The Burden of Heart, Lung, and Blood Diseases in the United States, 1990 to 2016

Perspectives from the National Heart, Lung, and Blood Institute

Eric Coles*, George A. Mensah†

Boston, MA, USA; and Bethesda, MD, USA

The National Heart, Lung, and Blood Institute (NHLBI) provides global leadership for a research, training, and education program to promote the prevention and treatment of heart, lung, and blood diseases and sleep disorders to enhance the health of all individuals so that they can live longer and more fulfilling lives [1]. Although the majority of research funded by the NHLBI is conducted in the United States (U.S.), the NHLBI works in collaboration with the Fogarty International Center and other Institutes, Centers, and Offices at the National Institutes of Health to support and advance health research abroad, especially in low- and middle-income countries [2]. The NHLBI commitment to global health research efforts such as the Centers of Excellence Global Health Initiative [3,4] and the Medical Education Partnership Initiative [5,6] that help to advance training and research capacity development in low- and middle-income countries is well-recognized. However, less recognized is what the U.S. can gain from global health research.

As pointed out by Glass [7], many health interventions developed and tested in other countries through NHLBI and other National Institutes of Health research support may provide important lessons for improving the health of U.S. residents. For example, the use of cell phones in Kenya and Haiti to improve medication adherence and overall health access for rural populations has been explored for improving adherence in low-resource and underserved settings in the U.S. [8,9]. Similarly, intervention strategies that have been effective in other high-income countries may prove useful in addressing the U.S. health disadvantage relative to peer high-income countries [10]. To stimulate this type of global health research with a potential to inform dissemination and implementation research to improve health in the U.S. aligned with the NHLBI Strategic Vision [11], we present the current status of the burden and trends of heart, lung, and blood diseases for the period 1990 to 2016.

In presenting these burden and trend data, we have used the most current, objective, internally consistent and comparable data from the GBD 2016 (Global Burden of Disease) study [12-17]. The GBD 2016 study encompasses 333 diseases and illnesses, 2,982 sequelae, and 84 risk factors across 195 country groups, sex groups, and multiple age groups. Since its initial publication in 1997, the GBD data have been increasingly used to inform decision-making processes by governments (e.g., United Kingdom, China, Rwanda, Botswana) and nongovernmental global organizations such as the World Health Organization, The World Bank, and the Bill and Melinda Gates Foundation [18,19]. However, GBD data have not been formally used to inform global health research in heart, lung, and blood diseases.

OBJECTIVE

In this perspective, our main objective is to describe the burden, risk factors, and trends of heart, lung, and blood diseases in the U.S. for the period of 1990 to 2016 using the data from the GBD 2016 study findings with appropriate comparisons to peer high-income countries and the burden and trends at the global level. We propose that the data detailed be used as part of the spectrum of data on the burden of diseases and risk factors to inform evidence-based global health research in NHLBI mission areas [1]. For example, NHLBI staff, research investigators, and grantees could use this data: 1) to support future stewardship decisions, and 2) to identify opportunities in dissemination and implementation research of global best practices in tackling heart, lung, and blood diseases. Ideally, when health metrics are available for sleep disorders in future GBD estimates, they may also be used in stewardship decisions.

METHODOLOGY

Data on disease burden and risk factors were retrieved from the Global Health Data Exchange of the Institute for Health Metrics and Evaluation (IHME) at the University of Washington [20]. Detailed descriptions of the IHME's data collection methodology have been published previously [12,15]. For the risk factor analysis, we included only the 10 leading risk factors in the U.S. as identified by Murray et al. [21]. The burden of disease metrics used include deaths, years of life lost (YLLs), years lost to disability (YLDs), and disability adjusted life years (DALYs) (which is the summation of YLLs and YLDs). Each metric is calculated from causes related to heart, lung, and blood diseases, which are listed in Table 1 and are further explained below.

In the IHME's GBD 2016 study methodology, causes of disease burden form a mutually exclusive, collectively exhaustive framework, which has 4 hierarchical levels that increase in granularity. The broadest level (Level 1) has 3 categories: Communicable, maternal, neonatal, and nutritional diseases; Non-communicable diseases; and Injuries [12]. Level 1 further expands from 3 to 21, 166, and 261

The authors report no relationships that could be construed as a conflict of interest.

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From the *Harvard TH Chan School of Public Health, Boston, MA, USA; and the †Center for Translation Research and Implementation Science, National Heart, Lung, and Blood Institute, National Institutes of Health, Bethesda, MD, USA. Correspondence: G. Mensah (George.Mensah@nih.gov).

