Mapping the Trends in Esophageal Cancer Disease Burden in the United States: Results from the Global Burden of Disease Study 2017

Di Lu
Nanfang Hospital
jianxue Zhai
Nanfang Hospital
Jintao Zhan
Nanfang Hospital
Xiguang Liu
Nanfang Hospital
Xiaoying Dong
Nanfang Hospital
Siyang Feng
Nanfang Hospital
Shijie Mai
Nanfang Hospital
Jianjun Jiang
Nanfang Hospital
Zhizhi Wang
Nanfang Hospital
Xiuyu Ji
Nanfang Hospital
Mei Li
Nanfang Hospital
Hua Wu
Nanfang Hospital
Kaican Cai (doc_cai@163.com)
Nanfang Hospital

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Abstract

Background: Esophageal cancer is the 10th leading cancer in US but given limited research attention. This study aimed to investigate the esophageal cancer disease burden more comprehensively in US.

Methods: Having retrieved states-categorized data on esophageal cancer incidence, mortality and disability-adjusted life years from the Global Burden of Disease study online resource, the current trends on esophageal cancer disease burden attributed to different risk factors and their relationship with economic status were analyzed using age-standardized rate and the estimated annual percentage change.

Results: In US, the esophageal cancer age-standardized rate of incidence has been stable but age-standardized rates of mortality and disability-adjusted life years trended to decreased with estimated annual percentage changes of -0.237% and -0.471% from 1990 to 2017. Age-standardized rate of incidence was higher in males than in females, but both didn't increase, so as age-standardized rates of mortality and disability-adjusted life years. The largest increase in age-standardized rates of incidence, mortality and disability-adjusted life years was observed in Oklahoma, whereas the largest decrease was seen in the District of Columbia. Age-standardized rates of mortality and disability-adjusted life years contributed to high BMI or diet low in fruits were growing. per capita disposable personal income trended to negatively correlated with estimated annual percentage changes of incidence, mortality and disability-adjusted life years.

Conclusions: The esophageal cancer disease burden in US decreased from 1990 to 2017 but was heavier in males than in females, and increased in economically weaker states and populations with high BMI and low-fruit diet.

Background

Esophageal cancer (EC), the 7th leading cancer globally, is becoming the fastest growing cancer in the Western world. In the United States (US), EC is now the 10th leading cancer overall, and the 7th leading cause of cancer deaths in males. The disease is contributing to increasing death rates (20%) among males in the US[1], and its overall mortality rate is approximately 85%[2]. Despite these, there is little attention on EC from government agencies and the research community, with a negative implication on the establishment of large-scale public health interventions[3].

Previous studies have reported regional, temporal, and ethnic differences in EC disease burden in the US [4–6]. However, most of these studies employ incidence as the sole parameter in analyzing disease burden, with only a few using multiple parameters and datasets.

The Global Health Data Exchange (GHDx) publishes the Global Burden of Disease (GBD) study, the most comprehensive catalog of surveys, censuses, vital statistics, and other health-related data in the world[7]. Additionally, GHDx uses a unique approach in generating estimates for all locations using all available data from literature, administrative hospital and medical claim records, and cause of death records[8]. Notably, GBD provides multi-angle epidemiological data on various diseases from different locations.

Disability-adjusted life years (DALYs) is a metric describing the total time lost due to a health condition, including premature death and disability. The World Health Organization GBD study of the year 1990 developed this metric, which is considered as a standard measure of disease burden since [7, 9].

Herein, we used GBD data to study EC disease burden in the US using three parameters, namely incidence, mortality, and Disability-adjusted Life Years DALYs, to provide a comprehensive understanding of EC. Besides, we elucidated the contribution of distinct risk factors in different states to EC burden, and the association between EC burden and the respective economic status.

Methods

Data availability

All data was obtained from the GBD online resource available at http://ghdx.healthdata.org. PCDPI of 50 states and the District of Columbia between 1990–2017 was obtained from the Bureau of Labor Statistics available at https://www.bls.gov/.

Data sources

Data related with incidence, mortality, and DALYs of EC in the US between 1990–2017 was retrieved from the GBD online repository. The retrieved data had been categorized by gender, year, measure, metric, age, location, and risk factors.

The per capita disposable personal incomes (PCDPIs) of the different states were retrieved from the US Bureau of Economic Analysis.

Institutional Review Board approval was not required since here we used publicly available data.

Statistical analysis

The age-standardized rate (ASR) and the estimated annual percentage change (EAPC) were used to analyze the EC burden. The age structures of the populations in different states are not similar and changes over time. This necessitates age standardization to limit the effect of different age structures on disease burden [8, 10]. EC ASR of incidence, mortality, and DALYs were acquired from the GBD.

The annual relative change is a method used to evaluate trends in age-adjusted rates, obtained from a log-linear modal as

$\log R = \beta 0 + \beta 1X + \varepsilon$, (1)

where R = age-adjusted rate, and X = calendar year. Annual percent change is given by $100\times [\exp(\beta 1))-1]$ [8, 11–13]. The age-standardized rate was presented as ASR and put into formula (1) ($\ln ASR = \beta 0 + \beta 1X + \varepsilon$), and EAPC of ASR was calculated as $100\times [\exp(\beta 1))-1]$. The ASR was considered increasing if the

EAPC estimation and the lower boundary of its 95% Confidence Interval (CI) were both greater than 0. In contrast, the ASR was considered decreasing if the EAPC estimation and the upper boundary of its 95% CI were both less than 0. Otherwise, ASR was considered stable over the period.

A linear regression model was plotted for PCDPI and ASR or EAPC of incidence, mortality, and DALYs to explore the association between the economic level and EC burden.

The data in this study were analyzed using the IBM SPSS version 23 software, and graphs were drawn using GraphPad Prism 8 and Microsoft Excel (Office 365). $P < 0.05$ was considered statistically significant.

Results

New cases, ASR of incidence rate and its EAPC

New EC cases in the US increased from 11391.02 in the year 1990 to 20690.21 in 2017. Although the EC ASR of incidence in 2017 (3.85 per 100,000) was higher compared with 1990 (3.61 per 100,000), there was no rising or down trend from 1990 to 2017 (EAPC was not statistically significant). In both 1990 and 2017, there was an over four-fold male population contribution over the female contribution to the EC incidence (Table 1). However, between 1990 and 2017, the ASR of EC incidence in males remained constant, whereas it decreased in females with an estimated annual percentage change of -0.444% (Table 1).

Table 1
New cases and age-standardized incidence rate of esophageal cancer in 1990 and 2017, and temporal trends from 1990 to 2017.

Category	New cases. ×1000 (95% UI)		ASR per 100,000 (95% UI)		EAPC % (95% CI)
	1990	2017	1990	2017	1990–2017
Overall	11391.02 (11247.59,11556,12)	20690.21 (20040.79, 21331.42)	3.61(3.56, 3.66)	3.85(3.73, 3.97)	0.007 (-0.186, 0.200)
Sex					
Male	8604.47 (8467.84, 8771.37)	16415.49 (15778.08, 17032.67)	6.28(6.18, 6.39)	6.64(6.38, 6.90)	-0.006 (-0.197, 0.186)
Female	2786.55 (2731.80, 2843.72)	4274.72 (4087.10, 4452.67)	1.50(1.47, 1.53)	1.45(1.39, 1.51)	-0.444 (-0.667, -0.220)

ASR, age-standardized rate; CI, confidence interval; EAPC, estimated annual percentage change; UI, uncertainty interval.

