



# Cancer burden in the United States—a review

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**Abstract:** The cancer burden in the United States is substantial, with more than 1.6 million new invasive cases of cancer (excluding non-melanoma skin cancers) and about 600,000 cancer deaths occurring each year. In this review, we provide a brief description of recent trends in cancer incidence, mortality, and survival; prevalence and trends in major potentially modifiable risk factors for cancer; uptake of recommended cancer screening tests; access to cancer treatment; and health insurance coverage in the United States. During the most recent 10 years of available data (2005–2014), overall cancer incidence rates declined by about 2% annually in men and were stable in women. The overall decline in the incidence rate among men has been largely driven by decreasing prostate, lung, and colorectal cancer rates; among women, declines in lung and colorectal cancer rates have been offset by increases in breast, corpus uteri, and thyroid cancer rates. The overall cancer death rate in the United States has declined 26% since peaking in 1991, and from 2006 to 2015 decreased annually by about 1.8% in men and 1.4% in women. Death rates continue to decline for many cancer types, including cancers of the colorectum, lung, prostate, and female breast, but are increasing for cancers of the liver and intrahepatic bile duct and corpus uteri. Cigarette smoking is the greatest contributor to cancer incidence and mortality in the United States—despite a substantial decline in prevalence—followed by excess body weight. Screening prevalence has substantially increased since 2000 for colorectal cancer but not for female breast or cervical cancer, and use of screening tests remain below public health targets. In addition, despite overall declines in cancer death rates in the United States, substantial disparities in progress against cancer persist by race/ethnicity, geographic location, and socioeconomic status. Comprehensive implementation of proven interventions to curb potentially modifiable risk factors, optimal participation in recommended cancer screening programs, and equitable access to preventive care and treatment could substantially reduce the cancer burden and disparities.

**Keywords:** Disparity; incidence; mortality; risk factor; survival

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## Introduction

Cancer is a major public health problem in the United States. It is the second leading cause of death—with 595,930 deaths occurring in 2015 alone—following heart disease (1). Herein, we review the current cancer burden and recent trends in cancer incidence, mortality, and survival in the United States. We also provide information on factors contributing

to trends in cancer occurrence and disparities, including prevalence and trends in major potentially modifiable risk factors for cancer, uptake of recommended cancer screening tests, access to treatment, and health insurance coverage.

## Cancer occurrence

Population-based cancer occurrence data were obtained

from a review of previously published annual reports by the American Cancer Society, the National Cancer Institute (NCI), the North American Association of Central Cancer Registries (NAACCR), and the Centers for Disease Control and Prevention (CDC) (1-4). These reports compile contemporary cancer incidence rates and trends based on data from the CDC's National Program of Cancer Registries (NPCR) and/or the NCI's Surveillance, Epidemiology and End Results (SEER) Registries, which combined provide complete cancer registration coverage for the United States. Select reports also provide mortality data based on death certificate information compiled by the CDC's National Center for Health Statistics' (NCHS) National Vital Statistics System (1,2,4). Cancer survival data were based on the Cancer in North America Survival data, compiled by NAACCR using combined data from SEER and NPCR registries (5). In the United States, projected complete cancer prevalence estimates are produced every three years by the NCI and the American Cancer Society and are currently available through 2016 (6). Importantly, the statistics presented herein do not include non-melanoma skin cancer cases, which are not required to be reported to population-based cancer registries. However, an estimated 3 million people were treated for non-melanoma skin cancer (keratinocyte carcinomas) in 2012, making it the most commonly diagnosed cancer in the United States (7). Statistics herein also do not include benign or *in situ* cancer of any type except for urinary bladder.

In this section, we provide information on overall cancer incidence, mortality, survival, prevalence, and disparities, followed by a brief description of childhood cancers (ages <15 years).

### ***Cancer incidence***

In the United States, about one in three persons are expected to be diagnosed with cancer in their lifetime, and more than 1.6 million new invasive cases of cancer (excluding non-melanoma skin cancers) are diagnosed annually (1). During the most recent 5 years of available data (2010–2014), the average age-standardized cancer incidence rate per 100,000 in the United States was about 20% higher in men compared to women (501.9 versus 417.9) (1). In general, rates for cancer types that occur in both sexes are higher in men than in women with some exceptions (e.g., breast, thyroid) (*Figure 1*).

