	31837.32 (17407.81 to 52006.13)	13.02 (7.08 to 21.32)	0.14 (-0.05 to 0.33)	0.876803
Tropical Latin America	8719.93 (6850.5 to 10919.45)	3.65 (2.86 to 4.6)	-1.76 (-2.58 to -0.93)	< 0.01	11137.53 (4872.43 to 19526.48)	5.26 (2.22 to 9.44)	-1.54 (-2.35 to -0.73)	< 0.01
North Africa and Middle East	50519.3 (39214.24 to 66447.61)	8.42 (6.57 to 11.03)	-0.08 (-0.25 to 0.09)	0.034172	63975.69 (41589.07 to 93104.13)	10.06 (6.58 to 14.65)	0.13 (0 to 0.26)	0.782643
South Asia	111627.97 (85395.87 to 149407.07)	6.23 (4.78 to 8.3)	0.13 (-0.16 to 0.41)	0.753686	119073.18 (69912.1 to 189141.11)	6.19 (3.71 to 9.77)	0.19 (-0.09 to 0.48)	0.428334
East Asia	276936.06 (224595.08 to 343544.28)	16.3 (13.22 to 20.29)	0.82 (0.55 to 1.1)	< 0.01	245933.41 (169852.04 to 335131.87)	21.53 (14.86 to 29.62)	1.37 (1.13 to 1.6)	< 0.01
Oceania	575.45 (444.65 to 765.34)	4.79 (3.72 to 6.32)	0.28 (0.19 to 0.37)	< 0.01	970.39 (595.12 to 1458.2)	6.34 (3.92 to 9.51)	0.3 (0.21 to 0.38)	< 0.01
Southeast asia	40246.5 (30727.03 to 53725.62)	5.82 (4.44 to 7.78)	0.14 (-0.08 to 0.37)	0.579501	46792.81 (28370.83 to 73213.05)	7.22 (4.37 to 11.31)	0.29 (0.03 to 0.55)	0.133507
Central Sub-Saharan Africa	5976.22 (4506.81 to 8113.07)	5.08 (3.87 to 6.81)	-0.06 (-0.29 to 0.17)	0.238808	8076.04 (4971.28 to 12325.55)	4.71 (3.05 to 6.98)	0.12 (-0.08 to 0.32)	0.607337
Eastern Sub-Saharan Africa	21919.55 (16295.79 to 29812.57)	5.97 (4.5 to 8)	0.08 (-0.17 to 0.33)	0.976247	31149.36 (18905.31 to 48066.13)	5.8 (3.77 to 8.62)	0.05 (-0.17 to 0.27)	0.783346
Southern sub-Saharan Africa	6077.21 (4473.92 to 8401.46)	7.83 (5.77 to 10.81)	-0.21 (-0.45 to 0.02)	0.012179	4973.62 (2817.93 to 8083.37)	5.98 (3.4 to 9.71)	-0.45 (-0.68 to -0.21)	< 0.01
Western Sub-Saharan Africa	26486.96 (19673.46 to 36244.01)	6.45 (4.85 to 8.74)	0 (-0.16 to 0.16)	0.261051	33940.91 (20708.39 to 50765.22)	5.48 (3.51 to 8.03)	0.03 (-0.14 to 0.19)	0.49903
	Deaths				DALYs (Disability-Adjusted Life Years)			
	Number,2019	ASR/10000	EAPC(%)	p	Number,2019	ASR/10000	EAPC(%)	p
	(95%UI)	2019(95%UI)	(95%CI)		(95%UI)	2019(95%UI)	(95%CI)	

