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

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Research

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

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Abstract

Background: Esophageal cancer is the 7th leading cancer globally and the 10th leading cancer in the United States. However, it is has received limited attention over more common malignancies. Only a few studies have comprehensively assessed disease burden from esophageal cancer in the United States (US).

Methods: Using states-categorized data on incidence, mortality, and Disability-adjusted Life Years (DALYs), this study analyzed the current trends in esophageal cancer disease burden. Data and risk factor indicators were obtained from Global Burden of Disease (GBD) online resource and used to determine annual relative change.

Results: We report here that between 1990 and 2017, the number of esophageal cancer new cases, deaths and DALYs in the US increased significantly, while the Age-standardized Rate (ASR) of disease incidence remained constant. During the same time, disease burden from esophageal cancer in males was higher than that in females. Economically stronger states trend to had lesser disease burden from esophageal cancer. Smoking and alcohol use contributed most of the burden while influence of high body-mass index and diet low in fruits grew largely.

Conclusions: This study provided an analysis of esophageal cancer disease burden in the United States that will inform the design of targeted strategies for disease prevention tailored to different states.

Keywords: **epidemiology, burden, esophageal cancer, Global Burden of Disease, estimated annual percentage change**

Background

Esophageal cancer, the 7th leading cancer globally, is becoming the fastest growing cancer in the Western world. In the United States, esophageal cancer is now the 10th leading cancer overall, and the 7th leading cause of cancer deaths in males. The disease contributes to 20% increase in US male death rates and approximately 85% country mortality rate. Despite of this, esophageal cancer still receive little attention from government agencies and the research community, with a negative implication on establishment of a large-scale public health intervention[1-3].

Previous studies have reported regional, temporal and ethnic differences in esophageal cancer disease burden in United States[4-6]. However, most of them employ incidence as the sole parameter for analyzing disease burden. Only a few have reported using multiple parameters and datasets to study esophageal cancer disease burden in the US.

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

This study used GBD data to study disease burden from esophageal cancer in the United States under three parameters; incidence, mortality, Disability-adjusted Life Years (DALYs) in an effort to provide a comprehensive view of esophageal cancer. In addition, esophageal cancer disease burden attributed to different risk factors in different states was studied, and association between burden and the respective economic status explored.

Methods

Incidence, mortality and DALYs estimates

Incidence, mortality and DALYs for esophageal cancer in the United States between 1990-2017 was obtained from the GBD online repository. Accessed data had been categorized by gender, year, measure, metric, age, location and risk factors.

DALYs is a metric describing the total time lost due to a health condition, including premature death and disability. The metric was developed by the World Health Organization (WHO) GBD study of the year 1990 and has been considered a standard measure of disease burden since then[7, 9].

Age-standardized rate and estimated annual percentage change

Age-standardized rate (ASR) and estimated annual percentage change（EAPC） were used to analyze the burden from esophageal cancer. Age structures of population in different states are not similar and changes over time. This necessitates age standardization to limit the effect of difference age structures on disease burden. ASR of incidence, mortality and disability-adjusted life years were acquired from the GBD.

Annual relative change is a method to evaluate trends in age-adjusted rates, obtained from a log-liner modal as

$$logR = \beta_0 + \beta_1 + \varepsilon,$$

where R = age-adjusted rate, and X = calendar year. Annual percent change is given by $100\times[exp\ (\beta_1)\ )-1]$[10-13]. Age-standardized rate was presented as ASR (obtained from $ln\ R = \beta_0 + \beta_1 X + \varepsilon$), and EAPC of ASR was calculated as $100\times[exp\ (\beta_1)\ )-1]$. The ASR was considered to be 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 to be decreasing if the EAPC estimation and the upper boundary of its 95% CI were both lesser than 0. Otherwise, ASR was considered stable over the period.

Per capita disposable personal income

To explore the relation between the economic level and burden from esophageal cancer, a linear regression model was drawn for per capita disposable personal income (PCDPI) and ASR or EAPC of incidence, mortality and DALYs.

Statistical analysis

Data was analyzed using the IBM SPSS statistics version 23, and graphs drawn using GraphPad Prism 8 and Microsoft Excel (Office 365).

Results

Incidence

New cases of esophageal cancer in the United States increased from 11391.02 ×1000 in the year 1990 to 20690.21 ×1000 in 2017. Although the age-standardized rate of esophageal cancer in 2017 (3.85 per 100,000) was higher than that of 1990 (3.61 per 100,000), there was no significance difference in the estimated annual percentage change. In both 1990 and 2017, the US male population contributed four-fold more incidences of new esophageal cancer cases over females (Table 1). However, between 1990-2017, the age-standardized rate of esophageal cancer incidences in males remained constant while it decreased in females with an estimated annual percentage change of -0.444% (Table 1).

At states level, between 1990 and 2017, the highest increase of new esophageal cancer 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%). In the District of Columbia, emergence of new cases decreased by -24.84%

(Figure 1A). The highest age-standardized rate 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 other hand, the lowest age-standardized rate of incidence in 2017 was recorded in Oklahoma (2.88 per 100,000), followed by Montana (3.03 per 100,000) and Kentucky (3.15 per 100,000) (Figure 1B).

