Global, regional, and national burden of pancreatic cancer from 1990 to 2021, its attributable risk factors, and projections to 2050: a systematic analysis of the global burden of disease study 2021

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Abstract

Background The incidence and mortality rates of pancreatic cancer are rising globally. This study examines global and regional trends in pancreatic cancer incidence, Disability Adjusted Life Years (DALYs), and mortality from 1990 to 2021, utilizing data from the most recent Global Burden of Disease (GBD) 2021 database.

Methods Data were sourced from the GBD database over the period from 1990 to 2021. Age-standardized rates for incidence, DALYs, and mortality were calculated per 100,000 population. We also calculated the proportion of DALYs and mortality attributable to risk factors. The Bayesian age-period-cohort model was applied to project future trends until 2050.

Results Between 1990 and 2021, the global incidence of pancreatic cancer increased significantly, with the number of cases rising from approximately 207,905 to 508,533 and the age-standardized incidence rate (ASIR) increasing from 5.47 to 5.96 per 100,000 population. The global burden of pancreatic cancer, measured in DALYs, rose from 5.21 million to 11.32 million. Mortality rates showed a similar upward trend, with the number of deaths increasing from around 211,613 to 505,752, and the age-standardized mortality rate (ASMR) rising from 5.655 to 5.948 per 100,000 population. Notable increases in ASIR and ASMR were observed in low-middle and low sociodemographic index regions with males experienced higher rates compared to females. Age-standardized DALYs rate (ASDR) and ASMR worldwide were attributable to tobacco smoking, high BMI, and high fasting plasma glucose. Furthermore, our projection model estimates that the ASIR and ASMR of pancreatic cancer will significantly decline, while the ASDR is anticipated to maintain a steady downward trend by 2050.

Conclusion This study offers a comprehensive analysis of pancreatic cancer trends, providing crucial insights for public health planning and policy-making. Addressing identified risk factors and targeting high-risk populations are essential for effective strategies to reduce the global burden of pancreatic cancer.

Keywords Pancreatic cancer, Global burden of disease study, Incidence, Mortality, Risk factors, Projections

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Li *et al. BMC Cancer*   (2025) 25:189

Page 2 of 26

Introduction

Pancreatic cancer remains one of the most lethal malignancies, characterized by a high mortality rate and a minimal five-year survival rate [1, 2]. According to the latest GLOBOCAN report, pancreatic cancer has one of the poorest prognoses among cancers, ranking as the sixth leading cause of cancer mortality [3]. As reported by the GBD 2017 Pancreatic Cancer Collaborators, there were an estimated 448,000 (95% UI: 439,000–456,000) new cases of pancreatic cancer worldwide in 2017. Among these, 232,000 (210,000–221,000; 51.9%) occurred in males. The age-standardized incidence rate of pancreatic cancer was 5.0 (4.9–5.1) per 100,000 person-years in 1990, rising to 5.7 (5.6–5.8) per 100,000 person-years by 2017 [4]. Despite advances in medical research and treatment, the global burden of pancreatic cancer continues to rise. Over the past three decades, the global burden of pancreatic cancer has evolved significantly, influenced by various demographic, lifestyle, and environmental factors [4, 5]. Understanding the epidemiological trends, risk factors, and projections of pancreatic cancer is crucial for developing effective public health strategies and policies.

To the best of our knowledge, the latest GBD data has not been utilized for a comprehensive epidemiological analysis of pancreatic cancer. In this study, we utilized the GBD database to examine trends in pancreatic cancer incidence, DALYs and mortality, including associated risk factors, from 1990 to 2021. This systematic analysis aims to provide a detailed overview of the global, regional, and national burden of pancreatic cancer from 1990 to 2021. By identifying the major risk factors attributable to pancreatic cancer and projecting future trends up to 2050, this study seeks to inform targeted prevention and intervention strategies. Understanding the dynamics of pancreatic cancer incidence, mortality, and associated risk factors is essential for healthcare policymakers, clinicians, and researchers to develop effective measures to combat this devastating disease.

Methods

Overview and data collection

The data used in this study were obtained from the Global Burden of Disease (GBD) 2021 study, which integrates data from national cancer registries, vital registration systems, household surveys, and hospital records. These data are systematically collected and validated by the Institute for Health Metrics and Evaluation (IHME) to ensure consistency and reliability. In the GBD 2021 study, missing data is addressed using advanced statistical methods such as MR-BRT (Meta-Regression Bayesian Regularized Trimmed), which adjusts for biases using correction factors derived from mixed-effects models. Additionally, DisMod-MR 2.1 employs Bayesian methods to generate consistent estimates of prevalence, incidence, and mortality by integrating data from higher geographical levels and using location-specific covariates to impute missing data, ensuring accuracy and consistency [6].

The GBD 2021 study evaluated the incidence, DALYs, and mortality rates, along with their uncertainty intervals, in 204 countries and territories from 1990 to 2021 [7, 8]. Using the Global Health Data Exchange query tool (https://vizhub.healthdata.org/gbd-results/) developed by GBD collaborators [9], we gathered standardized disease definitions, prevalence data, and other relevant information on pancreatic cancer patients. Additionally, we collected data on global risk factors contributing to pancreatic cancer mortality and DALYs. In the website, we selected the "Risk factors" for risk analysis and "Cause of death or injury" for the other analyses in the GBD Estimate section. In the Measure section, we chose Deaths, DALYs, and Incidence, and for the Metric section, we selected both Number and Rate. The specific cause we focused on was Pancreatic cancer. For the Location, we selected all GBD regions, and all countries and territories. For Age, we included all ages as well as age-standardized data. The Sex categories chosen were Male, Female, and Both, and the data span from 1990 to 2021.

Calculation of estimated annual percentage change (EAPC)

EAPC is derived by fitting a linear regression model to the natural logarithm of the age-standardized rates (ASR) over time [10, 11]. Specifically, the ASR values are log-transformed, and a linear regression is performed with time (year) as the independent variable and log(ASR) as the dependent variable. The slope of the regression model represents the EAPC, which indicates the average annual percentage change in the age-standardized rates. The formula for calculating EAPC is: $EAPC = 100 \times (\exp(\beta) - 1)$. where β is the slope of the regression line, and $\exp(\beta)$ represents the exponentiated value of the slope [12].

Sociodemographic index

The Sociodemographic Index (SDI) gauges a region's or country's level of development using data on fertility rates, educational attainment, and income per capita [9]. The SDI scale ranges from 0 to 1, with higher scores reflecting greater socioeconomic advancement. Countries and territories in the GBD 2021 dataset are stratified into five SDI categories based on their SDI scores: low (< 0.46), low-middle (0.46–0.60), middle (0.61–0.69), high-middle (0.70–0.81), and high (> 0.81) [13].

Attribution of DALYs and deaths to risk factors

The attribution of DALYs and deaths to specific risk factors in this study follows the comparative risk assessment framework employed by the GBD 2021 study [14]. This

Li *et al. BMC Cancer*   (2025) 25:189

Page 3 of 26

framework estimates the population attributable fraction (PAF) by comparing the current exposure levels of each risk factor to a theoretical minimum risk exposure level (TMREL), defined as the level of exposure associated with the lowest possible risk. The PAF quantifies the proportion of disease burden that could be avoided if exposure to a specific risk factor were reduced to the TMREL. These PAFs are then applied to the total DALYs and deaths to calculate the burden attributable to each risk factor. The framework incorporates relative risk estimates derived from systematic reviews and meta-analyses, combined with exposure data for each population. Adjustments are made to account for mediation effects when risk factors act through intermediate pathways. This approach provides robust estimates of the attributable burden, though it assumes the independence of risk factors and may not fully capture interactions or combined effects.

Statistical analysis

The burden of pancreatic cancer was assessed using incidence, mortality, DALYs, and their age-standardized rates per 100,000 population, with 95% uncertainty intervals calculated using the GBD algorithm (https://ghdx.healthdata.org/gbd-2021/code) [6, 7]. Age standardization was performed using the direct method to ensure comparability across regions and time periods. The calculation utilized the Global Burden of Disease (GBD) standard population as the reference population. Projections to 2050 were performed using a Bayesian age-period-cohort (BAPC) model, which separates the effects of age, period, and cohort [15, 16]. The age effect captures variations in disease burden based on age, the period effect reflects the impact of specific time periods (e.g., interventions or external events), and the cohort effect accounts for differences in disease patterns across generations. The model employs integrated nested Laplace approximations (INLA) for Bayesian inference, allowing robust trend forecasting [17, 18]. Detailed explanation of the BAPC model are presented in Supplementary file 1. All statistical analysis was performed using R software package (version 4.2.1).

Result

Global and reginal trends of pancreatic cancer incidence, DALYs, and mortality

Table 1 presents the incidence of pancreatic cancer at both the global and regional levels between 1990 and 2021. The data include the number of cases and the age-standardized rate per 100,000 population, along with the estimated annual percentage change (EAPC) during this period. The global incidence of pancreatic cancer has significantly increased from 1990 to 2021. In 1990, the total number of cases was approximately 207,905 with an age-standardized rate of 5.47 per 100,000 population. By 2021, the total number of cases rose to around 508,533 with an age-standardized rate of 5.96 per 100,000 population, reflecting an estimated annual percentage change of 0.34%. The regions showing the most notable trends include low-middle sociodemographic index (SDI) and low SDI regions. Specifically, in low-middle SDI regions, the age-standardized rate increased significantly from 1.39 to 2.20 per 100,000 population, with an annual percentage change of 1.57%. Similarly, in low SDI regions, the rate rose from 1.31 to 1.59 per 100,000 population, with an annual percentage change of 0.61%. In 2021, the age-standardized incidence rates (ASIR) per 100,000 population for pancreatic cancer showed notable disparities across various regions (Fig. 1A). The highest rates were recorded in High-income Asia Pacific, with a rate of 10.689, and in High-income North America, with a rate of 10.196. On the other hand, the lowest rates were observed in South Asia, with a rate of 1.411. From 1990 to 2021, both males and females experienced a notable increase in the incidence of pancreatic cancer. For males, the number of cases rose from approximately 110,396 in 1990 to 273,617 in 2021, with the age-standardized rate increasing from 6.30 to 6.96 per 100,000 population. For females, the number of cases increased from around 97,510 in 1990 to 234,916 in 2021, with the age-standardized rate rising from 4.71 to 5.05 per 100,000 population.

Several regions exhibited significant trends in the incidence of pancreatic cancer, as measured by EAPC. East Asia experienced the most dramatic rise, with cases increasing from 39,030 to 122,831, and the age-standardized rate rising from 4.51 to 5.64 per 100,000 population (EAPC 0.707%). Southern Sub-Saharan Africa also saw a significant rise in cases from 1,003 to 3,231, with the rate increasing from 3.80 to 5.76 (EAPC 1.372%). Central Asia's cases increased from 1,417 to 3,468, and the rate rose from 3.00 to 4.27 (EAPC 1.332%). In contrast, Central Latin America experienced a slight decrease, with the age-standardized rate changing from 4.36 to 4.54 per 100,000 population and an EAPC of −0.046% (Fig. 1D).

Table 2 summarizes the global and regional burden expressed in Disability Adjusted Life Years (DALYs). Globally, the total DALYs, which measure the years of healthy life lost due to disability and premature death, increased from approximately 5.21 million (95% UI: 4.97–5.48 million) in 1990 to 11.32 million (95% UI: 10.46–12.17 million) in 2021. Age-standardized rates per 100,000 population slightly increased from 129.32 (95% UI: 122.98–135.98) to 130.33 (95% UI: 120.52–140.13). Regions classified under the low-middle SDI category experienced a notable annual percentage

Li *et al. BMC Cancer*   (2025) 25:189

Page 4 of 26

Table 1 Incidence of pancreatic cancer between 1990 and 2021 at the global and regional level