	Prevalence				Incidence			
	Number,2019	ASR/10000	EAPC(%)	p	Number,2019	ASR/10000	EAPC(%)	p
	(95%UI)	2019(95%UI)	(95%CI)		(95%UI)	2019(95%UI)	(95%CI)	
Global	41142.25 (32957.28 to 45934.81)	0.52 (0.41 to 0.58)	-1.95 (-2.26 to -1.64)	< 0.01	1838312.36 (1465241.82 to 2101515.48)	23.48 (18.62 to 27.21)	-2.24 (-2.52 to -1.96)	< 0.01
Sex								
Males	27175.24 (20084.98 to 31351.35)	0.69 (0.51 to 0.8)	-2.07 (-2.41 to -1.73)	< 0.01	1214806.63 (905559.66 to 1418200.91)	30.73 (22.8 to 36.07)	-2.3 (-2.61 to -1.99)	< 0.01
Females	13967.01 (10557.59 to 16588.96)	0.34 (0.26 to 0.41)	-1.67 (-1.93 to -1.4)	< 0.01	623505.73 (467640.64 to 756551.35)	16.26 (12.05 to 20.06)	-2.11 (-2.34 to -1.88)	< 0.01
Social-demographic index								
Low SDI	5803.72 (4257.49 to 8729.12)	0.78 (0.61 to 1.09)	-0.44 (-0.57 to -0.32)	< 0.01	297032.81 (207365.9 to 487139.84)	30.01 (22.21 to 45.19)	-0.5 (-0.6 to -0.39)	< 0.01
Low-middle SDI	5829.64 (4300.41 to 6986.47)	0.36 (0.27 to 0.43)	-1.13 (-1.27 to -0.99)	< 0.01	307899.7 (220124.23 to 378175.4)	17.42 (12.54 to 21.44)	-1.41 (-1.52 to -1.3)	< 0.01
Middle SDI	11888.67 (8321.58 to 13842.99)	0.5 (0.35 to 0.58)	-0.86 (-1.14 to -0.58)	< 0.01	508553.26 (369387.51 to 581799.46)	21.05 (15.27 to 23.97)	-1.85 (-2.07 to -1.64)	< 0.01
High-middle SDI	15065.98 (13067.69 to 16569.59)	0.87 (0.76 to 0.95)	-3.01 (-3.56 to -2.47)	< 0.01	604689.84 (534668.88 to 660767.45)	39.08 (34.61 to 42.67)	-3.16 (-3.68 to -2.64)	< 0.01
High SDI	2543.52 (2379.91 to 2716.92)	0.21 (0.2 to 0.22)	-1.46 (-1.71 to -1.22)	< 0.01	119555.85 (109896.44 to 130171.01)	11.44 (10.52 to 12.46)	-1.48 (-1.76 to -1.2)	< 0.01
Region								
Central Asia	1123.54 (985.39 to 1310.46)	1.23 (1.09 to 1.43)	-2.64 (-2.96 to -2.32)	< 0.01	54866.17 (48212.71 to 63980.56)	57.15 (50.34 to 66.69)	-2.85 (-3.15 to -2.54)	< 0.01
Central Europe	746.24 (653.62 to 840.52)	0.48 (0.42 to 0.54)	-4.51 (-4.71 to -4.31)	< 0.01	28320.93 (24632.69 to 32107.24)	22.63 (19.77 to 25.7)	-4.45 (-4.66 to -4.23)	< 0.01
Eastern Europe	7789.55 (6900.89 to 8732.97)	2.98 (2.64 to 3.33)	-2.79 (-3.64 to -1.94)	< 0.01	314927.07 (278424.43 to 351729.93)	136.49 (121.29 to 151.85)	-2.85 (-3.67 to -2.01)	< 0.01
Australasia	27.05 (23.73 to 30.08)	0.09 (0.08 to 0.1)	-1.84 (-2.44 to -1.24)	< 0.01	1539.7 (1345.12 to 1753.64)	5.47 (4.77 to 6.21)	-1.79 (-2.3 to -1.27)	< 0.01
High-income Asia Pacific	343.84 (312.13 to 419.98)	0.14 (0.13 to 0.18)	-3.68 (-4.18 to -3.17)	< 0.01	16761.45 (14539.01 to 20683.91)	8.33 (7.22 to 10.46)	-3.75 (-4.31 to -3.19)	< 0.01
High-income North America	1132.91 (1044.02 to 1177.75)	0.27 (0.25 to 0.29)	0.68 (0.41 to 0.94)	< 0.01	53408.69 (48436.7 to 56963.48)	14.59 (13.22 to 15.55)	0.54 (0.25 to 0.84)	< 0.01

	Prevalence				Incidence			
	Number,2019	ASR/10000	EAPC(%)	p	Number,2019	ASR/10000	EAPC(%)	p
	(95%UI)	2019(95%UI)	(95%CI)		(95%UI)	2019(95%UI)	(95%CI)	
Southern Latin America	275.09 (247.09 to 297.51)	0.39 (0.34 to 0.42)	0.71 (0.13 to 1.29)	0.013336	13485.2 (12005.13 to 14864.56)	20.53 (18.11 to 22.84)	0.71 (0.12 to 1.29)	0.064088
Western Europe	536.08 (502.19 to 564.36)	0.09 (0.09 to 0.1)	-2.88 (-3.11 to -2.65)	< 0.01	24250.22 (21820.32 to 27273.28)	5.37 (4.84 to 6.02)	-2.65 (-2.89 to -2.42)	< 0.01
Andean latin america	48.4 (21.5 to 67.39)	0.08 (0.03 to 0.11)	1.15 (0.75 to 1.55)	< 0.01	2840.9 (1454.58 to 3871.46)	4.41 (2.27 to 6.01)	0.92 (0.54 to 1.3)	< 0.01
Caribbean	78.45 (50.66 to 180.73)	0.17 (0.11 to 0.38)	-1.35 (-1.85 to -0.85)	< 0.01	5098.88 (3320.1 to 10381.98)	11.22 (7.19 to 22.49)	-1.13 (-1.62 to -0.63)	< 0.01
Central Latin America	356.64 (306.57 to 411.51)	0.14 (0.12 to 0.17)	-2.2 (-2.34 to -2.07)	< 0.01	19827.76 (16888.59 to 22841.23)	7.88 (6.7 to 9.07)	-2.33 (-2.47 to -2.18)	< 0.01
Tropical Latin America	74.63 (66.86 to 79.77)	0.03 (0.03 to 0.03)	-1.77 (-2.04 to -1.49)	< 0.01	4396.01 (3871.12 to 4892.24)	1.94 (1.71 to 2.16)	-1.9 (-2.23 to -1.57)	< 0.01
North Africa and Middle East	2817.76 (1870.27 to 3629.5)	0.49 (0.33 to 0.64)	-1.75 (-1.79 to -1.71)	< 0.01	151154.95 (103138.9 to 197021.54)	24.26 (16.49 to 31.69)	-2.16 (-2.24 to -2.09)	< 0.01
South Asia	3630.48 (2431.02 to 4480.31)	0.21 (0.14 to 0.26)	-1.46 (-1.63 to -1.3)	< 0.01	221525.84 (144912.35 to 277969.55)	11.86 (7.74 to 14.82)	-1.32 (-1.47 to -1.17)	< 0.01
East Asia	15312.93 (10191.08 to 18394.32)	0.92 (0.62 to 1.09)	-0.45 (-0.78 to -0.11)	0.010381	590208.67 (403810.1 to 699317.92)	40.33 (28.37 to 46.97)	-1.41 (-1.7 to -1.12)	< 0.01
Oceania	30.22 (20.6 to 45.96)	0.27 (0.18 to 0.4)	0.71 (0.51 to 0.91)	< 0.01	1691 (1175.63 to 2688.98)	12.96 (9.1 to 19.56)	0.75 (0.55 to 0.95)	< 0.01
Southeast asia	660.58 (460.9 to 969.92)	0.1 (0.07 to 0.15)	-2.74 (-2.96 to -2.53)	< 0.01	37391.74 (27185.14 to 50990.18)	5.55 (4.05 to 7.6)	-2.6 (-2.78 to -2.42)	< 0.01
Central Sub-Saharan Africa	817.7 (525.64 to 1386.48)	1.14 (0.79 to 1.79)	0.26 (0.05 to 0.47)	0.01973	37549.82 (22871.74 to 69948.58)	38.65 (25.29 to 65.12)	0.28 (0.06 to 0.5)	0.372917
Eastern Sub-Saharan Africa	2968.84 (2283.8 to 4043.54)	1.46 (1.16 to 1.9)	-0.08 (-0.22 to 0.05)	0.129063	126966.92 (93341.56 to 184836.53)	44.79 (34.72 to 60.81)	-0.18 (-0.31 to -0.05)	< 0.01
Southern sub-Saharan Africa	294.31 (182.25 to 388.25)	0.37 (0.23 to 0.49)	-1.34 (-1.69 to -0.99)	< 0.01	18506.08 (11421.27 to 24938.55)	22.5 (13.86 to 30.29)	-1.2 (-1.46 to -0.94)	< 0.01
Western Sub-Saharan Africa	2077.02 (1393.93 to 3659.5)	0.71 (0.51 to 1.12)	-0.39 (-0.47 to -0.31)	< 0.01	113594.37 (72442.68 to 215831.72)	27.49 (18.82 to 47.33)	-0.4 (-0.46 to -0.33)	< 0.01
	YLDs (Years Lived with Disability)				YLLs (Years of Life Lost)			
	Number,2019	ASR/10000	EAPC(%)	p	Number,2019	ASR/10000	EAPC(%)	p
	(95%UI)	2019(95%UI)	(95%CI)		(95%UI)	2019(95%UI)	(95%CI)	