Between 1990-2017, the largest increase in ASR of incidence was observed in Oklahoma (EAPC = 1.301%), followed by West Virginia (EAPC = 1.187%) and Arkansas (EAPC = 0.999%), while the largest decrease was observed in the District of Columbia (EAPC = -2.112%), followed by Maryland (EAPC = -0.900%) and California (EAPC=-0.786%). In the same time, 6 states recorded a constant ASR of incidence (Figure 1C). A significant negative correlation was observed between EAPC of incidence and PCDPI in 1990 (Figure 1D), while there was no significant correlation between ASR of incidence and PCDPI in 2017 (Figure 1E).

Mortality

Deaths from esophageal cancer in the United States rose from 11391.02 ×1000 in 1990 to 15097.64 ×1000 in 2017. Nonetheless, in the same period, the ASR of mortality decreased from 2.91 per 100,000 to 2.79 per 100,000 with an average -0.347% per year change. In both 1990 and 2017, males contributed the majority of deaths recorded, with a quintuple higher ASR of mortality over females. However, the ASR of mortality decreased in both males and females, with an EAPC of -0.340% and -1.116%, respectively. Smoking was the leading risk factor in esophageal cancer mortality, followed by high body-mass index, alcohol consumption, low-fruit diet and chewing tobacco. Nonetheless, the fastest growing risk factor was high body-mass index (EAPC = 0.777%), followed by low-fruit diet (EAPC = 0.547%). Risk factor contribution by alcohol consumption remained constant while smoking (EAPC = -1.613%) and chewing tobacco (EAPC=-0.481%) decreased over time (Table 2).

The highest increased in deaths was observed in Nevada (236.67%), followed by Alaska (215.58%)

and Arizona (174.93%), while the lowest was observed in New York (11.15%), followed by New Jersey (19.63%) and Illinois (30.47%). District of Columbia was the only state recording a decrease in deaths (-34.75%) (Figure 2A). In 2017, the highest ASRs of mortality was recorded in District of Columbia (4.49 per 100,000), followed by Maine (3.79 per 100,000) and Ohio (3.60 per 100,000), while the lowest one was observed in Utah (1.95 per 100,000) followed by Hawaii (2.05 per 100,000) and California (2.12 per 100,000) (Figure 2B). Between 1990-2017, the District of Columbia had the highest ASR of mortality. Furthermore, its ASR of mortality recorded the fastest decrease (EAPC = -2.591%), followed by Maryland (EAPC = -1.325%) and New York (EAPC = -1.048%). The fastest growing ASR of mortality was recorded in Oklahoma (EAPC = 1.142%), followed by West Virginia (EAPC = 0.920%) and Arkansas (EAPC = 0.723%). Fourteen states sustained a constant ASR of mortality (Figure 2C). Moreover, a strong correlation was observed between PCDPI and EAPC of mortality that was not apparent in the ASR of mortality (Figure 2D, 2E).

In 2017, the highest contribution of risk factors (smoking, 2.33 per 100,000; alcohol use, 2.12 per 100,000; high body-mass index, 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. Chewing tobacco was the major risk factor in West Virginia (0.66 per 100,000). The investigated risk factors had the highest impact on the ASR of mortality in the District of Columbia, Maine and Ohio (Figure 3A). The highest increase in ASR of mortality resulting from alcohol use, high body-mass index and low-fruit diet was observed in Oklahoma with an EAPC of 1.495%, 2.612% and 2.229%, respectively. In Arkansas, chewing tobacco was a significant risk factor with an EAPC of 1.535%. Decrease in ASR of mortality as a result of smoking, alcohol use, high body-mass index and chewing tobacco was observed in the District of Columbia with an EAPC of -3.815%, -2.365%, -1.892% and -2.171, respectively. In California, low-fruit diet was the least contributing risk factor with an EAPC of -0.906%. Overall, the ASR of mortality attributed to smoking declined in all states except Oklahoma (with no significant EAPC). In contrast, the ASR of mortality attributed to high body-mass index and low-fruit diet increased in majority of sates as shown in Figure 3B. PCDPI was negatively correlated with ASR of mortality attributed to smoking, low-fruit diet and chewing tobacco (Figure 3C-G), and that of EAPC of mortality attributed to all risk factor investigated except for chewing tobacco (Figure 6H-L).

DALYs

Disability-adjusted life years of esophageal cancer in United States increased from 213467.95 years in 1990 to 330723.23 years in 2017. Additionally, the ASR of DALYs decreased from 70.92 years per 100,000 to 64.18 years per 100,000 in the same period with an average -1.238% per year change. In both 1990 and 2017, males made the largest contribution to DALYs and ASR of DALYs. However, a decreasing trend was recorded in the ASRs of DALYs for both males (EAPC = -0.576%) and females (EAPC = -0.563%). The most significant risk factor attributed to DALYs was smoking, while the largest ASR of DALYs was recorded in alcohol use, followed by high-body mass index, smoking, diet low in fruits and chewing tobacco. The ASR of DALYs contributable to smoking (EAPC = -1.912%) recorded the fasted dip, followed by chewing tobacco (EAPC = -0.627%) and alcohol use (EAPC = -0.197%). In contrast, change in DALYs and ASR of DALYs attributed to high body-mass index and low-fruit diet increased with an EAPC of 0.510% and 0.280%, respectively (Table 3).