Aside from non-melanoma skin cancer, the most commonly diagnosed cancers in the United States are

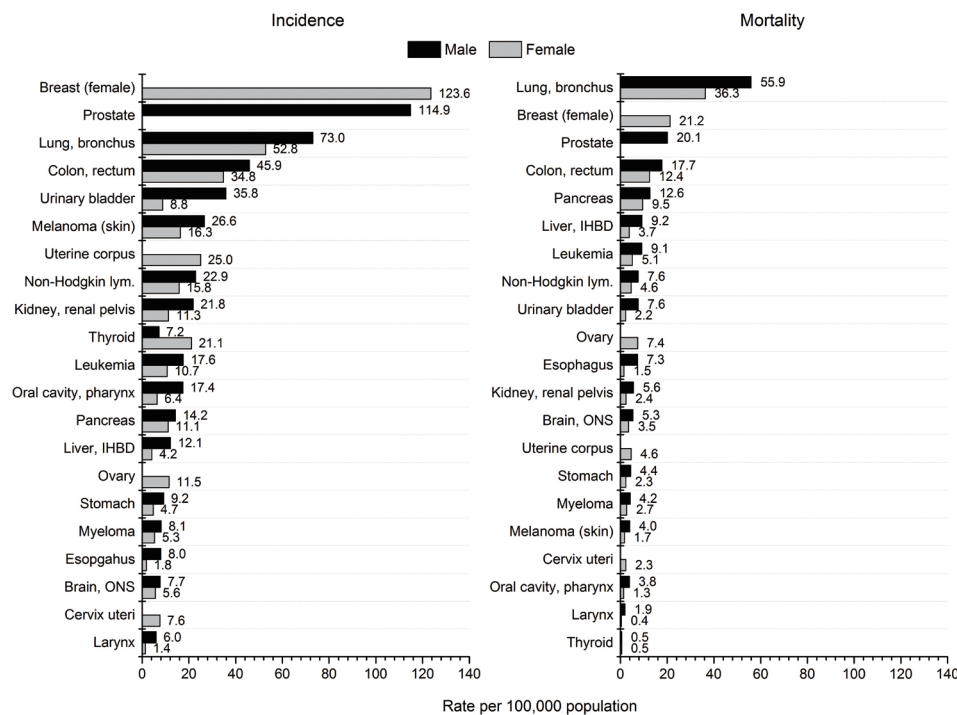
prostate cancer in men and breast cancer in women, followed by cancers of the lung and bronchus (lung) and colorectum in either sex (1,3). During the most recent 10 years of available data (2005–2014), overall age-standardized cancer incidence rates declined by about 2% annually in men and were stable in women (1), largely reflecting trends for the most common cancers. Among men, overall declines are driven by decreasing prostate, lung, and colorectal cancer rates, whereas among women, declines in lung and colorectal cancer rates are offset by increasing rates of breast, thyroid, and corpus uteri cancers. Annual declines in lung cancer rates from 2005–2014 were slightly larger among men (2.5%) than women (1.2%), largely reflecting a greater decrease in male smoking prevalence in the past few decades (1). The precipitous decline in prostate cancer incidence rates in recent years (about 10% annually from 2010–2014) is likely due to a reduction in prostate cancer screening use resulting from recent recommendations against routine use of the prostate specific antigen test (8), discussed in further detail below.

In contrast to declining trends for most cancer types, age-standardized incidence rates increased during 2005–2014 for cancers of the female breast (0.4% annually), liver and intrahepatic bile duct (about 3% in both sexes), pancreas (about 1% in both sexes), thyroid (about 4% in both sexes), and corpus uteri (1.2%) and for melanoma of the skin among men (1.8%) (1). Incidence rates appear to also be increasing for cancer of the oral cavity and pharynx, leukemia, and myeloma in both sexes (2).

For some cancer types, incidence trends vary strikingly by subtype or age group. For example, while the incidence rate of non-cardia gastric cancer is declining in the United States, the rate for gastric cardia cancer increased during 2007–2014 (9). Further, despite decreasing incidence trends for non-cardia gastric cancer, rates are increasing among younger women (9). As another example, overall declines in colorectal cancer incidence rates mask rising rates among whites aged 20–54 years, which are increasing for reasons not well understood but possibly related to the obesity epidemic in the United States (10), as discussed further below.

### ***Cancer mortality***

Similar to incidence, age-standardized cancer death rates per 100,000 during 2011–2015 were higher in men compared to women (196.7 versus 139.5, respectively) (1). Cancer death rates are highest for lung in either sex, followed by prostate



**Figure 1** Incidence and death rates for most common cancers in 2010–2014, United States. Rates are per 100,000 and age-standardized to the 2000 US standard population. IHBD, intrahepatic bile duct; lym., lymphoma; ONS, other nervous system.