	Prevalence				Incidence			
	Number,2019	ASR/10000	EAPC(%)	p	Number,2019	ASR/10000	EAPC(%)	p
	(95%UI)	2019(95%UI)	(95%CI)		(95%UI)	2019(95%UI)	(95%CI)	
Global	82847.33 (50525.7 to 127161.37)	1.04 (0.64 to 1.6)	-0.41 (-0.65 to -0.17)	< 0.01	1755465.03 (1383510.25 to 2023273.65)	22.43 (17.57 to 26.07)	-2.3 (-2.6 to -2.01)	< 0.01
Sex								
Males	40502.21 (24825.57 to 61912.64)	1.02 (0.63 to 1.57)	-0.24 (-0.46 to -0.01)	0.046163	1174304.42 (865604.25 to 1376430.25)	29.71 (21.75 to 34.96)	-2.35 (-2.67 to -2.03)	< 0.01
Females	42345.12 (25785.06 to 65428.1)	1.06 (0.65 to 1.64)	-0.56 (-0.81 to -0.31)	< 0.01	581160.61 (425013.78 to 714973.52)	15.19 (10.99 to 19.01)	-2.19 (-2.44 to -1.93)	< 0.01
Social-demographic index								
Low SDI	6621.59 (3951.28 to 10227.88)	0.62 (0.37 to 0.96)	0.02 (-0.19 to 0.22)	0.659252	290411.22 (201640.94 to 481338.88)	29.39 (21.42 to 44.47)	-0.5 (-0.62 to -0.39)	< 0.01
Low-middle SDI	13860.52 (8352.19 to 21421.32)	0.79 (0.48 to 1.21)	0.08 (-0.18 to 0.35)	0.444437	294039.18 (206617.51 to 365222.18)	16.63 (11.75 to 20.54)	-1.46 (-1.58 to -1.34)	< 0.01
Middle SDI	23206.35 (14039.17 to 35958.36)	0.93 (0.56 to 1.45)	-0.19 (-0.43 to 0.05)	0.13847	485346.91 (339068.71 to 559933.06)	20.12 (14.16 to 23.1)	-1.91 (-2.14 to -1.68)	< 0.01
High-middle SDI	23118.61 (14378.29 to 34786.44)	1.47 (0.91 to 2.24)	-0.4 (-0.61 to -0.2)	< 0.01	581571.23 (511410.52 to 636754.53)	37.61 (33.25 to 41.02)	-3.23 (-3.76 to -2.69)	< 0.01
High SDI	15998.68 (9715.21 to 24321.83)	1.44 (0.87 to 2.23)	-0.26 (-0.66 to 0.14)	0.167053	103557.17 (96512.1 to 111123.38)	10 (9.32 to 10.73)	-1.61 (-1.89 to -1.34)	< 0.01
Region								< 0.01
Central Asia	2310.9 (1432.33 to 3584.99)	2.48 (1.54 to 3.84)	0.77 (0.55 to 1)	< 0.01	52555.27 (46097.2 to 61782.34)	54.67 (48.02 to 64.03)	-2.94 (-3.26 to -2.62)	0.091961
Central Europe	3531.7 (2196.12 to 5359.3)	2.82 (1.73 to 4.31)	0.36 (0.08 to 0.63)	0.029857	24789.24 (21667.1 to 28025.65)	19.81 (17.36 to 22.4)	-4.79 (-5.02 to -4.55)	< 0.01
Eastern Europe	5165.76 (3326.04 to 7482.82)	2.18 (1.4 to 3.19)	-1.02 (-1.18 to -0.85)	< 0.01	309761.31 (274001.57 to 346597.64)	134.31 (119.12 to 149.76)	-2.87 (-3.7 to -2.03)	< 0.01
Australasia	271.6 (168.32 to 405.95)	0.86 (0.53 to 1.3)	-0.02 (-0.19 to 0.14)	0.875996	1268.1 (1100.47 to 1424.83)	4.6 (4 to 5.2)	-2.03 (-2.62 to -1.44)	< 0.01
High-income Asia Pacific	4391.79 (2645.27 to 6802.78)	2.13 (1.26 to 3.34)	-0.53 (-0.87 to -0.19)	< 0.01	12369.66 (11360.49 to 15934.7)	6.19 (5.69 to 8.31)	-4.37 (-4.95 to -3.78)	< 0.01
High-income North America	4696.52 (2891.46 to 7131.11)	1.19 (0.72 to 1.84)	-0.57 (-1.57 to 0.44)	0.258699	48712.16 (44573.74 to 50726.17)	13.4 (12.24 to 13.97)	0.64 (0.34 to 0.93)	< 0.01