GLOBAL HEART
Published by Elsevier Ltd. on behalf of World Heart Federation (Geneva).
VOL. 12, NO. 4, 2017
ISSN 2211-8160/$36.00.
https://doi.org/10.1016/j.gheart.2017.11.001

TABLE 1. GBD 2016 study causes of death related to heart, lung, and blood diseases

Heart Disease	
Level 3	Level 4
Rheumatic heart disease	
Ischemic heart disease	
Hypertensive heart disease	
Cardiomyopathy and myocarditis	
	Myocarditis
	Alcoholic cardiomyopathy
	Other cardiomyopathy
Atrial fibrillation and flutter	
Aortic aneurysm	
Peripheral vascular disease	
Endocarditis	
Other cardiovascular and circulatory diseases	

Lung Diseases	
Level 3	Level 4
Chronic obstructive pulmonary disease	
Pneumoconiosis	
	Silicosis
	Asbestosis
	Coal workers pneumoconiosis
	Other pneumoconiosis
Asthma	
Interstitial lung disease and pulmonary sarcoidosis	
Other chronic respiratory diseases	

Blood Diseases	
Level 3	Level 4
Hemoglobinopathies and hemolytic anemias	
	Thalassemias
	Thalassemia trait
	Sickle cell disorders
	Sickle cell trait
	G6PD deficiency
	G6PD trait G
	Other hemoglobinopathies and hemolytic anemias
Endocrine, metabolic, blood, and immune disorders	

G6PD, glucose-6-phosphate dehydrogenase deficiency; GBD, Global Burden of Diseases.

TABLE 2. Heart, lung, blood collective burden in United States, 1990–2016

	1990 Estimate	2016 Estimate	2016 95% CI
Deaths			
Heart	765,842	724,215	683,034–766,092
Lung	101,555	190,691	176,780–202,898
Blood	11,085	29,236	20,509–32,120
Total	878,482	944,142	880,324–1,001,112
YLLs			
Heart	11,633,133	10,402,231	9,757,843–11,021,405
Lung	1,699,310	2,829,534	2,611,363–3,010,760
Blood	316,330	655,607	496,105–711,021
Total	13,648,774	13,887,371	12,865,311–14,743,187
YLDs			
Heart	846,805	1,259,588	877,287–1,728,857
Lung	1,233,344	1,848,940	1,484,415–2,233,467
Blood	206,281	283,192	189,385–401,259
Total	2,286,429	3,391,720	2,551,088–4,363,583

CI, confidence interval; YLDs, years lost to disability; YLLs, years of life lost.

causes, respectively [12]. Of these causes, we identified 30 that are shown in Table 1 (16 from Level 3 and 14 from Level 4) that are related to NHLBI's disease portfolio and constitute the causes used to assess deaths, death rates, YLLs, YLDs, and DALYs for heart, lung, and blood diseases.

RESULTS

In 2016, heart, lung, and blood diseases collectively caused 994,142 deaths (34% of all deaths) 13,887,371 YLLs (28%), and 3,391,720 YLDs (8%) in the U.S. (Table 2). The degree of uncertainty around the estimates is represented by the confidence intervals in Table 2. In contrast, the corresponding percentages from heart, lung, and blood diseases in the U.S. in 1990 were 41% of deaths, 30% of YLLs, and 7% of YLDs. Figure 1 shows the comparisons between 1990 and 2016. Comparing age-standardized rates per 100,000 residents, the 1990 rates were 296 deaths and 5,690 DALYs, while in 2016 they were 187 and 3,918, respectively. The percentage composition of DALYs also changed. In the U.S. in 1990, the rate of DALYs was composed of 86% YLLs and 14% YLDs. In 2016, the percentage of YLDs increased to 20% and YLLs to 80%. Figure 2B shows the percentage composition of DALYs across 3 locations. Thus, mortality rates for heart, lung, and blood diseases fell by 37% and DALY rates by 46% in the U.S. between 1990 and 2016. Figures 1 and 2 show additional comparisons for 1990 and 2016.

We also compared the U.S. to peer high-income countries and all countries (global data). Heart, lung, and

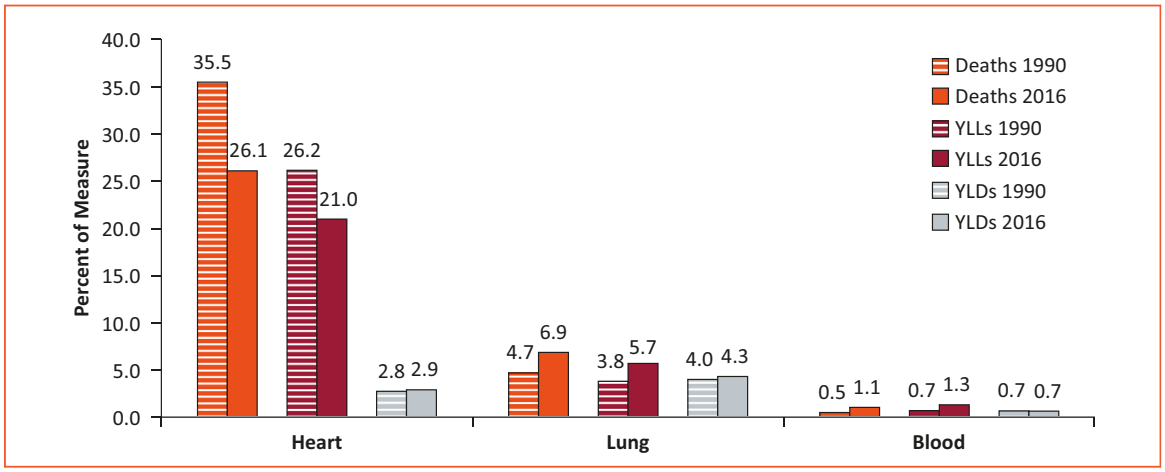

FIGURE 1. The percentage of deaths, years of life lost (YLLs) and years lived with disability (YLDs) in the United States in 2016 compared with 1990. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool).