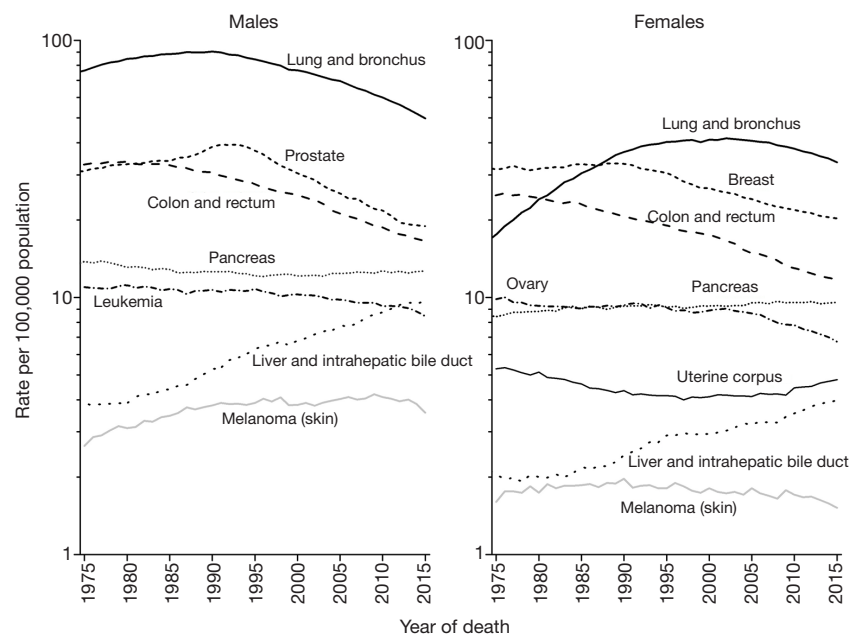
and colorectal cancers among men and breast and colorectal cancers among women (*Figure 1*) (4).

After increasing throughout much of the 20<sup>th</sup> century as a result of the tobacco epidemic, the overall age-standardized cancer death rate in the United States declined 26% from 1991 to 2015 (from 215.1 to 158.6 per 100,000) (1). This decline has been largely attributed to reductions in tobacco use and improvements in prevention, early detection, and treatment (1,2). During the most recent 10 years with available data (2006–2015), the overall cancer death rate declined by about 1.5% per year (1.8% in men *vs.* 1.4% in women) (1). Similar to recent incidence trends, death rates continued to decline for most cancers, including cancers of the colorectum (annual change of about 2.5% in both sexes), lung (3.3% in men and 1.9% in women), and prostate (2.9%), and increased for cancers of the liver and intrahepatic bile duct (2.3% in both sexes) and corpus uteri (1.6%) (*Figure 2*) (1). Death rates for melanoma of the skin declined among women only (1.8% per year), whereas pancreatic cancer death rate increased among men only (0.3%) (1). Despite a slight increase in female breast cancer incidence rates in recent years, death rates continued to

decline during 2006–2015 (1.8% annually) (1).

### Cancer survival

Five-year relative survival rates for all cancers combined and for many cancer types have been increasing in the United States for several decades (1,2). Among cancer patients diagnosed during 2007–2013, 5-year age-standardized relative survival was particularly high for cancers of the prostate (97%), melanoma of the skin (90%), and female breast (89%) (5), in part reflecting the large proportion of these cancer types diagnosed at a localized stage. It should be noted that despite a high 5-year survival rate, prostate cancer is among the three leading causes of cancer death among men in the United States. One reason for this difference could be the very high incidence rate of prostate cancer in the United States (114.9 per 100,000 men). Although the majority of prostate cancer cases are diagnosed at an early stage, the high mortality rate for the disease (20.1 per 100,000 in 2010–2014) (11) may in part be explained the substantial burden of distant stage disease, for which 5-year survival is relatively low. It should



**Figure 2** Trends in death rates for select common cancers, 1975–2015, United States.

be noted that a rapid increase in 5-year relative survival for prostate cancer from 83% in the late 1980s to 93% in the early 1990s and to 99% in the 2000s largely reflects lead time and over-diagnosis (12). However, a recent decline in the use of prostate-specific antigen testing (12) following changes in screening recommendations in the United States (discussed below) might affect prostate cancer survival rates by a possible reduction in detection of preclinical disease.

On the other hand, 5-year age-standardized relative survival rates remain low for other relatively common cancer types, such as pancreas (11%), liver (17%), esophagus (19%), and lung (21%) (5). Many of these cancer types are not only frequently diagnosed at an advanced stage, for which survival remains poor, but also continue to have comparatively low survival for early stage disease despite treatment advances. For example, the overall 5-year relative survival rate for liver cancer more than doubled from the early 1990's to the most recent time period but remains low (2), with the increase largely confined to localized (from 17% to 39%) and regional (from 8% to 14%) stage disease and little improvement for distant stage disease (13).

### **Cancer prevalence**

As of January 1, 2016, more than 15.5 million persons were living in the United States with a history of

cancer, a number that is expected to increase to at least 26.1 million persons by 2040 due to the growth and aging of the United States population alone (14). The most prevalent cancers among men in 2016 were prostate (3.31 million), colorectum (0.72 million) and melanoma of the skin (0.61 million). Among women, the most prevalent cancers were breast (3.56 million), uterine corpus (0.76 million) and colorectum (0.72 million). Despite lower incidence rates in women compared to men, cancer prevalence is higher among women (8.16 million) than among men (7.38 million) in the United States largely due to differences in cancer type distribution and life expectancy.