	Number of cases, 1990			Age-standardized rate per 100 000 population, 1990		
	Male	Female	Total	Male	Female	Total
Global	110395.572(104541.943-116510.200)	97509.658(90497.638-103233.000)	207905.230(196649.422-217778.458)	6.297(5.953-6.620)	4.708(4.343-4.990)	5.472(5.160-5.731)
Low SDI	1633.982(1245.090-1976.127)	1268.195(943.044-1583.581)	2902.177(2250.991-3479.198)	1.435(1.105-1.734)	1.180(0.872-1.461)	1.309(1.019-1.570)
Low-middle SDI	4757.221(3956.413-5546.520)	3558.983(2918.687-4247.462)	8316.204(7055.111-9705.589)	1.537(1.286-1.785)	1.235(1.012-1.464)	1.390(1.182-1.616)
Middle SDI	18275.630(16222.503-20589.614)	14107.504(12451.402-15846.504)	32383.134(29494.714-35579.924)	3.631(3.259-4.048)	2.749(2.436-3.081)	3.184(2.920-3.477)
High-middle SDI	36647.430(34070.172-39388.121)	29844.007(27832.458-32030.543)	66491.437(62906.165-70237.597)	8.525(7.949-9.145)	5.325(4.945-5.724)	6.754(6.379-7.136)
High SDI	48924.438(47492.791-50236.620)	48597.557(44692.238-50830.984)	97521.995(92265.825-100694.279)	10.547(10.196-10.832)	7.313(6.766-7.627)	8.752(8.287-9.030)
Eastern Europe	10503.307(10013.297-11310.268)	9537.552(8977.597-10158.940)	20040.859(19040.720-21303.814)	10.190(9.698-10.921)	5.197(4.892-5.538)	7.116(6.759-7.570)
Central Europe	6707.860(6438.583-6968.345)	5449.967(5153.802-5689.133)	12157.827(11640.013-12603.124)	10.380(9.961-10.778)	6.304(5.954-6.587)	8.131(7.783-8.441)
East Asia	23278.213(18935.801-28204.738)	15751.799(12704.405-19448.715)	39030.012(32969.703-45464.102)	5.515(4.545-6.575)	3.604(2.917-4.440)	4.509(3.827-5.244)
High-income North America	16077.886(15502.961-16470.612)	16691.793(15366.548-17845.876)	33069.680(30983.632-34192.919)	10.868(10.458-11.154)	8.056(7.381-8.424)	9.313(8.770-9.616)
Oceania	32.253(25.288-42.599)	18.651(14.381-24.408)	50.904(40.094-65.177)	2.207(1.760-2.921)	1.455(1.137-1.892)	1.849(1.492-2.341)
Central Asia	736.866(641.014-876.519)	679.883(588.352-791.023)	1416.749(1249.551-1646.792)	3.742(3.245-4.480)	2.449(2.117-2.857)	3.001(2.632-3.507)
Southeast Asia	2972.652(2610.075-3369.970)	2611.269(2118.171-3147.175)	5583.922(4807.621-6413.166)	2.442(2.156-2.760)	1.970(1.608-2.369)	2.196(1.901-2.518)
Australasia	944.251(894.636-990.515)	871.194(798.950-923.521)	1815.444(1721.946-1895.182)	9.113(8.630-9.567)	6.507(5.995-6.898)	7.697(7.283-8.028)
High-income Asia Pacific	10271.491(9873.803-10599.378)	8290.348(7571.882-8772.651)	18561.839(17616.382-19277.660)	12.186(11.687-12.577)	7.241(6.592-7.671)	9.376(8.840-9.763)
Caribbean	631.436(590.720-672.658)	559.684(509.063-605.724)	1191.121(1118.863-1265.881)	5.135(4.807-5.460)	4.217(3.832-4.558)	4.664(4.373-4.953)
Western Europe	23579.663(22787.359-24522.846)	24834.736(22728.884-26087.691)	48414.399(45663.433-50531.529)	9.899(9.539-10.288)	6.943(6.422-7.264)	8.274(7.830-8.621)
Tropical Latin America	2202.380(2128.775-2275.893)	1982.030(1851.385-2086.774)	4184.410(3992.363-4325.146)	5.249(5.045-5.435)	4.277(3.967-4.513)	4.746(4.486-4.917)
Southern Latin America	2017.023(1891.861-2167.739)	2058.525(1846.668-2293.967)	4075.548(3834.583-4335.290)	9.910(9.321-10.656)	7.947(7.147-8.832)	8.871(8.345-9.439)
Andean Latin America	396.822(332.781-468.760)	471.197(390.123-555.547)	868.019(729.085-1021.762)	4.073(3.445-4.808)	4.640(3.859-5.473)	4.377(3.684-5.156)
South Asia	3643.917(2848.459-4426.176)	2064.096(1516.369-2556.186)	5708.013(4495.018-6903.359)	1.201(0.941-1.461)	0.776(0.568-0.959)	0.999(0.783-1.209)
Central Latin America	1651.852(1607.324-1691.711)	1854.414(1780.538-1917.463)	3506.266(3405.670-3595.209)	4.194(4.070-4.299)	4.495(4.295-4.661)	4.355(4.215-4.477)
North Africa and Middle East	2862.990(2397.043-3415.293)	1841.870(1383.444-2259.700)	4704.860(3853.239-5553.977)	3.412(2.829-4.034)	2.350(1.745-2.880)	2.891(2.349-3.395)
Western Sub-Saharan Africa	466.967(393.177-546.844)	384.388(303.986-460.171)	851.354(726.854-980.898)	1.081(0.912-1.260)	0.919(0.727-1.101)	1.001(0.861-1.148)
Southern Sub-Saharan Africa	530.020(446.965-686.427)	472.628(398.702-569.921)	1002.648(861.351-1235.283)	4.525(3.800-5.886)	3.210(2.686-3.901)	3.804(3.246-4.741)
Central Sub-Saharan Africa	280.045(220.944-343.757)	196.308(145.711-263.632)	476.353(381.463-579.078)	2.697(2.185-3.303)	1.733(1.306-2.289)	2.186(1.776-2.643)
Eastern Sub-Saharan Africa	607.680(472.847-761.358)	587.324(438.111-720.675)	1195.004(927.330-1460.456)	1.647(1.294-2.054)	1.642(1.218-2.039)	1.646(1.281-2.012)

Li *et al. BMC Cancer* (2025) 25:189

Page 5 of 26

Table 1 (continued)

	Number of cases, 2021			Age-standardised rate per 100 000 population, 2021			Estimated annual percentage change, 1990-2021
	Male	Female	Total	Male	Female	Total	
Global	273617.074(250808.499-299347.632)	234915.630(205148.710-255434.628)	508532.704(462090.895-547207.623)	6.961(6.372-7.586)	5.049(4.415-5.490)	5.961(5.392-6.421)	0.335(0.308-0.363)
Low SDI	4113.084(3373.874-5077.587)	3717.225(2999.479-4455.226)	7830.309(6493.523-9394.393)	1.679(1.394-2.054)	1.508(1.215-1.805)	1.593(1.334-1.903)	0.613(0.457-0.769)
Low-middle SDI	16924.185(15572.007-18315.601)	14223.679(12912.072-15451.231)	31147.864(28918.910-33650.629)	2.462(2.275-2.656)	1.948(1.762-2.113)	2.198(2.036-2.374)	1.570(1.540-1.600)
Middle SDI	59272.796(51107.066-68782.602)	44303.054(38489.579-50372.716)	103575.850(91436.055-116662.529)	4.672(4.036-5.398)	3.161(2.736-3.589)	3.879(3.430-4.360)	0.608(0.563-0.654)
High-middle SDI	82216.480(72057.717-94434.394)	66080.619(57506.502-74467.776)	148297.099(132453.815-164406.418)	9.244(8.122-10.554)	5.931(5.177-6.688)	7.465(6.672-8.269)	0.339(0.298-0.379)
High SDI	110810.195(103440.434-116614.445)	106336.083(90284.464-115698.608)	217146.278(193740.713-231692.678)	11.538(10.805-12.133)	8.585(7.500-9.229)	9.998(9.078-10.606)	0.559(0.508-0.609)
Eastern Europe	14613.353(13080.196-16256.091)	14480.531(13072.395-15947.240)	29093.884(26856.141-31591.181)	10.811(9.682-12.014)	6.427(5.796-7.104)	8.280(7.645-8.983)	0.336(0.132-0.540)
Central Europe	10781.040(9873.763-11667.226)	9921.746(8997.259-10759.782)	20702.786(18929.699-22371.357)	11.364(10.413-12.304)	7.477(6.785-8.109)	9.267(8.488-10.035)	0.442(0.355-0.529)
East Asia	74689.342(56766.690-95315.599)	48141.464(36652.366-61133.782)	122830.806(98826.236-148854.998)	7.277(5.592-9.161)	4.182(3.182-5.303)	5.637(4.555-6.801)	0.707(0.656-0.757)
High-income North America	35069.412(32974.945-36432.650)	33098.836(29160.184-35347.209)	68168.248(62281.048-71457.311)	11.646(10.949-12.101)	8.905(7.967-9.443)	10.196(9.375-10.652)	0.354(0.299-0.408)
Oceania	98.792(76.897-134.279)	63.820(52.096-78.433)	162.612(131.933-207.422)	2.623(2.041-3.570)	1.908(1.577-2.335)	2.283(1.862-2.887)	0.787(0.743-0.831)
Central Asia	1903.833(1671.173-2157.261)	1564.163(1381.037-1761.045)	3467.996(3054.612-3893.047)	5.284(4.662-5.946)	3.480(3.077-3.914)	4.271(3.773-4.774)	1.332(1.135-1.529)
Southeast Asia	11550.259(9836.100-13560.886)	10151.615(8255.695-12325.572)	21701.873(18693.852-25155.751)	3.751(3.218-4.375)	2.948(2.397-3.555)	3.334(2.879-3.866)	1.311(1.251-1.372)
Australasia	2511.407(2262.784-2728.967)	2262.709(1896.441-2522.892)	4774.115(4244.629-5131.159)	9.862(8.946-10.676)	7.499(6.397-8.277)	8.625(7.767-9.235)	0.527(0.448-0.605)
High-income Asia Pacific	27281.961(24843.975-29014.404)	27491.416(21202.069-31285.176)	54773.376(46040.323-59823.730)	12.727(11.657-13.501)	8.838(7.180-9.831)	10.689(9.298-11.534)	0.594(0.506-0.682)
Caribbean	1445.985(1263.948-1631.755)	1301.365(1132.477-1482.836)	2747.349(2426.568-3098.863)	5.744(5.025-6.475)	4.487(3.902-5.112)	5.093(4.497-5.745)	0.731(0.578-0.885)
Western Europe	45888.036(42298.477-48730.199)	45832.503(39242.867-50451.220)	91720.538(82405.318-9843.779)	10.910(10.147-11.548)	8.287(7.329-9.019)	9.543(8.711-10.160)	0.675(0.609-0.741)
Tropical Latin America	7420.935(6984.493-7845.353)	7595.069(6906.586-8128.977)	15016.004(13928.067-15736.531)	6.452(6.052-6.828)	5.346(4.863-5.722)	5.864(5.415-6.155)	0.747(0.698-0.797)
Southern Latin America	3654.107(3416.559-3919.162)	3936.713(3539.476-4312.547)	7590.820(7018.966-8087.789)	9.527(8.894-10.213)	7.802(7.075-8.499)	8.614(7.979-9.172)	0.111(-0.011-0.233)

Li *et al. BMC Cancer*   (2025) 25:189

Page 6 of 26

Table 1 (continued)

	Number of cases, 2021			Age-standardised rate per 100 000 population, 2021			Estimated annual percentage change, 1990-2021
	Male	Female	Total	Male	Female	Total	
Andean Latin America	1324.883(1013.641-1662.767)	1684.995(1299.073-2123.520)	3009.878(2323.357-3797.022)	4.759(3.644-5.969)	5.511(4.246-6.940)	5.167(3.989-6.519)	0.529(0.417-0.640)
South Asia	12268.897(10590.659-14021.597)	8308.496(7238.818-9570.220)	20577.394(18297.434-22728.535)	1.713(1.480-1.944)	1.124(0.981-1.291)	1.411(1.252-1.558)	0.978(0.803-1.153)
Central Latin America	5332.991(4675.780-6085.381)	5950.743(5189.109-6653.316)	11283.734(10097.965-12537.335)	4.651(4.083-5.304)	4.429(3.854-4.949)	4.540(4.061-5.043)	-0.046(-0.155-0.064)
North Africa and Middle East	12234.267(10779.512-13842.398)	7378.111(6324.555-8401.516)	19612.377(17208.565-22096.466)	5.486(4.793-6.187)	3.539(3.021-4.048)	4.525(3.969-5.078)	1.724(1.545-1.904)
Western Sub-Saharan Africa	1676.508(1395.317-1965.754)	1913.766(1484.949-2280.908)	3590.275(2986.038-4167.470)	1.829(1.550-2.127)	1.998(1.579-2.359)	1.918(1.616-2.220)	2.386(2.297-2.475)
Southern Sub-Saharan Africa	1613.367(1410.762-1826.595)	1617.846(1383.000-1823.990)	3231.213(2842.640-3577.165)	6.722(5.917-7.581)	5.023(4.289-5.659)	5.764(5.089-6.360)	1.372(1.072-1.673)
Central Sub-Saharan Africa	709.247(495.483-972.363)	499.242(311.877-756.154)	1208.489(840.155-1665.973)	2.888(2.010-3.956)	1.776(1.097-2.694)	2.268(1.567-3.170)	0.046(-0.193-0.286)
Eastern Sub-Saharan Africa	1548.454(1253.155-2033.930)	1720.481(1364.796-2206.780)	3268.935(2665.937-4173.788)	1.929(1.575-2.511)	2.059(1.640-2.599)	2.007(1.657-2.531)	0.549(0.455-0.642)