blood diseases in high-income countries caused 31% of deaths, 25% of YLLs, and 8% of YLDs in 2016. Globally, the corresponding percentages were 29% of deaths, 18% of YLLs, and 8% of YLDs in 2016. Using age-standardized rates per 100,000, high-income countries had 143 deaths and 2,905 DALYs in 2016. In 1990, high-income countries had 266 deaths and 4,946 DALYs rates per 100,000 citizens. Therefore, high-income countries saw a decrease in mortality rates by 46% and DALY rates by 41% between 1990 and 2016. The U.S. continues to lag behind peer high-income countries in heart, lung, and blood mortality rate decline over the period of interest, although mortality rates have been declining in all high-income countries. Figure 3 shows the aggregate trends for the U.S., high-income countries, and the global data and further demonstrates the U.S. mortality disadvantage in comparison to the data from high-income countries. In fact, the mortality rate difference between the U.S. and high-income countries has widened since 1990 (Figure 3).

HEART DISEASES

In 2016, heart diseases were responsible for 26% of deaths, 21% of YLLs, and 3% of YLDs in the U.S. Most of this burden was due to ischemic heart disease (IHD), which was responsible for 75% of deaths and 68% of DALYs within the heart disease burden. No other single cause contributed more than 10% of the heart disease burden. The next largest causes were hypertensive heart disease at 6% of both deaths and DALYs, and cardiomyopathy and myocarditis at 4% of deaths and 6% of DALYs in the U.S. in 2016 (Table 3).

The age-standardized rates of heart disease per 100,000 population in the U.S. in 2016 were 142 deaths and 2,578 DALYs. In 1990, the age-standardized rates in the U.S. were 258 deaths and 4,416 DALYs. The composition of DALYs also changed. In 1990, the rate of DALYs was composed of 7% YLDs and 93% YLLs, while in 2016 they were 11% and 89%, respectively. Thus, heart disease—related mortality rates declined by 45% and DALYs by 42% in the U.S. between 1990 and 2016. Mortality rates decreased for all heart disease between 1990 and 2016. The overall decline in heart disease was due mainly to ischemic heart disease. The U.S. rate of ischemic heart disease fell by 50% from 1990 to 2016. However, not all DALY rates fell. For example, the rate of DALYs increased for atrial fibrillation and flutter (14%) and hypertensive heart disease (7%) during the period of 1990 to 2016.

High-income countries had age-standardized rates per 100,000 population of 112 deaths and 1,930 DALYs in 2016, with the largest burden attributed to ischemic heart disease at 80%. The rates of death and DALYs were 20% and 25% lower, respectively, in high-income countries than in the U.S. Ischemic heart disease played a large role in this gradient. The mortality rate for ischemic heart disease was 25% higher in the U.S. than in peer high-income countries. Figure 4 shows the trends in age-standardized rates of DALYs for the U.S., high-income countries, and at the global level and further demonstrates the U.S. disadvantage in comparison to peer high-income countries.

LUNG DISEASES

In 2016, lung diseases caused 7% of deaths, 6% of YLLs, and 4% of YLDs in the U.S. The largest cause of burden within lung diseases was chronic obstructive pulmonary disease, which was responsible for 86% of deaths and 75% of DALYs of the totals for lung diseases. The second largest cause of death was interstitial lung disease and pulmonary sarcoidosis at 10%. The second largest cause of DALYs was asthma at 15%. The rates of lung disease deaths per 100,000 population were 59 deaths and 1,449 DALYs in the U.S. in 2016. All other lung disease—related deaths, YLLs, and YLDs in the U.S. in 2016 are shown in Table 4. The composition of YLLs and YLDs in DALYs remained relatively unchanged; in 1990, DALYs were composed of