### **Disparities in cancer occurrence**

The estimated population of the United States as of July 1, 2017 was about 325.7 million; the proportion of major racial/ethnic groups was 62% non-Hispanic (NH) white, 18% Hispanic, 13% NH black, 6% Asian/Pacific Islander, and 1% American Indian/Alaska Native (AI/AN) (15). The median household income in 2016 was \$57,617 in the United States, but with a wide variation across racial/ethnic groups and states; it was \$80,720 among Asians, \$63,155 among NH whites, \$46,882 among Hispanics, and \$38,555 among blacks nationally, while by state it ranged from \$78,945 in Maryland to \$41,754 in

**Table 1** Incidence and death rates for select cancers by race/ethnicity in 2010–2014, United States

Cancer by sex	All race/ethnicities	NH white	Black	Asian/PI	Hispanic	AI/AN
<b>Male</b>						
All cancers						
Incidence	501.9	510.7	560.9	302.8	386.3	425.3
Mortality	200.5	204.1	247.3	122.7	142.6	184.0
Lung and bronchus						
Incidence	73.0	75.9	87.9	45.2	40.6	71.9
Mortality	55.9	58.4	68.0	31.7	27.3	46.3
Prostate						
Incidence	114.9	107.0	186.8	58.4	97.0	78.3
Mortality	20.1	18.7	42.0	8.8	16.5	19.4
Colon and rectum						
Incidence	45.9	45.2	56.4	37.0	41.9	50.1
Mortality	17.7	17.3	25.3	12.4	15.0	19.5
Liver and intrahepatic bile duct						
Incidence	12.1	10.0	17.2	20.0	19.8	20.1
Mortality	9.2	8.0	13.0	14.3	13.1	14.9
<b>Female</b>						
All cancers						
Incidence	417.9	436.0	407.4	287.6	329.6	388.7
Mortality	141.5	145.5	161.8	88.8	97.7	129.3
Lung and bronchus						
Incidence	52.8	57.6	50.1	27.9	25.2	55.9
Mortality	36.3	39.9	34.6	18.0	13.4	30.8
Breast						
Incidence	123.6	128.7	125.5	90.8	91.9	100.7
Mortality	21.2	21.2	29.2	11.3	14.4	14.1
Colon and rectum						
Incidence	34.8	34.5	41.7	27.0	29.3	41.3
Mortality	12.4	12.3	16.5	8.8	9.2	14.0
Liver and intrahepatic bile duct						
Incidence	4.2	3.4	5.1	7.6	7.6	8.8
Mortality	3.7	3.3	4.5	6.1	5.8	6.9

Rates are per 100,000 and age-standardized to the 2000 US standard population (1,4). Incidence rates for blacks are for NH blacks, whereas death rates are for all blacks irrespective of ethnicity. AI/AN, American Indian/Alaska Native; NH, non-Hispanic; PI, Pacific Islander.

Mississippi (16).

Among the major racial/ethnic groups in the United States, incidence and death rates among men overall are highest in NH blacks but lowest in Asians/Pacific Islanders (*Table 1*) (1,4). Among women, cancer incidence rates are highest in NH whites, whereas death rates are highest in NH blacks. While Asians/Pacific Islanders and Hispanics have lower cancer incidence and death rates overall, they have higher rates of infection-related cancers (e.g., stomach, liver), reflecting rates in immigrant countries of origin. AIs/ANs notably have the highest kidney cancer rates in the United States, potentially due to the prevalence of risk factors such as obesity and cigarette smoking (17). However, aggregated AI/AN rates mask wide variation by subregion. For example, colorectal cancer incidence rates in Alaska Natives are more than double those of NH whites and are 80% higher than those in NH blacks, whereas rates in other American Indian groups combined are similar to NH whites (18). Substantial heterogeneity in cancer rates has also been noted among Hispanic and Asian/Pacific Islander subgroups (19,20).

Racial/ethnic minorities also experience disparities in cancer survival. The 5-year relative survival rate for all cancers combined in 2007–2013 was 68% in whites versus 61% in blacks, with striking differences for specific cancer types, such as uterine corpus (84% *vs.* 62%, respectively) (1). Although blacks are more likely than whites to be diagnosed with cancer at advanced stages, stage-specific survival rates for most cancers are also lower in blacks, reflecting in part further disparities in access to and receipt of high quality treatment (1). Disparities by socioeconomic status and race/ethnicity are particularly evident in ages <65 years, who are typically not covered by Medicare health insurance and may experience more barriers to high quality care (1,21). In some instances, however, racial/ethnic disparities in cancer occurrence in the United States persist even after adjusting for socioeconomic differences. In one study, contemporary colorectal cancer death rates in NH blacks were higher than those in NH whites even when educational attainment, a proxy measure for socioeconomic status, was similar (22). Factors contributing to racial/ethnic disparities in cancer occurrence after adjustments for socioeconomic status may include racial/ethnic differences in susceptibility and tumor biology; the use and availability of preventive care, screening, and treatment; and quality of cancer care received even within the same socioeconomic level (23–25).

As an example of the substantial geographic variation in cancer disparities, in 2015, cancer death rates in ages

<65 years in Massachusetts were lower in NH blacks than in NH whites, whereas rates in the District of Columbia were nearly three-times higher in NH blacks (1). Some cancer disparities occur in cross-state regions. For example, county-level analyses have demonstrated that cancer death rates in certain regions in the United States, such as parts of Appalachia, have lagged behind national declines for lung (among women) and colorectal cancers (26,27).