Li *et al. BMC Cancer*   (2025) 25:189
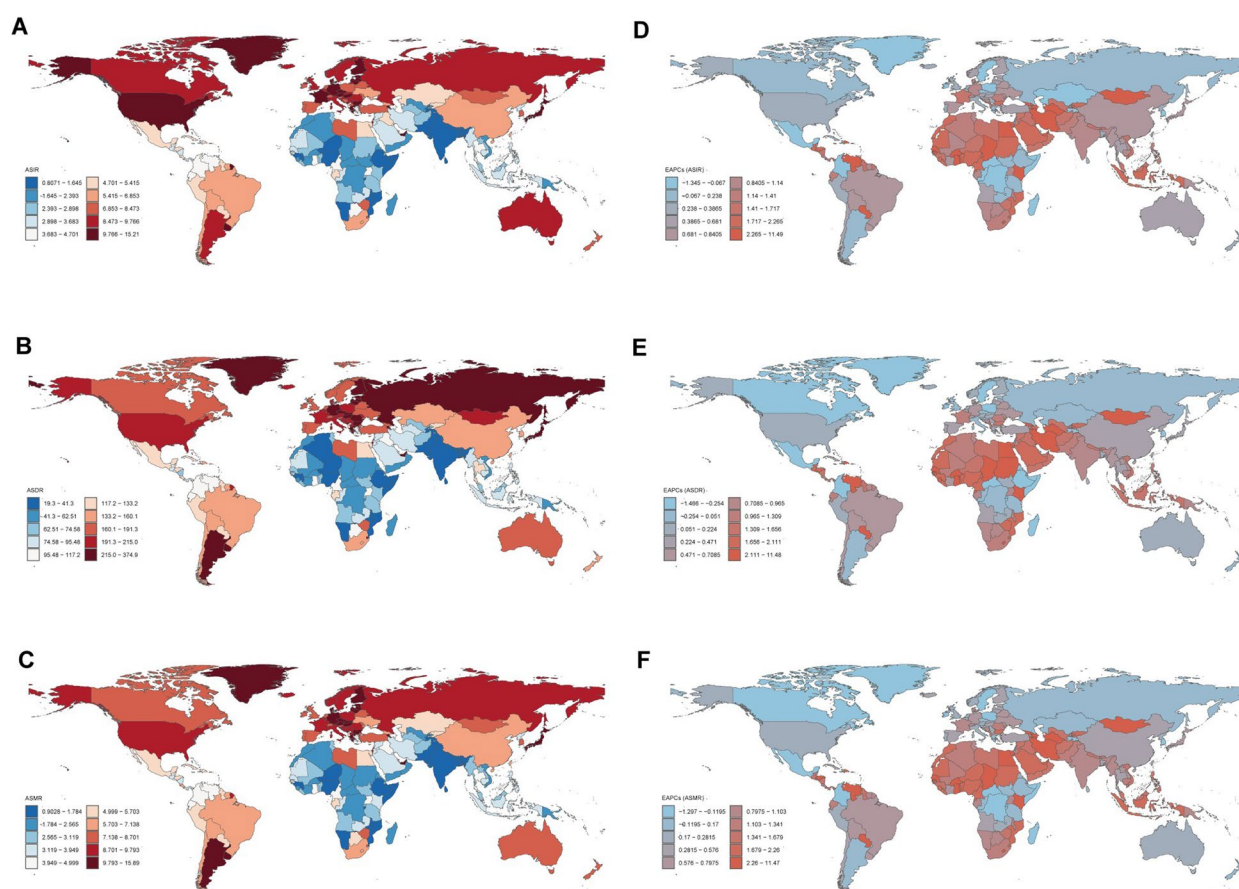
Page 7 of 26

Fig. 1 Global maps depicting the age-standardized incidence rate (ASIR), age-standardized DALYs rate (ASDR), and age-standardized mortality rate (ASMR) of pancreatic cancer in 2021. **A** ASIR per 100,000 population, **B** ASDR per 100,000 population, and **C** ASMR per 100,000 population. Panels **D-F** show the estimated annual percentage changes (EAPCs) for ASIR, ASDR, and ASMR respectively, from 1990 to 2021

change in DALYs at 1.460% (95% UI: 1.433−1.486). Significant increases in DALYs were observed in several regions. In 2021, the age-standardized DALY rate (ASDR) per 100,000 population varied significantly across regions. Central Europe had one of the highest rates at 227.268 (208.753–246.433), while Western Sub-Saharan Africa and South Asia had some of the lowest rates, at 48.348 (40.201−56.310) and 36.375 (32.289−40.204) respectively. From 1990 to 2021, Western Sub-Saharan Africa experienced the highest EAPC at 2.298%, with DALYs rising from 23,808 to 101,339. North Africa and the Middle East also saw a substantial increase, with an EAPC of 1.399% and DALYs growing from 133,125 to 506,970. Southeast Asia had an EAPC of 1.152%, with DALYs increasing from 165,074 to 597,956. Conversely, Central Latin America had a slight decrease in DALYs, with an EAPC of −0.078% and DALYs increasing from 95,747 to 289,852. Southern Latin America also showed a minimal decrease, with an EAPC of −0.022% and DALYs rising from 101,652 to 176,422 (Fig. 1E).

Table 3. summarizes the mortality rates between 1990 and 2021. Globally, the total number of deaths increased from approximately 211,613 (95% UI: 199,990−221,951) in 1990 to 505,752 (95% UI: 461,224–543,899) in 2021, with age-standardized mortality rates per 100,000 population rising from 5.655 (95% UI: 5.334−5.926) to 5.948 (95% UI: 5.396−6.405), and an EAPC of 0.208% (95% UI: 0.183−0.233). Significant increases in mortality rates were observed in low-middle SDI regions (EAPC: 1.553%, 95% UI: 1.520−1.586), with deaths rising from 8,671 to 32,553. In 2021, the regions with the most notable age-standardized mortality rates (ASMR) were Central Europe (9.275 per 100,000), and High-income Asia Pacific (9.563 per 100,000). Conversely, the regions with the lowest ASMRs were South Asia (1.512 per 100,000) and Western Sub-Saharan Africa (2.091 per 100,000) (Fig. 1C). Also, several regions exhibited significant trends in the mortality from 1990 to 2021 Western Sub-Saharan Africa experienced the highest EAPC at 2.393% (95% UI: 2.303−2.484), with deaths increasing from 901 to 3,774. Central Asia also saw a notable rise with an EAPC of 1.367% (95%

Li *et al. BMC Cancer* (2025) 25:189

Page 8 of 26

Table 2 DALY (disability adjusted life years) of pancreatic cancer between 1990 and 2021 at the global and regional level

	Number of cases, 1990			Age-standardised rate per 100 000 population, 1990		
	Male	Female	Total	Male	Female	Total
Global	2956334.160(2782367.355-3138634.894)	2254144.559(2113304.602-2406618.238)	5210478.719(4967404.872-5481660.623)	154.202(145.544-163.257)	105.708(98.831-112.855)	129.324(122.983-135.977)
Low SDI	48033.138(36565.743-58113.870)	36439.511(27083.290-45546.389)	84472.649(65503.286-101441.427)	38.591(29.563-46.705)	30.900(22.885-38.611)	34.822(27.010-41.702)
Low-middle SDI	141313.865(116957.837-165122.802)	100592.394(82778.038-120952.686)	241906.259(204321.914-283538.965)	41.855(34.801-48.793)	31.868(26.234-38.049)	36.991(31.336-43.210)
Middle SDI	553697.008(489591.582-629149.206)	391010.704(343744.442-441172.579)	944707.713(858505.533-1044034.033)	98.593(87.754-111.189)	70.533(62.266-79.445)	84.599(77.103-92.933)
High-middle SDI	1046955.179(967685.774-1131279.599)	736468.787(683516.204-794422.663)	1783423.966(1682491.745-1890335.335)	225.743(209.265-243.593)	130.546(120.999-140.943)	174.681(164.786-185.037)
High SDI	1162067.658(1134075.739-1188834.737)	986452.737(925176.428-1021797.971)	2148520.394(2062652.917-2203707.944)	243.451(237.255-249.125)	157.548(148.661-162.737)	197.128(189.388-202.046)
Central Europe	187514.711(180439.784-195431.754)	132402.222(126253.561-138114.186)	319916.933(307314.252-331300.854)	278.650(267.761-290.428)	155.030(147.852-161.906)	211.892(203.468-219.535)
Tropical Latin America	63046.341(61142.413-65096.229)	52061.604(49295.739-54619.144)	115107.945(110620.275-118750.078)	137.546(132.909-142.199)	105.003(98.892-110.370)	120.689(115.505-124.619)
East Asia	715002.553(577244.123-868465.999)	440641.122(352451.278-545118.263)	1155643.675(974049.973-1347640.701)	150.540(122.482-181.687)	94.540(75.903-116.809)	122.308(103.253-142.291)
South Asia	108875.645(84974.967-131820.815)	59564.748(43939.669-74165.827)	168440.393(132874.344-203392.609)	32.835(25.690-39.889)	20.372(14.961-25.289)	26.935(21.243-32.563)
High-income North America	361884.541(351687.500-369745.263)	330506.448(308010.260-343746.873)	692390.989(661106.889-710740.939)	243.058(236.066-248.558)	168.721(158.900-174.695)	202.854(194.361-207.976)
Eastern Sub-Saharan Africa	17855.720(13867.455-22432.891)	16900.581(12664.474-20815.251)	34756.301(26870.098-42510.175)	44.220(34.486-55.427)	42.445(31.651-51.982)	43.349(33.592-53.066)
Caribbean	16011.666(14992.980-17099.381)	13499.310(12209.380-14708.526)	29510.976(27572.041-31442.654)	125.985(118.069-134.582)	99.468(90.100-108.425)	112.403(105.011-119.685)
North Africa and Middle East	82107.847(68224.199-98543.888)	51016.656(38120.303-63553.450)	133124.503(109673.931-158604.805)	88.890(74.179-105.886)	58.995(44.205-72.811)	74.278(60.928-88.157)
High-income Asia Pacific	240327.810(231712.595-248533.571)	166717.764(155738.517-175244.898)	407045.574(391117.248-421297.820)	263.911(253.896-272.731)	145.914(136.266-153.293)	199.080(191.031-206.301)
Southeast Asia	90871.850(79625.997-103307.343)	74201.821(59609.297-89950.523)	165073.670(142221.427-189672.740)	67.598(59.367-76.821)	51.634(41.795-62.304)	59.315(51.059-68.037)
Western Sub-Saharan Africa	13411.085(11181.080-15808.979)	10397.129(8149.871-12423.949)	23808.214(20239.065-27490.039)	28.106(23.679-33.007)	23.348(18.334-27.872)	25.841(22.020-29.745)
Oceania	957.830(743.437-1279.088)	548.327(414.970-731.020)	1506.157(1174.256-1959.519)	58.103(45.840-77.529)	36.631(28.170-47.983)	47.839(37.933-61.417)

Li *et al. BMC Cancer*   (2025) 25:189

Page 9 of 26

Table 2 (continued)

	Number of cases, 1990			Age-standardised rate per 100 000 population, 1990		
	Male	Female	Total	Male	Female	Total
Central Latin America	46568.201(45406.876-47699.371)	49178.761(47455.076-50688.058)	95746.962(93525.209-97835.090)	108.999(106.159-111.535)	110.898(106.710-114.489)	110.063(107.260-112.701)
Central Asia	22510.710(19626.587-26685.874)	18240.632(15874.522-20921.437)	40751.342(35992.790-47069.092)	105.202(91.461-125.056)	64.969(56.442-74.719)	82.675(72.924-95.774)
Southern Latin America	53087.212(49560.684-57051.730)	48564.943(43987.240-53689.663)	101652.155(96226.286-107999.655)	251.035(234.761-269.729)	188.233(170.654-207.768)	217.818(206.065-231.181)
Eastern Europe	313857.795(298979.219-338968.313)	238909.348(224526.411-255053.467)	552767.143(526183.904-590425.481)	284.693(271.324-306.135)	134.567(126.574-143.657)	195.952(186.463-209.441)
Andean Latin America	11065.626(9220.820-13093.330)	12303.068(10027.787-14498.760)	23368.694(19361.296-27425.422)	106.143(88.695-125.965)	114.815(94.224-135.140)	110.786(92.104-130.153)
Australasia	21338.250(20197.099-22413.802)	17188.697(16024.545-18193.533)	38526.947(36829.078-40154.926)	198.757(188.066-208.626)	134.427(125.803-142.266)	164.738(157.338-171.523)
Southern Sub-Saharan Africa	15964.797(13437.903-20479.039)	12534.134(10733.559-14703.721)	28498.931(24725.139-34486.254)	122.895(103.398-159.338)	80.043(67.926-95.147)	99.654(85.593-122.156)
Central Sub-Saharan Africa	8385.653(6573.563-10372.231)	5740.528(4236.485-7725.973)	14126.181(11275.883-17396.018)	72.577(58.279-88.908)	45.008(33.715-60.128)	57.940(47.027-70.379)
Western Europe	565688.317(548061.136-587883.095)	503026.714(470030.094-524750.835)	1068715.031(1021579.375-1109466.991)	235.800(228.367-244.917)	152.335(143.552-158.545)	190.873(183.000-197.870)

Li *et al. BMC Cancer*   (2025) 25:189

Page 10 of 26

Table 2 (continued)