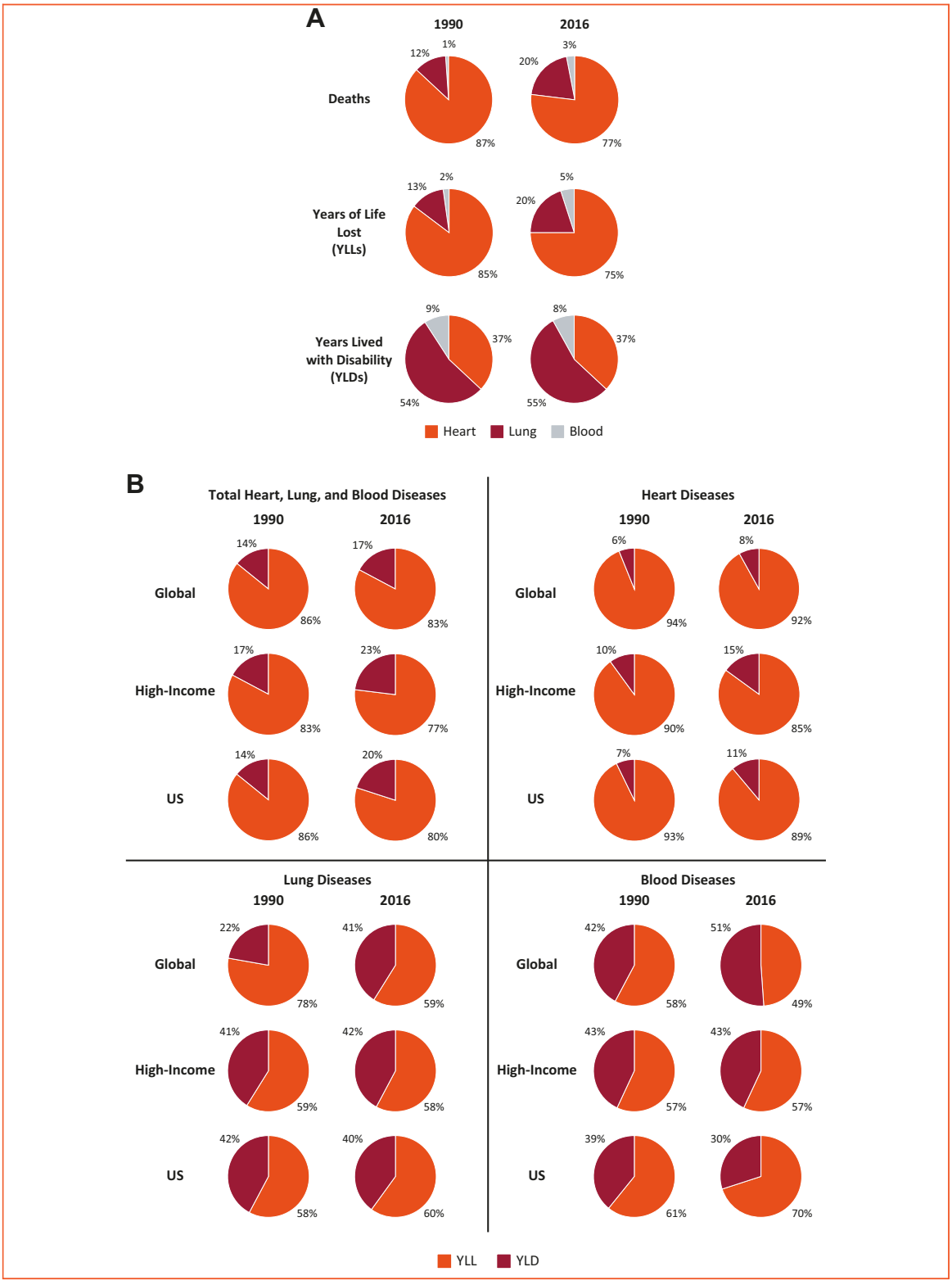

FIGURE 2. (A) The changing composition of deaths, years of life lost (YLLs), and years lost to disability (YLDs) across heart, lung, and blood diseases in the U.S. (United States) in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool). (B) The percentage composition of YLLs and YLDs within disability-adjusted life years (DALYs) for the United States, countries with high income, and the global level in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool).

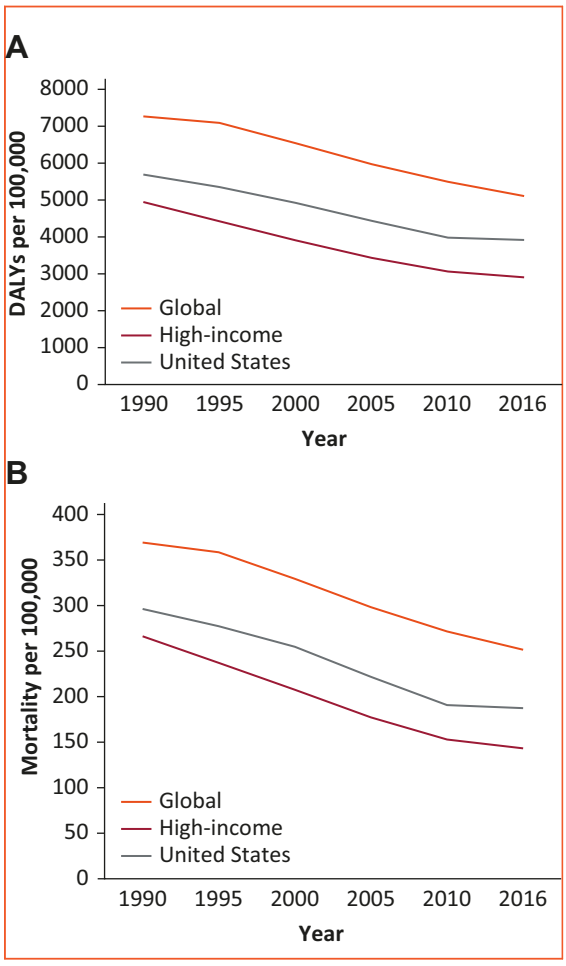

FIGURE 3. (A) Trends in the rate of disability-adjusted life years (DALYs) per 100,000 persons for all heart, lung, and blood diseases between 1990 and 2016 for the United States, countries with high income, and the global level in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool). (B) Trends in the rate of mortality rates per 100,000 citizens for all heart, lung, and blood diseases between 1990 and 2016 for the United States, countries with high income, and the global level in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool).