At the state level, between 1990 and 2017, the highest increase of new EC cases was recorded in Nevada (262.32%), followed by Alaska (246.51%), and Utah (208.88%). In contrast, the lowest increase of new cases was observed in New York (30.83%), followed by New Jersey (39.02%), and Michigan (49.40%). The emergence of new cases decreased by -24.84% in the District of Columbia (Fig. 1A). The highest ASR of incidence in 2017 was recorded in South Dakota (5.93 per 100,000), followed by Colorado (5.40 per 100,000), and Virginia (5.17 per 100,000). On the contrary, the lowest ASR of incidence in 2017 was recorded in Oklahoma (2.88 per 100,000), followed by Montana (3.03 per 100,000), and then Kentucky (3.15 per 100,000) (Fig. 1B).

Between 1990 and 2017, the highest increase in ASR of incidence was recorded in Oklahoma (EAPC = 1.301%), followed by West Virginia (EAPC = 1.187%), and then Arkansas (EAPC = 0.999%). However, the highest decrease was observed in the District of Columbia (EAPC = -2.112%), followed by Maryland (EAPC = -0.900%), and California (EAPC=-0.786%). At the same time, six states recorded a constant ASR of incidence (Fig. 1C). There was no marked correlation between ASR of incidence and PCDPI in 2017 (Fig. 1D). Nevertheless, a significant negative correlation was recorded between EAPC of incidence and PCDPI in 1990 (Fig. 1E).

Deaths, ASR of mortality rate and its EAPC

Deaths from EC in the US increased from 11143.45 in 1990 to 18814.92 in 2017. Nonetheless, in the same period, the ASR of mortality decreased from 3.48 per 100,000 to 3.46 per 100,000, with an average − 0.237% per year change. In both 1990 and 2017, male-fatalities accounted for the majority of the recorded deaths, with a about quintuple higher ASR of mortality over females. However, the ASR of mortality decreased in both males and females, with an EAPC of -0.214% and − 0.957%, respectively. Smoking was the leading risk factor (with the highest deaths and ASR of mortality) in EC mortality in 2017, followed by high BMI, alcohol consumption, low-fruit diet, and chewing tobacco. Nonetheless, the fastest-growing risk factor was high BMI (EAPC = 0.777%), followed by low-fruit diet (EAPC = 0.547%). Besides, risk factor contribution by alcohol consumption remained constant, whereas smoking (EAPC = -1.613%) and chewing tobacco (EAPC=-0.481%) decreased over time (Table 2).

Table 2
Deaths and age-standardized mortality rate of esophageal cancer in 1990 and 2017, and its temporal trends from 1990 to 2017.

Category	No. ×1000 (95% UI)		ASR per 100,000 (95% UI)		EAPC % (95% CI)
	1990	2017	1990	2017	1990–2017
Overall	9285.18 (9876.15, 8602.70)	15097.64 (16663.54, 13248.09)	2.91 (3.09, 2.70)	2.78 (2.44, 3.07)	-0.347 (-0.493, -0.200)
Sex					
Male	7281.27 (7730.07, 6754.50)	12586.16 (13927.15, 10928.60)	5.30 (5.63, 4.91)	5.07 (4.40, 5.61)	-0.340 (-0.492, -0.188)
Female	2003.91 (2301.55, 1682.34)	2511.48 (3020.14, 1960.36)	1.06 (1.21, 0.89)	0.83 (0.65, 0.99)	-1.116 (-1.267, -0.965)
Risk factors					
Smoking	6420.32 (5740.24, 7024.07)	7493.44 (6521.15, 8504.44)	2.00 (1.80, 2.18)	1.37 (1.19, 1.55)	-1.613 (-1.825, -1.400)
Alcohol use	3827.03 (2730.28, 4847.96)	6784.80 (4582.50, 8831.67)	1.23 (0.89, 1.55)	1.27 (0.86, 1.64)	0.055 (-0.094, 0.205)
High body-mass index	3153.58 (1062.05, 5545.67)	6981.15 (2429.76, 11398.00)	1.00 (0.34, 1.75)	1.29 (0.45, 2.11)	0.777 (0.560, 0.993)
Diet low in fruits	1507.13 (308.28, 2994.30)	2920.67 (615.42, 5594.33)	0.47 (0.10, 0.94)	0.54 (0.11, 1.03)	0.547 (0.470, 0.624)
Chewing tobacco	554.49 (321.24, 807.54)	879.89 (465.46, 1362.45)	0.17 (0.10, 0.25)	0.16 (0.09, 0.25)	-0.481 (-0.557, -0.405)

ASR, age-standardized rate; CI, confidence interval; EAPC, estimated annual percentage change; UI, uncertainty interval.

We recorded the highest increase in deaths in Nevada (242.96%), followed by Alaska (226.09%), and Arizona (177.66%) and the lowest in New York (16.76%), followed by New Jersey (24.48%), and Illinois (37.22%). A decrease in fatalities was only recorded in the District of Columbia (-30.98%) (Fig. 2A). In 2017, the District of Columbia (5.48 per 100,000) had the highest ASRs of mortality, followed by Maine (4.80 per 100,000), and New Hampshire (4.46 per 100,000), whereas Utah (2.52 per 100,000) had the lowest, followed by Hawaii (2.61 per 100,000), and California (2.70 per 100,000) (Fig. 2B). Between 1990 and 2017, we recorded the highest ASR of mortality in the District of Columbia. Furthermore, the District of Colombia had the most rapid decrease in the ASR of mortality (EAPC = -2.428%), followed by Maryland (EAPC = -1.235%), and New Jersey (EAPC = -0.947%). On the contrary, the fastest-growing ASR of mortality was observed in Oklahoma (EAPC = 1.175%), followed by West Virginia (EAPC = 1.015%), and Arkansas (EAPC = 0.827%). Twelve states had a constant ASR of mortality (Fig. 2C). Moreover, a strong correlation was observed between PCDPI and EAPC of mortality, which was not evident in the ASR of mortality (Fig. 2D, E).

In 2017, the highest contribution of 4 risk factors (smoking, 2.33 per 100,000; alcohol use, 2.12 per 100,000; high BMI, 2.16 per 100,000; and low-fruit diet, 0.75 per 100,000) to the ASR of mortality was recorded in the District of Columbia. The highest contribution of tobacco chewing to the ASR of mortality was recorded in West Virginia (0.66 per 100,000) (Fig. 3A). The highest increase in ASR of mortality resulting from alcohol use, high BMI, and low-fruit diet were recorded in Oklahoma with an EAPC of 1.495%, 2.612%, and 2.229%, respectively. The highest increase in ASR of mortality resulting from chewing tobacco was recorded in Arkansas with an EAPC of 1.535%. The rapidest decrease in EC ASR of mortality resulting from smoking, alcohol use, high BMI or chewing tobacco were observed in the District of Columbia with an EAPC of -3.815%, -2.365%, -1.892% and − 2.171, respectively. In California, the rapidest decrease in EC ASR of mortality resulting from low-fruit diet was recorded with an EAPC of -0.906%. Overall, the ASR of EC mortality attributed to smoking declined in all the US states except Oklahoma (with no significant EAPC change). In contrast, the ASR of mortality attributed to high BMI and low-fruit diet increased in a significant number of the states (Fig. 3B). Besides, PCDPI was negatively correlated with ASR of mortality attributed to smoking, low-fruit diet, and chewing tobacco (Fig. 3C-G) similar to the EAPC of mortality attributed to all investigated risk factors except tobacco chewing (Fig. 3H-L).