The highest increase in DALYs was observed in Nevada (67.54%), followed by Alaska (64.65%) and Utah (62.67%) while the lowest increase was recorded in New York (0.72%), New Jersey (10.12%) and Illinois (18.51%). The district of Columbia was the only state recording a decrease in deaths from esophageal cancer (-63.69%) (Figure 4A). In 2017, the highest ASR of DALYs was observed in District of Columbia (108.65 years per 100,000), followed by Maine (86.85 years per 100,000) and West Virginia (84.38 years per 100,000), while the lowest ASR was observed in Utah (44.92 years per 100,000), followed by California (46.64 years per 100,000) and Hawaii (49.12 years per 100,000) (Figure 4B). Although the ASR of mortality was highest in the District of Columbia, the state recorded a rapid dip in ASR of DALYs between 1990-2017 with an EAPC of -2.879%. This was closely followed by Maryland (EAPC =- 1.575%) and New York (EAPC = -1.456%). The highest increase in ASR of DALYs was observed in Oklahoma (EAPC = 1.109%), followed by West Virginia (EAPC = 1.013%) and Arkansas (EAPC = 0.709%). Ten states sustained a constant ASR of DALYs (Figure 4C). There was a significant association between PCDPI and EAPC of mortality that was not apparent in ASR of mortality (Figure 4D, 4E).

In 2017, the highest ASR of DALYs attributed to smoking, alcohol use, high body-mass index and low-fruit diet was observed in the District of Columbia (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), while that attributed to chewing tobacco was recorded in West Virginia (15.92 years per 100,000). In the states of District of Columbia, Maine, West Virginia and Ohio, high ASRs of DALYs was attributed to the investigated risk factors (Figure 5A). The highest increase in ASR of DALYs as a result of high body-mass index 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 body-mass index and chewing tobacco was recorded in the District of Columbia (EAPC -4.178%, -2.668%, -2.195% and -2.503%, respectively), while that of low-fruit diet was observed in California (EAPC = -1.276%).There was a decrease in ASR of DALYs attributed to smoking in all states except Oklahoma (with an insignificant EAPC). However, ASR of DALYs attributed to high body-mass index and low-fruit diet increased in most states (Figure 5B). A negative correlation was observed between PCDPI and ASR of DALYs as a result of smoking, low-fruit diet and chewing tobacco (Figure 5C-G), as well as the EAPC of DALYs attributed to all risk factor except chewing tobacco (Figure 5H-L).

Discussion

This study investigated disease burden from esophageal cancer under the parameters of incidence, mortality as well as DALYs. Findings presented an overview of disease burden in different states and the contribution of selected risk factors. Results from this study suggested that incidence rate of esophageal cancer in United States has kept stable during 1990 to 2017 while mortality rate and DALYs rate kept decreasing. During the same time, disease burden from esophageal cancer in males was higher than that in females. Additionally, states that were economically stronger had a lesser disease burden from esophageal cancer. Smoking was the most significant risk factor contributing to disease burden but high body-mass index and diet low in fruits played more and more important roles.

Studies show that esophageal adenocarcinoma (EA) has increased in the United States while esophageal squamous cell carcinoma (ESCC) is continually decreasing[5, 14, 15]. Studying different histological types as a whole, it was suggested in our study that respiting largely growing new cases, incidence rate of esophageal cancer in United States has kept stable during 1990 to 2017. During the same time, mortality rate and DALYs rate of esophageal cancer in United States decreased, though the total number of deaths and DALYs increased significantly. As reported by Global Burden of Disease Study 2017 (GBD 2017) Population Estimates 1950-2017, population in United States had risen from 2.534 billion in 1990 to 3.248 billion in 2017. This might be the reason why new cases, deaths and DALYs of esophageal cancer all rose enormously though incidence rate kept stable while mortality rate and DALYs rate decreased. The recorded declining disease burden from esophageal cancer in United States indicated that control strategies put in place have been effective.

Nicolas Patel and Bikramjit Benipal reported a higher incidence of esophageal cancer in males compared to females in the United States[5] which was similar to the report by Luckson N et al.[16]. From this study, disease burden from esophageal cancer in males was higher than that in females, with significantly larger ASRs of incidence, mortality and DALYs. Overall, we report a general decrease in disease burden from esophageal cancer in both the male and female population, which was more obvious in female population in incidence rate and mortality rate. This difference in disease burden from esophageal cancer suggested that female might be a protective factor for esophageal cancer. Females were in less risk of esophageal cancer, which might be resulted by different endocrine milieu in males and females. Studies had reported the effect of Estrogen in inhibiting esophageal squamous cell cancer growth both in vitro[17, 18] and in vivo[19]. The estrogen receptor ER beta was thought to be responsible to this anti-proliferative effect, which had reported to be expressed also in esophageal adenocarcinoma[20]. On the other hand, better prognosis was observed in females, as results of different endocrine milieu[21], lower alcohol consumption and smoking addiction[22], different gene expression[23] and so on.

