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Global, regional, and national pancreatitis burden and health inequality of pancreatitis from 1990 to 2019 with a prediction from 2020 to 2034

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Abstract

Background Pancreatitis is a digestive system disease that imposes a significant burden on society. However, there is a lack of comprehensive research on the incidence, prevalence, mortality, years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs) of pancreatitis, as well as on health inequalities and future trends.

Methods Pancreatitis burden data, including the number and age-standardized rates (ASR) of incidence, prevalence, deaths, years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs), were collected from the Global Burden of Diseases 2019 (GBD 2019). SDI and HDI were used to analyze the influence of societal development on the burden of pancreatitis in the population. Additionally, the Gini coefficient and the Concentration index were used to assess health inequalities in the burden of pancreatitis. Global population data from 1990 to 2034 was obtained from WHO. Based on the population data and pancreatitis burden data, a prediction model of the burden was constructed to calculate the number and ASR of incidence, prevalence, deaths, YLLs, YLDs, and DALYs from 2019 to 2034 using the BAPC package and the Nordpred package.

Results From 1990 to 2019, there has been a decreasing trend in the ASR of incidence, prevalence, deaths, YLLs, YLDs, and DALYs in pancreatitis. However, despite this decline, the number of cases has been on the rise. Furthermore, pancreatitis imposes a higher burden on males in comparison to females, and there exists a negative correlation between pancreatitis burden and both the Social Development Index (SDI) and the Human Development Index (HDI). Additionally, health inequalities have progressively worsened globally between 1990 and 2019, particularly concerning the burden of pancreatitis in countries with low Social Development Index (SDI). Looking to the future, it is projected that the number of deaths and new cases will continue to increase from 2020 to 2034.

Conclusions Pancreatitis remains a mounting worldwide burden. In order to alleviate this challenge, preventive strategies should focus on males and middle-aged or older individuals, specifically in countries with a low SDI.

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Pancreatitis is expected to predominantly impact Eastern Europe, characterized by a high ASR of incidence, and Asia, boasting a substantial population.

Keywords Pancreatitis, Health inequality, Death, Incidence, Prevalence, Years lived with disability, The years of life lost, Disability-adjusted life-years

Background

Pancreatitis refers to the process of self-digestion of the pancreas, which can lead to damage of distant organs. This condition encompasses acute pancreatitis, recurrent acute pancreatitis, and chronic pancreatitis. It is one of the causes for hospital admissions related to gastrointestinal diseases. Additionally, it is associated with significant morbidity, mortality, and socioeconomic burden [1].

There is a disparity in the global burden of pancreatitis. Understanding the epidemiological features of pancreatitis can assist in controlling and managing the public health issues associated with this condition. However, current research is incomplete in analyzing death rates, incidence, prevalence, and burden indices such as years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life-years (DALYs) [2, 3]. These studies only cover a portion of the aforementioned indices. Furthermore, the studies have not examined the association between the burden of pancreatitis and development of countries. To date, no study has reported the annual trends of years of life lost (YLLs) due to pancreatitis over time.

In this study, we conducted a comprehensive and comparable analysis of pancreatitis data from the Global Burden of Diseases Study (GBD) 2019. We examined the incidence, prevalence, deaths, YLLs, YLDs, and DALYs related to pancreatitis at global, regional, and national levels. We analyzed the data in terms of absolute numbers, age-specific rates, annual trends, and age-standardized rates (ASRs), stratifying the findings by sex, age, socio-demographic index (SDI), and human development index (HDI). The data covered the period from 1990 to 2019. Additionally, we discovered the health inequity associated with pancreatitis and predicted the trend of the condition from 2020 to 2034. This research provides accurate information on pancreatitis from various regions and countries, aiming to assist policymakers in reducing the burden of the disease.

Method and material

Data detriving of pancreatitis burden

The Global Burden of Disease Study 2019 (GBD 2019) compiles data from various sources to estimate mortality rates, causes of death, and prevalence of illnesses [4, 5]. GBD 2019 integrated data on acute pancreatitis, chronic pancreatitis, and idiopathic pancreatitis to calculate comprehensive pancreatic burden indexes including incidence, deaths, prevalence, YLLs, YLDs, and DALYs. Thus, the research got the data of pancreatitis burden from GBD 2019 (https://ghdx.healthdata.org/gbd-2019).The GBD 2019 Diseases and Injuries Collaborators, in analyzing pancreatitis, indicated in the methodology that the incidence rate describes acute pancreatitis, the prevalence rate describes chronic pancreatitis, and when describing the mortality rate, YLDs, YLLs, and DALYs of pancreatitis, they calculated the corresponding indicators for acute and chronic pancreatitis separately, weighted and summarized them to describe the overall level representing pancreatitis.

Data acquisition of population data

The population data, disaggregated by age and sex, was obtained from the Department of Economic and Social Affairs Population Dynamics of the United Nations (https://www.un.org/development/desa/pd/). This datase t encompasses regions, subregions, countries, and areas worldwide from 1990 to 2034. The World Health Organization (WHO) provided the population proportions for each age group (0–4, 5–9, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84, 85–89, 90–94, 95–99, 100+) for the period 2020–2034. These proportions were acquired from the Surveillance, Epidemiology, and End Results Program (https://seer.cancer.gov/stdpopulations/world.who.html), and were used for predicting the rates and numbers of pancreatitis cases.

EAPC(estimated annual percent change) and AAPC(annual average percent change) of age-standardized rates

Annual Percent Change (APC) is a valuable method for studying extended trends and determining the average yearly growth rate. Conversely, simple percentage change is better suited for quick comparisons at specific points, overlooking the trend's long-term continuity. Hence, to analyze the trajectory of ASR over time, this research utilizes two methods derived from APC - Exponentially Weighted Annual Percent Change (EAPC) and Average Annual Percent Change (AAPC) - to explore the link between ASR and the time span.

EAPC, an abbreviation for Estimated Annual Percent Change, is a widely used statistical measure in epidemiology and public health research. It enables researchers to estimate the average annual percentage change in a specific variable over a defined period of time. On the other hand, AAPC, which stands for Annual Average Percent Change, is another statistical measure that calculates the

average percentage change in a variable over a specified time period, generally on an annual basis. Both EAPC and AAPC serve the purpose of assessing and quantifying the average percentage change over time. However, while EAPC focuses on estimating the annual change in a specific variable, AAPC calculates the average change across the entire time period under investigation. The age-standardized rate's estimated annual percentage change (EAPC) was computed from 1990 to 2019 using the following formula: EAPC = 100 * (10β—1). This formula is based on a weighted log-linear regression, assuming a Poisson distribution [6]. The AAPC was calculated using the Joinpoint software.

Analysis on the impact of social development on pancreatitis disease burden

The Socio-demographic Index (SDI) and Human Development Index (HDI) are two different measures that assess different aspects of a country's development. The SDI provides a broader view of social development, while the HDI specifically measures human development with a focus on income, education, and health.

The Socio-Demographic Index (SDI) is a composite indicator that reflects the development status and its correlation with health outcomes. Based on their SDI values, countries and territories are categorized into high, high-middle, middle, low-middle, and low SDI categories. The methods used to generate the SDI are described in previous Global Burden of Disease (GBD) publications [6, 7]. The SDI serves as a tool to monitor progress in socio-economic development, identify regional development disparities within and across countries, and evaluate the impact of health policies on health outcomes(The SDI information for various regions globally from 1990 to 2019 can be found in the supplementary material SDI_1990_2019.csv).

According to the Human Development Reports (https://hdr.undp.org/), the Human Development Index (HDI) serves as a comprehensive indicator of average achievement in key aspects of human development, namely: having a long and healthy life, acquiring knowledge, and attaining a decent standard of living(The HDI information for various regions globally in the year 2019 can be found in the supplementary material "HDI_2019.csv").

Analysis on the health inequity of pancreatitis burden

The health levels of individuals vary across different backgrounds, social groups, and countries. Health inequalities have been acknowledged since the 1980s [8], yet significant differences in health persist among countries today [9]. Health inequities can be mitigated through reasonable means by identifying the sources of health inequality [8]. To measure epidemiological heterogeneity, the Gini coefficient, a macroeconomic descriptor of inequality, can be utilized [10, 11]. Another measure, the Concentration index, can quantify the distribution of individuals within a specified area and also evaluate epidemiological heterogeneity [12, 13]. In this study, the Gini coefficient and Concentration index are applied to assess health inequality related to pancreatitis. The calculations are performed using the INEQQERR module and CONCINDC module of STATA.

Prediction of pancreatitis burden from 2020 to 2034

Based on the WHO population and demographic data, utilizing the disease burden data from the Global Burden of Disease (GBD) study from 1990 to 2019, a pancreatitis burden model was constructed to calculate the ASR of pancreatitis from 2020 to 2034 in incidence and deaths. This will be used to estimate the global pancreatitis burden. The BAPC package [14] and Nordpred package [15] were used to predict the ASR and number of pancreatitis burden worldwide from 2020 to 2034(the details in the supplementary materials BAPC & Nordpred.pdf).

Results

Epidemiological characteristics of global incidence of Acute Pancreatitis

Globally, the number of new acute pancreatitis cases was 1,727,789.3 (1,452,132.4-2,059,695.3) in 1990 and 2,814,972.3 (2,414,361.3-3,293,591.8) in 2019, with an ASR of incidence of 37.9 (32-44.6) per 100,000 population in 1990 and 34.8 (29.8–40.7) in 2019. This rate decreased by an average of -0.34% (-0.4%--0.28%) per year from 1990 to 2019 (estimated average percent change, EAPC) (Table 1). The number of new cases of acute pancreatitis has been increasing globally from 1990 to 2019 (Fig. 1A). When stratified by sex, the ASR of incidence in men is always higher than in women, with a difference of over 8 per 100,000 population from 1990 to 2019 (Fig. 1B). When stratified by age, the ASR of incidence increases from 0 to 100 years old in 2019. Interestingly, although there is no significant difference in the trend of ASR of incidence between males and females across all age groups, the ASR of incidence in males is higher than in females between the ages of 25 and 60 (Fig. 1C).

At the regional level, the ASR of incidence decreases in almost all regions, but increases in two regions: Eastern Europe and North Africa & Middle East from 1990 to 2019. East Asia has the highest number of new cases of acute pancreatitis, with 396,687.7 (322,719.1–482,300.5) cases in 1990 and 526,066.5 (444,786.6–615,193.3) cases in 2019. Eastern Europe has the highest ASR of incidence, with rates of 71.2 (60.8–82.9) per 100,000 population in 1990 and 79.6 (68.2–92.5) in 2019. Oceania has the lowest number of new cases of acute pancreatitis, with 1,078.6 (884.9-1,322) cases in 1990 and 2,385.6

Table 1 Age-standardised rate (ASR) of incidence and EAPC of ASR in acute pancreatitis