42% YLDs and 58% YLLs compared with 40% and 60%, respectively, in 2016. Figure 2B shows the percentage composition across 3 locations.

Compared with the U.S. in 1990, death and DALY rates increased by 12% and 2% in 2016, respectively. Compared with high-income countries in 2016, rates of death in the U.S. were 32% higher and rates of DALYs were 28% higher (Figures 5A and 5B), again demonstrating substantial U.S. health disadvantage in comparison to peer high-income countries. Most importantly, Figure 5 demonstrates that the age-standardized DALY rate for lung diseases in high-income countries has been declining since

TABLE 3. Heart disease–related deaths, YLLs, and YLDs in the United States in 2016

Level 3	Level 4	Deaths			YLLs			YLDs		
		Total	95% CI	%	Total	95% CI	%	Total	95% CI	%
Rheumatic heart disease		10,933	10,538–11,352	1.5	162,863	156,669–169,289	1.6	7,344	5,120–9,974	0.6
Ischemic heart disease		544,832	531,694–557,484	75.2	7,605,275	7,409,584–7,802,401	73.1	296,068	210,960–395,435	23.5
Hypertensive heart disease		40,204	25,471–47,784	5.6	669,858	397,514–765,343	6.4	79,492	56,478–106,331	6.3
Cardiomyopathy and myocarditis		30,937	28,926–36,108	4.3	633,570	593,406–759,572	6.1	52,273	36,322–72,407	4.2
	Myocarditis	1,271	953–1,413	0.2	44,950	31,743–50,814	0.4	3,864	2,668–5,365	0.3
	Alcoholic cardiomyopathy	5,784	4,377–7,636	0.8	137,419	107,113–183,008	1.3	10,517	7,260–14,729	0.8
	Other cardiomyopathy	23,882	22,180–28,127	3.3	451,202	418,039–556,791	4.3	37,893	26,212–52,183	3.0
Atrial fibrillation and flutter		22,407	18,314–26,882	3.1	202,788	170,472–237,529	1.9	473,107	334,717–643,469	37.6
Aortic aneurysm		13,500	13,019–14,028	1.9	219,267	210,404–229,977	2.1	—	0–0	0.0
Peripheral artery disease		10,037	7,338–17,321	1.4	117,092	87,646–196,533	1.1	42,172	20,077–75,939	3.3
Endocarditis		9,132	6,837–11,596	1.3	154,624	116,930–199,701	1.5	3,610	2,511–5,058	0.3
Other cardiovascular and circulatory diseases		42,234	40,898–43,537	5.8	636,894	615,220–661,061	6.1	305,522	211,101–420,243	24.3
Total heart disease		724,215	683,034–766,092	100.0	10,402,231	9,757,843–11,021,405	100.0	1,259,588	877,287–1,728,857	100.0

Abbreviations as in Table 2.

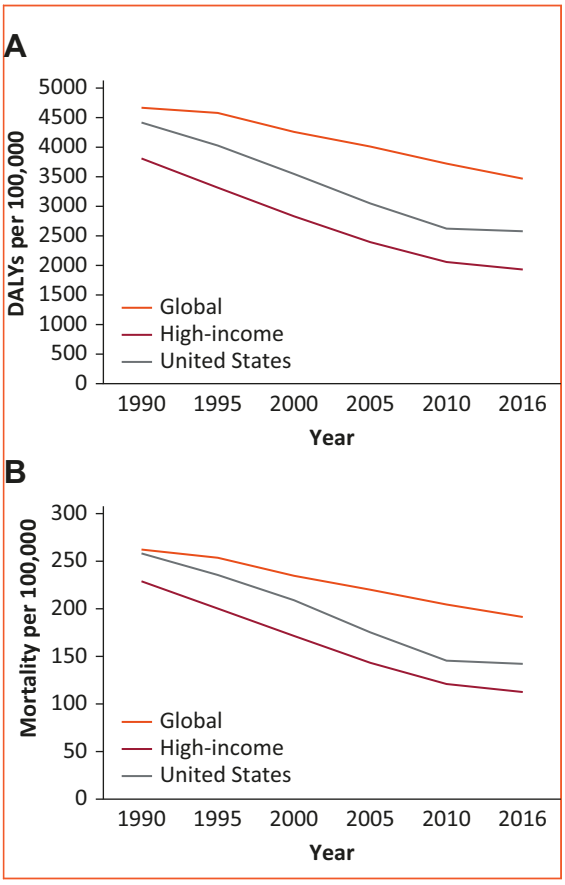

FIGURE 4. (A) Trends in the rate of disability-adjusted life years (DALYs) per 100,000 persons for all heart disease between 1990 and 2016 for the United States, countries with high income, and the global level in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool). (B) Trends in the rate of mortality rates per 100,000 persons for all heart diseases between 1990 and 2016 for the United States, countries with high income (SDI), and the global level in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool).