DALYs, ASR of DALYs and its EAPC

DALYs of EC in the US increased from 252664.30 years in 1990 to 405489.95 years in 2017. Additionally, the ASR of DALYs decreased from 83.73 years per 100,000 to 78.58 years per 100,000 in the same period, with an average − 0.471% per year change. In both 1990 and 2017, the DALYs and ASR of DALYs were more in males compared with females. However, a decreasing trend was recorded in the ASRs of DALYs for both males (EAPC = -0.449%) and females (EAPC = -1.084%). In 2017, the most significant risk factor contributing to DALYs was smoking (160233.75 years). On the contrary, alcohol use had the largest ASR of DALYs (31.01 years/100,000), followed by high BMI, smoking, low fruit-diet, and chewing tobacco. Smoking had the rapidest declining ASR of DALYs (EAPC = -1.912%), followed by chewing tobacco (EAPC

= -0.627%), and alcohol use (EAPC = -0.197%). In contrast, the changes in ASR of DALYs attributed to high BMI, and low-fruit diet increased with an EAPC of 0.510% and 0.280%, respectively (Table 3).

Table 3
The DALYs and age-standardized DALYs rate of esophageal cancer in 1990 and 2017, and its temporal trends from 1990 to 2017.

Category	Year ×1000 (95% UI)		ASR per 100,000 (95% UI)		EAPC % (95% CI)
	1990	2017	1990	2017	1990–2017
Overall	213467.95 (226157.04, 198788.43)	330723.23 (364856.87, 290539.06)	70.92 (75.17, 66.02)	64.18 (70.78, 56.44)	-1.238 (-1.121, -1.355)
Sex					
Male	172728.76 (183291.51, 160688.33)	281353.02 (311060.98, 245363.34)	126.79 (134.59, 117.80)	115.36 (127.51, 100.63)	-0.576 (-0.441, -0.711)
Female	40739.19 (46360.38, 34711.73)	49370.21 (58521.31, 39108.44)	23.91 (27.11, 20.44)	18.04 (21.33, 14.34)	-0.563 (-0.422, -0.703)
Risk factors					
Smoking	145477.43 (157890.44, 131987.58)	160233.75 (179799.14, 140237.02)	47.94 (51.97, 43.76)	30.48 (34.20, 26.71)	-1.912 (-1.719, -2.105)
Alcohol use	93814.69 (116931.38, 69625.24)	156948.51 (200340.05, 109707.07)	31.84 (39.44, 23.69)	31.01 (39.36, 21.96)	-0.197 (-0.055, -0.338)
High body-mass index	75075.05 (130926.43, 25248.13)	156932.18 (254322.82, 53341.17)	25.24 (43.73, 8.47)	30.52 (49.33, 10.33)	0.510 (0.716, 0.304)
Diet low in fruits	34341.41 (68026.85, 7056.94)	62790.16 (121273.22, 13272.90)	11.42 (22.64, 2.34)	12.26 (23.59, 2.61)	0.280 (0.360, 0.200)
Chewing tobacco	12574.38 (18307.86, 7217.65)	19609.44 (30394.92, 10350.81)	4.19 (6.13, 2.39)	3.81 (5.91, 2.05)	-0.627 (-0.542, -0.711)

DALYs, mortality and disability adjusted life years; ASR, age-standardized rate; CI, confidence interval; EAPC, estimated annual percentage change; UI, uncertainty interval.

The highest increase in DALYs was observed in Nevada (214.37%), followed by Alaska (190.52%), and Utah (169.73%), whereas the lowest increase was recorded in New York (5.23%), New Jersey (15.59%), and Illinois (28.39%). A decrease in EC DALYs was only recorded in the District of Columbia (-35.79%) (Fig. 4A). In 2017, the highest ASR of DALYs was observed in the District of Columbia (131.86 years per 100,000), followed by Maine (108.18 years per 100,000), and Ohio (102.15 years per 100,000). In contrast, the lowest ASR of DALYs was recorded in Utah (56.76 years per 100,000), followed by California (58.65 years per 100,000), and then Hawaii (61.16 years per 100,000) (Fig. 4B). Although the ASR of DALYs was highest in the District of Columbia, the state experienced a rapidest decline in ASR of DALYs between 1990 and 2017, with an EAPC of -2.730%. This was closely followed by Maryland (EAPC =-1.478%) and New York (EAPC = -1.332%). The highest increase in ASR of DALYs was observed in Oklahoma (EAPC = 1.151%), followed by West Virginia (EAPC = 1.103%), and Arkansas (EAPC = 0.811%). Ten states sustained a constant ASR of DALYs (Fig. 4C). There was not a significant association between PCDPI and EAPC of DALYs, neither between PCDPI and ASR of DALYs (Fig. 4D,E).

In 2017, the highest ASR of DALYs attributed to smoking, alcohol use, high BMI, and low-fruit diet was observed in the District of Columbia, i.e., 53.57 years per 100,000, 53.99 years per 100,000, 53.08 years per 100,000, 18.40 years per 100,000, respectively. In contrast, the highest ASR of DALYs attributed to tobacco chewing was recorded in West Virginia (15.92 years per 100,000) (Fig. 5A). The highest increase in ASR of DALYs as a result of high BMI and low-fruit diet was recorded in Oklahoma (EAPC = 2.505% and 2.186%, respectively), while that attributed to alcohol use was observed in West Virginia (EAPC = 1.462%), and chewing tobacco in Arkansas (EAPC = 1.556%). In contrast, the most significant decrease in ASRs of DALYs attributed to smoking, alcohol use, high BMI, and chewing tobacco was recorded in the District of Columbia (EAPC − 4.178%, -2.668%, -2.195%, and − 2.503%, respectively). The most significant decrease in ASRs of DALYs attributed to the low-fruit diet risk factor was recorded in California (EAPC = -1.276%). There was a decrease in ASR of DALYs attributed to smoking in all the states except Oklahoma (with an insignificant EAPC). However, ASR of DALYs attributed to high BMI, and low-fruit diet increased in a significant number of the states (Fig. 5B). A negative correlation was observed between PCDPI and ASR of DALYs attributed to smoking, low-fruit diet, and chewing tobacco (Fig. 5C-G) similar to the EAPC of DALYs attributed to all risk factors except chewing tobacco (Fig. 5H-L).