	Number of cases, 2021			Age-standardised rate per 100 000 population, 2021			Estimated annual percentage change, 1990-2021
	Male	Female	Total	Male	Female	Total	
Global	6462720.623(5913394.547-7710691.334)	4854242.728(4346324.142-5249520.881)	11316963.351(10464696.932-12169335.893)	157.115(143.867-172.290)	105.244(94.332-113.819)	130.331(120.517-140.126)	0.048(0.026-0.071)
Low SDI	120544.592(97570.048-151556.897)	103502.201(83024.632-125747.569)	224046.793(184706.531-272777.816)	44.350(36.311-55.023)	38.089(30.691-45.979)	41.207(34.186-49.788)	0.495(0.344-0.646)
Low-middle SDI	477968.973(438201.605-518899.494)	377299.025(342485.089-412433.936)	855267.998(792107.839-926182.857)	64.903(59.621-70.340)	49.001(44.422-53.406)	56.775(52.660-61.416)	1.460(1.433-1.486)
Middle SDI	1591441.223(1367128.920-1850414.594)	1093269.507(950621.076-1245134.285)	2684710.730(2362749.986-3027671.857)	118.450(101.987-137.447)	76.068(66.127-86.525)	96.614(85.177-108.883)	0.389(0.342-0.436)
High-middle SDI	2050154.901(1787608.034-2365086.669)	1436523.888(1266667.217-1629194.707)	3486678.789(3118892.692-3861181.040)	224.471(196.304-257.752)	133.088(117.164-150.947)	176.702(158.075-195.430)	0.002(-0.042-0.045)
High SDI	2215673.893(2098044.981-2329579.402)	1838110.409(1634565.654-1964802.083)	4053784.303(3742274.522-4283638.563)	240.124(227.786-252.354)	166.196(151.297-176.203)	202.039(188.274-212.614)	0.182(0.139-0.225)
Central Europe	267661.595(244674.460-290159.277)	213733.131(193951.849-231929.029)	481394.726(442737.839-521329.966)	286.508(262.007-310.858)	174.544(159.443-189.174)	227.268(208.753-246.433)	0.245(0.145-0.345)
Tropical Latin America	197209.316(186355.140-207880.904)	184766.559(170085.659-196267.261)	381975.875(361667.412-398097.273)	165.029(155.789-173.886)	130.188(119.846-138.316)	146.522(138.518-152.833)	0.656(0.612-0.700)
East Asia	1917348.834(1446575.129-2455176.375)	1115644.077(847702.510-1430871.836)	3032992.911(2404587.336-3684549.993)	179.402(136.599-227.316)	96.846(73.701-124.000)	137.206(109.157-166.027)	0.326(0.280-0.372)
South Asia	341568.171(293692.031-392578.008)	219620.320(190909.189-252833.105)	561188.492(496660.794-621786.406)	44.673(38.518-51.208)	28.299(24.587-32.616)	36.375(32.289-40.204)	0.821(0.648-0.994)
High-income North America	710816.305(679236.970-736015.524)	598422.493(547246.658-630964.873)	1309238.798(1232008.052-1359961.392)	241.237(230.878-249.824)	172.767(160.262-181.300)	205.407(194.745-212.769)	0.090(0.048-0.132)
Eastern Sub-Saharan Africa	46515.390(37277.796-61836.096)	48288.095(38106.042-63540.064)	94803.485(76368.314-123274.721)	51.387(41.544-67.467)	51.610(40.806-66.714)	51.692(41.975-66.275)	0.458(0.369-0.547)
Caribbean	37562.570(32566.847-42558.318)	30497.795(26456.950-34887.261)	68060.365(59618.840-77425.529)	147.292(127.780-166.844)	107.050(92.954-122.784)	126.504(110.702-144.057)	0.775(0.639-0.911)
North Africa and Middle East	320301.934(281749.943-362339.883)	186667.951(159315.638-213911.507)	506969.884(444632.794-573272.725)	130.346(115.164-147.182)	82.072(70.277-93.588)	106.741(93.756-120.316)	1.399(1.236-1.562)
High-income Asia Pacific	473830.511(438487.384-501939.620)	391112.260(318376.556-435216.566)	864942.771(760424.522-931628.754)	243.226(226.715-257.322)	155.076(132.992-168.432)	197.599(178.865-210.600)	0.092(0.018-0.165)
Southeast Asia	332772.199(281816.406-392262.808)	265183.829(213812.645-325557.858)	597956.028(515406.876-697938.088)	99.554(84.745-116.713)	73.144(59.361-89.517)	85.921(73.816-99.745)	1.152(1.089-1.215)

Li *et al. BMC Cancer*   (2025) 25:189

Page 11 of 26

Table 2 (continued)

	Number of cases, 2021			Age-standardised rate per 100 000 population, 2021			Estimated annual percentage change, 1990-2021
	Male	Female	Total	Male	Female	Total	
Western Sub-Saharan Africa	49305.504(40086.035-58535.524)	52033.378(40071.897-62601.767)	101338.882(83266.437-119898.553)	47.848(39.768-56.250)	48.775(38.277-58.197)	48.348(40.201-56.310)	2.298(2.213-2.384)
Oceania	2902.300(2250.241-3986.635)	1842.033(1485.961-2302.348)	4744.332(3789.140-6109.203)	68.444(53.224-93.643)	47.764(39.116-58.846)	58.560(47.492-74.750)	0.750(0.709-0.792)
Central Latin America	142030.199(124444.930-162214.925)	147822.269(129239.864-165827.664)	289852.468(260613.473-321737.168)	119.581(104.755-136.603)	108.177(94.637-121.321)	113.646(102.011-126.186)	-0.078(-0.182-0.026)
Central Asia	55744.177(48787.616-63473.969)	41560.965(36435.446-47070.091)	97305.143(85156.048-109802.620)	140.313(123.467-158.986)	87.967(77.258-99.313)	111.638(97.939-125.600)	1.099(0.900-1.298)
Southern Latin America	89869.605(83874.581-96471.950)	86552.341(79689.375-93952.284)	176421.947(165592.407-187883.754)	232.611(216.954-249.672)	180.605(166.386-195.384)	205.038(192.654-218.298)	-0.022(-0.142-0.099)
Eastern Europe	395963.419(354951.654-440964.346)	327832.453(295364.419-363444.656)	723795.872(666446.621-786751.566)	287.446(257.923-319.472)	154.806(139.137-172.038)	212.428(195.583-230.762)	0.031(-0.162-0.225)
Andean Latin America	34324.414(26124.954-43301.014)	40374.746(30830.311-51052.438)	74699.160(57561.543-93984.915)	119.151(90.691-150.271)	130.310(99.410-164.615)	125.209(96.378-157.378)	0.366(0.251-0.481)
Australasia	46921.970(43204.436-50588.101)	38141.223(32989.880-41925.804)	85063.192(78185.649-90378.639)	193.582(178.360-209.503)	138.329(122.141-150.953)	164.911(153.045-175.069)	0.152(0.072-0.232)
Southern Sub-Saharan Africa	47348.265(41144.946-54107.479)	42161.280(36349.875-47992.667)	89509.545(78897.067-99669.706)	176.750(154.613-200.516)	123.715(106.685-140.134)	147.281(129.758-162.994)	1.305(0.998-1.613)
Central Sub-Saharan Africa	21847.329(15089.927-30266.906)	14261.793(8764.289-22125.739)	36109.122(24941.022-50577.553)	76.144(53.141-105.207)	45.298(27.893-69.524)	59.434(41.040-83.015)	0.011(-0.224-0.246)
Western Europe	930876.614(877888.805-984756.376)	807723.739(715844.255-875669.811)	1738600.354(1598781.054-1842151.609)	235.316(223.341-248.408)	165.945(150.762-177.808)	199.419(185.678-210.225)	0.333(0.270-0.396)

Li *et al. BMC Cancer*   (2025) 25:189

Page 12 of 26

Table 3 Mortality of pancreatic cancer between 1990 and 2021 at the global and regional level

	Number of cases, 1990			Age-standardised rate per 100 000 population, 1990		
	Male	Female	Total	Male	Female	Total
Global	111022.999(105146.923-117266.506)	100589.702(93631.353-106565.087)	211612.701(199990.312-221950.988)	6.480(6.125-6.821)	4.898(4.524-5.193)	5.655(5.334-5.926)
Low SDI	1698.074(1300.806-2054.484)	1331.014(986.257-1658.337)	3029.088(2350.753-3633.538)	1.543(1.196-1.857)	1.278(0.939-1.577)	1.412(1.102-1.695)
Low-middle SDI	4923.551(4101.968-5737.607)	3747.947(3069.086-4459.307)	8671.498(7355.252-10120.725)	1.642(1.374-1.904)	1.342(1.101-1.587)	1.496(1.273-1.740)
Middle SDI	18732.408(16675.685-21095.216)	14851.344(13148.201-16671.445)	33583.752(30682.505-36872.087)	3.871(3.489-4.306)	2.976(2.646-3.329)	3.415(3.140-3.721)
High-middle SDI	37384.545(34751.187-40200.992)	31457.989(29352.321-33734.163)	68842.535(65128.295-72746.181)	8.929(8.328-9.580)	5.646(5.242-6.068)	7.093(6.687-7.505)
High SDI	48121.357(46705.174-49418.648)	49058.112(45080.849-51302.245)	97179.469(91895.640-100353.417)	10.465(10.124-10.752)	7.304(6.746-7.624)	8.700(8.221-8.978)
Central Asia	751.497(653.048-893.007)	721.880(621.586-841.594)	1473.378(1295.106-1715.703)	3.922(3.403-4.701)	2.611(2.244-3.051)	3.165(2.768-3.709)
High-income Asia Pacific	9694.645(9340.555-10009.121)	7894.758(7219.988-8359.266)	17589.403(16680.576-18265.518)	11.614(11.151-11.997)	6.906(6.291-7.319)	8.927(8.413-9.286)
Western Europe	24085.677(23243.238-25045.711)	26188.924(23940.536-27533.528)	50274.601(47367.202-52445.746)	10.178(9.797-10.577)	7.194(6.637-7.530)	8.522(8.048-8.877)
Caribbean	675.889(632.839-719.203)	606.583(551.657-656.661)	1282.473(1205.030-1361.883)	5.565(5.214-5.915)	4.611(4.189-4.986)	5.075(4.767-5.382)
North Africa and Middle East	2928.102(2445.648-3485.670)	1940.148(1451.514-2380.533)	4868.251(3971.866-5751.335)	3.606(2.989-4.256)	2.559(1.897-3.138)	3.093(2.502-3.636)
East Asia	23663.463(19229.186-28656.672)	16451.098(13375.193-20307.669)	40114.561(33980.725-46655.876)	5.863(4.871-6.981)	3.862(3.136-4.753)	4.793(4.087-5.563)
Central Sub-Saharan Africa	289.319(230.721-354.726)	204.099(151.999-275.146)	493.418(397.765-603.222)	2.904(2.353-3.584)	1.887(1.421-2.476)	2.365(1.928-2.850)
Eastern Europe	10575.216(10085.297-11351.748)	10090.868(9519.298-10738.390)	20666.083(19658.383-21939.013)	10.510(10.025-11.236)	5.470(5.159-5.826)	7.372(7.004-7.829)
High-income North America	15387.169(14843.830-15769.440)	16466.703(14858.352-17327.662)	31853.872(29802.585-32996.706)	10.430(10.033-10.713)	7.693(7.035-8.060)	8.908(8.366-9.216)
Western Sub-Saharan Africa	490.129(414.119-575.933)	411.164(324.714-492.512)	901.293(772.172-1036.523)	1.177(1.004-1.370)	1.003(0.794-1.201)	1.090(0.934-1.247)
Central Europe	6960.977(6685.671-7227.743)	5880.116(5557.147-6142.751)	12841.094(12286.523-13313.665)	10.959(10.514-11.375)	6.814(6.428-7.123)	8.658(8.277-8.992)
Australasia	905.753(861.249-947.827)	841.244(773.563-892.816)	1746.997(1660.716-1822.529)	8.823(8.377-9.234)	6.248(5.764-6.641)	7.410(7.026-7.746)
Oceania	33.267(26.205-44.172)	19.398(14.908-25.373)	52.665(41.651-67.464)	2.381(1.910-3.160)	1.596(1.244-2.068)	2.008(1.619-2.546)
Tropical Latin America	2297.289(2219.268-2373.254)	2119.882(1977.041-2233.243)	4417.171(4210.321-4567.477)	5.653(5.418-5.857)	4.685(4.326-4.951)	5.152(4.855-5.346)
Southeast Asia	3052.914(2684.250-3475.564)	2737.677(2228.495-3296.312)	5790.591(4994.875-6651.304)	2.598(2.294-2.940)	2.123(1.743-2.545)	2.350(2.034-2.697)
Central Latin America	1739.532(1692.575-1781.256)	1982.757(1900.485-2052.696)	3722.289(3610.691-3818.467)	4.527(4.391-4.638)	4.918(4.701-5.107)	4.736(4.578-4.871)
Eastern Sub-Saharan Africa	632.277(493.646-792.020)	617.724(458.121-759.731)	1250.001(969.011-1525.224)	1.773(1.400-2.209)	1.789(1.320-2.228)	1.783(1.387-2.183)
South Asia	3764.340(2948.119-4578.308)	2159.457(1585.060-2672.645)	5923.798(4666.459-7178.729)	1.281(1.002-1.562)	0.837(0.612-1.034)	1.070(0.839-1.295)
Southern Sub-Saharan Africa	547.328(460.605-711.040)	508.989(427.441-617.541)	1056.317(902.629-1308.296)	4.850(4.068-6.309)	3.526(2.935-4.303)	4.121(3.506-5.158)
Andean Latin America	420.672(355.614-498.375)	509.797(424.003-602.931)	930.468(784.077-1096.188)	4.404(3.744-5.211)	5.097(4.259-6.031)	4.777(4.045-5.634)
Southern Latin America	2127.543(1999.090-2291.102)	2236.437(2003.522-2501.193)	4363.979(4096.580-4641.246)	10.625(10.004-11.431)	8.653(7.759-9.650)	9.579(8.993-10.195)