1990 at a time when the rate in the U.S. was rising, leading to a widening of the health gap between the 2.

BLOOD DISEASES

In 2016, blood diseases were responsible for approximately 1% of deaths, 1% of YLLs, and 1% of YLDs in the U.S. About 90% of this burden was due to a categorical cause, "endocrine, metabolic, blood, and immune disorders," which includes dozens of ICD-10 codes such as, acquired hemolytic anemia, methemoglobinemia, Cushing's syndrome, and other myopathies. The age-adjusted rates of death and DALYs per 100,000 caused by blood diseases in the U.S. in 2016 were 6.5 deaths and 250 DALYs. The percentage composition of DALYs changed from 39% and

TABLE 4. Lung disease–related deaths, YLLs, and YLDs in the United States in 2016

Level 3	Level 4	Deaths			YLLs			YLDs		
		Total	95% CI	%	Total	95% CI	%	Total	95% CI	%
Asthma		4,125	3,846–4,767	2.2	114,116	104,227–124,677	4.0	590,987	393,836–832,399	32.0
Chronic obstructive pulmonary disease		163,793	158,234–172,062	85.9	2,347,404	2,267,810–2,463,471	83.0	1,184,557	1,035,130–1,307,272	64.1
Interstitial lung disease and pulmonary sarcoidosis		19,215	12,141–21,457	10.1	300,552	193,724–336,533	10.6	30,515	20,540–43,331	1.7
Other chronic respiratory diseases		2,502	1,585–3,484	1.3	53,639	32,804–71,313	1.9	31,992	27,260–35,679	1.7
Pneumoconiosis		1,056	974–1,129	0.6	13,823	12,798–14,767	0.5	10,889	7,649–14,787	0.6
	Asbestosis	613	490–756	0.3	7,807	6,639–9,884	0.3	7,040	4,898–9,553	0.4
	Coal workers pneumoconiosis	279	88–364	0.0	3,549	1,062–44,53	0.1	1,677.3	1,174–2,289	0.1
	Other pneumoconiosis	71	61–118	0.0	1,028	890–1,529	0.0	1,606	1,093–2,238	0.1
	Silicosis	94	76–176	0.0	1,440	1,145–2,469	0.1	566	372–810	0.0
	Total lung	190,691	176,780–202,898	100	2,829,534	2,611,363–3,010,760	100	1,848,940	1,484,415–2,233,467	100

Abbreviations as in Table 2.

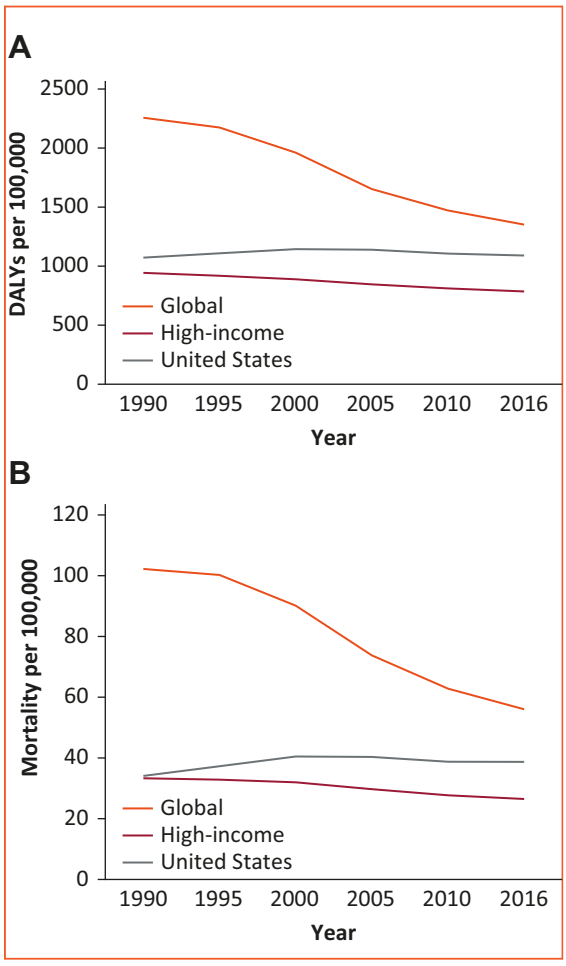

FIGURE 5. (A) Trends in the rate of disability-adjusted life years (DALYs) per 100,000 persons for all lung causes between 1990 and 2016 for the United States, countries with high income, and the global level in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool). (B) Trends in the rate of mortality rates per 100,000 citizens for all lung diseases between 1990 and 2016 for the United States, countries with high income, and the global level in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool).

61% YLDs and YLLs in 1990, to 30% YLDs and 70% YLLs in 2016. Figure 2B shows the percentage composition across 3 locations. Both rates have increased in the U.S. since 1990, by about 3 deaths and 50 DALYS per 100,000 citizens (Table 5). The burden of blood disease is also higher in the U.S. than in high-income countries. There are 3 more deaths and 70 more DALYs per 100,000 in the U.S. than in high-income countries (Figure 6). In addition, the age-standardized rate of DALYs for the U.S. rose consistently during the period of 1990 to 2005 and then stabilized thereafter, whereas it remained unchanged in high-income countries throughout the period of interest.