Discussion

Here, we investigated EC disease burden in the US under the parameters of incidence, mortality as well as DALYs. Our findings presented an overview of the EC disease burden in different states of the US and the contribution of selected risk factors. We established that the EC ASR of incidence in the US remained constant from 1990 to 2017, whereas the EC ASRs of mortality and DALYs had a decreasing trend. During the same period, the EC disease burden was higher in males compared with females. Additionally, the economically stronger states had a lesser EC disease burden. Smoking and alcohol use were the most significant risk factors contributing to EC disease burden, and high BMI and low-fruit diet had more and more significant contributions.

Studies show that esophageal adenocarcinoma has increased in the US, whereas esophageal squamous cell carcinoma is continually decreasing [5, 14, 15]. Studying different histological types as a whole we suggested in our study that respiting largely growing new cases, the EC ASR of incidence in the US has remained constant from 1990 to 2017. During the same time, the EC ASRs of DALYs and mortality in the US decreased, although the total number of deaths and DALYs increased significantly. As reported by the Global Burden of Disease Study 2017 Population Estimates 1950–2017, the US population rose from 2.534 billion in 1990 to 3.248 billion in 2017. This could explain the rapid increase in EC new cases, deaths, and DALYs, although the EC ASR of incidence remained constant, whereas the EC ASRs of mortality and DALYs decreased. The recorded declining EC disease burden in the US indicated that the control strategies put in place are effective.

Nicolas Patel and Bikramjit Benipal reported a higher EC incidence in males compared with females in the US [5] consistent with Luckson N et al. [16]. In the current study, the EC disease burden in males was higher than that in females, with significantly larger ASRs of incidence, mortality, and DALYs. Overall, we reported a general decrease in EC disease burden in both male and female populations, which was more evident in the female population regarding ASR of mortality and ASR of DALYs. This gender-difference in EC disease burden suggests that females harbor EC protective factors. Females are less susceptible to EC, which could be attributed to different endocrine milieu between males and females. The findings of studies show that estrogen inhibits esophageal squamous cell cancer growth both in vitro [17, 18] and in vivo [19]. The estrogen receptor ER-beta is thought to be responsible in the anti-proliferative effect, which has also been reported to be expressed in esophageal adenocarcinoma [20]. Moreover, optimal prognosis has been reported in females because of the different endocrine milieu [21], lower alcohol consumption, addiction to smoking [22], different gene expression [23], among others.

Jennifer Drahos et al. reported significant geographical variability in the incidence rates of esophageal adenocarcinoma and esophageal squamous cell carcinoma by census region (the Northeast, Midwest, South, and West) [6]. In this study, although averagely, the ASR of EC incidence did not change over time, while the ASR of EC mortality and DALYs decreased, all the three parameters increased in the states of Oklahoma, West Virginia, Arkansas, North Dakota, Iowa, Kansas, Indiana, Kentucky, South Dakota, Utah, Idaho, Wyoming, Maine, Ohio, Nebraska, and Tennessee. Interestingly, states in the coastal area, there was a decreasing trend in the EC ASR of incidence, mortality, and DALYs. Our findings suggested that the geographical variability could be attributed to the economic variabilities among states. We explored the association between economic level and EC disease burden to explain the geographic variability observed in the EC disease burden. Our findings indicated that economically stable states have a lesser EC disease burden. This was particularly evident in the EC burden attributed to smoking, alcohol use, high BMI, or low-fruit diet. Economic factors play an essential role in the incidence rate and mortality rate of EC. Low socioeconomic status is associated with the higher EC incidence, which results from the combined influence of increased alcohol use and smoking, lower annual income, lower annual expenditure on food, lower yearly expenditure on fruit and vegetables, higher unemployment rate, and higher employment rate in agriculture and construction sectors [24–26]. Additionally, low socioeconomic status is associated with a dismal prognosis, resulting from inadequate awareness of the malignant disease, reduced access to health services, and less performed resection and chemotherapy [27–29].

Numerous risk factors contribute to EC [3, 9, 15, 30–34]. GBD lists smoking, alcohol use, high BMI, low-fruit diet, and chewing tobacco as the five leading risk factors associated with EC. Our findings revealed that smoking and alcohol use were the most significant risk factors contributing to EC disease burden in the US. In most states, the effect of smoking and chewing tobacco either reduced or did not vary over time. However, high BMI and low-fruit diet were shown to play profound roles, with the EC disease burden attributed to these factors increasing in most states. The population change with different factors could explain the trend of EC disease burden attributed to various factors to a certain extent. Data from The Behavioral Risk Factor Surveillance System (BRFSS) indicated that the smoking population reduced from 22.4% in 1995 to 17.1% in 2017, while alcohol use increased from 52.8% in 1995 to 54.7% in 2017, high BMI from 52.0% in 1995 to 66.2% in 2017, low-fruit diet from 39.2% in 2013 to 36.8% in 2017, chewing tobacco from 4.3% in 2013 to 4.0% in 2017 (BRFSS recommended not to compare fruit and vegetable intake from 2017 to previous years because of the changes in methodology). These were in some degree consistent with the trends in EC burden contributable to related risk factors. However, the trends in some factors could not be explained. For instance, smoking was the most significant risk factor, although its association with the population was not the most distinct. Besides, the trends of mortality rate and DALYs rate attributed to the low-fruit diet conflicted with the population change associated with the low-fruit diet. The effects of different risk factors on EC prognosis are different, which could be the possible explanation. However, a more profound explanation is required.

This study had a few limitations that constrain its findings. First, the GBD online resource lacks data on different histological types of EC, different races and different tumor stages; thereby, limiting our ability to compare disease burden between histological types, different races and different tumor stages. Secondly, it was not feasible to distinguish whether an individual was affected by one or more risk factors; therefore, evaluating the interactions among different risk factors and their influence on EC disease burden was not possible. Thirdly, the datasets from the GBD repository are estimates of quantified health loss. Therefore, the accuracy of the results may be different to that of results from other database.

In Conclusion, herein, we provide trends in EC burden in the US, which are significant in informing the design of efficient prevention strategies tailored for different states. We recommend that the US should strengthen efforts in controlling smoking and alcohol use while encouraging and supporting optimal BMI and inclusion of fruits in diets. Finally, economically weaker states (Oklahoma, West Virginia, among others, in which ASRs of EC incidence, mortality, and DALYs all increased) should make deliberate efforts to mitigate the growing EC disease burden.

List Of Abbreviations

EC esophageal cancer

GHDx Global Health Data Exchange

GBD the Global Burden of Disease

DALYs disability-adjusted life years

BMI body-mass index

PCDPI the per capita disposable personal income

ASR age-standardized rate

EAPC estimated annual percentage change

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets analyzed for this study can be found in the GBD online resource available at http://ghdx.healthdata.org. PCDPI of 50 states and the District of Columbia between 1990-2017 was obtained from the Bureau of Labor Statistics available at https://www.bls.gov/ The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

Competing interests

The authors declare that they have no competing interests

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Author Contributions

DL, JZ (Jianxue Zhai) and KC conceptualized the study. DL, JZ (Jianxue Zhai) and JZ (Jintao Zhan) designed the study. JZ (Jintao Zhan) and XL acquired the epidemiology / PCDPI data. DL, JZ (Jintao Zhan), XL and XD analyzed the data. SF, JZ (Jianxue Zhai) and SM (Shijie Mai) drew the statistic figures and tables. JJ, ZW and XJ reexamined the results. DL and JZ (Jintao Zhan) wrote the first draft of the manuscript. ML, HW and KC revised the manuscript. All authors reviewed the manuscript and approved the final version of the manuscript.