### *Childhood cancer*

Cancer in children <15 years is rare in the United States, accounting for less than 1% of all newly diagnosed cancer cases and 2% of cancer deaths estimated to occur in the United States in 2018 (1). The average age-standardized cancer incidence rate per 100,000 in children aged <15 years during 2009–2013 was 16.5, ranging from 11.5 in AIs/ANs to 17.1 in NH whites (2). During that period, incidence rates increased in all race/ethnicities combined by 0.8% per year on average, with the annual percent increases ranging from 0.4% among Hispanics to 1.5% among blacks; rates remained stable in AIs/ANs (2). Among all cancers in ages <15 years (including benign and borderline malignant brain tumors), leukemia is the most common malignancy, accounting for 29% of cancers, followed by brain and other nervous system tumors (26%) and lymphomas and reticuloendothelial neoplasms (12%); approximately one-half of the latter group are non-Hodgkin lymphomas (including Burkitt lymphoma) and one-quarter are Hodgkin lymphomas (1).

Cancer is the second leading cause of death in children ages 1 to 14 years in the United States, following accidents (1). Average cancer death rates in ages <15 years during 2010–2014 was 2.1 per 100,000, ranging from 1.8 in Asians/Pacific Islanders and AIs/ANs to 2.2 in whites (2). In contrast to recent incidence rates, cancer death rates during 2010–2014 declined in all racial/ethnic groups except AIs/ANs, for which the average annual percent change was not calculated due to sparse data. The average decline per year in all race/ethnicities combined was 1.6%, ranging from 1.5% in whites to 2.6% in Asians/Pacific Islanders (2). The 5-year relative survival rate during 2007–2013 for all cancers combined in ages <15 years was 83%; the rate was >90% for lymphoid leukemia (91%), non-Hodgkin (91%) and Hodgkin (98%) lymphoma, and renal tumors (92%), but was lower for acute myeloid leukemia (65%), central nervous system neoplasms (73%), soft tissue sarcomas (75%), and neuroblastoma (79%) (1).

## Factors contributing to trends in cancer occurrence and disparities

Trends and differences in exposure to cancer risk factors and access to and utilization of cancer screening and treatment can largely explain trends in cancer incidence, death, and survival rates and variations by race/ethnicity, geographic location, and socioeconomic status in the United States. Exposure to risk factors is the major driver of trends and inequalities in cancer incidence, except for cervical and colorectal cancer, for which cancer screening have greatly contributed to a decline in incidence rates by detecting precancerous lesions (28). Increased screening for prostate cancer, however, was the main contributor to a substantial increase in prostate cancer incidence rates in the 1990s (29). Trends and inequalities in cancer death rates in many cases are also largely driven by patterns of exposure to risk factors, particularly for cancers with little improvement in survival. An example is the substantial decrease in lung cancer death rates following declines in smoking prevalence in the United States, as well as differences in lung cancer mortality by sex, race/ethnicity, and geography according to smoking prevalence in corresponding subpopulations (30). For cancers with a great improvement in survival, cancer screening (e.g., cervical cancer) and/or improvement in treatment (e.g., childhood hematologic malignancies) generally play an important role in declining mortality rates (1,28). A combination of these factors may determine trends and inequalities in cancer occurrence for some other cancers.

In this section, we review trends in prevalence of potentially modifiable risk factors of cancer and some of the recommended measures to reduce the exposure in the United States. We also briefly discuss the status of cancer screening and treatment. Finally, we provide information on health insurance coverage as one of the main indicators of access to cancer preventive care, screening, and treatment in the United States.

### *Potentially modifiable risk factors of cancer*

A substantial proportion of cancers in the United States are caused by potentially modifiable risk factors and thus could be prevented (31-34). This proportion was estimated to be about 42% of all incident cancers (excluding non-melanoma skin cancers) and 45% of all cancer deaths in 2014; the corresponding proportions for cases and deaths by sex were 43% and 48% among men, respectively, and 42% among

women (34).

The proportion of specific cancer types attributable to potentially modifiable risk factors varies greatly. For example, the proportion of attributable cancer cases in both sexes combined is more than 80% for cervical cancer, Kaposi sarcoma, melanoma of the skin, and cancer of the anus, lung and bronchus, and larynx but 5% or less for Hodgkin's lymphoma and ovarian cancer (34). For some cancers, such as brain cancer, few major modifiable risk factors have been established.

### **Smoking**

Smoking is the greatest contributor to cancer incidence and mortality in the United States despite a substantial decline in prevalence during past decades (34-36). An estimated 19% of all cancer cases (24% in men and 15% in women) and 29% of all cancer deaths (33% among men and 24% among women) are attributable to cigarette smoking (34). However, this proportion varies across states. Among men, the proportion of cancer deaths attributable to smoking is about 30% or more in all states (except Utah, 22%), but it is greater in southern states (38-40% in Kentucky, West Virginia, Tennessee, Louisiana, and Arkansas) (36). Among women, the proportion ranges from 11% in Utah and 19% in Hawaii and California to 26-29% in Tennessee, Arkansas, Nevada, Alaska, and Kentucky (36).