Jennifer Drahos et al. reported significant geographical variability in esophageal adenocarcinoma incidence rate and esophageal squamous cell carcinoma incidence rate by census region (the Northeast, Midwest, South, and West)[6]. From this study, although in average the ASR of incidence did not change over time while the ASR of mortality and DALYs decreased, all 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, in coastal area states, ASR of incidence, mortality and DALYs recorded a decreasing trend. It seemed this geographical variability might to some extent be resulted by economical variability in different states. To explain why geographical variability was observed in disease burden from esophageal cancer, we explored the association between economic level and disease burden from esophageal cancer. Findings indicated that states that were economically stronger had a lesser disease burden from esophageal cancer. This was particularly apparent in the burden attributed to smoking, alcohol use, high body-mass index or diet low in fruits. Economic factor plays an important part in incidence rate and mortality rate of esophageal cancer. Low socioeconomical status was in relation to the higher incidence, which might be a result of combined influence of more alcohol use and smoking, lower annual income, lower annual expenditure on food, lower annual expenditure on fruit and vegetables, higher percentage of unemployment, and higher percentage of employment in agriculture and construction sectors and so on[24-26]. In addition, low socioeconomical status was in relation to poorer prognosis, resulted by poorer cognition of the malignant disease, poorer access to health services, less performed resection and chemotherapy and so on[27-29].

Numerous risk factors contribute to esophageal cancer[3, 9, 15, 30-34]. GBD lists smoking, alcohol use, high body-mass index, diet low in fruits and chewing tobacco as the five main risk factors associated with esophageal cancer. From our analysis, smoking was the most significant risk factor contributing to disease burden from esophageal cancer in United Sates. In most states, the effect of alcohol use and chewing tobacco either did not vary or reduced over time. However, high body-mass index and diet low in fruits played more and more important roles, with the disease burden from esophageal cancer attributed increasing in most states. The change of population with different factors might explain the trend of disease burden from esophageal cancer attributed to different factors to a certain degree. Data from The Behavioral Risk Factor Surveillance System (BRFSS) reported that the population with smoking had decreased from 22.4% in 1995 to 17.1% in 2017, while alcohol use from 52.8% in 1995 to 54.7% in 2017, high body-mass index from 52.0% in 1995 to 66.2% in 2017, Chewing tobacco from 4.3% in 2013 to 4.0% in 2017(It was not recommended by BRFSS to compare fruit and vegetable intake from 2017 to prior years due to the changes in methodology). However, there were still some doubts not settled. For example, why smoking was the most significant risk factor though its related population was not the largest? Why were the trends of mortality rate and DALYs rate contributed to diet low in fruits in conflict with the change of population who with low-fruits diets? A possible explain was that the effects of different risk factors on prognosis of esophageal cancer were different, but the deeper reason needed further explore.

This study had a few limitations that constrained the range of insights generated from our analysis. First, GBD online resource lack data on different histological types of esophageal cancer, thereby limiting our ability to compare disease burden between histological types. Secondly, it was not feasible distinguishing whether a person was affected by one or more risk factors, thereby missing the opportunity to analyze the interactions among different risk factors and their influence on disease burden from esophageal cancer. Thirdly, datasets from the GBD are estimates of quantified health loss. Therefore, accuracy of the results is as good as the data collected and shared by the GBD consortium.

Conclusions

We provide here trends in esophageal cancer burden in the United States that will inform design of efficient prevention strategies tailored for different states. A recommendation is fronted for the United States to strengthen efforts in controlling smoking while encouraging and supporting optimal body-mass index and inclusion of fruits in diets. Ultimately, economically weaker states (Oklahoma, West Virginia and so on, in which ASRs of incidence, mortality and DALYs all increased) should make deliberate efforts to contain the growing disease burden from esophageal cancer.

List of abbreviations

GBD	Global Burden of Disease
DALYs	Disability-adjusted Life Years
PCDPI	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

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/.

Competing interests

The authors alone are responsible for the views expressed in this article and they do not necessarily represent the views, decisions, or policies of the institutions with which they are affiliated. The authors declare that they have no competing interest.

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Authors' contributions

DL, JZ (Jintao Zhan) and KC conceptualized the study. DL, JZ (Jintao Zhan) and XL 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 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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Figure legends

Figure 1. Maps of parameters of incidence, and the correlation between PCDPI and EAPC.

(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. Maps of parameters of mortality, and the correlation between PCDPI and EAPC.

(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. Heat map of EAPCs of mortality, and the correlation between PCDPI and EAPC.

(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. Maps of parameters of DALYs, and the correlation between PCDPI and EAPC.

(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. Heat map of EAPCs of DALYs, and the correlation between PCDPI and EAPC.