Li *et al. BMC Cancer*   (2025) 25:189

Page 13 of 26

Table 3 (continued)

	Number of cases, 2021			Age-standardised rate per 100 000 population, 2021			Estimated annual percentage change, 1990-2021
	Male	Female	Total	Male	Female	Total	
Global	270037.420(247469.936-295172.854)	235714.744(206198.632-256636.844)	505752.164(461224.424-543899.407)	6.934(6.354-7.548)	5.058(4.430-5.506)	5.948(5.396-6.405)	0.208(0.183-0.233)
Low SDI	4272.387(3511.944-5266.203)	3926.233(3162.572-4728.299)	8198.619(6799.644-9862.419)	1.809(1.505-2.208)	1.644(1.323-1.980)	1.726(1.446-2.071)	0.637(0.481-0.794)
Low-middle SDI	17514.024(16116.236-18930.306)	15039.083(13636.445-16345.645)	32553.107(30234.771-35163.497)	2.614(2.417-2.819)	2.100(1.898-2.276)	2.349(2.175-2.534)	1.553(1.520-1.586)
Middle SDI	60403.531(52205.184-69895.327)	46362.955(40174.610-52675.943)	106766.486(94341.660-119905.939)	4.856(4.202-5.599)	3.340(2.887-3.790)	4.056(3.595-4.544)	0.521(0.483-0.560)
High-middle SDI	82660.506(72735.441-94545.272)	68419.393(59511.428-76996.862)	151079.899(135113.165-166837.215)	9.372(8.267-10.666)	6.101(5.326-6.870)	7.606(6.800-8.395)	0.235(0.197-0.272)
High SDI	104897.378(97804.370-110527.721)	101695.825(86452.685-110699.832)	206593.203(184625.822-220561.548)	10.854(10.147-11.426)	8.031(7.026-8.652)	9.375(8.515-9.957)	0.347(0.307-0.386)
Central Asia	1950.831(1715.605-2203.801)	1645.214(1454.971-1854.392)	3596.046(3169.472-4041.135)	5.601(4.959-6.263)	3.719(3.289-4.190)	4.533(4.009-5.075)	1.367(1.169-1.567)
High-income Asia Pacific	24760.323(22608.871-26242.074)	24855.536(19164.436-28319.647)	49615.859(41694.497-54352.818)	11.483(10.567-12.159)	7.840(6.385-8.705)	9.563(8.336-10.338)	0.352(0.264-0.441)
Western Europe	45346.447(41815.375-48136.138)	46019.126(39200.878-50681.053)	91365.573(81860.901-97826.132)	10.616(9.867-11.237)	8.022(7.058-8.738)	9.256(8.429-9.844)	0.455(0.398-0.511)
Caribbean	1518.148(1327.157-1712.056)	1401.750(1217.594-1605.012)	2919.898(2574.884-3301.666)	6.055(5.297-6.833)	4.797(4.167-5.493)	5.404(4.761-6.109)	0.659(0.503-0.816)
North Africa and Middle East	12089.839(10670.418-13666.745)	7695.409(6598.545-8759.410)	19785.247(17372.736-22240.459)	5.562(4.907-6.284)	3.795(3.239-4.348)	4.689(4.115-5.257)	1.628(1.447-1.810)
East Asia	74575.744(56743.916-94783.680)	49243.709(37601.245-62408.237)	123819.453(99918.406-149380.502)	7.360(5.676-9.222)	4.285(3.275-5.424)	5.715(4.634-6.866)	0.529(0.468-0.590)
Central Sub-Saharan Africa	725.470(507.382-999.560)	523.081(322.827-799.835)	1248.552(862.735-1745.513)	3.124(2.163-4.360)	1.937(1.184-3.001)	2.455(1.683-3.487)	0.049(-0.191-0.288)
Eastern Europe	14770.478(13257.571-16441.885)	15347.146(13842.775-16938.831)	30117.624(27830.825-32639.721)	11.022(9.893-12.242)	6.716(6.064-7.434)	8.523(7.877-9.230)	0.324(0.127-0.522)
High-income North America	32430.004(30437.232-33724.760)	30608.468(26967.592-32730.216)	63038.471(57497.465-66152.873)	10.709(10.056-11.134)	8.086(7.230-8.597)	9.318(8.564-9.753)	0.200(0.160-0.240)
Western Sub-Saharan Africa	1746.039(1461.983-2046.952)	2027.989(1597.763-2413.467)	3774.028(3151.455-4388.059)	1.979(1.681-2.301)	2.190(1.751-2.578)	2.091(1.766-2.422)	2.393(2.303-2.484)
Central Europe	11258.370(10313.598-12170.960)	10719.174(9730.140-11630.351)	21977.543(20086.484-23742.998)	11.859(10.870-12.834)	7.925(7.213-8.594)	9.725(8.912-10.518)	0.389(0.310-0.468)
Australasia	2287.207(2080.852-2476.496)	2040.173(1693.401-2284.839)	4327.381(3860.618-4637.696)	8.919(8.149-9.640)	6.658(5.638-7.386)	7.727(6.972-8.238)	0.262(0.181-0.343)
Oceania	101.731(78.992-138.946)	66.058(54.070-81.339)	167.789(136.102-214.145)	2.815(2.198-3.868)	2.069(1.706-2.537)	2.461(2.004-3.116)	0.766(0.723-0.809)
Tropical Latin America	7788.660(7318.561-8239.079)	8168.796(7381.684-8756.677)	15957.455(14734.411-16749.306)	6.870(6.436-7.271)	5.745(5.195-6.157)	6.272(5.764-6.594)	0.713(0.662-0.764)

Li *et al. BMC Cancer*   (2025) 25:189

Page 14 of 26

Table 3 (continued)

	Number of cases, 2021			Age-standardised rate per 100 000 population, 2021			Estimated annual percentage change, 1990-2021
	Male	Female	Total	Male	Female	Total	
Southeast Asia	11792.489(10059.579-13806.526)	10621.127(8587.771-12883.857)	22413.615(19334.724-26000.565)	3.950(3.383-4.591)	3.144(2.542-3.785)	3.530(3.043-4.101)	1.274(1.215-1.334)
Central Latin America	5588.722(4896.589-6367.104)	6329.451(5532.945-7070.368)	11918.173(10667.349-13218.597)	4.931(4.330-5.606)	4.734(4.137-5.287)	4.835(4.327-5.360)	-0.110(-0.218-0.002)
Eastern Sub-Saharan Africa	1598.354(1292.381-2097.481)	1818.206(1441.951-2337.707)	3416.559(2782.994-4358.427)	2.074(1.698-2.699)	2.252(1.798-2.845)	2.180(1.798-2.746)	0.563(0.470-0.657)
South Asia	12803.520(11055.469-14590.921)	8789.444(7651.646-10114.346)	21592.963(19209.465-23811.318)	1.834(1.583-2.076)	1.210(1.054-1.391)	1.512(1.346-1.670)	0.986(0.815-1.157)
Southern Sub-Saharan Africa	1659.656(1453.650-1880.500)	1726.403(1475.150-1941.068)	3386.059(2979.880-3744.424)	7.203(6.357-8.122)	5.476(4.683-6.165)	6.224(5.491-6.858)	1.355(1.052-1.658)
Andean Latin America	1401.842(1072.883-1756.643)	1814.476(1396.480-2271.045)	3216.318(2487.252-4027.177)	5.089(3.896-6.367)	5.952(4.578-7.443)	5.559(4.299-6.967)	0.486(0.375-0.597)
Southern Latin America	3843.548(3596.168-4121.338)	4254.008(3817.568-4666.552)	8097.556(7453.471-8633.199)	10.064(9.397-10.790)	8.300(7.516-9.061)	9.128(8.419-9.722)	0.063(-0.059-0.185)

Li *et al. BMC Cancer*   (2025) 25:189

Page 15 of 26

UI: 1.169–1.567), and deaths increasing from 1,473 to 3,596. Southeast Asia reported an EAPC of 1.274% (95% UI: 1.215–1.334), with deaths rising from 5,791 to 22,414. In contrast, Central Latin America had a slight decrease in EAPC at −0.110% (95% UI: −0.218 to −0.002), with deaths increasing from 3,722 to 11,918 (Fig. 1F).

Trends in age-standardized incidence, DALY and mortality rates

First, we analyzed trends in ASIR (Fig. 2A), ASDR (Fig. 2B), and ASMR (Fig. 2C) per 100,000 population from 1990 to 2021, categorized by sex and five different SDI levels. Overall, high SDI regions consistently show the highest rates across all metrics, while low SDI regions exhibit the lowest rates. Males generally have higher rates than females. There are slight increasing trends globally for ASIR and ASMR, whereas ASDR shows a slight decrease and stabilization. To provide a more intuitive understanding of the trend changes, we also presented the Estimated Annual Percentage Change (EAPC) in age-standardized incidence, DALYs, and mortality rates for pancreatic cancer from 1990 to 2021, stratified different SDI levels (Supplementary Table 1). We have also added a visualisation of separate maps for the ASIR, ASDR, and ASMR for 1990, 2000, and 2010 to better illustrate the temporal trends (Supplementary Fig. 1).

We also displayed trends for males and females across 21 GBD regions. Figure 3A shows that high-income Asia Pacific, North America, and Central Europe have the highest ASIR, with males consistently exhibiting higher
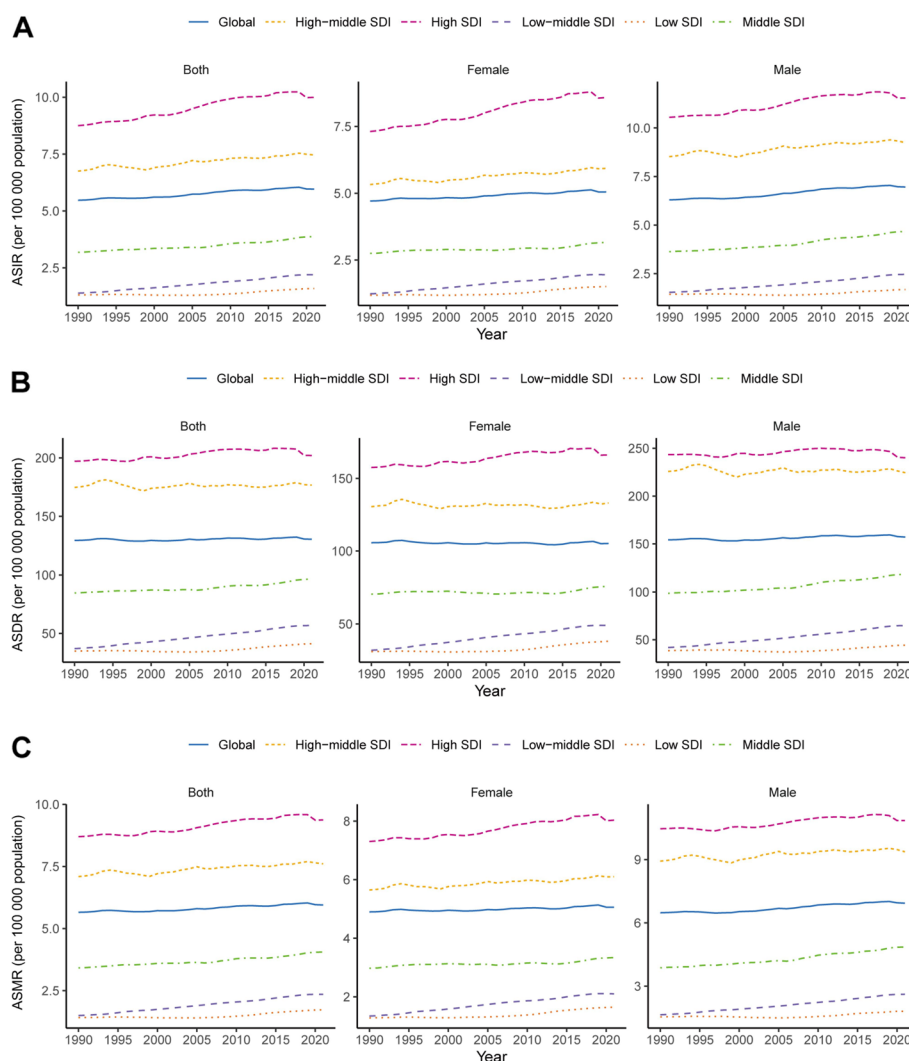
Fig. 2 Trends in the age-standardized incidence rate (ASIR), age-standardized DALYs rate (ASDR), and age-standardized mortality rate (ASMR) of pancreatic cancer from 1990 to 2021, stratified by sex and socio-demographic index (SDI). **A** ASIR per 100,000 population, **B** ASDR per 100,000 population, and **C** ASMR per 100,000 population. Each panel shows trends for both sexes combined, females, and males across different SDI levels: high, high-middle, middle, low-middle, and low
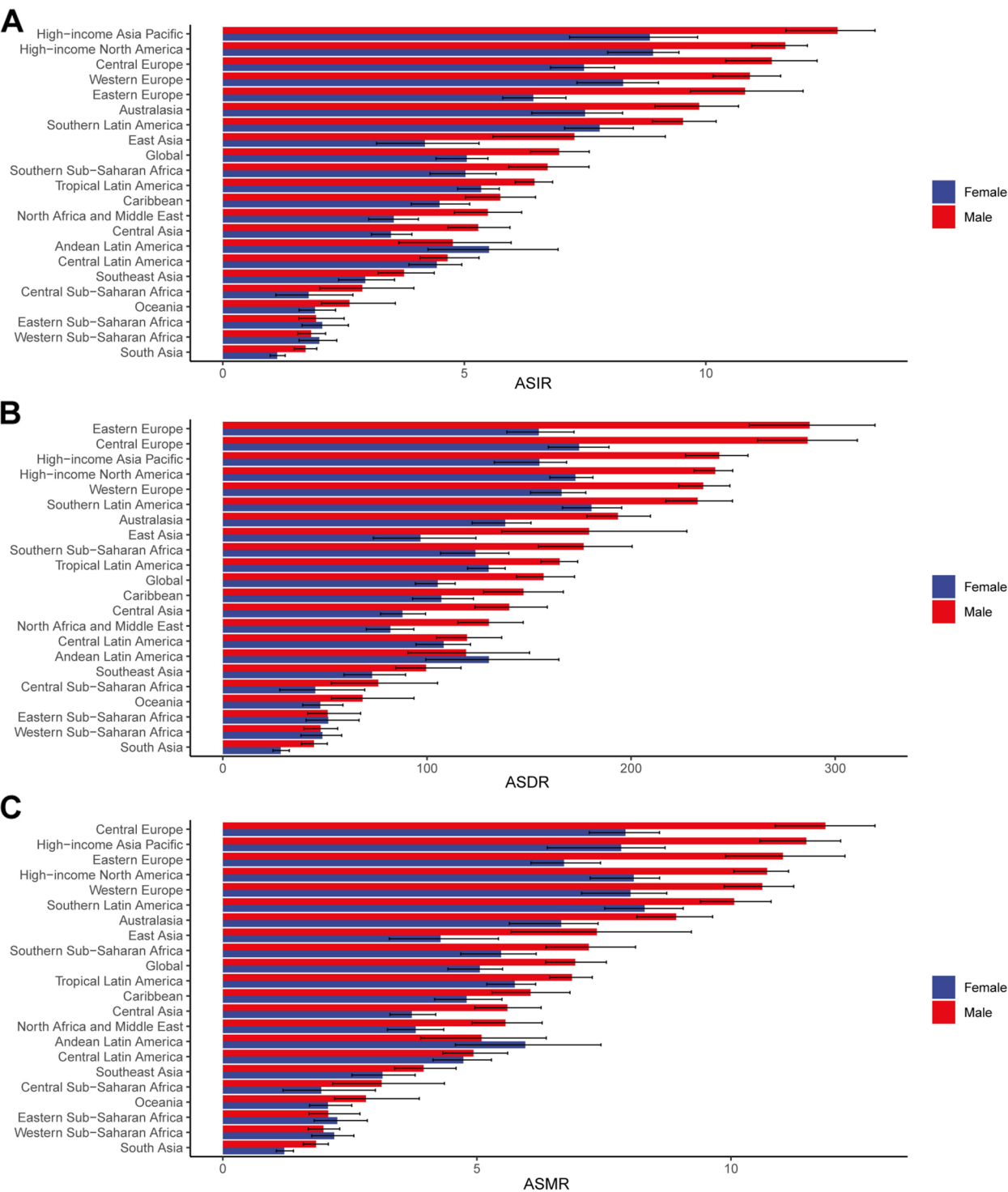
Fig. 3 Age-standardized incidence rate (ASIR), age-standardized DALYs rate (ASDR), and age-standardized mortality rate (ASMR) of pancreatic cancer by region and sex in 2021. **A** ASIR per 100,000 population, **B** ASDR per 100,000 population, and **C** ASMR per 100,000 population. Bars represent regional data with blue indicating females and red indicating males