There is also a substantial disparity in smoking prevalence and related cancer burden by socioeconomic status in the United States (30,37). For example, age-adjusted prevalence of current cigarette smoking among NH white men aged  $\geq 25$  years in 2015 ranged from 7% among those with a Bachelor's or higher to 27% among those with no high school diploma (38). Likewise, average annual age-adjusted death rates per 100,000 in 2008-2010 for lung cancer in NH white men ranged from 8.8 among those with  $\geq 16$  years of education to 52.8 among those with  $\leq 12$  years of education (30). Similar disparities in smoking prevalence and related cancer burden exist across states and racial/ethnic groups (30,38). There is also wide variation across states in the number and intensity of implemented tobacco control measures, including excise taxes, which appear to have the strongest effect in the United States, followed by smoke-free laws (39,40). Some proven strategies to reduce smoking include tobacco taxation, promotion of tobacco-free environments and smoking cessation, implementation of warning labels (notably with color graphics) and mass-media education campaigns, and tobacco advertisement bans (41). No state has yet fully implemented those measures at the

levels recommended by CDC (39).

### **Excess body weight, alcohol, poor diet, and physical inactivity**

Excess body weight accounts for the second highest proportion of all cancer cases and deaths in the United States, preceded by smoking, about 8% of cancer cases (5% in men and 11% in women) and 7% of cancer deaths (6% in men and 7% in women) (34). From the 1960s to 2013–2014, the prevalence of obesity (BMI  $\geq 30$  kg/m<sup>2</sup>) and class 3 obesity (BMI  $\geq 40$  kg/m<sup>2</sup>) in the United States increased from 13% to 38% and from 1% to 8%, respectively, while overweight (BMI 25.0–29.9 kg/m<sup>2</sup>) prevalence remained high at 32–34% (42,43). By race/ethnicity, obesity prevalence among men is similar in NH whites, blacks, and Hispanics (35%–38%), but is lower in Asians (12%) (43). Among women, obesity prevalence ranges from 13% in Asians to 38% in NH whites, 47% in Hispanics, and 57% in blacks (43). Among college graduates, obesity prevalence is lower among NH white men and women, NH black women, and Hispanic women, whereas there is no statistically significant difference in obesity prevalence by education level among NH black and Hispanic men and Asian men and women (44). By state, obesity prevalence in 2014 ranged from 21% in Colorado to 36% in Arkansas (45).

Nearly 6% of all cancer cases (5% in men and 6% in women) and 4% of all cancer deaths in both sexes are attributable to alcohol drinking (34). Alcohol-related cancer is mainly associated with excessive drinking, which includes binge drinking ( $\geq 4$  and  $\geq 5$  drinks per occasion for a woman or a man, respectively) and heavy drinking ( $\geq 8$  and  $\geq 15$  drinks per week for a woman or a man, respectively) (46). Approximately 38 million people (17% of adults) binge drink in the United States, making it the most common type of excessive alcohol drinking in the country (46). Past-month binge drinking prevalence among adults aged  $\geq 50$  years saw a relative increase of 19% from 2005–2006 to 2013–2014 (47). Although binge drinking is more common among men, the increase in prevalence occurred in both sexes (47). Compared with NH whites, binge drinking prevalence is similar in blacks, lower in Asians, and slightly higher in Hispanics (13). By state, prevalence of binge drinking in 2014 ranged from 11% in West Virginia to 25% in North Dakota (45); however, the intensity of binge drinking (the number of drinks per occasion) is highest in the central South and parts of the Midwest (13).

Approximately 4% of cancer cases and 5% of cancer

deaths in the United States are attributable to unhealthy diet, including high consumption of red and processed meat and low dietary intake of fruit and vegetables, fiber, and calcium (34). Many Americans do not meet dietary recommendations. For example, daily consumption of  $\geq 3$  servings of vegetables and  $\geq 2$  servings of fruits was reported by only 16% and 29% of adults in 2015, respectively (48). Similarly, despite a modest increase in leisure physical activity prevalence over the past few decades, 44% of men and 50% of women aged  $\geq 18$  years in the United States in 2015 did not meet recommended aerobic and muscle-strengthening activities (38). Prevalence of unhealthy diet and physical inactivity varies across states and is higher among lower socioeconomic groups (38,45,49).

The combination of excess weight, alcohol consumption, unhealthy diet, and physical inactivity accounts for 18% of all cancer cases (14% in men and 22% in women) and 16% of all cancer deaths (15% in men and 17% in women) in the United States (34). More research is needed to increase adherence to comprehensive guidelines on weight control, alcohol, diet, and physical activity. Some measures include family- and school-based interventions, implementation of preventive measures (consultation, screening, and treatment) in the health care system, increasing awareness through education campaigns, and public health laws (such as taxation and reducing marketing of nonessential high-calorie foods and beverages and alcohol) (50–55).