	Prevalence				Incidence			
	Number,2019 (95%UI)	ASR/10000 2019(95%UI)	EAPC(%) (95%CI)	p	Number,2019 (95%UI)	ASR/10000 2019(95%UI)	EAPC(%) (95%CI)	p
Southern Latin America	1079.73 (657.79 to 1628.84)	1.56 (0.95 to 2.35)	1.13 (0.97 to 1.29)	< 0.01	12405.47 (10936.64 to 13649.48)	18.97 (16.57 to 21.1)	0.68 (0.06 to 1.3)	< 0.01
Western Europe	5672.78 (3513.32 to 8539.22)	1.19 (0.72 to 1.81)	-0.06 (-0.2 to 0.09)	0.384482	18577.44 (17597.25 to 19417.17)	4.18 (3.93 to 4.38)	-3.14 (-3.37 to -2.91)	< 0.01
Andean latin america	410.22 (249.75 to 642.98)	0.65 (0.39 to 1.01)	0.62 (0.53 to 0.71)	< 0.01	2430.68 (1057.08 to 3442.1)	3.76 (1.63 to 5.31)	0.96 (0.52 to 1.41)	< 0.01
Caribbean	617.76 (371.92 to 952.93)	1.28 (0.77 to 1.98)	0.72 (0.62 to 0.82)	< 0.01	4481.12 (2745.33 to 9764.7)	9.94 (5.96 to 21.22)	-1.31 (-1.84 to -0.78)	< 0.01
Central Latin America	2502.9 (1442.42 to 3980.68)	0.99 (0.57 to 1.56)	-0.23 (-0.41 to -0.05)	0.014928	17324.86 (14803.01 to 19996.7)	6.9 (5.89 to 7.98)	-2.53 (-2.68 to -2.39)	< 0.01
Tropical Latin America	698.5 (415.42 to 1091.22)	0.3 (0.18 to 0.47)	-1.89 (-2.71 to -1.07)	< 0.01	3697.51 (3273.72 to 3979.54)	1.65 (1.45 to 1.78)	-1.9 (-2.17 to -1.62)	0.356572
North Africa and Middle East	5214.89 (3145.38 to 8045.32)	0.86 (0.52 to 1.32)	-0.34 (-0.53 to -0.14)	< 0.01	145940.06 (97657.19 to 191366.7)	23.41 (15.61 to 30.66)	-2.21 (-2.29 to -2.13)	< 0.01
South Asia	12520.2 (7557.05 to 19284.35)	0.69 (0.42 to 1.06)	-0.01 (-0.29 to 0.27)	0.907673	209005.64 (133048.89 to 266468.53)	11.17 (7.1 to 14.2)	-1.38 (-1.54 to -1.21)	< 0.01
East Asia	22548.96 (13740.2 to 34229.89)	1.41 (0.85 to 2.15)	0.49 (0.18 to 0.8)	< 0.01	567659.71 (380308.5 to 677363.21)	38.92 (26.95 to 45.57)	-1.45 (-1.76 to -1.15)	< 0.01
Oceania	60.85 (36.36 to 94.25)	0.49 (0.29 to 0.75)	0.24 (0.15 to 0.33)	< 0.01	1630.15 (1123.47 to 2628.78)	12.48 (8.43 to 19.05)	0.77 (0.56 to 0.98)	< 0.01
Southeast asia	4054.51 (2366.15 to 6397.83)	0.59 (0.34 to 0.92)	0.04 (-0.16 to 0.25)	0.465955	33337.23 (23392.99 to 47143.92)	4.96 (3.49 to 6.96)	-2.8 (-2.99 to -2.61)	< 0.01
Central Sub-Saharan Africa	742.83 (447.36 to 1144.25)	0.6 (0.36 to 0.92)	-0.1 (-0.34 to 0.14)	0.561209	36806.98 (22022.36 to 69049.44)	38.05 (24.57 to 64.49)	0.29 (0.06 to 0.51)	< 0.01
Eastern Sub-Saharan Africa	2560.84 (1507.94 to 4011.54)	0.66 (0.39 to 1.04)	0.08 (-0.18 to 0.33)	0.406205	124406.08 (90694.56 to 182067.89)	44.13 (33.88 to 60.22)	-0.18 (-0.32 to -0.05)	< 0.01
Southern sub-Saharan Africa	710.34 (404.26 to 1110.54)	0.91 (0.52 to 1.43)	-0.13 (-0.38 to 0.12)	0.326998	17795.74 (10768.61 to 24149.88)	21.59 (13 to 29.39)	-1.24 (-1.51 to -0.97)	< 0.01
Western Sub-Saharan Africa	3083.76 (1794.94 to 4877.55)	0.72 (0.42 to 1.13)	0.02 (-0.14 to 0.17)	0.627087	110510.62 (69131.82 to 213219.14)	26.78 (18.04 to 46.62)	-0.41 (-0.48 to -0.34)	< 0.01