(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.

Tables

Table 1. New cases, ASRs of incidence of esophageal cancer in 1990 and 2017 and temporal trends.

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

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

Table 2. Deaths and ASRs of mortality of esophageal cancer in 1990 and 2017 and temporal trends.

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. DALYs and ASRs of DALYs of esophageal cancer in 1990 and 2017 and temporal trends.

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

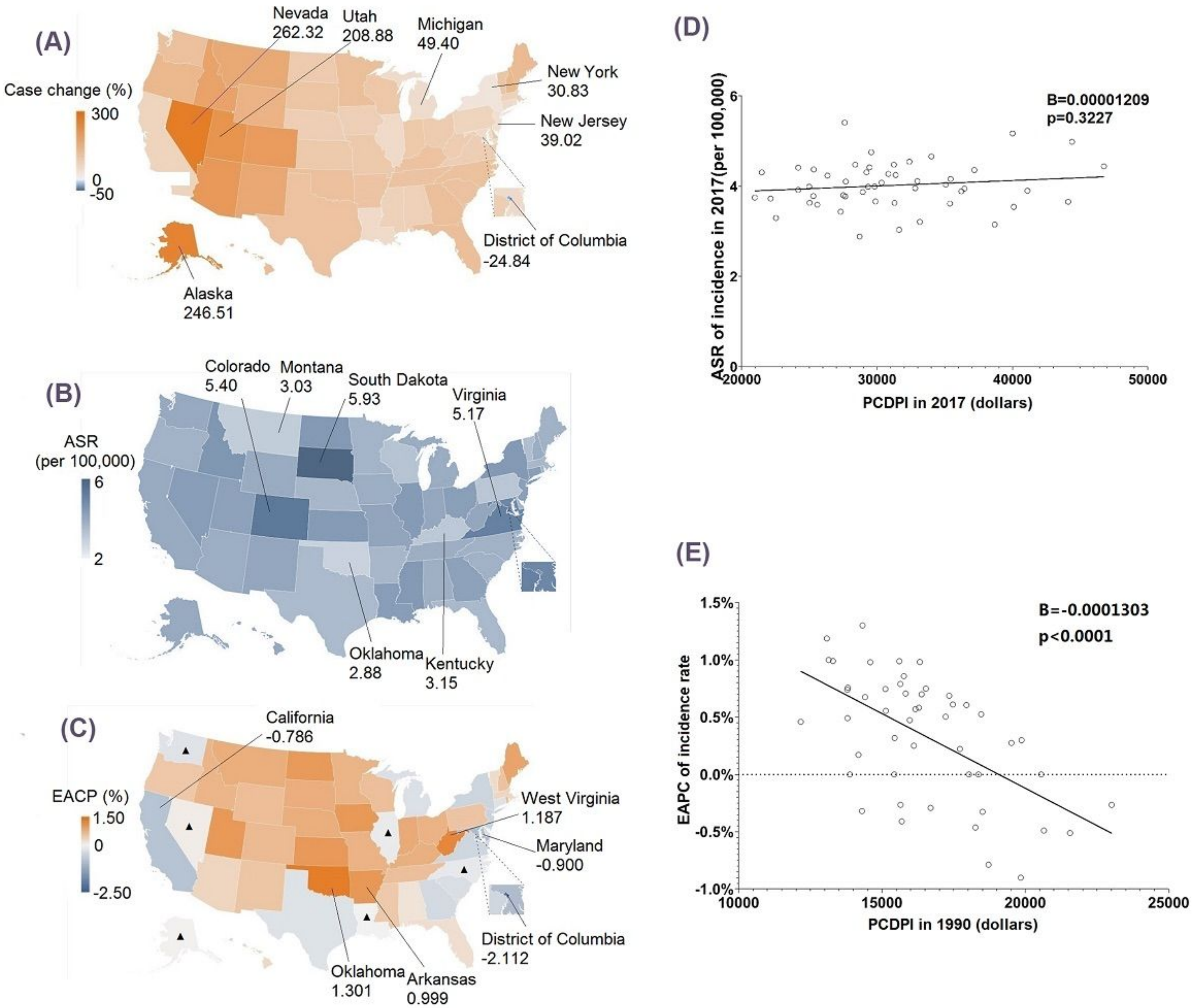


Figure 1

Maps of parameters of incidence, and the correlation between PCDPI and EAPC. (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.