Location	Incidence in 1990		Incidence in 1990		EAPC between 1990 to 2019
	Num_1990	ASR_1990	Num_2019	ASR_2019	EAPC_CI
Global	1727789.3 (1452132.4-2059695.3)	37.9 (32-44.6)	2814972.3 (2414361.3-3293591.8)	34.8 (29.8–40.7)	-0.34 (-0.4–0.28)
Gender					
Female	798760.6 (677669.1-943983.6)	34.5 (29.2–40.3)	1273955.2 (1098304.6-1478594.1)	30.6 (26.4–35.6)	-0.45 (-0.52–0.39)
Male	929028.7 (774587.6-1115575.6)	41 (34.3–48.5)	1541017.1 (1307264.4-1814454.3)	38.8 (33.1–45.5)	-0.22 (-0.28–0.16)
SDI					
Low SDI	101,572 (83136.7-123390.1)	28.4 (23.8–33.7)	236892.3 (194235.9-286220.7)	29.2 (24.7–34.7)	0.13 (0.11–0.15)
Low-middle SDI	297240.1 (244736.5-361676.3)	34.9 (29-41.8)	602857.5 (500546.7-725661.6)	36.8 (30.9–44)	0.24 (0.21–0.27)
Middle SDI	455054.8 (373090.6-554469.3)	33.7 (27.8–40.1)	771495.2 (647793.3-910392.7)	30.2 (25.6–35.7)	-0.44 (-0.58–0.29)
High-middle SDI	482857.1 (406521.4-568658.8)	43.2 (36.6–50.6)	668929.4 (571034-771708.3)	36.8 (31.6–42.8)	-0.62 (-0.69–0.56)
High SDI	390419.1 (335676.7-452156.8)	41.3 (35.4–48)	533633.2 (477729.8-597075.3)	38.1 (33.9–42.7)	-0.38 (-0.44–0.31)
Region					
Andean Latin America	12751.6 (10888.9-14964.7)	45.8 (39.6–52.9)	26446.1 (23242.3-30101.7)	43.5 (38.4–49.3)	0 (0–0)
Australasia	8618.4 (7250-10167.5)	38.6 (32.5–45.3)	14394.8 (12298.7-16770.4)	37.6 (31.7–44)	-0.13 (-0.16–0.11)
Caribbean	8807.7 (7294.7-10668.9)	28.8 (23.9–34.3)	14155.4 (11772.9-16692.7)	28.4 (23.5–33.6)	-0.03 (-0.05–0.02)
Central Asia	18365.6 (15467.5-21700)	33.7 (28.4–39.4)	29035.3 (24076.9-34326.1)	32.9 (27.7–38.5)	-0.07 (-0.09–0.05)
Central Europe	67402.6 (57280.6-78292.3)	49.4 (42-57.3)	73015.8 (64542.3-82156.6)	45.2 (40.1–50.9)	-0.41 (-0.45–0.36)
Central Latin America	46647.8 (39437-55591.9)	37.6 (32.1–44)	96777.3 (83302.4-112767)	38.6 (33.3–44.7)	-0.05 (-0.08–0.02)
Central Sub-Saharan Africa	7427.2 (6052.5-9165.5)	21.1 (17.6–25)	18256.3 (14929.3-22374.1)	20.8 (17.5–24.7)	-0.03 (-0.04–0.02)
East Asia	396687.7 (322719.1-482300.5)	38 (31.1–45.4)	526066.5 (444786.6-615193.3)	27.6 (23.5–32.2)	-1.25 (-1.55–0.96)
Eastern Europe	182577.6 (155056.7-211692.2)	71.2 (60.8–82.9)	221945.2 (188142.5-258013.8)	79.6 (68.2–92.5)	0.38 (0.31–0.45)
Eastern Sub-Saharan Africa	25232.9 (20531.3-31140.5)	21.1 (17.7–25.2)	57965.7 (46838.7-71275.5)	21.1 (17.7–25.2)	0 (0–0)
North Africa and Middle East	61824.3 (50782.1-75020.1)	26.7 (22.3–31.5)	140637.9 (117038.5-168090.2)	26.6 (22.5–31.2)	0.02 (0-0.03)
Oceania	1078.6 (884.9–1322)	24.9 (20.7–29.6)	2385.6 (1934.6-2925.5)	24.1 (20-28.7)	-0.11 (-0.11–0.1)
South Asia	328618.8 (267223.4-401086.7)	38.1 (31.6–45.9)	743,524 (611176-901906.4)	43 (35.9–51.7)	0 (0–0)
Southeast Asia	93540.7 (76473.3-113689.3)	26 (21.6–30.9)	174246.5 (143846.9-208675.3)	25.3 (21.2–30.1)	-0.1 (-0.11–0.09)
Southern Latin America	15849.3 (13664.8-18265.2)	33.6 (28.9–38.6)	24167.2 (20962.5-27835.3)	31.6 (27.4–36.6)	-0.32 (-0.35–0.29)
Southern Sub-Saharan Africa	8604.9 (7042-10531.2)	22.1 (18.5–26.4)	15207.3 (12560.8-18528.5)	21.7 (18.1–25.9)	-0.1 (-0.13–0.06)
Tropical Latin America	23704.1 (20682.2-27345.5)	20.1 (17.7–22.7)	47509.1 (41862.2-53770)	19.4 (17.1–21.9)	-0.12 (-0.17–0.07)
Western Europe	123270.9 (107562.6-140276.4)	25.4 (22.1–29.2)	170344.2 (149047.3-194756.8)	26.3 (22.8–30.1)	-0.05 (-0.14-0.04)
Western Sub-Saharan Africa	33289.8 (27664.2-40190.6)	26 (22-30.6)	82116.6 (68165.6-98901.6)	26.7 (22.7–31.4)	0 (0–0)

(1,934.6-2,925.5) cases in 2019. Tropical Latin America has the lowest ASR of incidence, with rates of 20.1 (17.7–22.7) per 100,000 population in 1990 and 19.4 (17.1–21.9) in 2019. Eastern Europe has the highest estimated average percent change (EAPC) of ASR, with a rate of 0.38% (0.31-0.45%) per year, while East Asia has the lowest EAPC of ASR in incidence, with −1.25% (-1.55%--0.96%) per year. Overall, there appears to be an inverse relationship between higher Socio-Demographic Index (SDI) and lower EAPC in incidence.

In 2019, the ASR of incidence of acute pancreatitis varied widely across different countries, ranging from 8.7 to 82 cases per 100,000 population. The three countries with the highest ASR of incidence were the Russian Federation (82 cases per 100,000 population, with a range of 70.1-95.12), the Republic of Moldova (71.3 cases per 100,000 population, with a range of 60.8–82.7), and Ukraine (77 cases per 100,000 population, with a range of 65.5–90). On the other hand, the three countries with the lowest ASR of incidence were Singapore (17.2 cases per 100,000 population, with a range of 16.4–18), the Netherlands (8.8 cases per 100,000 population, with a range of 7.2–10.3), and Portugal (15.6 cases per 100,000 population, with a range of 13.3–18). A global analysis from 1990 to 2019 (Fig. 1D) demonstrated the annual percent change (AAPC) in ASR for acute pancreatitis

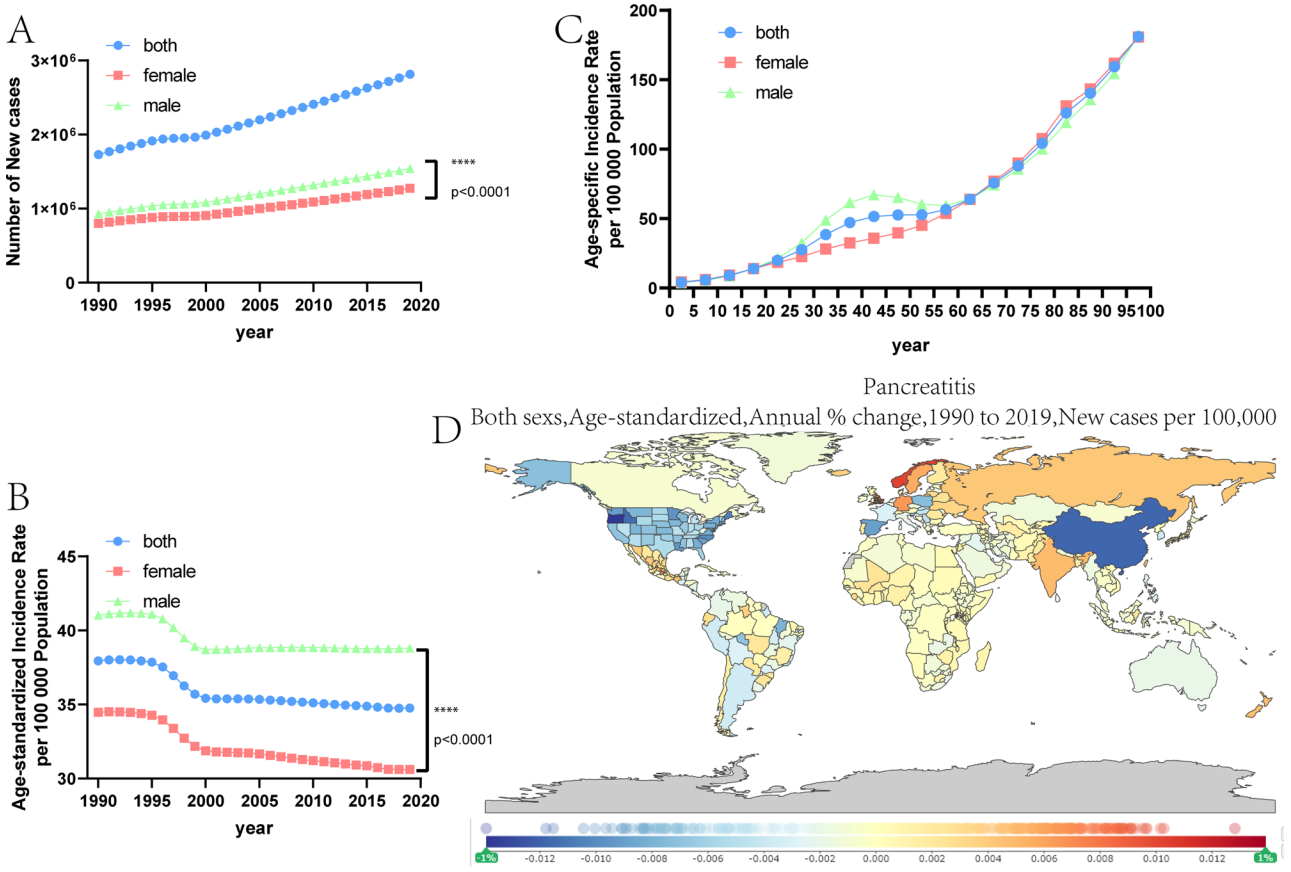

Fig. 1 The incidence of acute pancreatitis wordwide from 1990 to 2019. (**A**) The number of incidence. (**B**) ASR of incidence among different genders. (**C**) ASR of incidence among different age groups. (**D**) The map of annual change of ASR of incidence wordwide

incidence. The five countries with the highest AAPC in ASR of incidence were Germany (AAPC=0.611%), Norway (AAPC=0.993%), Singapore (AAPC=1.274%), Sweden (AAPC=0.546%), and the United Kingdom (AAPC=0.548%). In contrast, the five countries with the lowest AAPC in ASR of incidence were China (AAPC=-1.206%), Poland (AAPC=-0.746%), Slovenia (AAPC=-0.662%), Spain (AAPC=-1.115%), and the United States of America (AAPC=-0.685%). Additional details and figures can be found in the supplementary materials (Fig S1 & incidence.aapc.xls).

Epidemiological characteristics of global prevalence of chronic pancreatitis

The prognosis of patients with acute pancreatitis significantly influences the prevalence of chronic pancreatitis. When acute pancreatitis persists and recurs without resolution, patients with acute pancreatitis may transition to become patients with chronic pancreatitis. The prevalence rate of chronic pancreatitis, combined with the incidence rate of acute pancreatitis, can comprehensively reflect the disease burden of pancreatitis.

The age-standardized prevalence(ASR) of chronic pancreatitis has remained basically stable since 1990, without showing a clear downward trend. This trend differs significantly from the changes in age-standardized incidence rate of acute pancreatitis and prevalence rate of chronic pancreatitis. However, the number of individuals with chronic pancreatic diseases has been increasing globally since 1990. For details on the prevalence characteristics of pancreatitis globally and in various countries and regions, please refer to the supplementary material (the details in Supplementary Material Prevalence.pdf).