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Tables

Table 1. New cases and age-standardized incidence rate of esophageal cancer in 1990 and 2017, and temporal trends from 1990 to 2017.

Category	New cases. ×1000 (95% UI)		ASR per 100,000 (95% UI)		EAPC % (95% CI)
	1990	2017	1990	2017	1990-2017
Overall	11391.02 (11247.59,11556,12)	20690.21 (20040.79, 21331.42)	3.61(3.56, 3.66)	3.85(3.73, 3.97)	0.007 (-0.186, 0.200)
Sex					
Male	8604.47 (8467.84, 8771.37)	16415.49 (15778.08, 17032.67)	6.28(6.18, 6.39)	6.64(6.38, 6.90)	-0.006 (-0.197, 0.186)
Female	2786.55 (2731.80, 2843.72)	4274.72 (4087.10, 4452.67)	1.50(1.47, 1.53)	1.45(1.39, 1.51)	-0.444 (-0.667, -0.220)

ASR, age-standardized rate; CI, confidence interval; EAPC, estimated annual percentage change; UI, uncertainty interval.

Table 2. Deaths and age-standardized mortality rate of esophageal cancer in 1990 and 2017, and its temporal trends from 1990 to 2017.

Category	No. ×1000 (95% UI)		ASR per 100,000 (95% UI)		EAPC % (95% CI)
	1990	2017	1990	2017	1990-2017
Overall	9285.18 (9876.15, 8602.70)	15097.64 (16663.54, 13248.09)	2.91 (3.09, 2.70)	2.78 (2.44, 3.07)	-0.347 (-0.493, -0.200)
Sex					
Male	7281.27 (7730.07, 6754.50)	12586.16 (13927.15, 10928.60)	5.30 (5.63, 4.91)	5.07 (4.40, 5.61)	-0.340 (-0.492, -0.188)
Female	2003.91 (2301.55, 1682.34)	2511.48 (3020.14, 1960.36)	1.06 (1.21, 0.89)	0.83 (0.65, 0.99)	-1.116 (-1.267, -0.965)
Risk factors					
Smoking	6420.32 (5740.24, 7024.07)	7493.44 (6521.15, 8504.44)	2.00 (1.80, 2.18)	1.37 (1.19, 1.55)	-1.613 (-1.825, -1.400)
Alcohol use	3827.03 (2730.28, 4847.96)	6784.80 (4582.50, 8831.67)	1.23 (0.89, 1.55)	1.27 (0.86, 1.64)	0.055 (-0.094, 0.205)
High body-mass index	3153.58 (1062.05, 5545.67)	6981.15 (2429.76, 11398.00)	1.00 (0.34, 1.75)	1.29 (0.45, 2.11)	0.777 (0.560, 0.993)
Diet low in fruits	1507.13 (308.28, 2994.30)	2920.67 (615.42, 5594.33)	0.47 (0.10, 0.94)	0.54 (0.11, 1.03)	0.547 (0.470, 0.624)
Chewing tobacco	554.49 (321.24, 807.54)	879.89 (465.46, 1362.45)	0.17 (0.10, 0.25)	0.16 (0.09, 0.25)	-0.481 (-0.557, -0.405)

ASR, age-standardized rate; CI, confidence interval; EAPC, estimated annual percentage change; UI, uncertainty interval.

Table 3. The DALYs and age-standardized DALYs rate of esophageal cancer in 1990 and 2017, and its temporal trends from 1990 to 2017.

Category	Year ×1000 (95% UI)		ASR per 100,000 (95% UI)		EAPC % (95% CI)
	1990	2017	1990	2017	1990-2017
Overall	213467.95 (226157.04, 198788.43)	330723.23 (364856.87, 290539.06)	70.92 (75.17, 66.02)	64.18 (70.78, 56.44)	-1.238 (-1.121, -1.355)
Sex					
Male	172728.76 (183291.51, 160688.33)	281353.02 (311060.98, 245363.34)	126.79 (134.59, 117.80)	115.36 (127.51, 100.63)	-0.576 (-0.441, -0.711)
Female	40739.19 (46360.38, 34711.73)	49370.21 (58521.31, 39108.44)	23.91 (27.11, 20.44)	18.04 (21.33, 14.34)	-0.563 (-0.422, -0.703)
Risk factors					
Smoking	145477.43 (157890.44, 131987.58)	160233.75 (179799.14, 140237.02)	47.94 (51.97, 43.76)	30.48 (34.20, 26.71)	-1.912 (-1.719, -2.105)
Alcohol use	93814.69 (116931.38, 69625.24)	156948.51 (200340.05, 109707.07)	31.84 (39.44, 23.69)	31.01 (39.36, 21.96)	-0.197 (-0.055, -0.338)
High body-mass index	75075.05 (130926.43, 25248.13)	156932.18 (254322.82, 53341.17)	25.24 (43.73, 8.47)	30.52 (49.33, 10.33)	0.510 (0.716, 0.304)
Diet low in fruits	34341.41 (68026.85, 7056.94)	62790.16 (121273.22, 13272.90)	11.42 (22.64, 2.34)	12.26 (23.59, 2.61)	0.280 (0.360, 0.200)
Chewing tobacco	12574.38 (18307.86, 7217.65)	19609.44 (30394.92, 10350.81)	4.19 (6.13, 2.39)	3.81 (5.91, 2.05)	-0.627 (-0.542, -0.711)

DALYs, mortality and disability adjusted life years; ASR, age-standardized rate; CI, confidence interval; EAPC, estimated annual percentage change; UI, uncertainty interval.