Li *et al. BMC Cancer*   (2025) 25:189

Page 17 of 26

rates than females across all regions. Figure 3B indicates that Eastern Europe and Central Europe have the highest ASDR, again with males showing higher rates than females. Figure 3C reveals that Central Europe, high-income Asia Pacific, and Eastern Europe have the highest ASMR, with males surpassing females in all regions.

Then, the temporal trends and regional disparities in ASIR, ASDR, and ASMR for the years 1990, 2000, 2010, and 2021 across 21 GBD regions was analyzed. Figure 4A shows that ASIR has generally increased over time in most regions, with high-income Asia Pacific and North America consistently having the highest rates. Figure 4B indicates that ASDR has decreased in many regions, particularly in high-income areas, but remains high in Eastern Europe and Central Asia. Figure 4C reveals that High-income Asia Pacific and Central Europe show notable decreases in ASMR, though they still remain among the highest in 2021. Central Europe and Central Asia exhibit high ASMR, with a more gradual decrease compared to high-income regions.

Age and sex-specific trends in pancreatic cancer incidence, DALYs, and mortality

We present age-specific and sex-specific trends in the incidence, DALYs, and mortality of pancreatic cancer in 1990 (Supplementary Fig. 2A, C,E), 2000 (Supplementary Fig. 2B, D,F), and 2021 (Fig. 5). Figure 5A shows that the incidence numbers and rates per 100,000 population increase with age, peaking in the 65–69 years age group for both males and females. Figure 5B indicates that DALYs also rise with age, reaching a peak in the 65–69 years age group, with males exhibiting slightly higher DALYs than females across most age groups. Figure 5C presents the death numbers, which increase with age and peak in the 70–74 years age group, with males generally showing higher mortality rates compared to females.

SDI-related differences in pancreatic cancer burden

Overall, we reveal a positive correlation between SDI and ASR for pancreatic cancer across 21 various global regions between 1990 and 2021. Figure 6A shows that higher SDI levels correspond to increased ASIR. Figure 6B indicates a similar trend for ASDR. Figure 6C reveals that ASMR also rise with increasing SDI. We also revealed the positive relationship between the SDI and age-standardized rates across the 204 countries and territories (Supplementary Fig. 3A-C). Overall, regions with higher SDI experience greater incidence, DALYs, and mortality rates for pancreatic cancer.

Proportion of deaths and DALYs attributable to risk factors

The global and regional proportions of DALYs and deaths attributable to three major risk factors: high body-mass index, high fasting plasma glucose, and tobacco use were analyzed. High fasting plasma glucose has the highest impact on DALYs and deaths, particularly in North America and Central Latin America. High body-mass index significantly affects North America and North African and Middle East, while tobacco use is most burdensome in Central Europe and East Asia (Fig. 7A and B). Age-wise, the proportion of DALYs and deaths attributable to high BMI increases with age, peaking in the 60–64 age group. High fasting plasma glucose shows a similar age-related trend, with higher proportions in older age groups aged 70–90 years. The impact of tobacco on both DALYs and deaths is also significant particularly among individuals aged 40–60 years (Fig. 7C and D).

Prediction of pancreatic cancer-related burden globally in the next 29 years

We further provided the projected trends for ASIR, ASDR, and ASMR from 1990 to 2050, with observed data up to 2021 and forecasts beyond that point. Post-2021 projections indicate a gradual decline in ASIR, suggesting that the mortality rate is expected to decrease over time. By 2050, the ASIR is projected to drop to 5.618 per 100,000 population (Fig. 8A). The ASDR, having remained stable from 1990 (127.336 per 100,000 population) to 2021 (130.604 per 100,000 population), is expected to steadily decrease to 116.357 per 100,000 population by 2050 (Fig. 8B). From 1990 to 2021, the ASMR has shown a steady increase, peaking around 2019 (8.703 per 100,000 population). The projections suggest a decline in ASMR post-2021, with the rate expected to decrease progressively until 2050 (7.284 per 100,000 population) (Fig. 8C).

Discussion

The findings of our study revealed significant variations in incidence, DALYs, and mortality of pancreatic cancer across 204 countries and territories, highlighting the need for targeted identification of at-risk populations. Addressing the limitation and outdated results of previous studies [4, 19, 20], we provide up-to-date statistics on a comprehensive range of health metrics, illustrating trends from 1990 to 2021. We revealed that (1) the global incidence of pancreatic cancer significantly increased from 1990 to 2021, with the number of cases rising from approximately 207,905 to 508,533 and the age-standardized rate (ASR) increasing from 5.47 to 5.96 per 100,000 population; (2) regions with lower SDI, such as low-middle and low SDI regions, exhibited the most notable increases in ASR, with annual percentage changes of 1.57% and 0.61%, respectively; (3) males experienced higher ASRs of incidence, mortality, and DALYs compared to females, with the number of cases
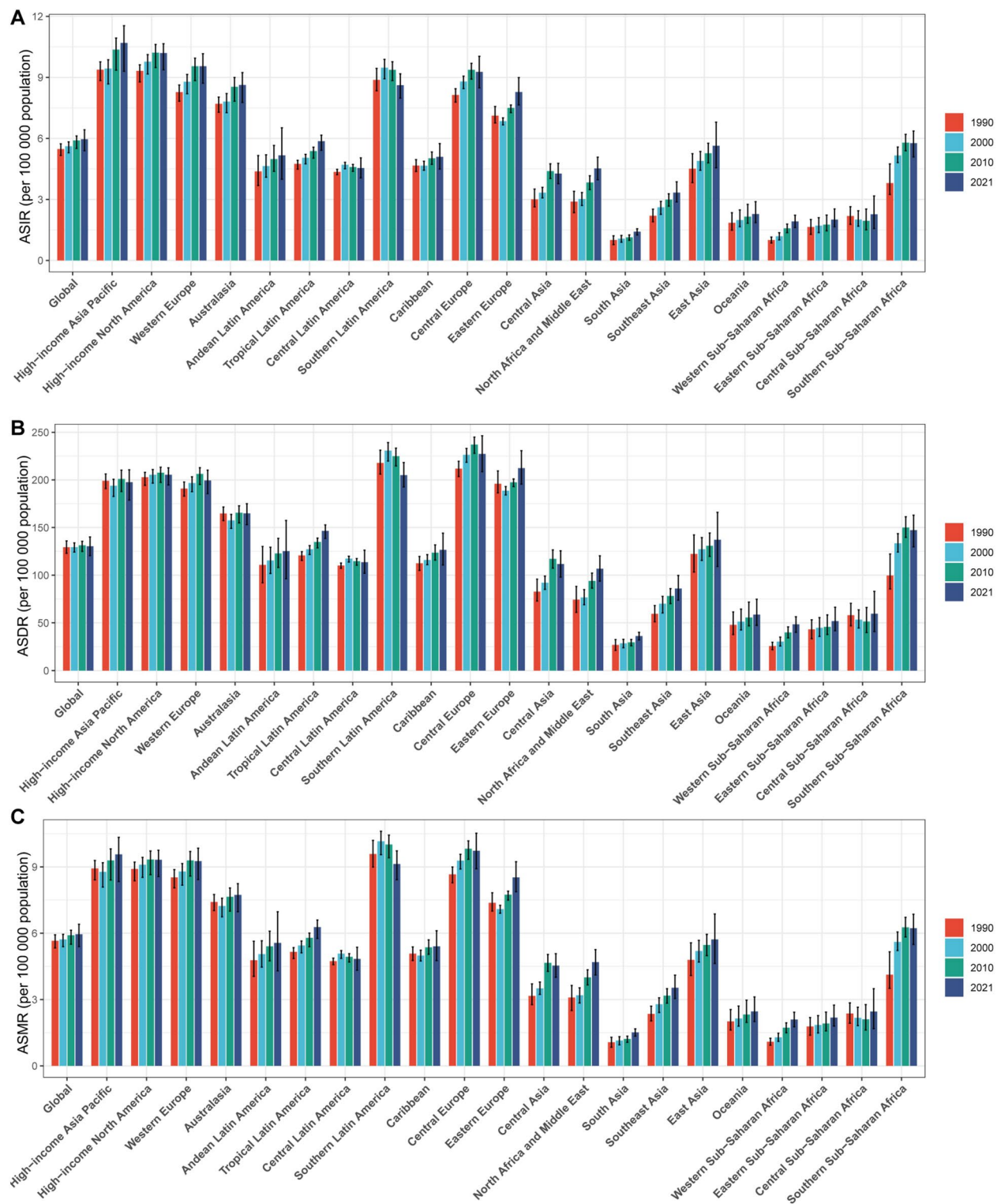
Li *et al. BMC Cancer* (2025) 25:189