The CDC has recommended a set of strategies and associated measurements that could be used by communities and local governments to promote healthy diet (e.g., through increasing the availability of affordable healthy food and beverages and supporting healthy choices) and physical activity (e.g., through creation of safe environments) and other measures to prevent obesity (e.g., encouraging breastfeeding) (56,57). As behavioral choices are often shaped within the context of the community, these strategies target different settings, including individuals, healthcare providers, communities, schools, public service venues, and worksites (56). Although some states have enacted public health laws to promote healthy diet or physical activity, those laws have largely focused on a few policy areas (e.g., school-based interventions), and all states are far from the implementation of comprehensive strategies to maintain normal weight and substantially reduce excess body weight (58,59).

Recommended strategies by the Community Preventive Services Task Force to prevent excessive alcohol drinking include increasing alcohol tax, regulating alcohol outlet



density and days and hours of sale, enforcing laws prohibiting sales to minors and making retail establishments liable for injuries or harms caused by illegal sales/service, maintaining government controls over alcohol sales, and alcohol screening and brief intervention provided in clinical settings or using electronic devices (e.g., cellphones) (46). More information is needed on implementation of these strategies across states and how to measure it (60).

### Infections

Nearly 3% of all cancer cases and deaths in both sexes in the United States are attributable to carcinogenic infections with available data, including human papillomavirus (HPV), *Helicobacter pylori*, hepatitis B and C viruses, and human herpes virus type 8 (34). Persistent infection with HPV accounts for the majority of the cancer cases (2%) attributed to infections (34), despite substantial decreases in cervical cancer incidence rates following the widespread uptake of cervical cancer screening (61). The rise in oropharyngeal and anal cancer rates in the United States has been mainly attributed to an increase in persistent HPV infection in corresponding organs (34,62). Effective preventive measures against cancer are available for HPV (vaccination and cervical cancer screening), hepatitis B virus (vaccination), and hepatitis C virus (curative treatment) infections. However, utilization of these measures is generally suboptimal, with variations across states and socioeconomic groups (48). For example, only 43% of adolescents ages 13–17 years were up to date with HPV vaccination as of 2016, ranging from 27% in Wyoming to 71% in Rhode Island (63). One-time hepatitis C virus testing is recommended for those born in 1945–1965 in the United States (also called “baby boomers”), who account for the majority of chronic HCV infections, but only a small fraction of this population has reported testing (14% in 2015) and even fewer have received treatment (13,64).

### Other risk factors

Ultraviolet radiation from sun exposure and indoor tanning contributes to 95% of skin melanomas—or 5% of all cancers excluding non-melanoma skin cancer—in the United States (34). In addition, there are a number of other potentially modifiable risk factors that are generally less common and/or lack nationally representative data, such as radiation other than ultraviolet, air pollution, chemical agents, occupational hazards, and reproductive factors (65,66). However, a few studies have estimated proportion of cancers attributable to some of those risk factors

(67–70). For example, an estimated 8,800 lung cancer deaths in the United States in 2012 were attributed to ambient air pollution (70), accounting for approximately 6% of lung cancer deaths in that year (12).

### Cancer screening

In the United States, routine screening for early detection of cancers of the cervix, colorectum, and female breast and precancerous lesions of the cervix and colorectum is recommended and has contributed to declining cancer death rates, as well as cervical and colorectal cancer incidence rates, in recent decades (1,61,71,72). Routine lung cancer screening with low-dose spiral computed tomography became recommended in 2013 in the United States for current or former (quit within the last 15 years) heavy smokers. Additional inclusion criteria for screening vary across cancer types (48,61). Previously, screening for prostate cancer using prostate-specific antigen was also recommended, but routine use of this test among asymptomatic men aged  $\geq 75$  years since 2008 and for men of all ages since 2012 is no longer recommended by the U.S. Preventive Services Task Force (USPSTF) due to complications associated with over-diagnosis and treatment (48). The American Cancer Society and the American College of Physicians currently support shared decision making regarding the use of prostate-specific antigen testing after receiving information about potential benefits, risks, and uncertainties associated with prostate cancer screening; the USPSTF has a similar proposition in its more recent draft recommendation (48).

From 2000–2015, cancer screening uptake remained stable for breast cancer, increased for colorectal cancer, and slightly declined for cervical cancer (73). In 2015, the proportion of eligible individuals that were up to date with screening consistent with the USPSTF recommendations was 71.5% for female breast cancer, 83.0% for cervical cancer, and 62.4% for colorectal cancer (73). These proportions remain below the *Healthy People 2020* targets, which are 81.1% for breast cancer; 93.0% for cervical cancer, and 70.5% for colorectal cancer (73). Lung cancer screening among eligible current and recent heavy smokers has been low (only 3.9% in 2015) (74). In 2015, 34.4% of men 50 years or older had undergone prostate-specific antigen testing within the past year (48).