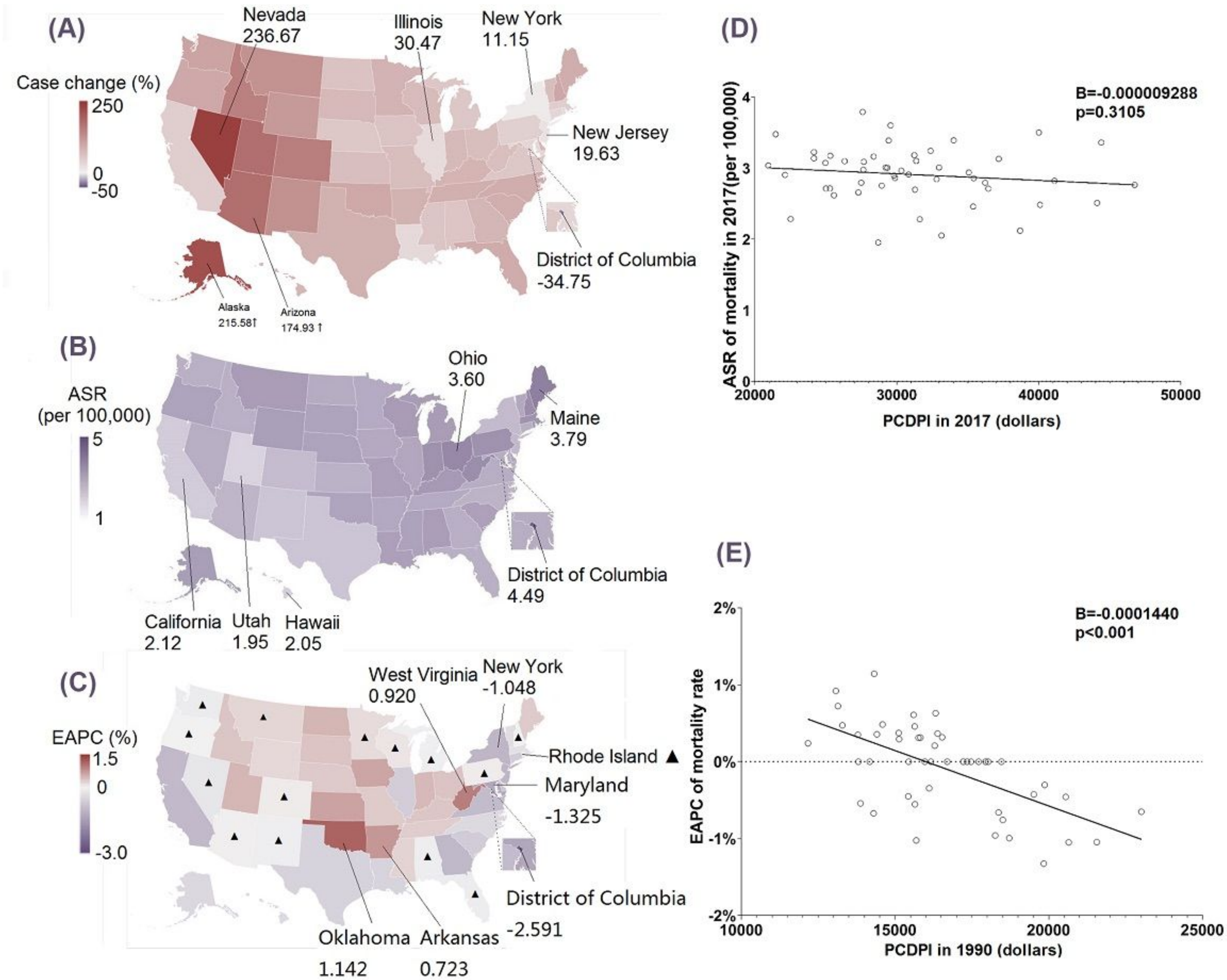


Figure 2

Maps of parameters of mortality, and the correlation between PCDPI and EAPC. (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.