Epidemiological characteristics of global death of pancreatitis

Globally, the number of deaths due to acute pancreatitis and chronic pancreatitis was 69,817.6 (62,046.7–82,529.3) in 1990 and 115,053.2 (104,304.4–128,173.4) in 2019. The ASR of mortality was 1.7 (1.5-2) per 100,000 population in 1990 and 1.4 (1.3–1.6) in 2019. Over the period from 1990 to 2019, this rate decreased by -0.69% (-0.78% to -0.6%) per year, as the estimated average percent change (EAPC) (Table 2). The number of death cases has significantly increased from 1990 to 2019 (Fig. 2A). When stratified by sex, the ASR of death was consistently higher in males compared to females, with a difference of over 1 per 100,000 population from 1990 to 2019

Table 2 Age-standardised rate (ASR) of death and EAPC of ASR in pancreatitis

Location	Death in 1990		Death in 2019		EAPC between 1990 to 2019
	Num_1990	ASR_1990	Num_2019	ASR_2019	EAPC_CI
Global	69817.6 (62046.7-82529.3)	1.7 (1.5-2)	115053.2 (104304.4-128173.4)	1.4 (1.3–1.6)	
Gender					
Female	26688.6 (23528.9-32952.8)	1.3 (1.1–1.6)	43,070 (36592.6-50773.7)	1 (0.8–1.2)	-0.89 (-0.98–0.81)
Male	43,129 (37615.8-51561.2)	2.2 (1.9–2.6)	71983.2 (63882.3-81418.6)	1.9 (1.7–2.1)	-0.57 (-0.65–0.48)
SDI					
Low SDI	6385.7 (4653.4-8612.9)	2.4 (1.7–3.3)	12232.2 (9722.6-15560.5)	2.1 (1.7–2.7)	0 (0–0)
Low-middle SDI	14314.8 (11855.7-18507.1)	2.2 (1.8–2.8)	26440.8 (21686.3-30710.8)	1.9 (1.5–2.2)	-0.43 (-0.49–0.37)
Middle SDI	15561.3 (13213.7-20288.1)	1.4 (1.2–1.9)	25776.2 (22835.9-30111.2)	1.1 (1-1.3)	-0.92 (-0.96–0.87)
High-middle SDI	21366.4 (19824.1-25093.1)	2 (1.9–2.4)	34,393 (31194.4-37307.4)	1.8 (1.6–1.9)	0 (0–0)
High SDI	12,159 (11441-13388.5)	1.2 (1.1–1.3)	16,160 (14600.9-18476.3)	0.9 (0.8-1)	-1.24 (-1.33–1.16)
Region					
Andean Latin America	1076.8 (811.2-1299.4)	4.6 (3.4–5.6)	1444.9 (1122.3-1971.2)	2.5 (2-3.5)	21366.4 (19824.1-25093.1)
Australasia	215.9 (198.6-233.7)	0.9 (0.9-1)	339 (292.5-396.5)	0.7 (0.6–0.8)	-1.27 (-1.42–1.12)
Caribbean	384.3 (338.7-436.9)	1.4 (1.3–1.6)	659 (557.6-795.7)	1.3 (1.1–1.6)	-0.33 (-0.41–0.25)
Central Asia	1179.1 (1016.3-1321.5)	2.4 (2.1–2.8)	1653.3 (1381.5-1884.1)	2.1 (1.8–2.4)	-0.89 (-1.25–0.53)
Central Europe	4476.7 (4274.1-5033.9)	3.2 (3.1–3.6)	5140.4 (4513.4–5828)	2.7 (2.4–3.1)	-0.72 (-0.88–0.56)
Central Latin America	2018.5 (1909.5-2130.6)	2.1 (1.9–2.2)	4332.6 (3728.8-5065.2)	1.8 (1.6–2.1)	0 (0–0)
Central Sub-Saharan Africa	452.4 (302.2-763.6)	1.8 (1.2–3.1)	911.5 (530.4-1648.7)	1.4 (0.8–2.7)	-0.76 (-0.87–0.64)
East Asia	9323.9 (7503.7-12418.1)	1.1 (0.9–1.5)	11289.8 (8798.1-13450.7)	0.6 (0.5–0.7)	-1.96 (-2.02–1.91)
Eastern Europe	7662.1 (6921.7-10789)	2.9 (2.6–4.1)	15578.4 (13366.9-17734.7)	5.3 (4.5-6)	1.91 (1.41–2.41)
Eastern Sub-Saharan Africa	1398.2 (899.1-2104.9)	1.7 (1-2.6)	2769.3 (1710.4-4739.2)	1.5 (0.9–2.7)	-0.5 (-0.58–0.42)
North Africa and Middle East	1718.7 (1389-2350.2)	1.1 (0.9–1.5)	3394.9 (2654.5-4069.2)	0.9 (0.7–1.1)	-0.69 (-0.78–0.59)
Oceania	36.8 (25.7–52.2)	1.1 (0.7–1.5)	76.7 (53.7-107.9)	0.9 (0.7–1.3)	-0.45 (-0.47–0.44)
South Asia	14050.3 (11344.3-19215)	2.3 (1.8–3.1)	25936.8 (20085.4-31351.7)	1.8 (1.4–2.2)	-0.7 (-0.85–0.56)
Southeast Asia	4993.4 (3842.9-7457.8)	1.8 (1.4–2.6)	7913.5 (6540.7-11170.8)	1.3 (1.1–1.8)	-1.11 (-1.16–1.06)
Southern Latin America	1267.6 (1136-1374.1)	2.8 (2.5-3)	1495.7 (1347-1732.5)	1.8 (1.7–2.1)	-1.74 (-1.95–1.53)
Southern Sub-Saharan Africa	325.4 (263.3-414.7)	1 (0.8–1.3)	573.9 (453-675.4)	0.9 (0.7–1.1)	0 (0–0)
Tropical Latin America	2329.6 (2212.2-2485.9)	2.3 (2.1–2.4)	5557.4 (4793.8-5987.2)	2.3 (2-2.5)	0.35 (0.22–0.47)
Western Europe	7986.7 (7447.9-8873.5)	1.4 (1.4–1.6)	9984.5 (8925.7-11455.5)	1.1 (1-1.2)	-1.19 (-1.26–1.11)
Western Sub-Saharan Africa	3781 (2498.4-5769.9)	3.8 (2.5–5.8)	8310.1 (5927.1-11883)	3.6 (2.7–5.1)	-0.07 (-0.13–0.01)

(Fig. 2B). Stratifying by age, the ASR of death showed an increasing trend across all ages in 2019, with a notable rise starting from 60 years old and above. Interestingly, there was no significant difference in the trend of ASR of death between males and females across all age groups (Fig. 2C).

At the regional level, the ASR of death decreases in almost all regions, except for Eastern Europe (1.91% (1.41-2.41%) per year) and Tropical Latin America (0.35% (0.22-0.47%) per year) from 1990 to 2019. South Asia records the highest number of deaths from pancreatitis, with 14050.3 (11344.3-19215) cases in 1990, increasing to 25936.8 (20085.4-31351.7) cases in 2019. In 1990, Andean Latin America had the highest ASR of death (4.6 (3.4–5.6) per 100,000 population), while in 2019, Eastern Europe held the highest ASR of death (5.3 (4.5-6) per 100,000 population). In contrast, Oceania has the lowest number of death cases attributed to pancreatitis, with 36.8 (25.7–52.2) cases in 1990, increasing to 76.7 (53.7-107.9) cases in 2019. Australasia (0.9 (0.9-1) per 100,000 population) had the lowest ASR of death in 1990, and in 2019, East Asia (0.6 (0.5–0.7) per 100,000 population) recorded the lowest ASR of death. Eastern Europe experienced the highest EAPC of ASR from 1990 to 2019, at 1.91% (1.41-2.41%) per year, while Andean Latin America had the lowest EAPC at -2.23% (-2.35%--2.11%) per year. Overall, it appears that higher SDI is associated with a lower EAPC in mortality.

At the country level, the ASR of death ranged from 0.37 to 5.7 cases per 100,000 population in 2019. The three countries with the highest ASR of death are the Russian Federation (5.7 (4.78–6.72) per 100,000 population), Kazakhstan (4.97 (3.75–6.01) per 100,000 population), and Guinea-Bissau (4.78 (3.15–6.79) per 100,000 population). Conversely, the three countries with the lowest ASR of death are Singapore (0.38 (0.31–0.43) per 100,000 population), Sri Lanka (0.41 (0.29–0.57) per 100,000 population), and Iraq (0.43 (0.32–0.65) per 100,000 population). The annual percent change of ASR for deaths caused by pancreatitis was analyzed globally from 1990 to 2019 (Fig. 2D). The five countries with the highest AAPC of ASR are Georgia (AAPC=2.1%),

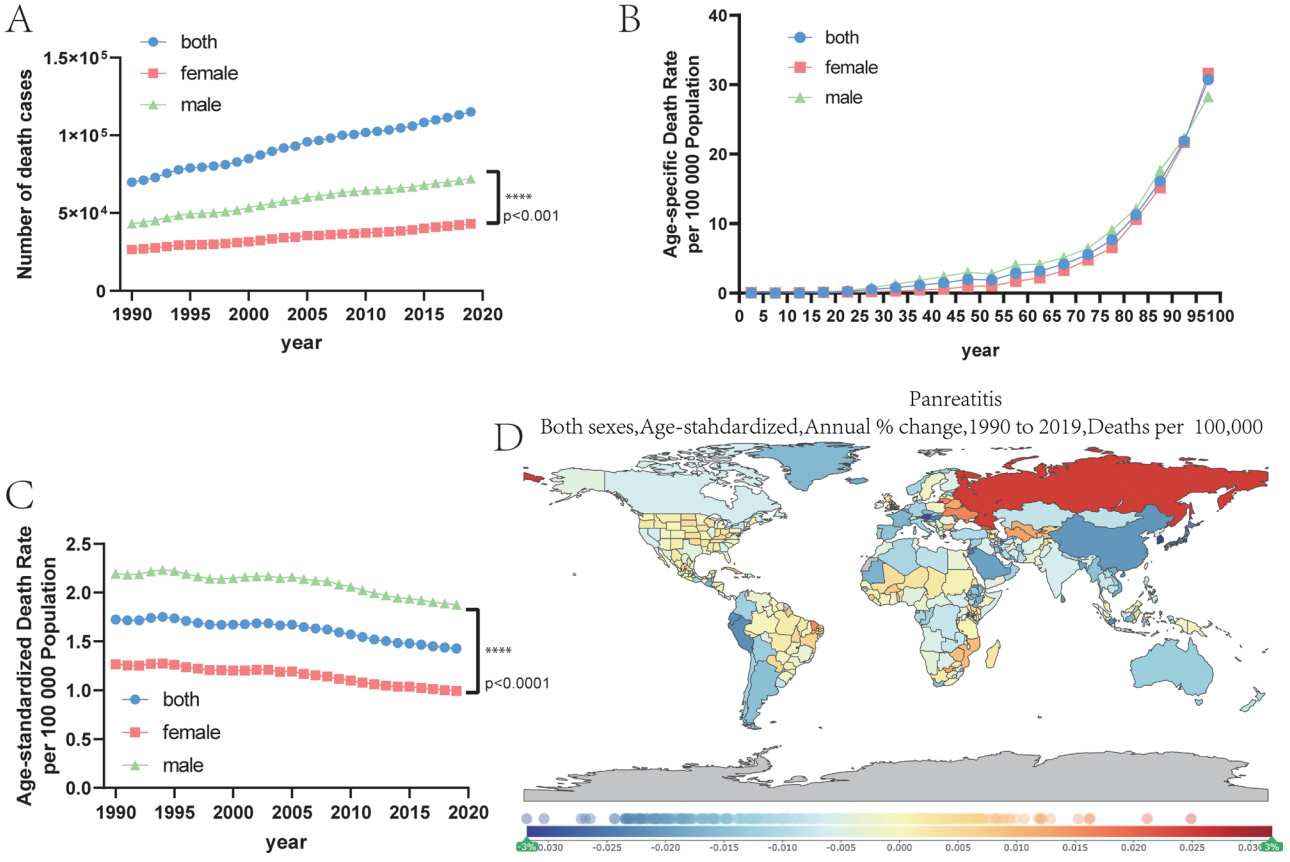

Fig. 2 The death of pancreatitis wordwide from 1990 to 2019. (**A**) The number of death. (**B**) ASR of death among different genders. (**C**) ASR of death among different age groups. (**D**) The map of annual change of ASR of death wordwide

Lithuania (AAPC=1.8%), the Russian Federation (AAPC=2.3%), Turkmenistan (AAPC=1.3%), and Ukraine (AAPC=1.6%). In contrast, the five countries with the lowest AAPC of ASR are Austria (AAPC=-3.1%), Maldives (AAPC=-2.7%), the Republic of Korea (AAPC=-3.1%), Slovenia (AAPC=-2.7%), and Singapore (AAPC=-2.4%) (see Supplementary Materials, Fig S2 & death.aapc.xls).

Epidemiological characteristics of global burden of pancreatitis

Disability-Adjusted Life Years (DALYs) serve as a crucial indicator of the collective disease burden within a population, quantifying the years lost due to ill health, disability, or untimely mortality. Although acute pancreatitis and chronic pancreatitis have different disease courses, they both contribute to the increase in DALYs associated with pancreatitis.

Globally, the number of DALYs of pancreatitis was 2437815.7 (2179992.9-2885021.2) in 1990 and 3641105.7 (3282952.5-4026948.1) in 2019, with an ASR of DALYs of 53.9 (48.2–63.3) in 1990 and 44.4 (40.1–49.1) in 2019 per 100,000 population; this rate decreased by -0.76% (-0.86%--0.67%) per year from 1990 to 2019(estimated average percent change, EAPC) (Table 3). The number of DALYs of pancreatitis has been increasing from 1990 to 2019 in global (Fig. 3A). Stratified by sex, ASR of DALYs of man is always higher than that of woman and the difference value is over 40 per 100,000 population from 1990 to 2019(Fig. 3B). Stratified by age, per 100,000 population increases from 0 to 100 years old in 2019, rapidly from 20 to 100 years old. Interestingly, there seems to be not significant in the tendency of ASR between male and female in full age(p=0.0594) (Fig. 3C). But, ASR of male is higher than that of woman between 20 and 90 years old and is lower between 90 and 100 years old.