National and territorial level

In 2019, the three lowest ASIR countries were Pakistan (3.72, 95%UI 2.27 to 5.73), Bangladesh (3.87, 95%UI 2.33 to 5.97), and Central African Republic (3.93, 95%UI 2.63 to 5.67) respectively. The highest incidence rate of the three countries was Estonia (77.97, 95%UI 51.69 to 109.40), Latvia (68.25, 45.13 to 97.70), and Lithuania (65.53, 95%UI 45.30 to 90) (Fig. 3A, Additional file 2 table 1).

The countries with the highest ASPR were Estonia (51.02 (95% UI 41.13 to 65.68)), Latvia (44.33 (95% UI 35.70 to 56.68)) and Lithuania (38.64 (95% UI 31.68 to 48.47)). The countries with the lowest ASPR were Pakistan (3.51 (95% UI 2.60 to 4.76)), Bangladesh (3.52 (95% UI 2.66 to 4.76)), and Brazil (3.65 (95% UI 2.86 to 4.60)).

The countries with the highest ASDR were Republic of Moldova (3.59 (95% UI 3.14 to 4.06)), Russian Federation (3.13 (95% UI 2.71 to 3.61)) and Belarus (2.71 (95% UI 1.92 to 3.62)) respectively. The lowest countries were Barbados (0.02 (95% UI 0.01 to 0.02)), Singapore (0.02 (95% UI 0.02 to 0.03)) and Suriname (0.03 (95% UI 0.02 to 0.04)) (Fig. 3B, Additional file 2 table 2).

The highest ASR of DALYs were Republic of Moldova (145.67 (95% UI 127.63 to 163.84)), Russian Federation (144.02 (95% UI 125.34 to 164.49)) and Ukraine (125.10 (95% UI 100.92 to 149.59)) respectively. The lowest three countries were Thailand (1.84 (95% UI 1.21 to 2.50)), Maldives (1.86 (95% UI 1.34 to 2.38)) and Brazil (1.92 (95% UI 1.68 to 2.13)).

All the data of national and territorial levels are in Additional file 2 Table 1–3. The ASR and EAPC of prevalence, deaths, DALYs, YLDs, and YLLs are listed in Additional file 2 Fig. 1–10.

Age and sex patterns

Compared to 1990 by age and SDI regions, in 2019, most of ACOP parameters were lower (Fig. 4). In 2019, whether it's by age or SDI regions, ASPR, ASIR, ASDR, YLDs, and YLLs were higher in males (Fig. 2 & Fig. 5). ASPR, ASDR, and YLDs increased with age. However, ASIR showed a trend of increasing first and then decreasing, and its peak was about 15–19 years old, which was the same trend in males and females. For females, YLLs and DALYs also indicated a trend of increasing with age, while the males group peaked after 35–39 years old and maintained a high level, which was very different.

Risk factors

There are two risk factors listed in the database: alcohol use and occupational injury. In the past 30 years, occupational injury is the main risk of ACOP. By sexes, the risk of occupation the risk of males is higher than that of females (Fig. 6). The 30-year-trend of global deaths, DALYs, YLDs, and YLLs are listed in Fig. 7. The figure of different SDI regions (e.g., Low SDI, Low-middle SDI, Middle SDI, Middle-high SDI, High SDI) are listed in the Additional file 2 Fig. 11–15. Most of them are in line with the law.

As shown in Fig. 7, the two risks are similar in countries with different SDIs. By sexes, the pattern is similar to before. Males patients were more than female patients, and occupation injury accounted for a larger proportion than alcohol use.

ACOP and economic parameters

From Fig. 8A, Eastern Europe is the highest ACOP ASIR, ASDR, ASPR, DALYs, YLDs, and YLLs region. Central Europe, Central Asia, and High-income North America are highly in ASIR, ASDR, and YLDs.

While investigating at the national and territorial level, the results are clearer. On the whole, ASIR rises with the rise of SDI, while ASDR is the opposite, and falls with the rise of SDI (Fig. 9A&B). The ASR of prevalence and YLDs have the same trend as ASIR (Additional file 2 Fig. 20, 22). The ASR of DALYs and YLLs have the same trend as ASDR (Additional file 2 Fig. 21, 23). On a whole, in 2019, the countries with lower SDI have a lower ACOP morbidity, but higher mortality.

As shown in Fig. 10, the global level of ACOP parameters was nonlinear fitting with SDI from 1990 to 2019. We find that the nonlinear fittings between parameters are very significant. The figures of different SDI regions' nonlinear fittings are list in Additional file 2 Fig. 24–28. Then we calculated the correlation coefficient and p-value between ACOP parameters and economic parameters (e.g., Australia coal price, CPI, GDP per capita (PPP), GNI per capita (PPP), SDI) by different periods. All data are listed in Additional file 3 and Additional file 4. The percentages of countries that are significantly related to these factors are counted in Fig. 11 and the specific data is listed in Additional file 2 table 4–5 and Fig. 29–30. Due to the turmoil in certain countries in the 1990s and the dramatic decline in global ACOP mortality around 2005, the data from 2010 to 2019 are considered more stable and representative. We take ASIR and ASPR in 2010 to 2019 by SDI as an example to show the national and territorial level of correlation coefficients in Fig. 11 C, D. Most countries had the same trend in ASIR and ASDR in the past 10 years, and SDI is the most relevant economic parameter with ACOP.