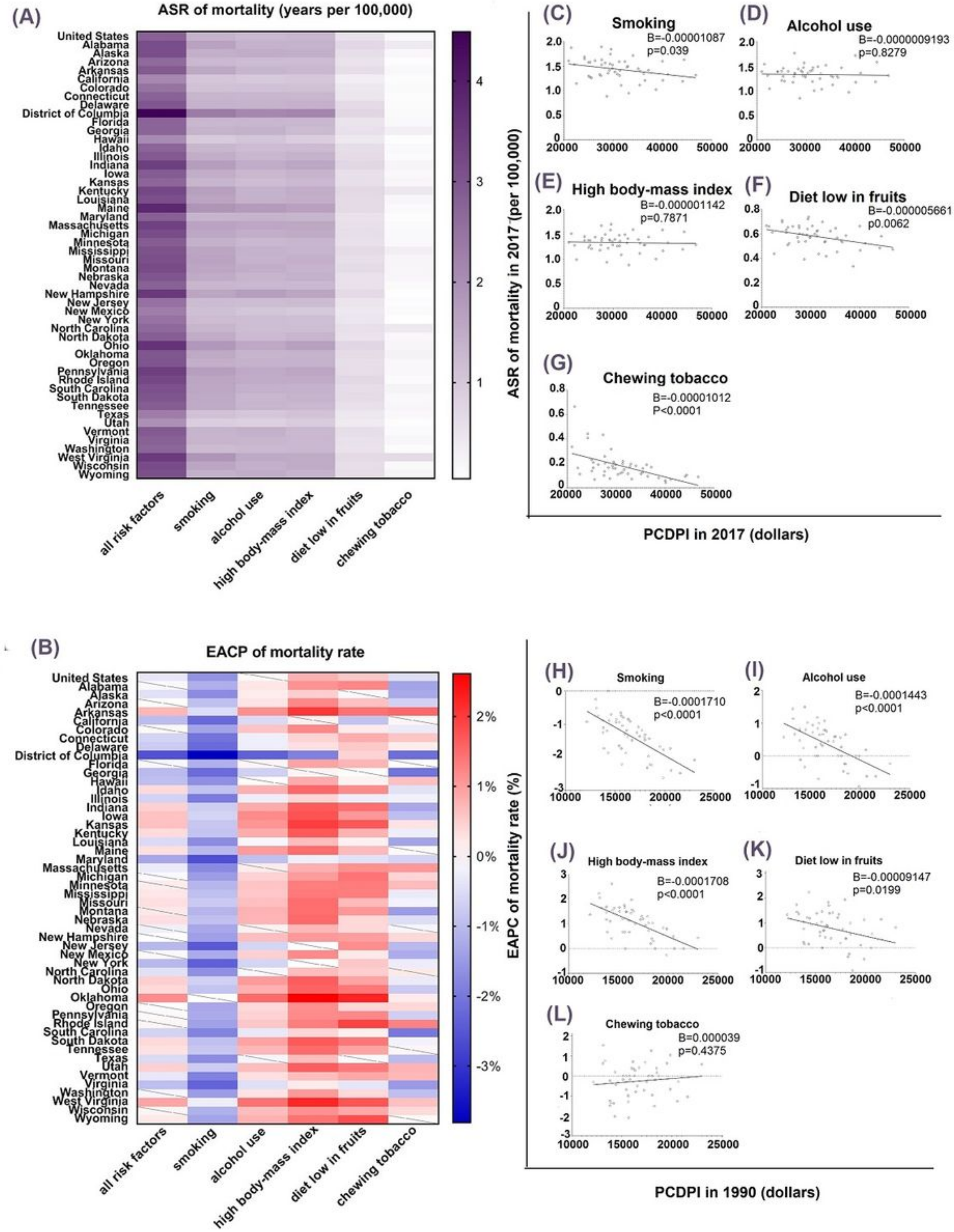


Figure 3

Heat map of EAPCs of mortality, and the correlation between PCDPI and EAPC. (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.