At the regional level, the ASR of DALYs decreased in most regions, except for Eastern Europe, where it increased by 1.95% (95% CI: 1.37-2.54%) per year from 1990 to 2019. South Asia has the highest number of DALYs cases for pancreatitis, with 548,424.8 (95% CI: 448,431.7–759,731.1) in 1990, which increased to 909,993.5 (95% CI: 707,700-1,093,715.6) in 2019. Andean Latin America had the highest age-standardized DALYs rate at 144.8 (95% CI: 108.3-173.2) in 1990, while Eastern Europe had the highest rate at 206.7 (95% CI: 178.3-237.9) in 2019. In contrast, Oceania had the lowest number of DALYs cases, with 36.8 (95% CI: 25.7–52.2)

Table 3 Age-standardised rate (ASR) of DALYs and EAPC of ASR in pancreatitis

Location	DALYs in 1990		DALYs in 2019		EAPC between 1990 to 2019
	Num_1990	ASR_1990	Num_2019	ASR_2019	EAPC_CI
Global	2437815.7 (2179992.9-2885021.2)	53.9 (48.2–63.3)	3641105.7 (3282952.5-4026948.1)	44.4 (40.1–49.1)	-0.76 (-0.86–0.67)
Gender					
Female	804802.9 (691735-1038584.8)	35.2 (30.6–44.8)	1138667.5 (969571.1-1334422.8)	27 (22.9–31.5)	-1 (-1.08–0.92)
Male	1633012.8 (1426941.6-1942851.5)	72.4 (63.4–85.9)	2502438.2 (2224864.1-2842383.8)	62 (55.2–70.4)	-0.6 (-0.69–0.5)
SDI					
Low SDI	244,325 (185104.9-330618.6)	75.1 (55.2-100.8)	459380.2 (367333.8-583539.5)	64 (50.8–81.3)	0 (0–0)
Low-middle SDI	549,795 (462013.9-726880.2)	68.4 (57-88.3)	919232.5 (751488.8-1066251.6)	58 (47.3–66.8)	-0.54 (-0.59–0.49)
Middle SDI	580739.7 (498484.7-739252.5)	43.7 (37.3–56.4)	813217.3 (727039.6-960672.8)	31.6 (28.2–37.2)	0 (0–0)
High-middle SDI	720,516 (667787.2-839145.4)	63.7 (59.1–74.2)	1057814.6 (962196.3-1156821.3)	57.1 (51.9–62.4)	-0.6 (-0.89–0.31)
High SDI	341420.8 (321211-370387.3)	35.3 (33.2–38.3)	389932.5 (360177.7-429354.3)	25.7 (23.8–28.4)	-1.37 (-1.45–1.29)
Region					
Andean Latin America	41681.2 (30752.3-49404.7)	144.8 (108.3-173.2)	43654.9 (34042.4-57110.3)	72.5 (56.6–96)	-2.74 (-2.89–2.59)
Australasia	5562.6 (5108.7-6030.6)	24.4 (22.4–26.5)	7137.4 (6312.5-8100.2)	16.6 (14.7–18.8)	-1.56 (-1.75–1.36)
Caribbean	13236.4 (11659.6-15634.5)	44.5 (39.3–51.6)	20254.6 (16880.2-24620.4)	40.1 (33.3–48.7)	-0.37 (-0.47–0.28)
Central Asia	41215.8 (36642.2-45305.5)	77.1 (68.3–85.3)	60311.2 (51431.9-69088.5)	67.4 (57-76.9)	0 (0–0)
Central Europe	147739.5 (141054.8-161428.9)	106 (101.2-115.9)	140,578 (123451.4-158896)	84.4 (74-95.6)	-1.05 (-1.21–0.9)
Central Latin America	80017.9 (74360-84085.9)	67 (63.3–70.8)	141733.4 (121885.5-165140.4)	56.5 (48.7–65.7)	0 (0–0)
Central Sub-Saharan Africa	17,413 (11986.3-29045.2)	54.4 (36.7–90.9)	35823.5 (21454.6-62656.8)	44.6 (26.5–80)	-0.69 (-0.81–0.57)
East Asia	333276.6 (266027.9-431225.3)	31.7 (25.7–41.5)	319,973 (255865.5-381413.7)	16.5 (13.2–19.6)	-2.38 (-2.42–2.34)
Eastern Europe	283386.3 (254907.8-383366.6)	109.2 (98.2-146.8)	558129.2 (481178.6-640436.3)	206.7 (178.3-237.9)	1.95 (1.37–2.54)
Eastern Sub-Saharan Africa	51548.1 (34736.6-78409.9)	49.6 (32.1–74.6)	103,187 (65327.8-170638.8)	43.3 (27.1–73.7)	-0.54 (-0.62–0.46)
North Africa and Middle East	50,486 (42546.5-69094.5)	25.8 (21.5–35)	91833.5 (74033.1-111078.4)	19.5 (15.7–23.3)	-1.01 (-1.09–0.93)
Oceania	1540.1 (1100.1-2186.2)	33.9 (23.9–47.8)	3181.1 (2194.1-4459.1)	30.3 (21.4–42)	-0.43 (-0.46–0.4)
South Asia	548424.8 (448431.7-759731.1)	69.9 (56.5–95.3)	909993.5 (707700-1093715.6)	55.3 (43.1–66.4)	-0.78 (-0.9–0.66)
Southeast Asia	187984.2 (145388–286963)	54.5 (42.3–81.1)	254592.2 (204677-376978.7)	37.9 (30.8–54.8)	-1.46 (-1.52–1.4)
Southern Latin America	37055.6 (33771.4-40031.4)	78.6 (71.7–85)	40292.4 (36539.8-45858.7)	51.6 (46.8–58.8)	-1.78 (-2–1.56)
Southern Sub-Saharan Africa	12983.4 (10471.3-16365.4)	34.6 (28.1–43.7)	21220.6 (16850.1-25384.5)	30 (23.8–35.7)	-0.9 (-1.27–0.52)
Tropical Latin America	90244.6 (85172.8-95308.1)	75.4 (71-79.9)	175860.2 (155755.4-189220.5)	70.6 (62.5–76)	0 (-0.11-0.11)
Western Europe	196013.5 (184807.6-212945.9)	38.8 (36.6–41.9)	199700.1 (183864.2-224326.9)	27.1 (25.2–30.4)	0 (0–0)
Western Sub-Saharan Africa	143538.8 (95218.6-213834.4)	122.5 (80.9-189.4)	320090.3 (226679.1-458546.1)	115.5 (82.3-165.9)	-0.16 (-0.23–0.1)

in 1990, which increased to 76.7 (95% CI: 53.7-107.9) in 2019. Australasia had an ASR of 24.4 (95% CI: 22.4–26.5) in 1990, which decreased to 16.6 (95% CI: 14.7–18.8) in 2019 per 100,000 population. Eastern Europe had the highest annual estimated average percent change (EAPC) in ASR at 1.95% (95% CI: 1.37-2.54%) from 1990 to 2019, while Andean Latin America had the lowest EAPC at -2.74% (95% CI: -2.89%--2.59%) per year. Overall, there appears to be an inverse relationship between higher Socio-Demographic Index (SDI) and lower EAPC in DALYs.

At the country level, the age-standardized rates (ASR) of disability-adjusted life years (DALYs) ranged from 9.3 to 217.3 per 100,000 population in 2019. The three countries with the highest ASR of DALYs are the Republic of Moldova (173.1; 95% CI: 144.1-208.2), the Russian Federation (217.3; 95% CI: 182.5-256.5), and Ukraine (196.2; 95% CI: 154.3-243.8) per 100,000 population. Conversely, Singapore (10.1; 95% CI: 8.4–12.2), Oman (9.3; 95% CI: 5.8–12.2), and Iraq (11.8; 95% CI: 8.9–15.6) per 100,000 population reported the lowest ASR of DALYs. Worldwide, the annual percent change in the ASR of DALYs associated with pancreatitis has been observed from

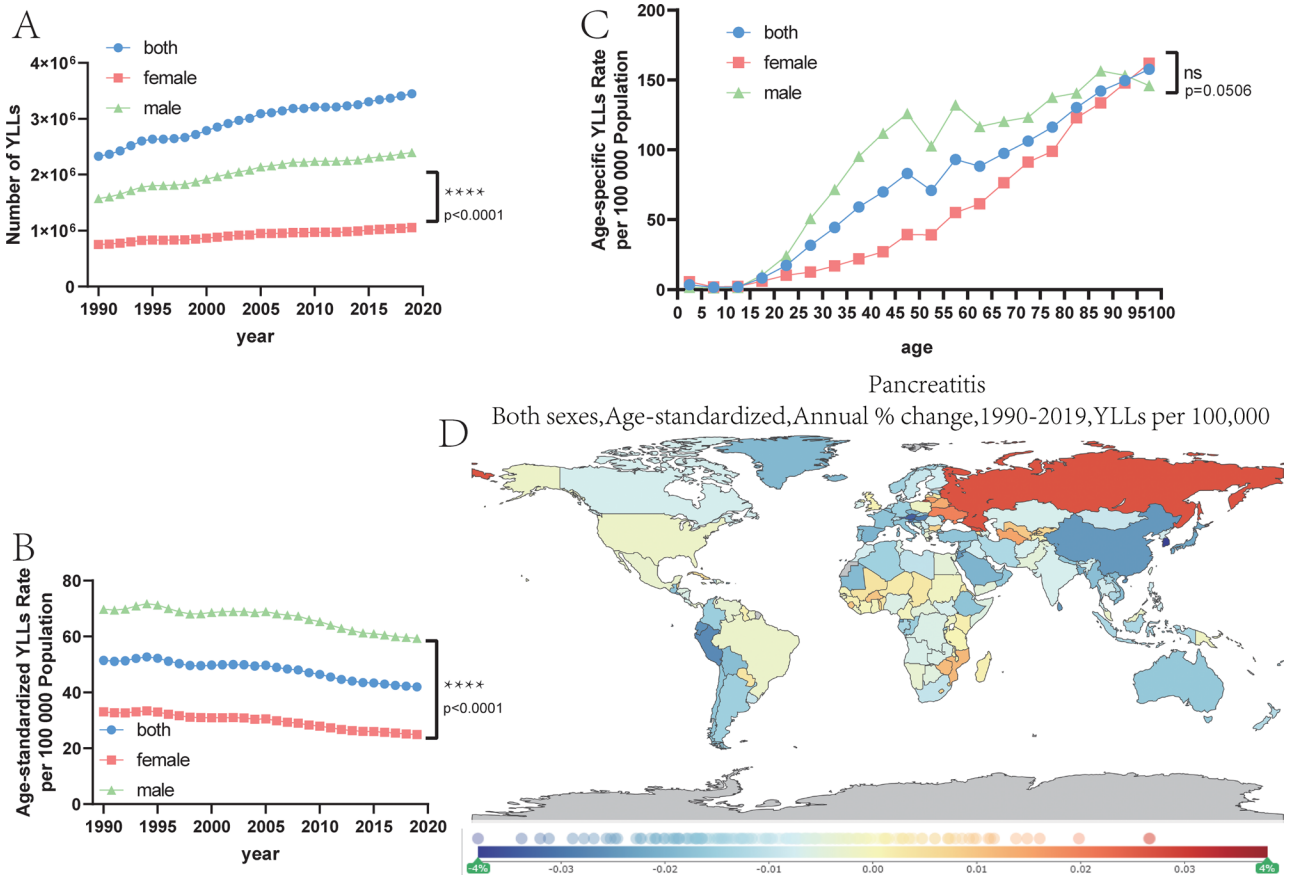

Fig. 3 The DALYs of pancreatitis wordwide from 1990 to 2019. (**A**) The number of DALYs. (**B**) ASR of DALYs among different genders. (**C**) ASR of DALYs among different age groups. (**D**) The map of annual change of ASR of DALYs wordwide

1990 to 2019 (Fig. 3D). The countries with the highest average annual percent change (AAPC) of ASR are Georgia (AAPC=2.3%), Lithuania (AAPC=1.8%), the Russian Federation (AAPC=2.8%), Turkmenistan (AAPC=1.6%), and Ukraine (AAPC=1.9%). On the other hand, Austria (AAPC=-3.1%), the Maldives (AAPC=-2.9%), the Republic of Korea (AAPC=-3.3%), Slovenia (AAPC=-2.9%), and Hungary (AAPC=-2.8%) showed the lowest AAPC of ASR (for details, see the supplemental material, Fig S3 & DALYS.aapc.xls).