From Additional file 3, there are only 14 countries in which ASIR and SDI are negatively correlated from 2010 to 2019 (Belarus, Belgium, Greenland, Iran, Islamic Rep., Kazakhstan, Lithuania, Moldova, Mongolia, Myanmar, Nepal, Pakistan, Romania, Russian Federation, Ukraine). (Belarus, Belgium, Greenland, Iran, Islamic Rep., Kazakhstan, Lithuania, Moldova, Mongolia, Myanmar, Nepal, Pakistan, Romania, Russian Federation, Ukraine). Among them, Belgium, Greenland, Iran, Islamic Rep., Kazakhstan, Pakistan, Russian Federation are significantly correlated ($r \geq 0.8$ & $p \leq 0.05$). The remaining countries are positively correlated with SDI. For ASDR, the trend is the opposite. There are 12 countries in which ASDR and SDI are significantly positively correlated ($r \geq 0.8$ & $p \leq 0.05$) from 2010 to 2019 (Albania, Andorra, Bangladesh, Burkina Faso, Costa Rica, Dominica, Dominican Republic, Iceland, San Marino, Suriname, Venezuela, RB, Zimbabwe).

For risk factors, there are 10 countries in which ASDR and SDI are significantly positively correlated from 2010 to 2019 by occupational injuries (Andorra, Austria, Dominican Republic, Estonia, Iceland, North America, Norway, Portugal, Solomon Islands, Somalia). And 14 countries in which ASR of DALYs and SDI are significantly positively correlated from 2010 to 2019 by occupational injuries (Andorra, Austria, Dominican Republic, Estonia, Iceland, Maldives, North America, Norway, Portugal, Slovenia, Solomon Islands, Somalia, St. Kitts and Nevis, Trinidad, and Tobago). More details such as sexes, different periods, and risk factors are listed in table s.

ACOP trend after excluding the influence of SDI

As ACOP parameters are highly correlated to SDI in most countries, SDI or the economic development behind it could affect the trend of ACOP. We use SDI as a confounding factor in multiple regression analysis. All the results are list in Additional file 5 and 6.

From Additional file 5, 143 countries have the growing trend of ASIR from 2010 to 2019, and 34 countries are significantly related to year (Afghanistan, Azerbaijan, Bahrain, Barbados, Belarus, Brazil, Burundi, Israel, Jordan, Kuwait, Lao PDR, Lebanon, Libya, Malaysia, Maldives, Mauritius, Moldova, Oman, Poland, Saudi Arabia, Sri Lanka, St. Lucia, Sudan, Timor-Leste, Turkey, Ukraine, United Arab Emirates, United Kingdom, Yemen, Rep., Bermuda, Niue, San Marino, Slovakia, Venezuela, RB). The data of ASDR are serious too. 100 countries have the growing trend of ASDR from 2010 to 2019, and 34 countries are significantly related to the year (Barbados, Cambodia, Denmark, Dominican Republic, Guinea, Jordan, Kiribati, Libya, Qatar, South Africa, Tajikistan, Yemen, Rep., American Samoa).

From Additional file 6, there are 99 countries in which had an increasing trend of ASDR from 2010 to 2019 by occupational injuries, and there are significantly related to the year in 13 countries (Australia, Belgium, China, Jordan, Nigeria, Poland, Serbia, Seychelles, Tajikistan, Timor-Leste, Yemen, Rep., Bermuda, Eritrea). For ASR of DALYs, 101 countries had the increasing trend, and 15 countries are statistically related to the year (Australia, Barbados, China, Finland, Hungary, Jordan, Nigeria, Poland, Serbia, Seychelles, Tajikistan, Timor-Leste, Yemen, Rep., Bermuda, Eritrea). More details such as sexes, different periods, and risk factors are listed in table s.

Discussion

This report provides the most up-to-date estimates of incidence, prevalence, deaths, DALYs, YLDs, and YLLs for ACOP in 204 countries and territories from 1990 to 2019. ACOP accounted for 0.97 million incident cases, 0.92 million prevalent cases, 41,142 deaths cases, 1.84 million DALYs, 82847.33 YLDs, and 1.76 million YLLs in 2019. The national-level burden of ACOP in 2019, not previously reported, has been included in this study derived from the publicly available GBD 2019 Study.

Previously, Lippi and Mattiuzzi researched ACOP based on GBD 2017[12] Their research studied the incidence and mortality rate from 1992 to 2017. And they investigated the effects of age and sexes on ACOP mortality in 2017. Most of their conclusions are consistent with our article. This article further expands the previous research conclusions.

From 1990 to 2019, the age-standardized rate of incidence, prevalence, deaths, DALYs, YLDs, and YLLs of ACOP all decreased. It is worth noting that the age-standardized rate of deaths, DALYs, YLLs, and other data all have an inflection point around 2005, especially in Low-middle SDI regions. After 2005, the probabilities of these data have dropped rapidly, and similar trends exist in regions with different economic levels. Two articles [20, 21] were published in top medical journals in the early 21st century that the application of hyperbaric oxygen can effectively cure ACOP. Based on the above, we considered that hyperbaric oxygen is one of the main reasons for the decline in ASR of deaths, DALYs, and YLLs of ACOP.