Figures

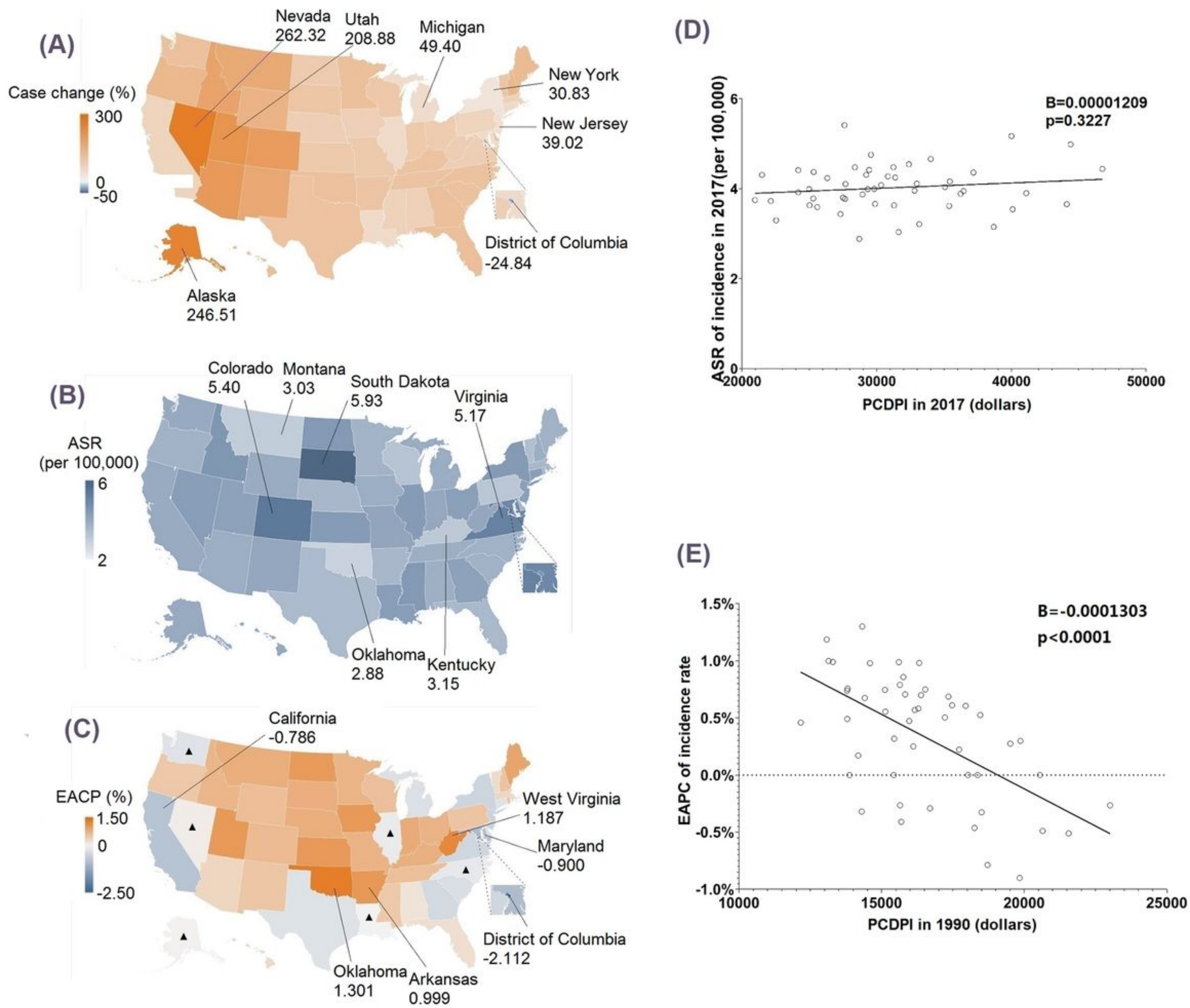

Figure 1

(A) The relative change in new cases of esophageal cancer between 1990 and 2017. (B) The ASR of incidence of esophageal cancer in 2017 (C) The EAPC of ASR of incidence of esophageal cancer from 1990 to 2017. (D)The correlation between PCDPI and ASR of incidence of esophageal cancer. (E) The correlation between PCDPI and EAPC. The B indices and p values presented in (D) and (E) were derived from Pearson correlation analysis. The circles in (C) to (L) represent states. ASR, age-standardized rate; EAPC, estimated annual percentage change. ▲, EAPC is not significant. District of Columbia was not included in (D) and (E) because of its outlier high PCDPI.

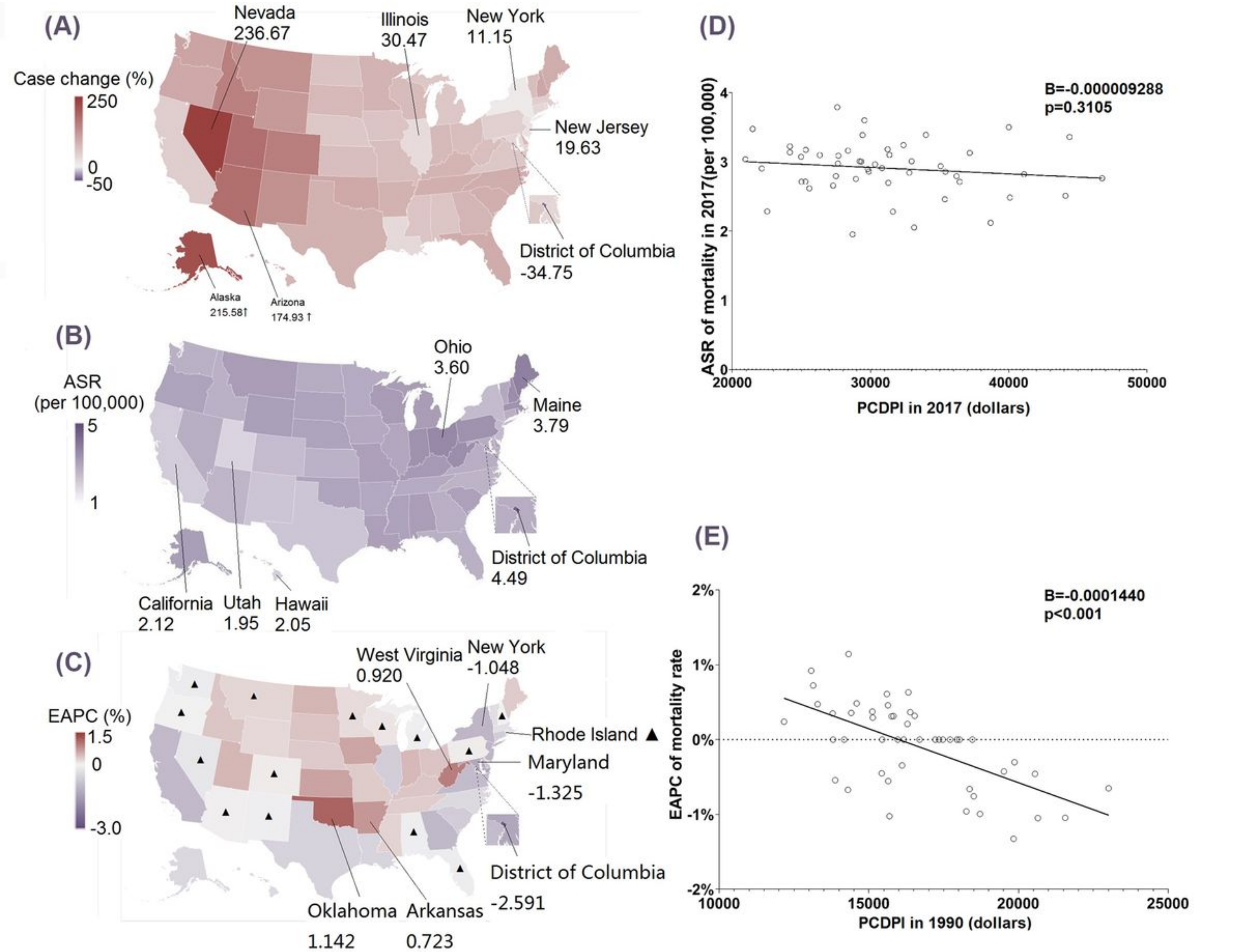

Figure 2

(A) ASRs of mortality of esophageal cancer attributed to different risk factors in different states. (B) EAPC of mortality of esophageal cancer attributed to different risk factors in different states. (C-G) The correlation between PCDPI and ASR of mortality of esophageal cancer attributed to certain risk factor and its EAPC. (H-L) The correlation between PCDPI and EAPC of mortality of esophageal cancer attributed to certain risk factor and its EAPC. ASR, age-standardized rate; EAPC, estimated annual percentage change. Boxes with slashes mean that EAPC is not significant. The circles represent states. The B indices and p values were derived from Pearson correlation analysis. ASR, age-standardized rate; EAPC, estimated annual percentage change. District of Columbia was not included in (C) and (L) because of its outlier high PCDPI.