Disability-Adjusted Life Years (DALYs) represent the cumulative years of healthy life impacted by premature mortality (Years of Life Lost, YLLs) and the duration of living with a disability (Years Lived with Disability, YLDs). The characteristics of YLLs in pancreatitis align with DALYs in pancreatitis (the details in Supplementary Material YLLs.pdf). However, there is a disparity between the global characteristics of YLDs and DALYs in pancreatitis. While the global Age-Standardized Rate (ASR) of YLDs in pancreatitis showed a continuous decline from 1990 to 2000 and then stabilized, the global ASR of DALYs in pancreatitis has consistently decreased since 1990 (the details in Supplementary Material YLDs.pdf). This finding suggests that in order to further alleviate the global burden of pancreatic diseases, more efforts should be focused on reducing the global ASR of YLDs.

The influence factors of pancreatitis burden

Alcohol consumption is a recognized risk factor for pancreatitis as it can harm the pancreas. By interfering with the pancreas's normal functionality, alcohol triggers the release of digestive enzymes that may harm and inflame pancreatic tissue, potentially causing acute pancreatitis. The results of the relationship between alcohol use and pancreatitis burden in different regions are as follows.

In the Global Burden of Disease (GBD) study, the only risk factor considered for pancreatitis is alcohol use, which is also a behavioral risk factor for pancreatitis. Based on death and disability-adjusted life years (DALYs) calculations, the impact of alcohol use is positively correlated with SDI. The proportion of burden attributed to alcohol use increases with SDI, resulting in higher rates of death and DALYs. In countries with high SDI and high-middle SDI, alcohol use can account for approximately half of all cases.

On a regional level, alcohol use contributes to over 40% of the burden leading to death and DALYs in Australasia (42.7% death, 47.2% DALYs), Central Europe (44.5% death, 50.3% DALYs), Eastern Europe (48.8% death, 52% DALYs), Western Europe (45.4% death, 49.4% DALYs), and Southern Latin America (42.2% death, 44.2% DALYs). In contrast, the burden attributed to alcohol use is less than 10% in North Africa and the Middle East (3% death, 4.3% DALYs) and Oceania (7.1% death, 8.7% DALYs) (Fig S4). Overall, alcohol use remains a significant concern for pancreatitis patients in Europe.

In addition, this study analyzed potential disease factors contributing to the occurrence of pancreatitis using the correlation of age-standardized global incidence rates of diseases. The results showed that there is no statistical difference in the correlation between the age-standardized incidence rate of pancreatitis and the age-standardized incidence rate of liver cancer.(cor=-0.32, p=0.07). However, the age-standardized incidence rate of pancreatitis was negatively correlated with pancreatic cancer and had a statistical difference (cor=-0.81, p=2.2e-11), while the age-standardized incidence rate of pancreatitis was positively correlated with lung cancer and had a statistical difference (cor=0.61, p=2.1e-4). These results suggest a possible association between pancreatic cancer and lung cancer with the occurrence of pancreatitis, but the specific causal relationship requires further research for confirmation. Nevertheless, these results indicate that researchers studying pancreatitis need to pay attention to the role played by tumors(Fig. 4).

Relationship of SDI and pancreatitis burden

The Socio-demographic Index (SDI) is a comprehensive indicator of a country's socio-demographic development, which encompasses income per capita, average years of education, and total fertility rate. Researchers and policymakers commonly employ the SDI to analyze and compare disease burdens across different countries and regions, and to identify disparities in healthcare accessibility and outcomes.

Regionally, the Socio-Demographic Index (SDI) is associated with the estimated annual percentage change (EAPC) of ASR for incidence, prevalence, death, YLLs, YLDs, and DALYs in the context of pancreatitis. SDI shows a positive correlation with ASR of incidence (R=0.3, p=2.7e-14). Notably, the ASR of incidence has

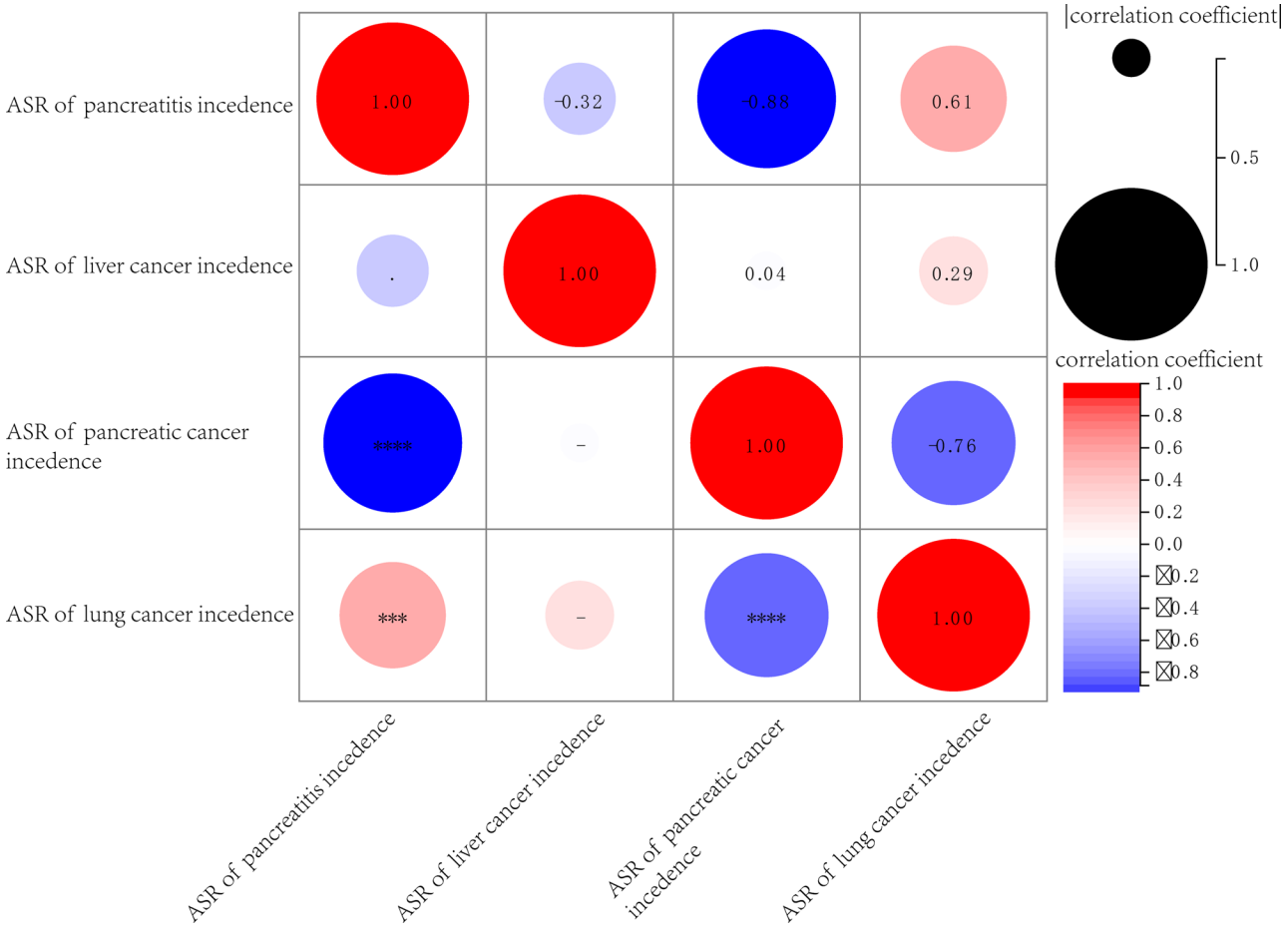

Fig. 4 The correlation of globally ASR incidence among pancreatitis, liver cancer, pancreatic cancer and lung cancer

shown a consistent upward trend in South Asia and Eastern Europe, corresponding to the rise in SDI from 1990 to 2019 (Fig. 5A). SDI exhibits a positive correlation with ASR of prevalence (R=0.54, p<2.2e-16). Moreover, the ASR of prevalence has experienced substantial growth in Eastern Europe as SDI has increased from 1990 to 2019 (Fig. 5B). The SDI shows no significant association with ASR of death (R= -0.046, p=0.26). However, it is evident

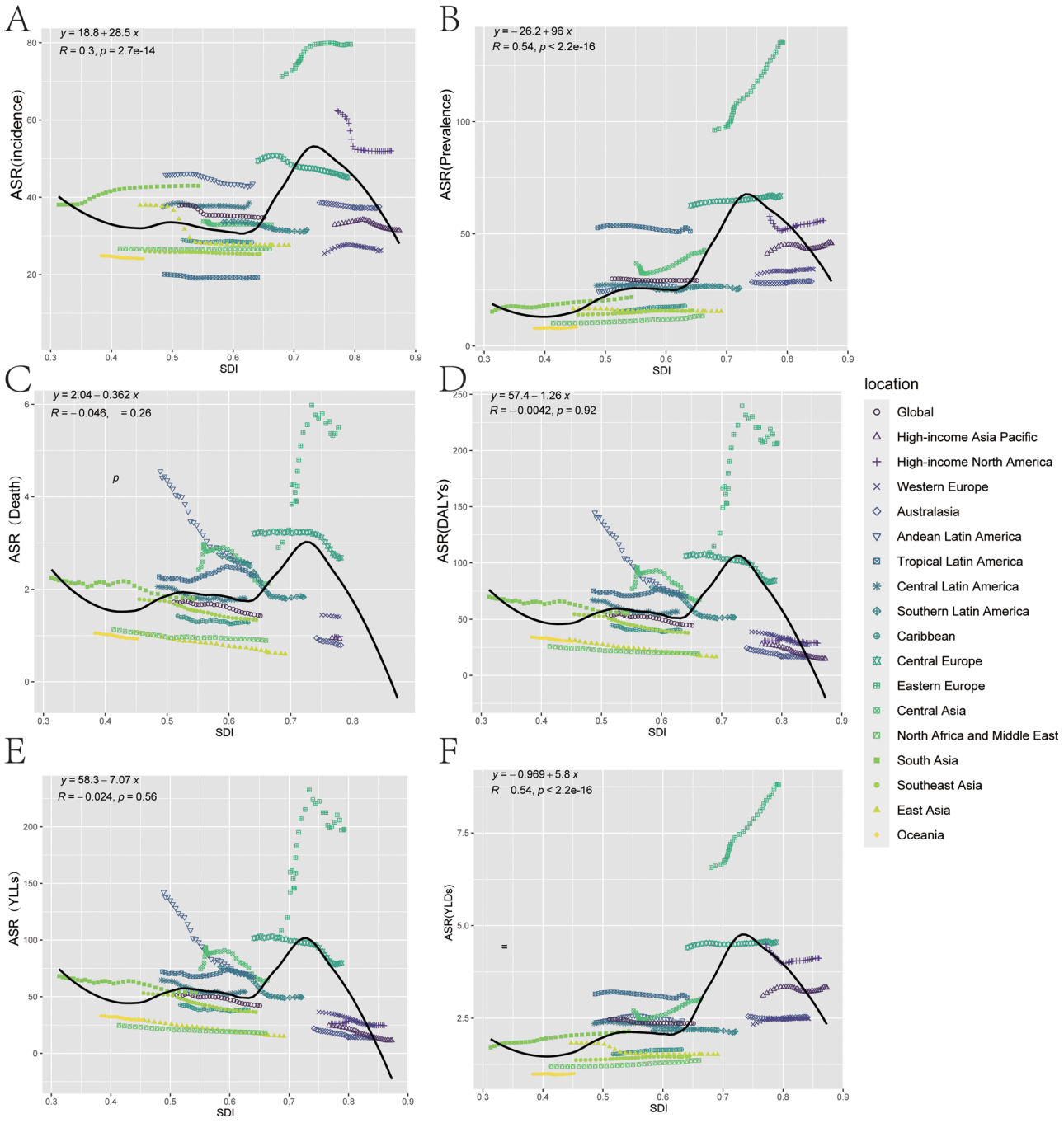

Fig. 5 The correlation of SDI and ASR in incidence, prevalence, death, YLLs, YLDs and DALYs. at the level of regions from 1990 to 2019. Each category of points represents a region, and the SDI information for each region from 1990 to 2019, spanning a period of 30 years, is shown on the horizontal axis of the graph, while the corresponding burden of pancreatitis is shown on the vertical axis. The information of the fitted curve and its test (correlation coefficient R and P-value) is shown in the graph. (**A**) The correlation between SDI and ASR of incidence at the regional level from 1990 to 2019. (**B**) The correlation between SDI and ASR of prevalence at the regional level from 1990 to 2019. (**C**) The correlation between SDI and ASR of death at the regional level from 1990 to 2019. (**D**) The correlation between SDI and ASR of DALYs at the regional level from 1990 to 2019. (**E**) The correlation between SDI and ASR of YLLs at the regional level from 1990 to 2019. (**F**)The correlation between SDI and ASR of YLDs at the regional level from 1990 to 2019

that SDI has a negative relationship with ASR of death, contradicting the trend observed in Eastern Europe where ASR of death has notably increased alongside SDI from 1990 to 2019 (Fig. 5C). Similarly, the SDI appears to have no impact on the ASR of DALYs (R= -0.0042, p=0.96) and the ASR of YLLs (R= -0.024, p=0.56). Nevertheless, it is evident that the SDI exhibits a negative association with ASR of DALYs and ASR of YLLs, contradicting the upward trajectory observed in Eastern Europe in terms of ASR of DALYs and ASR of YLLs alongside SDI from 1990 to 2019 (Fig. 5D-E). SDI demonstrates a positive correlation with ASR of years lived with disability (YLDs) (R=0.54, p<2.2e-16). Additionally, the ASR of YLDs has experienced significant growth in Eastern Europe alongside the increase in SDI from 1990 to 2019 (Fig. 5F).