By sex, on the whole, females have a higher ASR of incidence than males. However, the ASDR of females is lower than that of males. This pattern exists in different years, regions, and ages. Previous studies[22–24] have shown that estrogen and estrogen receptors can effectively enhance the tolerance of cardiomyocytes and neurons to respond to hypoxia injury. This article appointed that the females' ACOP mortality rate rises rapidly after the age of 60, and the increased rate exceeded that of males. However, the ACOP mortality rate of females up to the age of 80 did not match that of males. Therefore, it is still uncertain whether estrogen and estrogen receptors are the main reasons for females' lower mortality of ACOP. For different poisoning factors, the severity of COP is often different. For different occupations, their sexes are often uneven. For example, there are more male employees than women in heavy industries such as steelmaking. What's more, some technologies can lower the probability of ACOP in certain scenarios. For instance, many countries have seen a substantial reduction in lethal car exhaust poisoning with the rise of catalytic converters.[25, 26] This may be the reason for the different severity of COP in different sexes.

The GBD 2019 study only counts two risks of ACOP – occupational injuries and alcohol use. In terms of mortality, occupational injuries are the primary cause of deaths and disability from COP, while alcohol use is the secondary cause in most regions with different SDI level. By sexes, males are more than females. On the whole, COP is more like an occupational disease, and most COP patients are caused by occupational injuries.

Just like other reports based on the GBD database[27, 28], the correlation between disease-related parameters and SDI was investigated too. In 2019, the countries with lower SDI have lower ACOP morbidity and higher mortality. Besides, it has a strong correlation with SDI in the past 30 years in global and different SDI regions. Then we included some economic parameters, including Australia coal price, CPI-adjusted, GDP per capita (PPP), GNI per capita (PPP), and SDI. The ACOP-related parameters of most countries in the world are not related to Australia's coal price, while there is a significant linear correlation between more than 60% of countries' parameters and GDP per capita (PPP), GNI per capita (PPP), and SDI. Within these parameters, SDI has the best correlation. Some studies[29, 30] have reported that economic development or the pollution caused by it is related to the incidence of certain diseases.

The application of fuel is closely related to economic development, and the former is also closely related to the incidence of ACOP. Therefore, we try to use SDI as a confounding factor to evaluate the trend of ACOP parameters under the non-economic influence. The influence of non-economic factors mainly stems from the promotion of medical technology, culture, domestic, and international political environment. The results show that when the economic impact is excluded, the ASIR of most countries in the world and the ASDR of nearly half of the countries are on the rise. Considering that severe CO poisoning can cause serious sequelae to patients, for these countries, the prevention, and control of carbon monoxide poisoning is still very important.

It is worth noting that some traditional developed countries such as the United Kingdom and Denmark have also appeared on the list, which seems very puzzling. On the one hand, it may be caused by errors in some data. On the other hand, taking the United Kingdom as an example, Roca-Barceló et al. [6] investigated the epidemiology of carbon monoxide poisoning in the United Kingdom. They found that the morbidity of ACOP has obvious area-level characteristics (i.e., deprivation, rurality, and ethnicity) from 2002 to 2016. The increase in morbidity may be due to the increase in the poor population, and the increase in the poor population may come from the polarization of the rich and the poor. We have tried to download the GINI coefficient from the database of the WORLD BANK, but the GINI coefficient has too many nulls for effective and reasonable analysis. This is very regrettable.

The research of this article also has certain defects. First of all, exposure to carbon monoxide by self-poisoning or undetermined intent are not included, which contrasts with most countries where suicidal poisoning (car exhaust or charcoal) is one of the leading causes of diagnosed COP. In Australia, for example, accidental poisoning accounts for less than 10% of calls about COP, and the deaths often outnumber admissions.[31] Secondly, the CPI data was predicted and filled by predictive mean matching, which will cause data distortion. For GDP and GNI data, we directly discard the null value. Although this can ensure the accuracy and authenticity of the data, it may still cause errors between the data and the real situation. Thirdly, our consideration of ACOP parameters and economic parameters is largely based on the data from the last ten years. Mainly because of the social instability in some countries in the early 1990s, and there was a strong transition in ASDRs, DALYs, and YLLs around 2005. After overall consideration, most countries around the world are in a stage of stable development from 2010 to 2019, so the data is more convincing. However, this will result in low values for the 2010–2019 group in Fig. 11.

Conclusion

In conclusion, except for a few countries and regions, the incidence of accidental carbon monoxide poisoning has shown a slow upward trend in the past 30 years, and this trend is highly correlated with economic development in most countries, which may be due to the occupational disease attribute by ACOP. We also try to evaluate the development of medical systems in different countries by multiple linear regression. Some countries must pay more attention to the development of national medical service.

Abbreviations

ACOP: accidental carbon monoxide poisoning; GBD: Global Burden of Disease; ASR: age-standardized rate; ASDR: age-standardized death rate; ASIR: age-standardized incidence rate; ASPR: age-standardized prevalence rate; DALYs: disability-adjusted life years; YLDs: lived with disability; YLLs: Years of Life Lost;

EAPC: estimated annual percentage change; SDI: socio-demographic index.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Yes, all authors consent for publication.

Availability of data and materials

Yes, all the data and materials can be asked from the author.

Competing Interests

The authors have declared that they have no competing interests.

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Authors' contributions

MZ designed the research. XL collected most of data. FL performed data analysis, data interpretation, and writing.