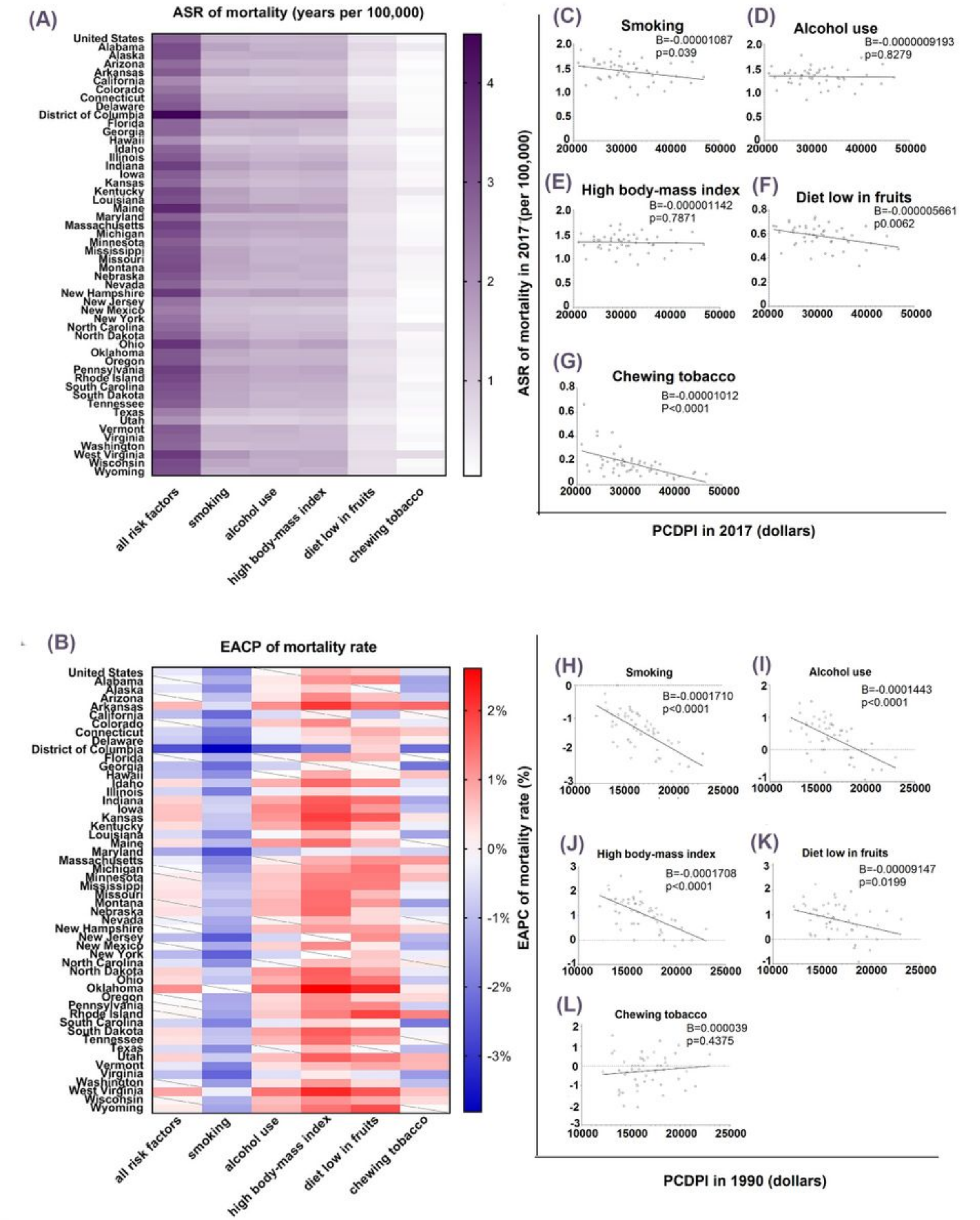

Figure 3

(A) ASRs of mortality of esophageal cancer attributed to different risk factors in different states. (B) EAPC of mortality of esophageal cancer attributed to different risk factors in different states. (C-G) The correlation between PCDPI and ASR of mortality of esophageal cancer attributed to certain risk factor and its EAPC. (H-L) The correlation between PCDPI and EAPC of mortality of esophageal cancer attributed to certain risk factor and its EAPC. ASR, age-standardized rate; EAPC, estimated annual percentage change.

Boxes with slashes mean that EAPC is not significant. The circles represent states. The B indices and p values were derived from Pearson correlation analysis. ASR, age-standardized rate; EAPC, estimated annual percentage change. District of Columbia was not included in (C) and (L) because of its outlier high PCDPI.