Analyzing country-level data for the year 2019 provides a clearer understanding of the relationship between SDI and ASR of incidence, prevalence, death, YLLs, YLDs, and DALYs. SDI exhibits a negative correlation with ASR of death (R= -0.33, p=1.5e-06), DALYs (R= -0.31, p=7.7e-06), and YLLs (R= -0.33, p=1.6e-06) (Fig S5C, D, F) Conversely, SDI demonstrates a positive correlation with the ASR of prevalence (R=0.38, p=3.1e-08), incidence (R=0.29, p=2.2e-05), and YLDs (R=0.4, p=4.8e-09) (Fig S5A, B, E). A threshold exists for SDI, wherein the ASR of incidence, prevalence, death, YLLs, YLDs, and DALYs decrease significantly when SDI exceeds 0.75. Additionally, when considering the annual change of ASR, SDI is also associated with the estimated annual percentage change (EAPC) of incidence, prevalence, death, YLLs, YLDs, and DALYs (between 1990 and 2019). SDI shows a negative correlation with the EAPC of incidence (R= -0.18, p=0.019), death (R= -0.25, p=6e-04), YLLs (R= -0.27, p=0.00027), and DALYs (R= -0.25, p=0.00065) (Fig. 6A, C). Conversely, SDI does not significantly impact the EAPC of prevalence (R=0.1, p=0.16) and YLDs (R= -0.088, p=0.24) (Fig. 6B).

Countries with higher Socio-demographic Index (SDI) scores are generally characterized by superior healthcare infrastructure, resources, and treatment options, potentially resulting in reduced disease burden compared to countries with lower SDI scores. These results suggest that the allocation of resources into social public healthcare plays a crucial role in alleviating the societal burden of pancreatitis.

Relationship of HDI and pancreatitis

The HDI focuses on health, education, and income, while the SDI takes a more comprehensive approach by considering multiple social indicators. Therefore, this study utilizes the HDI to analyze the relationship between population development level and the burden of pancreatic disease.

Regionally, HDI is also related to the annual change in age-standardized rates (ASR) for incidence, prevalence, death, years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs). The HDI shows a negative correlation with the annual percentage change (EAPC) for incidence (R= -0.18, p=0.028), death (R= -0.32, p=5e-05), YLLs (R= -0.35, p=4.8e-06), and DALYs (R= -0.33, p=1.8e-05) (Fig. 7A, B). However, HDI does not have any significant effects on the EAPC for prevalence (R= -0.13, p=0.12) and years lived with disability (YLDS) (R= -0.11, p=0.18) (Fig. 7C).

Among the four dimensions of HDI, life expectancy at birth, gross national income, and expected years of schooling show a negative correlation with the age-standardized rate (ASR) of DALYS. Similarly, life expectancy at birth, gross national income, and expected years of schooling are negatively associated with the age-standardized rate (ASR) of death. Among these dimensions, only life expectancy at birth significantly affects the age-standardized rate (ASR) of incidence and is inversely related to it. In contrast, life expectancy at birth, gross national income, mean years of schooling, and expected years of schooling are negatively correlated with the age-standardized rate (ASR) of YLLs (Fig S6).

These results indicate that in addition to socio-economic factors, individuals' health education plays a positive role in reducing the burden of pancreatic disease. Therefore, for regions with a heavy burden of pancreatic disease, consideration can be given to enhancing health education for high-risk populations, which will have a rapid benefit in reducing the burden of pancreatic disease.

The problem of health inequalities in pancreatitis

The age-standardized rate (ASR) of DALYs in pancreatitis exhibits significant variation among countries in 2019, compared to 1990 (Fig. 8A, C). This suggests that the burden of pancreatitis has changed significantly across different countries from 1990 to 2019.

Understanding the trend in the burden of pancreatitis can assist in implementing more effective strategies to control the disease. The distribution of DALYs in pancreatitis is analyzed using the Gini coefficient and the Concentration index to examine the issue of health inequalities. The Gini coefficient of the ASR of incidence of pancreatitis globally has shown a consistent increase from 1990 to 2019, with rapid growth observed between 1990 and 2007 and stability from 2008 to 2019 (Fig. 8B). This suggests a clear increase in the disparity of ASR of DALYs among countries from 1990 to 2019. Furthermore, the Concentration index of the ASR of DALYs reveals a concentration of higher DALY rates in lower socio-demographic index (SDI) countries from 1990 to 2019 (Fig. 8D). These findings clearly demonstrate a

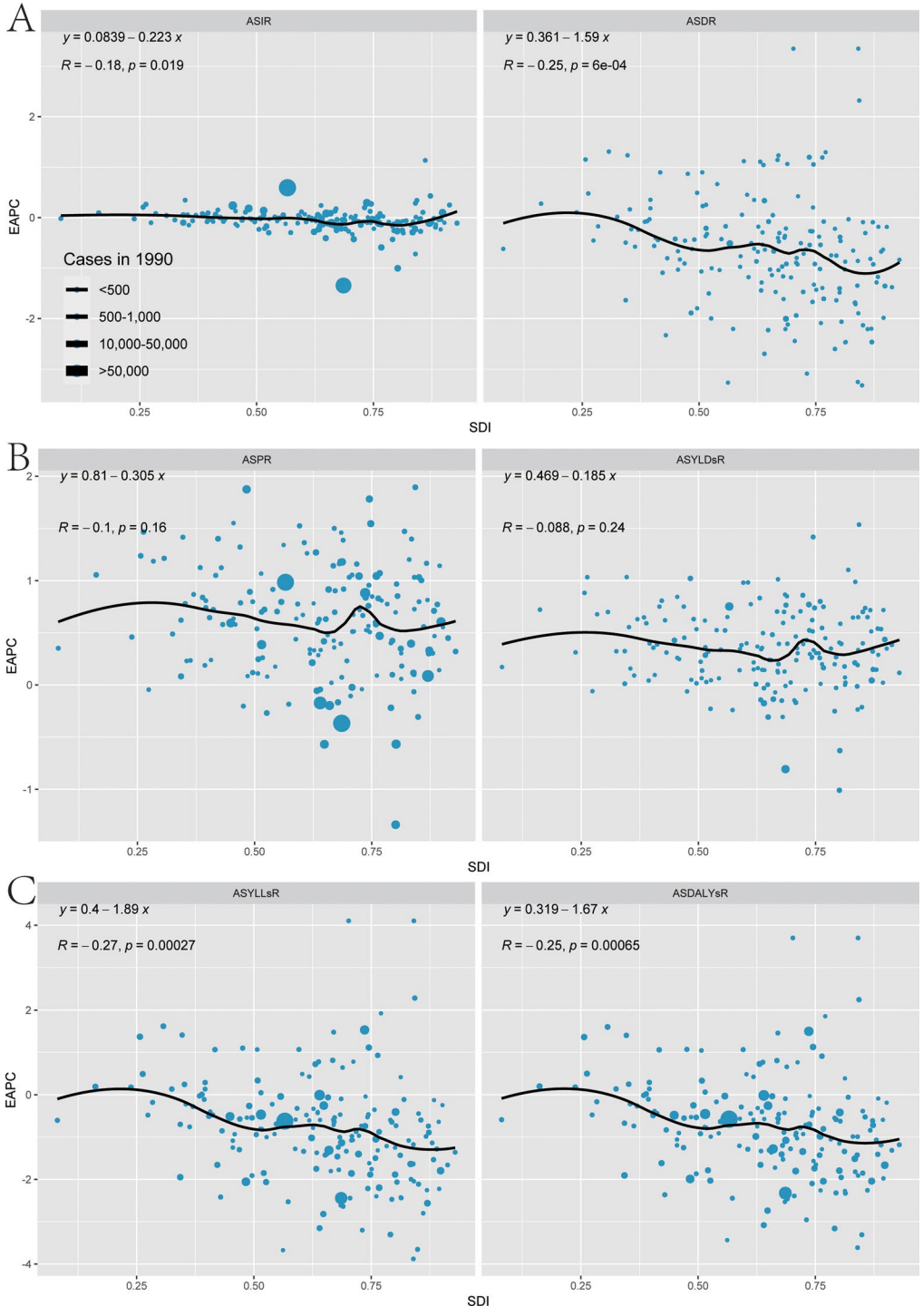

Fig. 6 The correlation of SDI and estimated annual percentage change (EAPC) (between 1990 to 2019) in incidence, prevalence, death, YLLs, YLDs and DALYs at the level of countries. The SDI information for each region is shown on the horizontal axis of the graph, while the corresponding EAPC of pancreatitis burden is shown on the vertical axis. Each point represents a country, and the size of the point represents the range of quantities. The information of the fitted curve and its test (correlation coefficient R and P-value) is shown in the graph. (**A**) The correlation of SDI and EAPC (between 1990 to 2019) in incidence and death at the level of countries. Left: The correlation of SDI and EAPC of ASIR (ASR of incidence), Right: The correlation of SDI and EAPC of ASDR (ASR of death). (**B**) The correlation of SDI and EAPC (between 1990 to 2019) in prevalence and YLDs at the level of countries. Left: The correlation of SDI and EAPC of ASPR (ASR of prevalence),Right: The correlation of SDI and EAPC of ASYLDsR (ASR of YLDs). (**C**) The correlation of SDI and EAPC (between 1990 to 2019) in YLLs and DALYs at the level of countries. Left: The correlation of SDI and EAPC of ASYLLsR (ASR of YLLs), Right: The correlation of SDI and EAPC of ASDALYsR (ASR of DALYs)