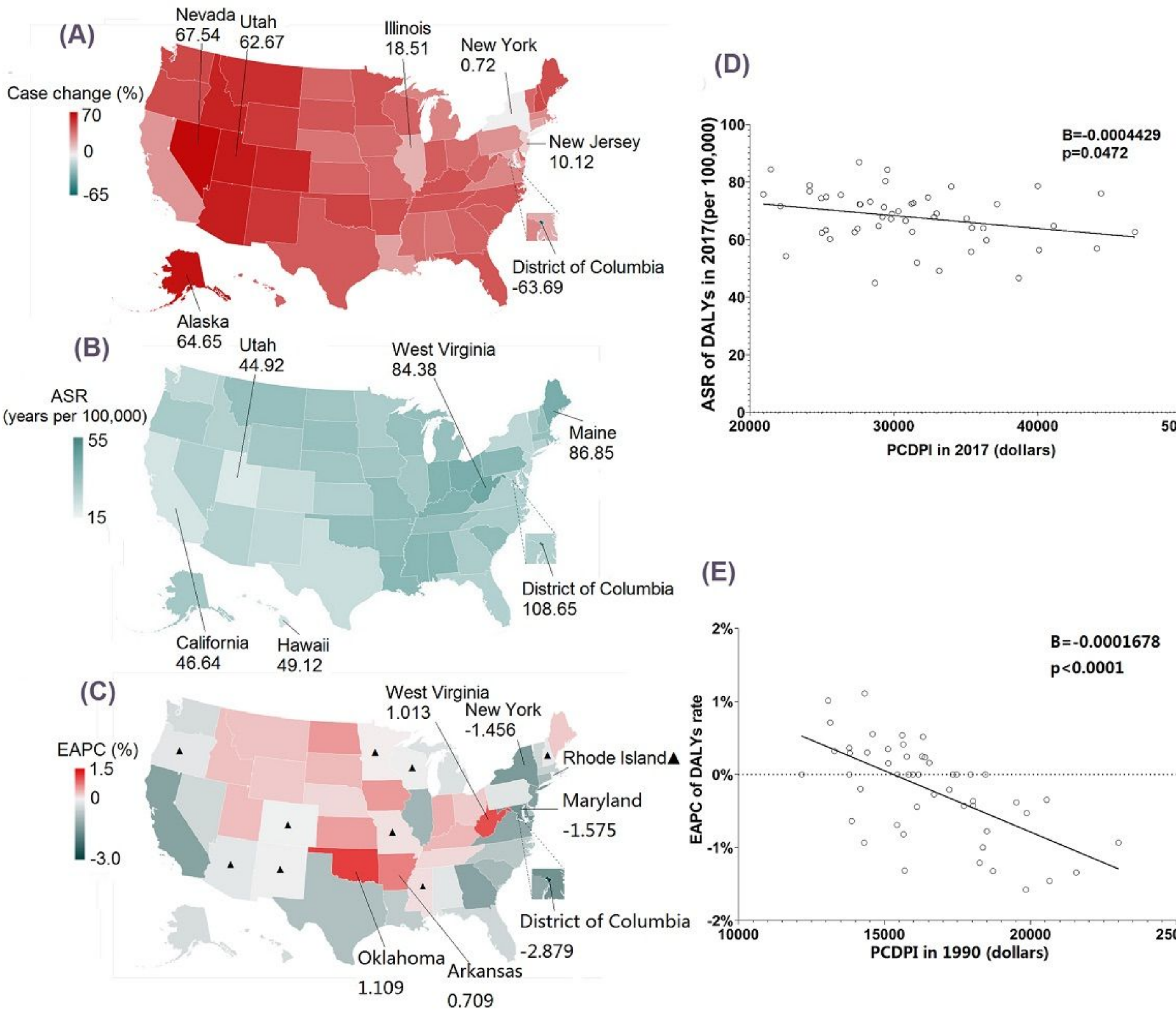
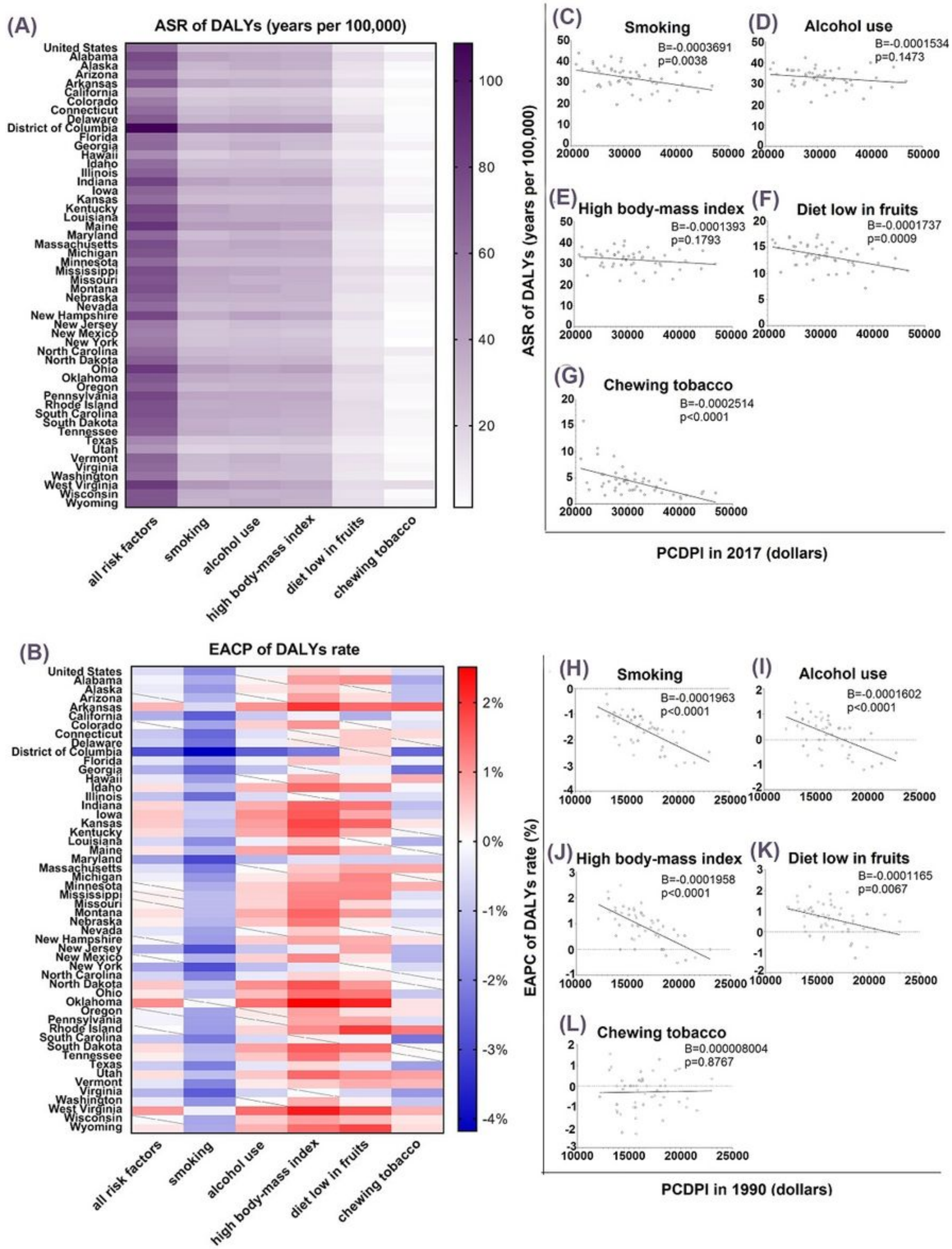


Figure 4

Maps of parameters of DALYs, and the correlation between PCDPI and EAPC. (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.



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