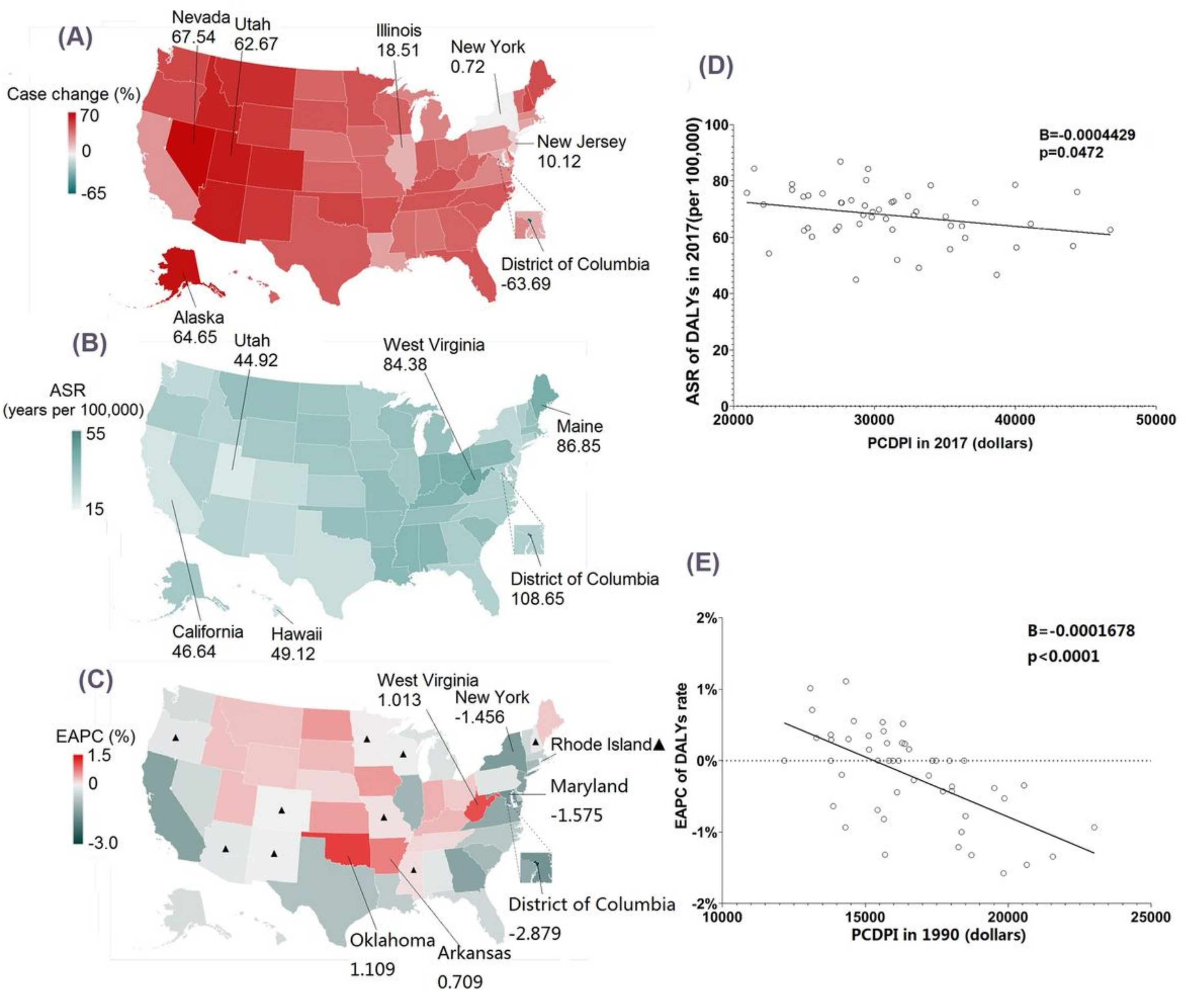

Figure 4

(A) The relative change in DALYs of esophageal cancer between 1990 and 2017. (B) The ASR of DALYs of esophageal cancer in 2017. (C) The EAPC of ASR of DALYs of esophageal cancer from 1990 to 2017. (D) The correlation between PCDPI and ASR of DALYs of esophageal cancer. (E) The correlation between PCDPI and EAPC. The B indices and p values presented in (D) and (E) were derived from Pearson correlation analysis. The circles in (C) to (L) represent states. DALYs, mortality and disability adjusted life years; ASR, age-standardized rate; EAPC, estimated annual percentage change. ▲, EAPC is not significant. District of Columbia was not included in (D) and (E) because of its outlier high PCDPI.

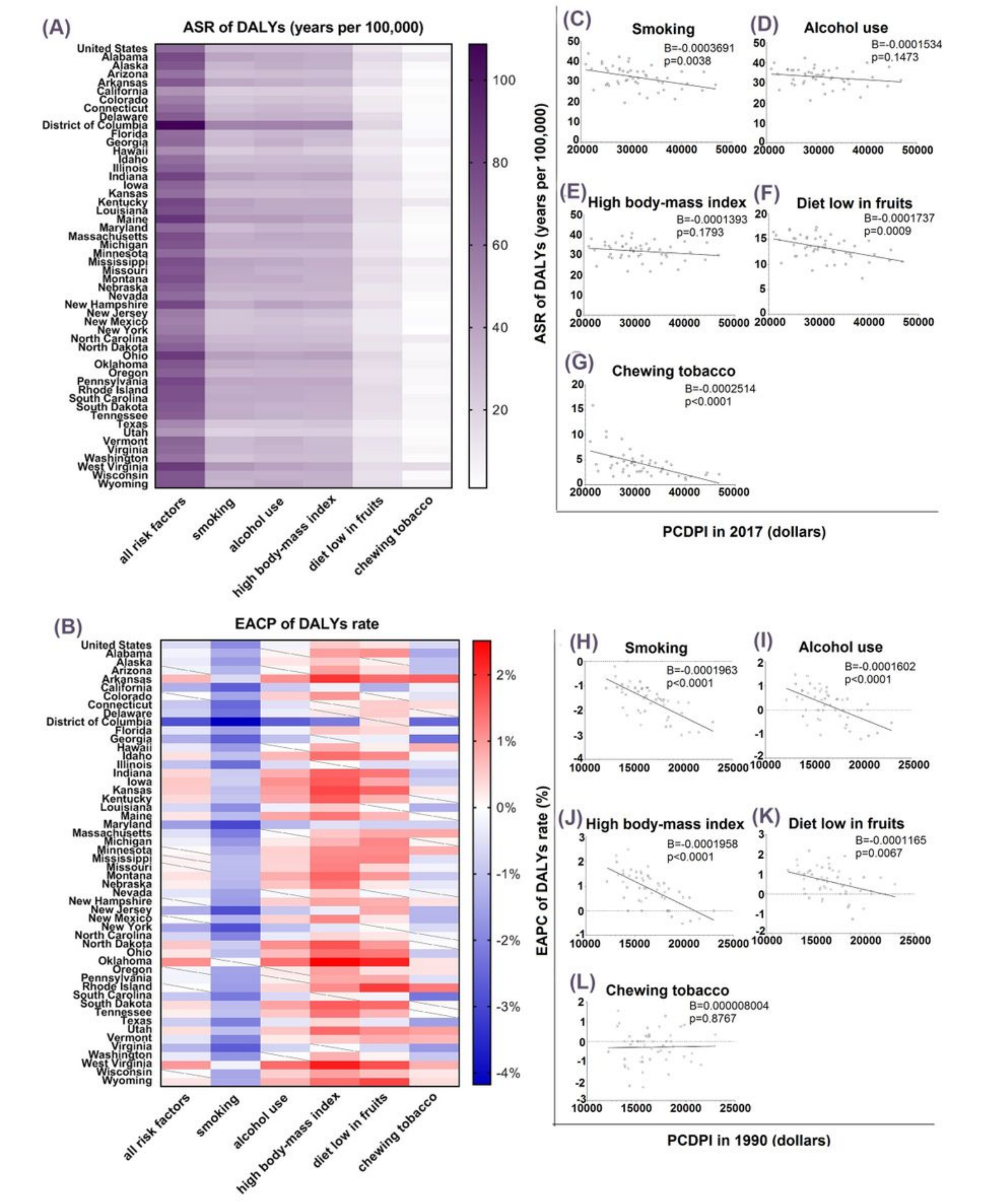

Figure 5

(A) ASRs of DALYs of esophageal cancer attributed to different risk factors in different states. (B) EAPC of DALYs of esophageal cancer attributed to different risk factors in different states. (C-G) The correlation between PCDPI and ASR of DALYs of esophageal cancer attributed to certain risk factor and its EAPC. (H-L) The correlation between PCDPI and EAPC of DALYs rate of esophageal cancer attributed to certain risk factor and its EAPC. ASR, age-standardized rate; EAPC, estimated annual percentage change. Boxes with slashes mean that EAPC is not significant. The circles represent states. The B indices and p values were derived from Pearson correlation analysis. DALYs, mortality and disability adjusted life years; ASR, age-standardized rate; EAPC, estimated annual percentage change. District of Columbia was not included in (C) to (L) because of its outlier high PCDPI.