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Figures

Figure 1

The linear regression between ACOP ASIR (A) and ASDR (B) and SDI at the national level.

Figure 1

The ASR of different regions' ACOP ASR of incidence (A), prevalence (B), deaths (C), DALYs (D), YLDs (E), and YLLs (F) by ages, sexes, and SDI regions in 2019. The solid black line shows expected values across the spectrum of the SDI. SDI=Socio-demographic Index.

Figure 1

The number, percent, rate of deaths, DALYs, YLDs, and YLLs of global ACOP of two risk factors and sexes. The number (A), percent (B), and rate (C) of deaths of global ACOP of two risk factors and sexes. The number (D), percent (E), and rate (F) of DALYs of global ACOP of two risk factors and sexes. The number (G), percent (H), and rate (I) of YLDs of global ACOP of two risk factors and sexes. The number (J), percent (K), and rate (L) of YLLs of global ACOP of two risk factors and sexes.

Figure 1

The ASR of different regions' ACOP ASR of incidence (A), prevalence (B), deaths (C), DALYs (D), YLDs (E), and YLLs (F) in 1990 and 2019 by sexes.

Figure 1

The linear regression of ASR of incidence (a), prevalence (b), death (c), DALYs (d), YLDs (e), and YLLs (f).

Figure 1

Age-standardized incidence rate (ASIR) (A) and ASIR EAPC (B) of ACOP per 100,000 population in 2019, by country. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 1

The ASR of different regions' ACOP ASR of incidence (A), prevalence (B), deaths (C), DALYs (D), YLDs (E), and YLLs (F) by ages and SDI regions in 1990 and 2019.

Figure 1

The ASR of different regions' ACOP ASR of incidence (A), prevalence (B), deaths (C), DALYs (D), YLDs (E), and YLLs (F) in 1990 and 2019 by sexes.

Figure 1

The 30-year-trend of ACOP ASR of incidence (A), prevalence (B), deaths (C), DALYs (D), YLDs (E), and YLLs (F) by SDI regions.

Figure 1

The number, percent, rate of deaths, DALYs, YLDs, and YLLs of global ACOP of two risk factors and sexes. The number (A), percent (B), and rate (C) of deaths of global ACOP of two risk factors and sexes. The number (D), percent (E), and rate (F) of DALYs of global ACOP of two risk factors and sexes. The number (G), percent (H), and rate (I) of YLDs of global ACOP of two risk factors and sexes. The number (J), percent (K), and rate (L) of YLLs of global ACOP of two risk factors and sexes.

Figure 1

The ASR of different regions' ACOP ASR of incidence (A), prevalence (B), deaths (C), DALYs (D), YLDs (E), and YLLs (F) by ages, sexes, and SDI regions in 2019. The solid black line shows expected values across the spectrum of the SDI. SDI=Socio-demographic Index.

Figure 1

The linear regression between ACOP ASIR (A) and ASDR (B) and SDI at the national level.

Figure 1

Age-standardized rate of deaths (A), DALYs (B), YLDs (C), and YLLs (D) for ACOP for 21 world regions, 1990–2019. The solid black line shows expected values across the spectrum of the SDI. SDI=Socio-demographic Index.

Figure 1

The ASR of different regions' ACOP ASR of incidence (A), prevalence (B), deaths (C), DALYs (D), YLDs (E), and YLLs (F) by ages and SDI regions in 1990 and 2019.

Figure 1

The 30-year-trend of ACOP ASR of incidence (A), prevalence (B), deaths (C), DALYs (D), YLDs (E), and YLLs (F) by SDI regions.

Figure 1

Age-standardized rate of incidence and deaths for ACOP for 21 world regions, 1990–2019 The solid black line shows expected values across the spectrum of the SDI. SDI=Socio-demographic Index.

Figure 2

The linear regression of ASIR of incidence (a), prevalence (b), death (c), DALYs (d), YLDs (e), and YLLs (f).

Figure 2

Heatmap of amounts of countries which's a significant correlation to economics parameters through different periods. The amounts of countries which are ACOP parameters (A) and risk parameters (B) is a significant correlation to economic parameters through different periods. The closer the color is to the red, the larger the value, and the closer the color is to blue, the smaller the value. (C) Correlation coefficient between ACOP ASIR per 100,000 population and SDI from 2010 to 2019, by country. (D) Correlation coefficient between ACOP ASDR per 100,000 population and SDI from 2010 to 2019, by country. Note: The designations employed and the

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Figure 3

Age-standardized incidence rate (ASIR) (A) and ASIR EAPC (B) of ACOP per 100,000 population in 2019, by country. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 6

Age-standardized rate of deaths (A), DALYs (B), YLDs (C), and YLLs (D) for ACOP for 21 world regions, 1990–2019. The solid black line shows expected values across the spectrum of the SDI. SDI=Socio-demographic Index.

Figure 8

Age-standardized rate of incidence and deaths for ACOP for 21 world regions, 1990–2019 The solid black line shows expected values across the spectrum of the SDI. SDI=Socio-demographic Index.

Figure 11

Heatmap of amounts of countries which's a significant correlation to economics parameters through different periods. The amounts of countries which are ACOP parameters (A) and risk parameters (B) is a significant correlation to economic parameters through different periods. The closer the color is to the red, the larger the value, and the closer the color is to blue, the smaller the value. (C) Correlation coefficient between ACOP ASIR per 100,000 population and SDI from 2010 to 2019, by country. (D) Correlation coefficient between ACOP ASDR per 100,000 population and SDI from 2010 to 2019, by country. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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