As expected, there are substantial disparities in participation in screening programs in the United States by indicators of socioeconomic status, such as education level and more importantly, health insurance coverage (48,73).

For example, the proportion of individuals who were up to date with screening for breast cancer in 2015 was 76.7% among those with private insurance and 35.3% among those with no insurance; the corresponding proportions were 86.8% and 63.8% for cervical cancer and 65.6% and 25.1% for colorectal cancer (73).

### **Cancer treatment**

Improvements in cancer treatment, availability of an increasing number of new anticancer drugs, and an increase in access to timely treatment has been associated with an increase in survival and decrease in mortality rates for some cancers in the United States (75). Some of the most striking increases in survival have occurred for hematologic and lymphoid malignancies due to advances in treatment. For example, the 5-year relative survival rate for chronic myeloid leukemia increased from 22% in the mid-1970s to 68% in 2007–2013, largely as a result of the introduction of tyrosine kinase inhibitors (1).

For many cancers, however, survival remains relatively poor, even for early stage disease in some cancers. For example, although surgical resection, ablation, and liver transplantation are potentially curative treatments for liver cancer (76), the 5-year relative survival rate in the United States is only 37% for localized, 13% for regional, and 4% for distant stage liver cancer (13). However, some of the new biologic therapies have shown promising results in treating more advanced cases of certain cancers. For example, adjuvant therapy with pembrolizumab or nivolumab (monoclonal antibodies against programmed death 1) has increased progression-free and overall survival in advanced melanoma (77,78). Progress in the selection of appropriate treatment based on molecular characteristics of the tumor (also known as precision or personalized medicine) has also been associated with an increase in efficacy and/or avoidance of unnecessary adverse effects for some cancer patients, including breast cancer cases with certain genetic biomarkers (79). However, despite rapid progress, these new treatments are currently available for only a relatively small group of cancer patients, and in some cases, the increase in the survival is short. For example, sorafenib (an oral multikinase inhibitor) has increased the survival in advanced stage liver cancers for only a few months in average (76). Further, these treatments generally have a high cost, making them less accessible to lower socioeconomic groups (79). Inequality in the receipt of appropriate treatment also exists for more traditional

treatments (including surgical excision, radiotherapy, and chemotherapy) across racial/ethnic groups and states (80,81).

### **Health insurance coverage**

The proportion of individuals without health insurance coverage in the United States decreased considerably after 2014, when many provisions of the Affordable Care Act went into effect. For example, the proportion of those without insurance for the entire calendar year declined from 13.3% (or 41.8 million individuals) in 2013 to 8.8% (28.1 million individuals) in 2016 (82). However, the proportion of uninsured individuals is higher in ages <64 years (10.1% *vs.* 1.2% in older ages in 2016), as U.S. residents aged 65 years or more have near-universal healthcare coverage through Medicare (82). There is also variation in the proportion of uninsured individuals across states. In 2014, the proportion of adults aged 18–64 years without current health insurance coverage ranged from 5.3% in Massachusetts to 29.0% in Texas (83). One of the main factors exacerbating this disparity appears to be differences in state-level Medicaid expansion, which allows individuals earning up to 138% of the federal poverty level to apply for the government-funded health insurance program. In 2014, the proportion of adults aged 18–64 years without current health insurance coverage ranged from 5.3% to 20.6% in Medicaid expansion states, whereas it ranged from 10.4% to 29.0% in non-expansion states (83). By January 1, 2014, 24 states and the District of Columbia had expanded Medicaid eligibility; this number increased to 30 states and the District of Columbia by January 1, 2016 (82). However, the recent repeal of the individual mandate to purchase health insurance (which will go into effect from 2019) and efforts to reduce requirements in the health insurance exchanges are likely to increase the proportion of uninsured individuals or those with less comprehensive insurance plans in the United States in the future (84).

### **Conclusions**

Despite the steady decline in both incidence (male only) and death rates over the past decades, about 1.6 million new cancer cases and 600,000 cancer deaths occur in the United States annually, with more than 40% of these cases/deaths attributed to potentially modifiable risk factors. A decrease in smoking prevalence over the past five decades has resulted

in a decline in incidence and death rates of lung cancer and other smoking-related cancers, but smoking remains the major contributor to cancer incidence and mortality in the United States. Excess body weight, unhealthy diet, excessive alcohol drinking, and physical inactivity accounts for a considerable proportion of cancers in the country, second only to smoking. Although the prevalence of certain oncogenic infections (e.g., HCV/HBV) is relatively low in the United States, infections have also contributed to the rise in the occurrence of some cancers, including cancers of the liver (notably among baby boomers), oropharynx, and anus. Comprehensive implementation of successful interventions to curb smoking, excess body weight, and other potentially modifiable risk factors could prevent many cancer cases and avoid morbidity and premature mortality. Optimal participation in recommended cancer screening programs and equitable access to preventive care and treatment could further reduce the burden of cancer in the United States.

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