Page 18 of 26

Fig. 4 Temporal trends in the age-standardized incidence rate (ASIR), age-standardized DALYs rate (ASDR), and age-standardized mortality rate (ASMR) of pancreatic cancer from 1990 to 2021 by region. **A** ASIR per 100,000 population, **B** ASDR per 100,000 population, and **C** ASMR per 100,000 population. Regions are grouped and color-coded for the years 1990, 2000, 2010, and 2021
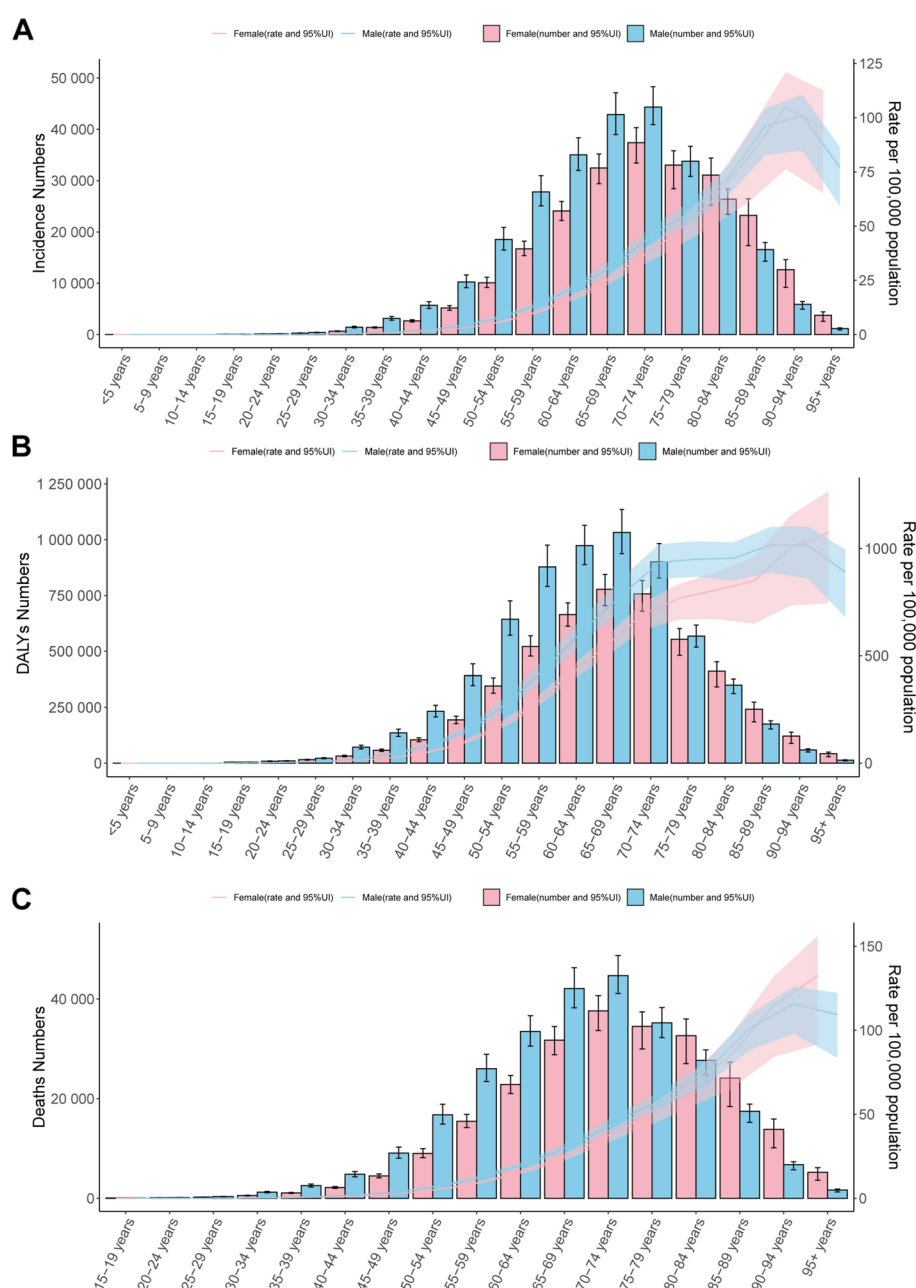
Fig. 5 Incidence, disability-adjusted life years (DALYs), and death numbers of pancreatic cancer by age and sex in 2021 from all countries. **A** Incidence numbers, **B** DALYs numbers, and **C** Deaths numbers. Pink bars represent female data, blue bars represent male data, and lines with shaded areas show the rates per 100,000 population with 95% uncertainty intervals (UI)

for males increasing from 110,396 to 273,617, and for females from 97,510 to 234,916; (4) significant regional trends were observed, with East Asia experiencing the most dramatic rise in incidence (EAPC 0.707%), followed by Southern Sub-Saharan Africa (EAPC 1.372%) and Central Asia (EAPC 1.332%), whereas Central Latin America saw a slight decrease (EAPC −0.046%); (5) the global burden in terms of DALYs also increased, with total DALYs rising from 5.21 million to 11.32 million, and regions like Western Sub-Saharan Africa and North Africa showing the highest increases in EAPC for DALYs at 2.298% and 1.399%, respectively; (6) the total number of deaths increased globally from 211,613 to 505,752, with notable increases in low-middle SDI regions (EAPC 1.553%); (7) trend analysis showed that high SDI regions consistently had the highest ASRs, while low SDI regions
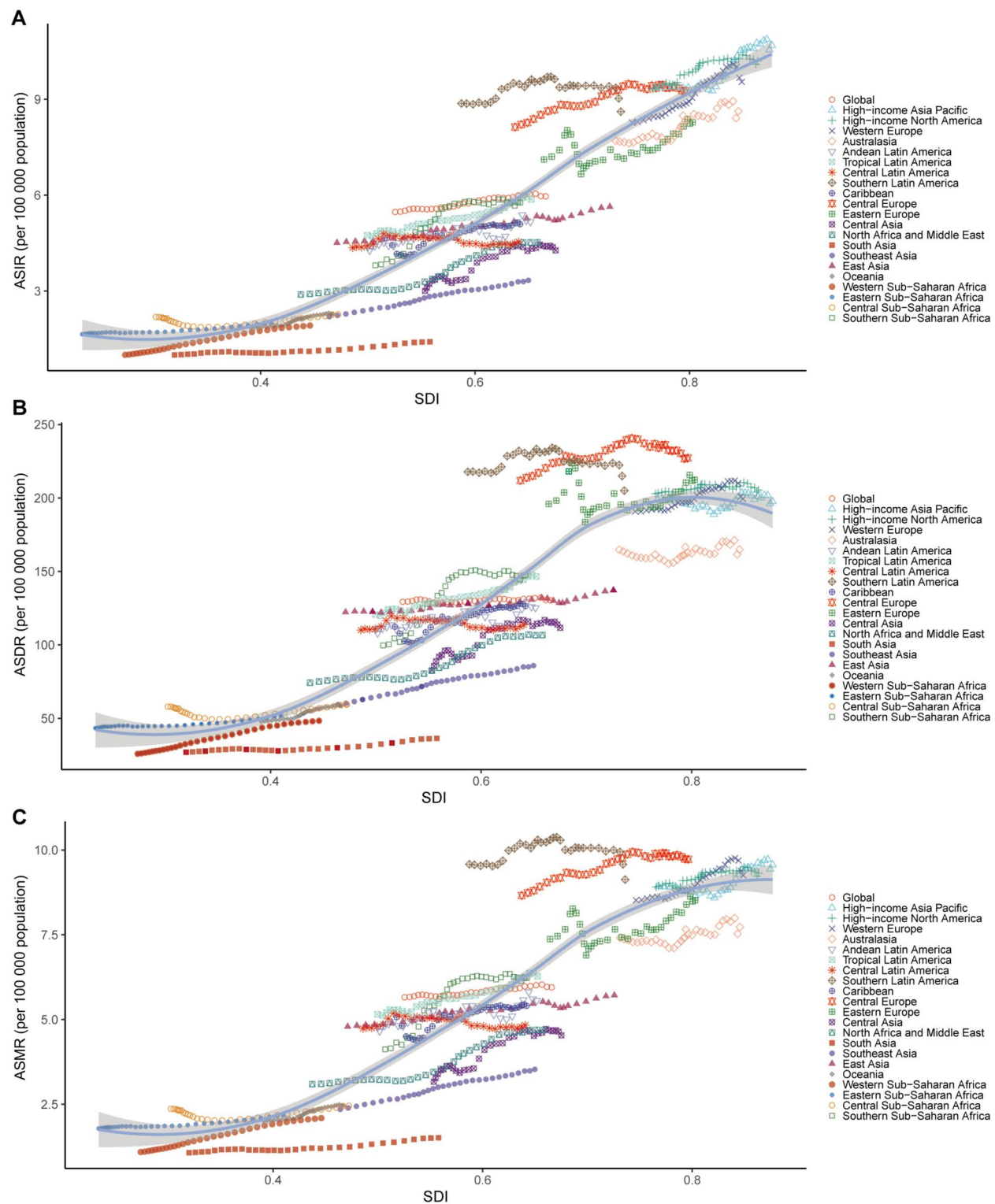
Fig. 6 Relationship between the socio-demographic index (SDI) and pancreatic cancer burden in terms of (**A**) age-standardized incidence rate (ASIR), **B** age-standardized DALYs rate (ASDR), and **C** age-standardized mortality rate (ASMR) in 2021. Each point represents a region, with trends illustrating the correlation between SDI and the respective rates. The fitted curves were generated using a locally weighted smoothing (LOESS) method, which provides a flexible, non-parametric approach to visualize trends without assuming a specific functional form. The shaded bands around the curves represent the 95% confidence intervals, indicating the uncertainty in the estimated relationships

Li *et al. BMC Cancer*   (2025) 25:189

Page 21 of 26
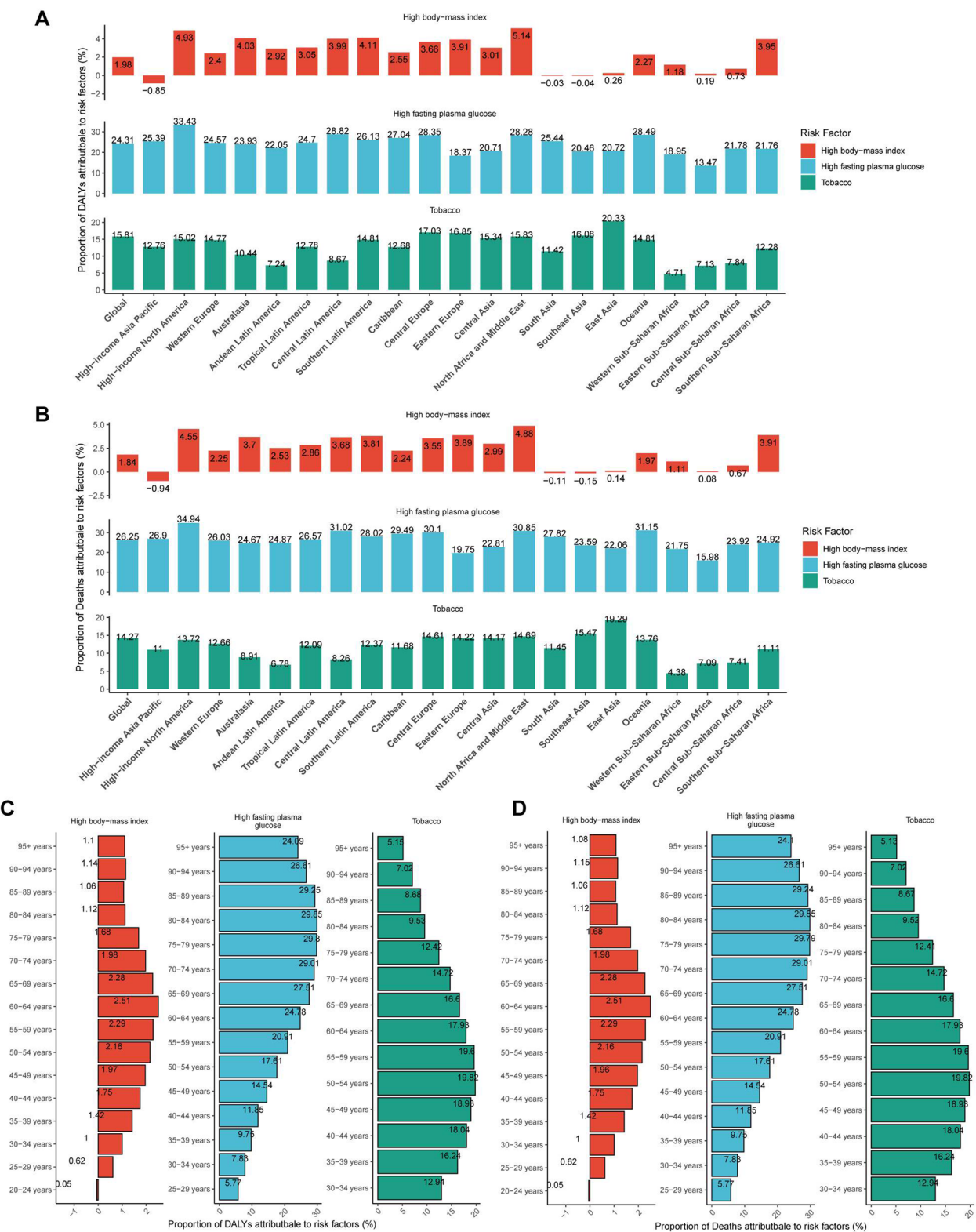
Fig. 7 Proportion of DALYs and deaths attributable to key risk factors for pancreatic cancer in 2021. **A** Proportion of DALYs and **B** proportion of deaths attributable to high body-mass index, high fasting plasma glucose, and tobacco use by region. **C**, **D** Age-specific proportion of DALYs and deaths attributable to these risk factors