RISK FACTORS

The GBD 2016 study uses risk-outcome pairs to evaluate attributable risk from selected factors. The overall study includes 84 risk factors, which created 481 risk-outcome pairs. We examined the 10 largest risk factors as identified in Murray et al. [21]. Comparing these risk factors with the heart, lung, and blood diseases identified, we found 51 pairs that measure attributable risks. Figure 7 shows the magnitude of deaths in the U.S. attributed to these risk factors. Dietary risks constituted the largest risk factor, with 380,647 attributable deaths. The second highest was high systolic blood pressure with 348,770 attributable deaths.

The GBD 2016 study noted an increase in the risk of alcohol use, stating it was among the leading global risk factors, especially in Eastern Europe and Central Asia [16]. However, the impact of alcohol use in heart, lung, and blood disorders in the U.S. in 2016 had a confidence interval that included 0. The low estimate was negative, suggesting alcohol use had a protective effect on U.S. health, while the high estimate was positive. For the 30 causes that we examined, alcohol use was part of a risk-outcome pair for 4: atrial fibrillation and flutter, hypertensive heart disease, cardiomyopathy and myocarditis, and IHD. As stated in the GBD 2016 study, alcohol has been shown to have a protective effect for IHD. The protective effect of alcohol use on IHD was larger in absolute terms than the adverse effects of alcohol use on atrial fibrillation and flutter and hypertensive heart disease. Thus the aggregate effect was protective. It should be noted that, given lack of certainty on the health impacts of low levels of alcohol consumption, GBD reports a wide uncertainty interval for IHD due to alcohol use. This wide uncertainty is a result of the GBD approach of estimating a dose response curve for relative risk due to alcohol and including uncertainty in the estimation of both relative risk, alcohol exposure, and cardiovascular disease burden.

DISCUSSION

Heart, lung, and blood diseases continue to be major causes of disease burden, accounting for over one-third of deaths and about one-fifth of DALYs in the U.S. in 2016. Since 1990, the burden of heart, lung, and blood diseases in the U.S. has declined. Mortality rates fell by 37% during this period, driven primarily by declines in age-adjusted rates of death from heart diseases, which accounted for 77% of all heart, lung, and blood deaths, and fell by 44% relative to 1990. In particular, the 50% decline in ischemic heart disease was especially important in lowering overall death rates. However, noting the trend line in Figure 4, the downward trend in heart diseases appears to be decelerating since 2010 in both the U.S. and high-income countries. This finding is consistent with the observation previously made by Sidney et al. [22].

Lung and blood diseases did not show the dramatic declines in age-adjusted mortality rates seen in heart

TABLE 5. Blood disease–related deaths, YLLs, and YLDs in the United States, 2016

Level 3	Level 4	Deaths			YLLs			YLDs		
		Total	95% CI	%	Total	95% CI	%	Total	95% CI	%
Hemoglobinopathies and hemolytic anemias		2,987	2,675–4,139	10.2	67,919	60,118–87,384	10.4	71,069	45,332–108,955	25.1
	G6PD deficiency	271	240–332	0.9	9,395	8,287–11,266	1.4	425	283–602	0.2
	G6PD trait	—	—	0.0	—	—	0.0	30	20–42	0.0
	Sickle cell disorders	744	631–982	2.5	29,284	24,905–37,090	4.5	3,984	2,862–5,288	1.4
	Sickle cell trait	—	—	0.0	—	—	0.0	20,977	12,648–34,125	7.4
	Thalassemias	120	106–157	0.4	7,617	6,805–9,778	1.2	747	494–1,070	0.3
	Thalassemias trait	—	—	0.0	—	—	0.0	39,029	24,528–604,37	13.8
	Other hemoglobinopathies and hemolytic anemias	1,852	1,651–2,705	6.3	21,624	19,317–30,605	3.3	5,876	3,984–8,486	2.1
Endocrine, metabolic, blood, and immune disorders		26,249	17,834–27,982	89.8	587,687	435,988–623,637	89.6	212,123	144,054–292,304	74.9
	Total blood	29,236	20,509–32,120	100	655,607	496,105–711,021	100	283,192	189,385–401,259	100

Empty cells are estimates that were not calculated by the GBD 2016 study.
Abbreviations as in Tables 1 and 2.