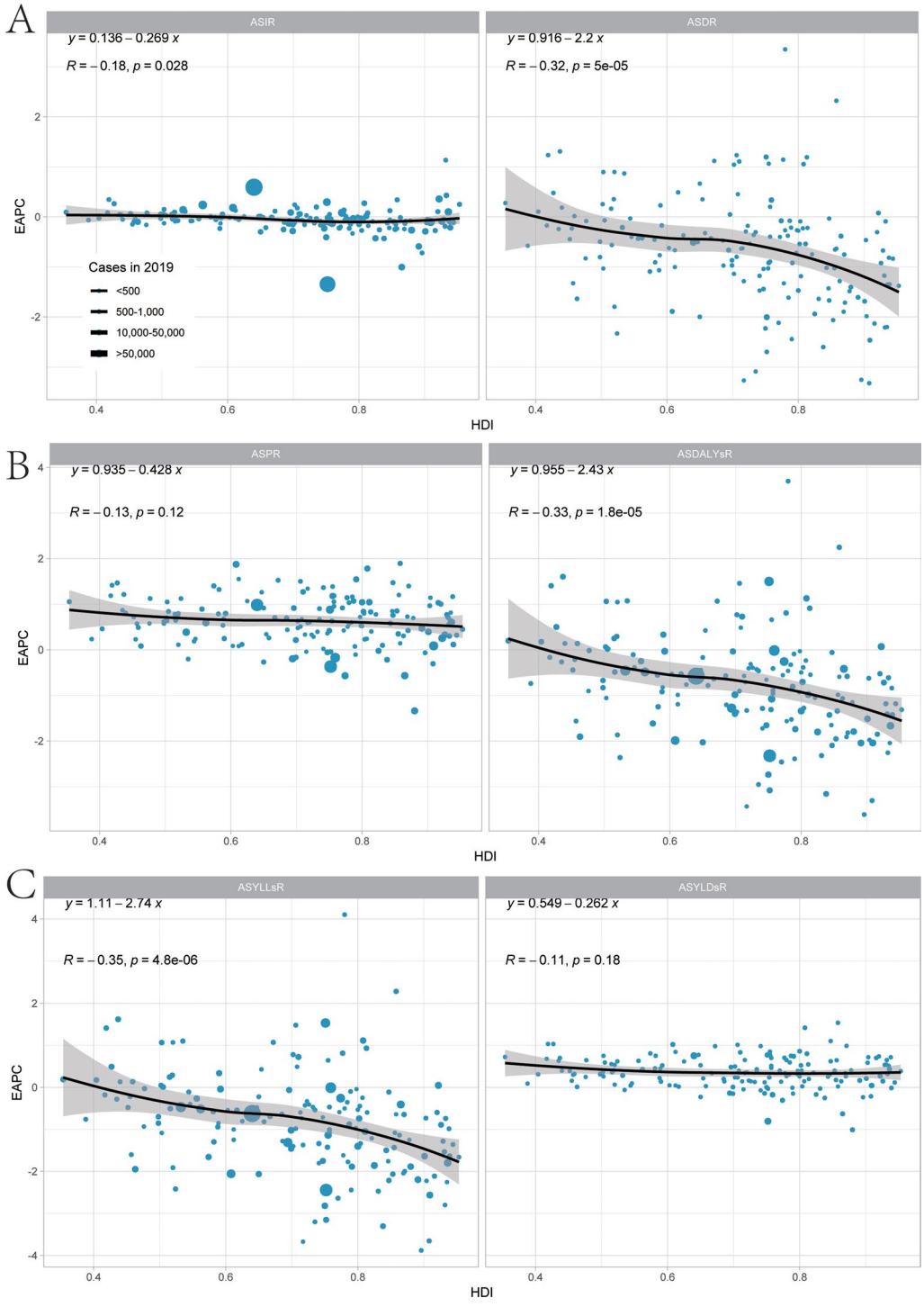

Fig. 7 The correlation of HDI and estimated annual percentage change (EAPC) (between 1990 to 2019) in incidence, prevalence, death, YLLs, YLDs and DALYs at the level of countries. The HDI information for each region is shown on the horizontal axis of the graph, while the corresponding EAPC of pancreatitis burden is shown on the vertical axis. Each point represents a country, and the size of the point represents the range of quantities. The information of the fitted curve and its test (correlation coefficient R and P-value) is shown in the graph. (**A**) The correlation of HDI and EAPC (between 1990 to 2019) in incidence and death at the level of countries. Left: The correlation of HDI and EAPC of ASIR (ASR of incidence), Right: The correlation of HDI and EAPC of ASDR (ASR of death). (**B**) The correlation of HDI and EAPC (between 1990 to 2019) in prevalence and DALYs at the level of countries. Left: The correlation of HDI and EAPC of ASPR (ASR of prevalence), Right: The correlation of HDI and EAPC of ASDALYsR (ASR of DALYs). (**C**) The correlation of HDI and EAPC (between 1990 to 2019) in YLLs and YLDs at the level of countries. Left: The correlation of HDI and EAPC of ASYLLsR (ASR of YLLs), Right: The correlation of HDI and EAPC of ASYLDsR (ASR of YLDs)

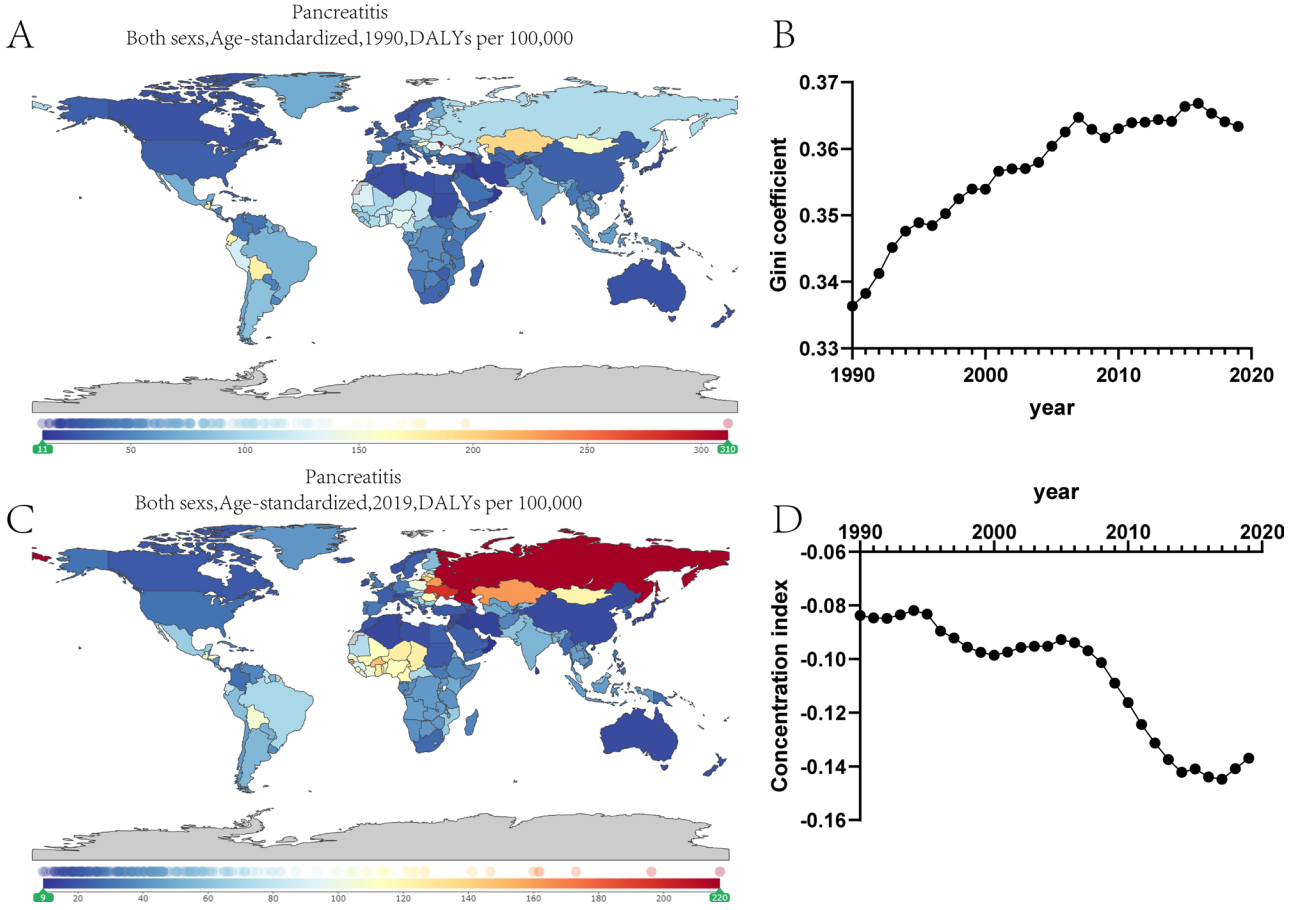

Fig. 8 The distribution inequalities of DALYs worldwide. (**A**) The map of age-standardized DALYs rate in 1990. (**B**) Gini coefficient of age-standardized DALYs rate from 1990 to 2019 based on SDI. (**C**) The map of age-standardized DALYs rate in 2019. (**D**) Concentration index of age-standardized DALYs rate from 1990 to 2019 based on SDI

significant increase in the burden of pancreatitis from 1990 to 2019, indicating a critical issue in global health inequalities.

Prediction of pancreatitis burden from 2020 to 2034

The burden of pancreatitis is predicted using the Nordpred model and BAPC model. The prediction results for ASR of incidence and death are similar between the Nordpred model and BAPC model.

According to the prediction results, the age-standardized rate (ASR) of incidence is expected to slightly increase from 2020 to 2034 (Fig. 9A). When stratified by sex, the ASR of incidence is projected to slightly increase in males from 2020 to 2034, as well as in females (Fig. 9B-C). Additionally, the ASR of incidence for males remains higher than that for females, exceeding 8 per 100,000. Correspondingly, the number of new cases is also anticipated to increase from 2020 to 2034. The trend of new cases in males is similar to that in females, but there is a higher number of new cases of pancreatitis in males compared to females (Fig. 9D).

According to the prediction results, the age-standardized rate (ASR) of death is still expected to decrease from 2020 to 2034 (Fig. 10A). When stratified by sex, the ASR of death is projected to decrease in males from 2020 to 2034 (Fig. 10B-C). Furthermore, the ASR of death for males remains higher than that for females, exceeding 8 per 100,000. As a result, the number of new cases is anticipated to continue increasing from 2020 to 2034. The trend in new cases for males is similar to that for females, although the number of new cases of pancreatitis is higher in males than in females (Fig. 10D).

Discussion

As demonstrated in the paper, except for the age-standardized rate (ASR) of prevalence, the ASR of death, incidence, YLDs, YLLs, and DALYs associated with pancreatitis have consistently decreased globally from 1990 to 2019.However, previous research reports that ASR of YLDS and ASR of prevalence increased globally from 1990 to 2013 [16]. The difference indicates that greater attention and improved control measures have been implemented for pancreatitis. The number indexes

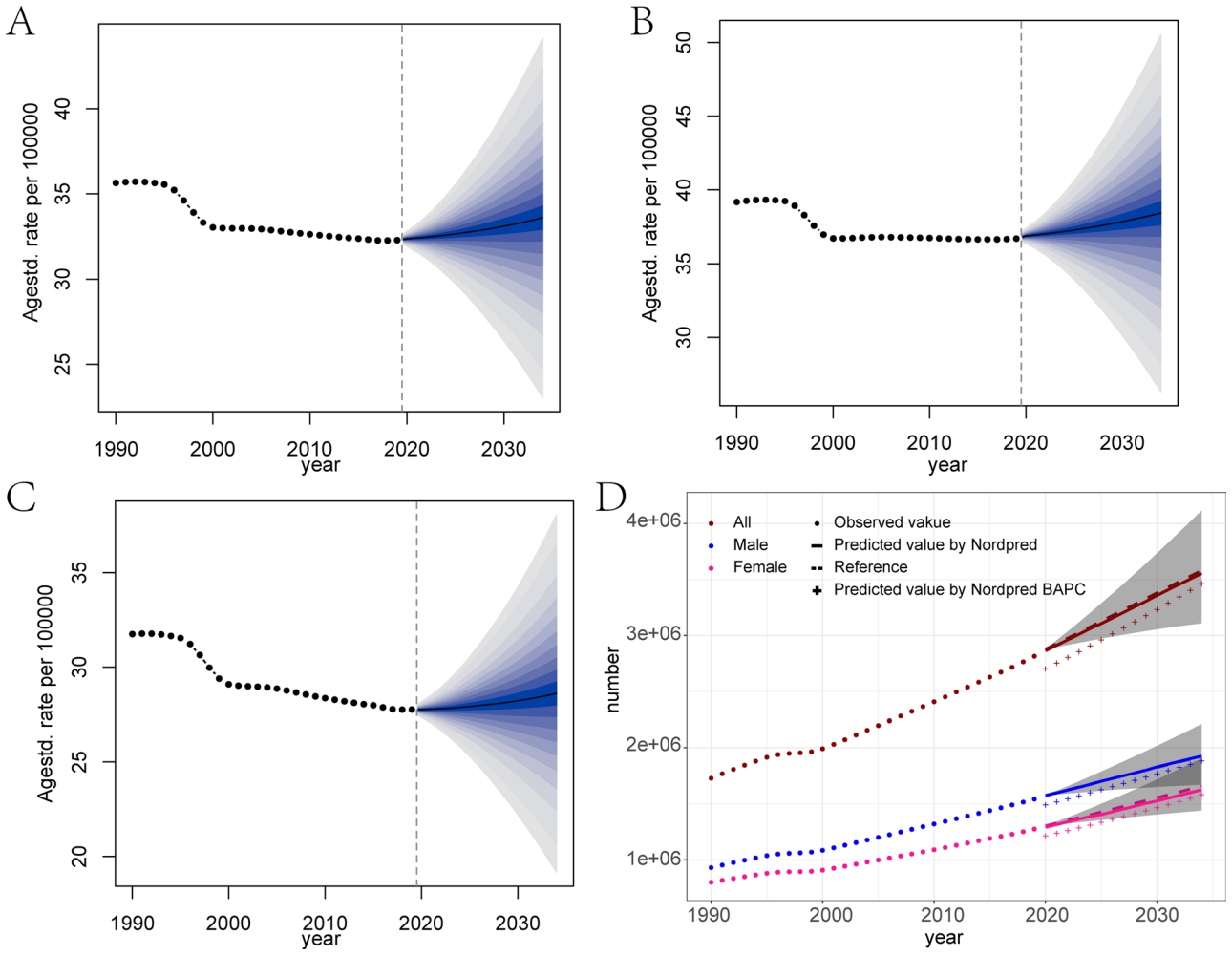

Fig. 9 The prediction of incidence in pancreatitis from 2020 to 2034 all over the world. (**A**) Prediction of age-standardized incidence rates for the entire population. (**B**) The prediction of age-standardized death rate in female. (**C**) The prediction of age-standardized incidence rate in male. (**D**) Prediction of the total number of incidence for the entire population

of pancreatitis burden were often ignored in previous research [3, 5, 16]. In the research, it is evident that the number of six key indicators for the global burden of pancreatitis burden of pancreatitis has continued to increase while ASR of six key indicators decreased globally. These seemingly contradictory results can be better understood by taking into account two factors: population growth and an aging population. With a larger population, the burden of pancreatitis is naturally higher. Additionally, our results highlight that the ASR of prevalence, death, incidence, YLDs, YLLs, and DALYs increase with age within the population. It demonstrated that age was an independent risk factor for pancreatitis [17, 18].