Li *et al. BMC Cancer* (2025) 25:189

Page 22 of 26
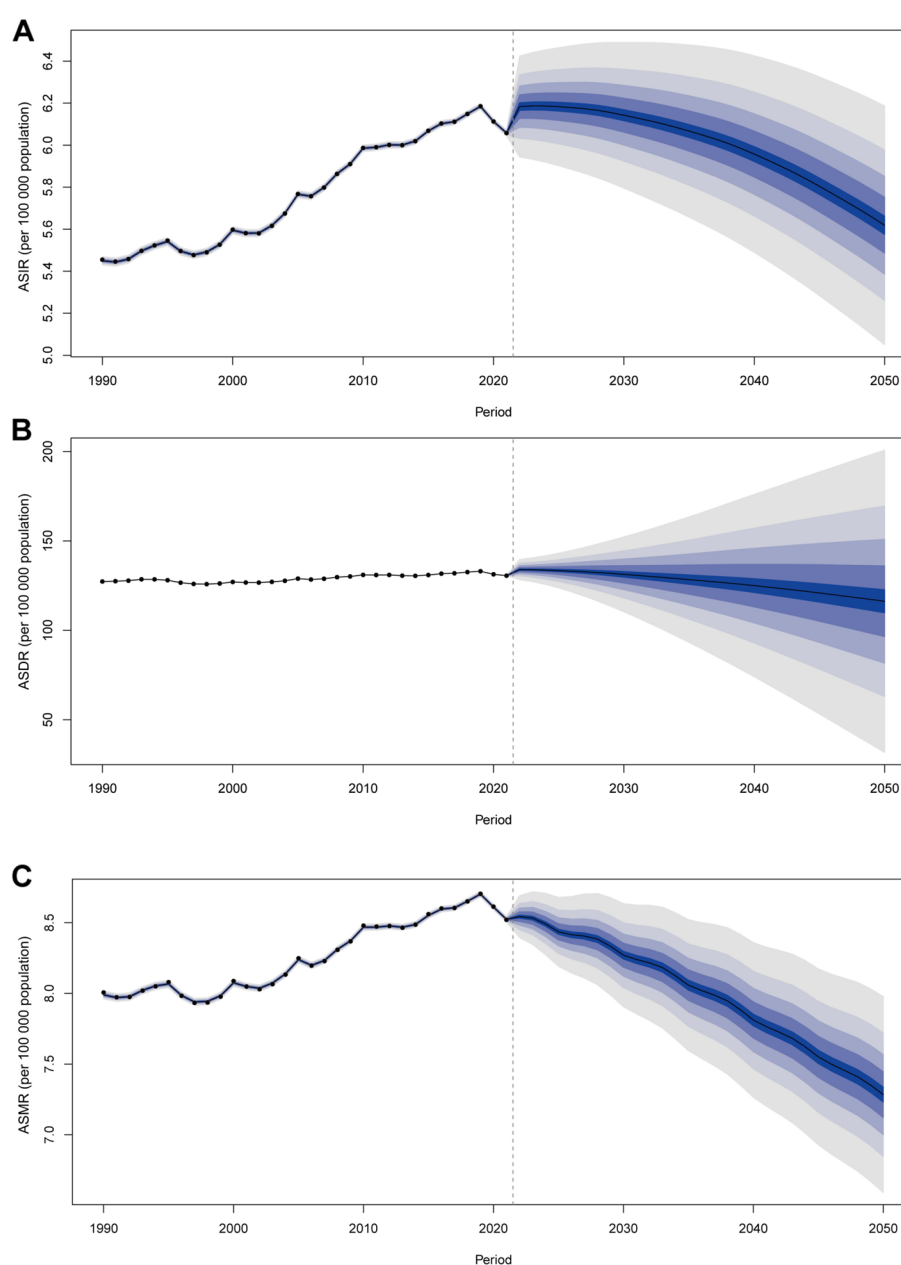
Fig. 8 Projected trends in the age-standardized incidence rate (ASIR), age-standardized DALYs rate (ASDR), and age-standardized mortality rate (ASMR) of pancreatic cancer from 2022 to 2050. **A** ASIR per 100,000 population, **B** ASDR per 100,000 population, and **C** ASMR per 100,000 population. Shaded areas represent the 95% uncertainty intervals for the projections

exhibited the lowest rates, with males showing higher rates than females across all metrics; (8) the proportion of deaths and DALYs attributable to known risk factors included high fasting plasma glucose, high BMI, and tobacco use; (9) projections indicate a gradual decline in the age-standardized rates of incidence, DALYs, and mortality for pancreatic cancer by 2050.

The increase in pancreatic cancer cases in low-middle and low SDI regions could be attributed to

several factors, including improved diagnostic capabilities, lifestyle changes, and population aging [16, 21]. High-income regions, such as the Asia Pacific and North America, continue to exhibit the highest incidence rates, likely due to better reporting and more widespread screening practices [22]. These trends underscore the need for targeted public health interventions to address the growing burden of pancreatic cancer in both high and low SDI regions. The high-incidence age group for

Li *et al. BMC Cancer*   (2025) 25:189

Page 23 of 26

pancreatic cancer typically ranges from 60 to 80 years. Epidemiological data show that the incidence of pancreatic cancer increases with age, particularly in individuals aged 65 and older [23, 24]. Similarly, our analysis of age-specific trends underscored the critical need for targeted interventions and healthcare strategies for elderly aged 65–75 years, who are at greater risk of developing and succumbing to pancreatic cancer. Public health initiatives should focus on early detection and preventive measures, particularly for older adults, to mitigate the rising burden of this disease.

We identified tobacco smoking, high BMI, and high fasting plasma glucose (FPG) as significant risk factors for pancreatic cancer, contributing notably to the disease burden. These findings align with previous research [4, 25]. Tobacco smoke contains numerous carcinogens, such as nitrosamines and polycyclic aromatic hydrocarbons, which can generate oxidative stress and promote cellular damage, leading to mutations and cancer development [26, 27]. Also, smoking induces chronic inflammation, which can create a microenvironment conducive to cancer growth [28]. A meta-analysis by Iodice et al. revealed that cigarette smoking increases the risk of pancreatic cancer by 75% compared to non-smokers [29], and this elevated risk persists for nearly 20 years after smoking cessation [30]. Obesity is linked to dysfunctional adipose tissue, adipocyte death, and chronic low-grade inflammation, all of which can create a microenvironment conducive to tumor development [31]. High fasting plasma glucose is an abnormal metabolic condition, commonly manifested as diabetes. Excess body fat along with high FPG can lead to insulin resistance, leading to elevated insulin and insulin-like growth factors, which can inhibit apoptosis and stimulate cancer cell proliferation [32, 33]. Numerous studies have confirmed the association between high fasting plasma glucose and an increased global burden of cancer-related deaths [34, 35]. Addressing these risk factors through public health interventions and lifestyle modifications is crucial for reducing the incidence and mortality of pancreatic cancer. Enhanced screening and preventive measures targeting these modifiable risks could significantly impact the global burden of this deadly disease [19].

The observed regional disparities in pancreatic cancer burden can be attributed to a combination of modifiable and systemic factors that vary across socioeconomic and geographic contexts [36, 37]. High-income regions, such as North America and Asia Pacific, report the highest age-standardized incidence rates, likely reflecting the cumulative impact of modifiable risk factors such as high BMI, diabetes, and smoking prevalence, alongside advanced healthcare systems that facilitate early detection and comprehensive case registration [38–40]. In contrast, regions with low or low-middle SDI, such as Sub-Saharan Africa and South Asia, are experiencing a sharp increase in cancer burden. This may be due to the adoption of urbanized lifestyles, characterized by higher rates of obesity and dietary shifts towards processed foods [41, 42], combined with limited public health resources and inconsistent cancer registries [43–45]. For instance, in Sub-Saharan Africa, the rising ASIR coincides with increasing tobacco consumption and urbanization, yet diagnostic delays and healthcare access disparities likely result in significant underreporting [46, 47]. These findings suggest a pressing need for tailored public health interventions in low-SDI regions and region-specific interventions, such as tobacco cessation programs, public awareness campaigns targeting modifiable risk factors, and the establishment of more robust cancer surveillance systems, particularly in resource-limited settings.

The projections analysis indicates a gradual decline in ASIR, suggesting a potential reduction in new pancreatic cancer cases over time. By 2050, the ASIR is expected to drop significantly. Similarly, ASDR, which remained stable from 1990 to 2021, is forecasted to steadily decrease by 2050. This decline suggests an improvement in the overall quality of life and a reduction in the years of healthy life lost due to pancreatic cancer. While ASMR showed a steady increase from 1990, peaking around 2019, post-2021 projections suggest a decline, with the rate expected to progressively decrease by 2050. The projected decline in pancreatic cancer incidence and mortality by 2050 is underpinned by several anticipated developments. First, advancements in early detection techniques, such as circulating tumor DNA and improved imaging technologies, are expected to facilitate earlier diagnosis in asymptomatic or high-risk populations, thereby reducing late-stage diagnoses and improving treatment outcomes [1, 48]. Second, significant progress in therapeutic interventions, including personalized medicine approaches such as next-generation sequencing to identify actionable mutations, may result in more effective treatments with improved survival rates. For instance, the increasing integration of immune checkpoint inhibitors and CAR-T cell therapies holds promise for enhancing long-term control of pancreatic cancer [49, 50]. Third, widespread implementation of public health measures targeting modifiable risk factors, such as global anti-smoking campaigns, diabetes prevention programs, and interventions to address obesity, may lead to a measurable reduction in disease incidence, particularly in high-risk regions [51].

This study is among the first to apply the most recent Global Burden of Disease 2021 database to analyze pancreatic cancer trends. This timely update ensures that

Li *et al. BMC Cancer*   (2025) 25:189

Page 24 of 26

our findings reflect the current state of pancreatic cancer epidemiology, offering a valuable resource for public health planning and policy-making. Unlike studies that focus on specific regions and apply advanced statistical techniques such as time series modeling, disease mapping, and age-period-cohort models [52–55], our study uses exploratory data analysis to incorporate data from multiple countries worldwide. This approach aims to provide a descriptive global overview of pancreatic cancer burden and trends, rather than focusing on localized or highly specific statistical analyses.

However, several limitations must be acknowledged. First, the analysis heavily relied on the GBD database. The database accuracy is constrained by the availability of national registry data, and the number of undiagnosed cases of pancreatic cancer. Secondly, age-standardized rates can vary significantly over short geographical distances due to differences in lifestyle and environment, necessitating more detailed geographical data in future research. Thirdly, data gaps in certain regions introduce bias, particularly in underdeveloped countries. Thirdly, the lack of histological data in the GBD framework limits our ability to accurately stratify patients, potentially leading to overestimated incidences where data may come from a single regional registry. Besides, using data up to 2021 may not capture the most recent trends, highlighting the need for updated statistics to inform timely public health interventions. Also, inherent limitations of the GBD database, including its reliance on aggregated population-level data, preclude the ability to assess individual-level interactions between key risk factors and socio-demographic factors. Lastly, another notable limitation is the widening confidence intervals observed in the projections for the 2040–2050 period, which reduce the reliability of the estimates. This uncertainty reflects the challenges of accounting for future demographic shifts, variability in healthcare advancements, and the unpredictable evolution of global risk factors, necessitating cautious interpretation of long-term trends. Addressing these limitations will allow for more precise and effective strategies in combating pancreatic cancer globally.

Conclusion

Current trends and future projections of pancreatic cancer incidence and mortality exhibit significant geographic variability among countries with varying income levels. To address health inequities in the burden of pancreatic cancer, it is essential to consider the disparities in healthcare accessibility between high-income countries and those with low or lower-middle incomes.

Abbreviations

ASIR	Age-Standardized Incidence Rate
ASMR	Age-Standardized Mortality Rate
ASDR	Age-Standardized DALYs Rate
DALYs	Disability-Adjusted Life Years
GBD	Global Burden of Disease
SDI	Socio-Demographic Index
EAPC	Estimated Annual Percentage Change
BAPC	Bayesian Age-Period-Cohort Model
FPG	Fasting Plasma Glucose
BMI	Body Mass Index
UI	Uncertainty Interval

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12885-025-13597-z.

Supplementary Material 1: Supplementary Fig. 1: Global maps depicting the age-standardized incidence rate (ASIR), age-standardized DALYs rate (ASDR), and age-standardized mortality rate (ASMR) of pancreatic cancer in 1990 (A, D,G), 2000 (B, E,H), and 2010 (C, F,I).

Supplementary Material 2: Supplementary Fig. 2: Global incidence, DALYs, and death numbers of pancreatic cancer by age and sex in 1990 (A, C,E) and 2000 (B, D,F).

Supplementary Material 3: Supplementary Fig. 3: The relationship between SDI and age-standardized incidence (A), DALYs (B), and mortality (C) rates across 204 regions.

Supplementary Material 4.

Supplementary Material 5.

Supplementary Material 6.

Data availability
The code related to this study has been uploaded in the Supplementary file 2. The datasets used during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The Global Burden of Disease (GBD) study is conducted under the guidelines of the Institute for Health Metrics and Evaluation (IHME) and complies with the Declaration of Helsinki. The data utilized in this study were obtained from publicly available, de-identified datasets, which do not require individual participant consent. The IHME ensures all ethical considerations are addressed, and the use of de-identified health data is approved by their institutional review board. Therefore, separate ethics approval and consent to participate were not required for this secondary data analysis.

Li *et al. BMC Cancer*   (2025) 25:189

Page 25 of 26

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Li *et al. BMC Cancer*   (2025) 25:189

Page 26 of 26

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