Besides age, the gender ratio in a population can also affect the burden of pancreatitis. In certain areas or populations, males may be more prone to developing pancreatitis, resulting in a greater burden of this condition in that particular region or population. This could be attributed to factors such as lifestyle, dietary habits, genetics, and other factors that contribute to the occurrence of pancreatitis in males [19]. In the paper, it's easily observed that the burden of pancreatitis is significantly higher in males than in females. The burden of pancreatitis aligns with the aforementioned epidemiological characteristics, as the ASR of YLLs, YLDs, and DALYs is higher in males than in females from 25 years to 75 years. Previous research also suggests that pancreatitis predominantly affects those who are middle-aged or older [24, 25].Furthermore, the largest increases in the incidence of pancreatitis were observed in two specific groups: young women aged less than 35 years and young/middle-aged men aged 35 to 54 years, associated with alcoholic pancreatitis rather than gallstone-related pancreatitis [20]. Notably, the results indicate that approximately 50% of deaths and DALYs in Eastern Europe are attributed to alcohol-related causes.

In this study, in addition to examining individual characteristics, our research also aimed to investigate the

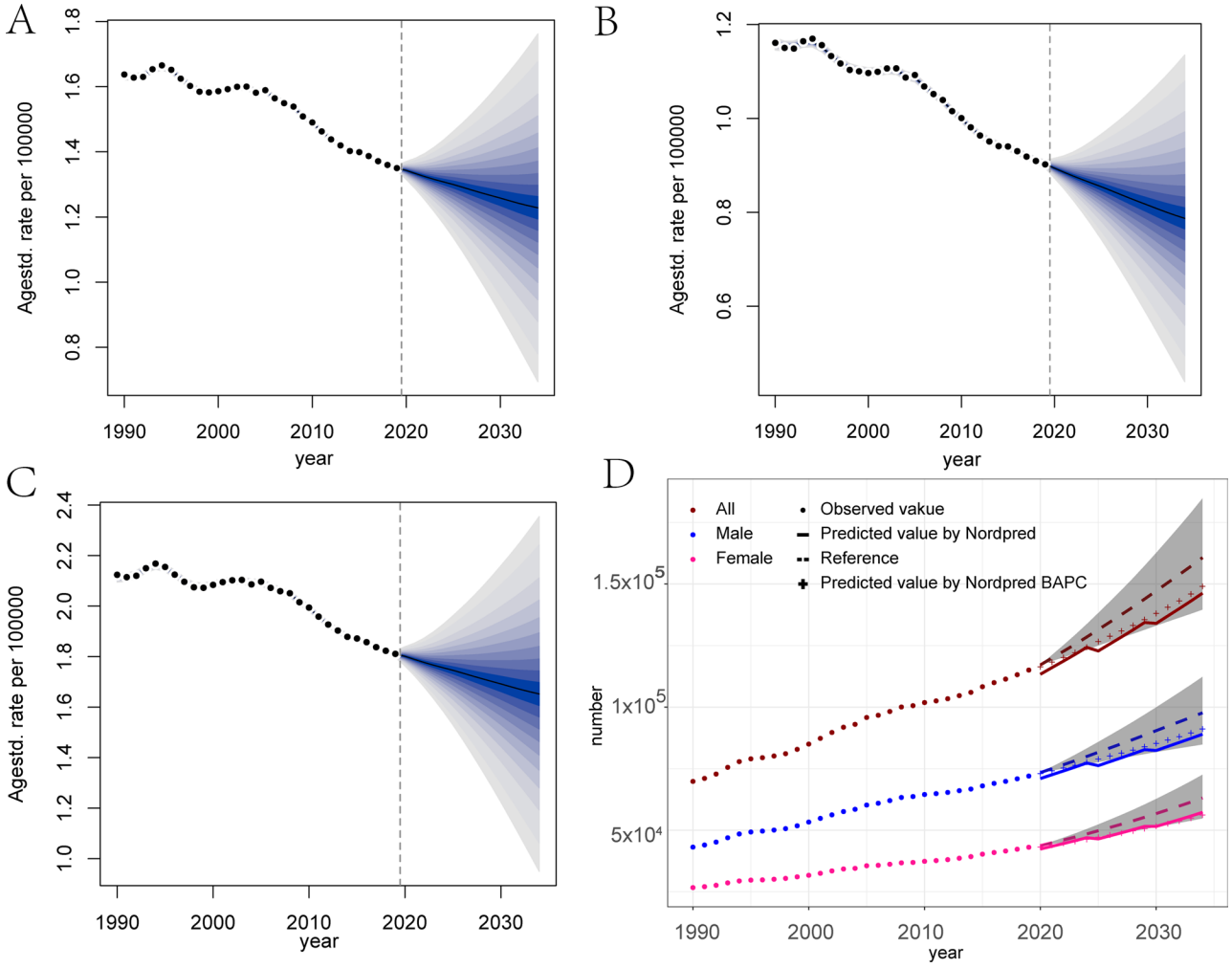

Fig. 10 The prediction of death in pancreatitis from 2020 to 2034. (**A**) Prediction of age-standardized death rates for the entire population. (**B**) The prediction of age-standardized death rate in female. (**C**) The prediction of age-standardized death rate in male. (**D**) Prediction of the total number of deaths for the entire population

impact of social factors on the burden of pancreatitis. We conducted comprehensive studies to explore the relationship between social development and the burden of pancreatitis in order to gain insights into how these factors influence the occurrence and severity of the condition using the SDI. Only one study has reported a positive correlation between the ASR of YLDs of pancreatitis and the SDI [3]. Furthermore, we explored the relationship between SDI and the ASR of incidence, prevalence, death, YLLs, and DALYs. Our findings reveal a positive correlation between SDI and the ASR of incidence, prevalence, and YLDs at the regional level. Additionally, there is a positive association between SDI and the ASR of prevalence, incidence, and YLDs at the country level. However, there is a negative relationship between the ASR of YLLs, DALYs, and death and SDI, which aligns with the regional data except for Eastern Europe. Interestingly, countries such as the Russian Federation, Lithuania, Belarus, Moldova, and Ukraine, despite being part of Eastern Europe, exhibit a high ASR of pancreatitis, indicating their defiance of the influence of SDI. This deviation in the pattern of pancreatitis in Eastern Europe compared to other regions may be attributed to alcohol abuse. Moreover, we utilized the Human Development Index (HDI) to investigate the relationship between human development and the burden of pancreatitis. Our analysis revealed a negative correlation between pancreatitis and the four dimensions of HDI, specifically the ASR of DALYs, death, incidence, and YLLs, with life expectancy at birth. Furthermore, an increase in expected years of schooling was found to contribute to a reduction in the ASR of DALYs, death, incidence, and YLLs. Additionally, an improvement in mean years of schooling can help decrease the ASR of YLLs. These findings underscore the crucial role of education in mitigating the burden of pancreatitis.

Comparing the ASR of DALYs for pancreatitis in 2019 and 1990, it can be found that the burden of pancreatitis has polarized over the past thirty years. As a result, although the global burden of pancreatitis has been controlled, regional disparities have become increasingly severe. There is a trend indicating that countries with lower SDI experience a higher burden of pancreatitis in terms of DALYs. This disparity underscores the issue of health inequity in pancreatitis and emphasizes the importance for policymakers to optimize the allocation of limited medical resources. At the regional level, Eastern Europe stands out as the only region where all six indexes have continuously increased from 1990 to 2019. Considering the total number of cases across all age groups, Asia has the highest burden of pancreatitis. East Asia has the largest number of new cases and YLDs, while South Asia has the highest number of deaths, YLLs, YLDs, and DALYs. Eastern Europe has the highest number of prevalent cases of pancreatitis and the highest ASR. At the country level, fourteen countries including Bangladesh, Belarus, Bhutan, Lithuania, Nepal, Germany, Norway, Singapore, Sweden, United Kingdom, Georgia, Russian Federation, Turkmenistan, and Cabo Verde should prioritize efforts in controlling pancreatitis. From 1990 to 2019, these countries have experienced an increase in at least one of the six indexes. The Russian Federation stands out as the sole country where almost all six indexes have continuously increased.

According to the results of prediction of ASR and number of death and DALYs, the burden of pancreatitis will still increase. Our results can serve as a guide for the implementation of prevention strategies in pancreatitis. Allocating more medical resources to Eastern Europe (due to high ASR of incidence and death) and Asia (due to large population) would be beneficial in controlling pancreatitis burden as a public health measure. In terms of primary prevention, increased health education efforts should be targeted towards middle-aged and older individuals, particularly males, to reduce the ASR of incidence. Similarly, healthcare professionals should pay closer attention to middle-aged and older individuals, especially males, presenting with abdominal symptoms as part of secondary prevention in order to reduce morbidity. Lastly, focusing on tertiary prevention, managing diabetes mellitus, osteoporosis, and exocrine dysfunction in the middle-aged and older population can help alleviate the burden associated with pancreatitis [21–25].

This article has several limitations that should be acknowledged. Firstly, the data utilized in this study is a synthesis of acute pancreatitis and chronic pancreatitis from the Global Burden of Disease (GBD) dataset, thus our findings only capture the overall outcomes of both conditions. Secondly, our analysis did not examine health inequities within each country, which is an important factor in understanding the burden of pancreatitis. Thirdly, while the risk factors for pancreatitis include hyperlipidemia, alcohol consumption, gallstones, and others, our paper solely focuses on alcohol as a contributing factor. In future research, our team intends to address these limitations and provide a more comprehensive analysis.

Conclusion

Although the ASR of pancreatic burden indicators have been continuously decreasing worldwide, the corresponding numbers indicators of indicators are still on the rise, and this trend is expected to continue until 2034. In addition to the gender ratio and age composition of the population, the economic development of society and human development also have an impact on the burden of pancreatic inflammation. On the other hand, since 1990, the health inequality in pancreatic burden among countries worldwide has been worsening, which is an important point to consider for prevention of pancreatic burden. South Asia and Eastern Europe are the regions with the highest pancreatic burden globally. The countries that need to allocate more resources to control pancreatic burden are Bangladesh, Belarus, Bhutan, Lithuania, Nepal, Germany, Norway, Singapore, Sweden, United Kingdom, Georgia, Russian Federation, Turkmenistan, and Cabo Verde.

Abbreviations

YLDs	Years lived with disability
YLLs	The years of life lost
DALYs	Disability-adjusted life-years
GBD	Global Burden of Disease
ASR	Age-Standardised Rates
EAPC	Estimated Average Percent Change
AAPC	Average Annual Percent Change
SDI	Socio-Demographic Index
HDI	Human Development Index

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-20796-z.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

Supplementary Material 6

Supplementary Material 7

Supplementary Material 8

Supplementary Material 9

Supplementary Material 10

Supplementary Material 11

Supplementary Material 12

Supplementary Material 13

Supplementary Material 14

Supplementary Material 15

Supplementary Material 16

Supplementary Material 17

Supplementary Material 18

Supplementary Material 19

Author contributions
YXW, YL and YW wrote the main manuscript text and YXW prepared Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10.ZZJ, YPH and LX prepared Tables 1, 2 and 3.All authors reviewed the manuscript.

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Data availability
The data of pancreatitis were obtained publicly from Global Health Data Exchange (GHDx) website (https://ghdx.healthdata.org/gbd-2019). The data of population was got from Department of Economic and Social Affairs Population Dynamics of United Nations(https://www.un.org/development/desa/pd/).

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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