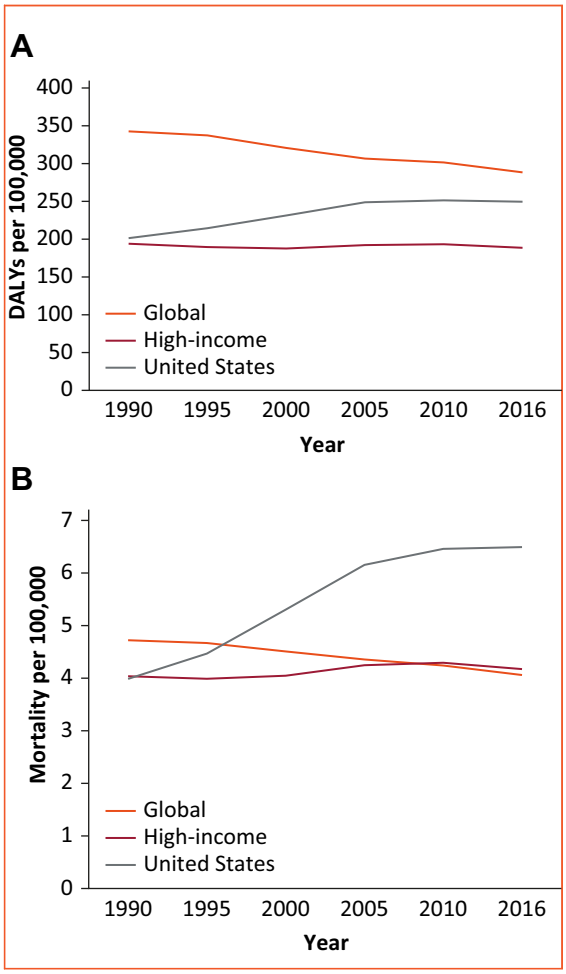

FIGURE 6. (A) Trends in the rate of disability-adjusted life years (DALYs) per 100,000 persons for all blood causes between 1990 and 2016 for the United States, countries with high sociodemographic index (SDI), and the global level in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool). (B) Trends in the rate of mortality rates per 100,000 persons for all blood diseases between 1990 and 2016 for the United States, countries with high SDI, and the global level in 1990 and 2016. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool).

diseases. Lung diseases accounted for 20% of the U.S. deaths in 2016 and saw an age-adjusted decrease of 4% compared with rates in 1990. The difference in the age-adjusted rates of death and DALYs for lung disease between the U.S. and high-income countries has also increased, reflecting a U.S. health disadvantage in comparison to these peer high-income countries. Blood diseases in the U.S. have had an increase in age-standardized rates since 1990. This increase was seen mainly from 1990 to 2005. Since then, age-adjusted rates remained stable. Examination of absolute rates shows that the burden of

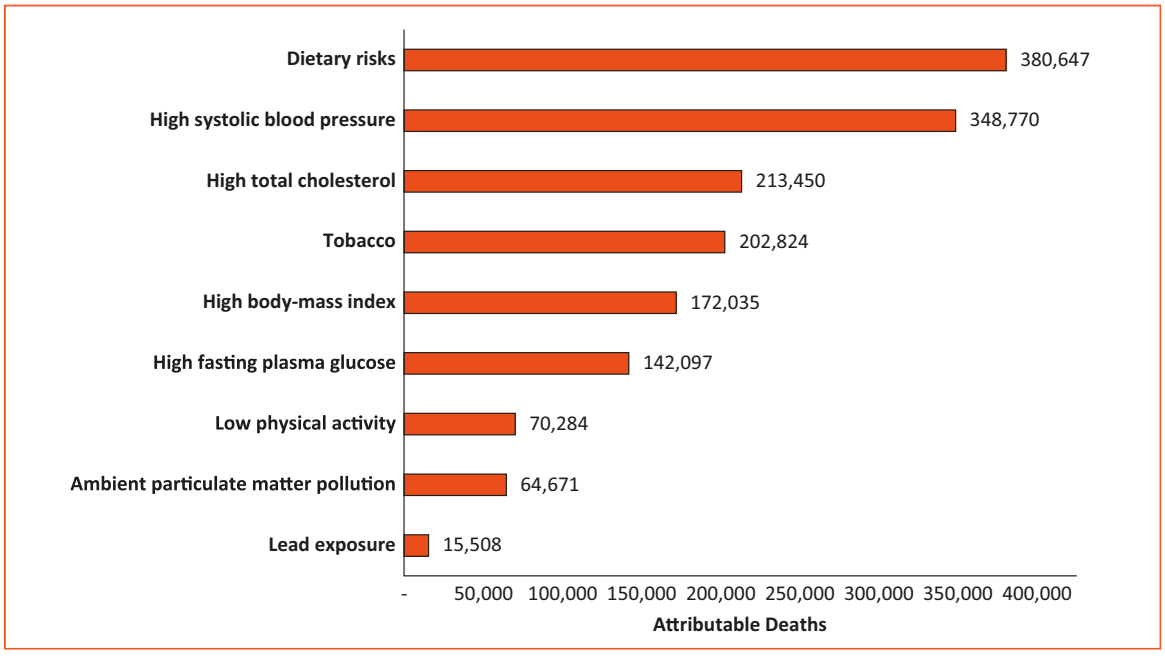

FIGURE 7. The leading risk factors for deaths in heart, lung, and blood diseases, United States. Source of data: GBD Results tool (http://ghdx.healthdata.org/gbd-results-tool).

blood disease has increased, from 208 to 290 DALYs per 100,000, from 1990 to 2016. This increase has been steeper than that observed in high-income countries. These findings provide an opportunity for global health research to understand the primary drivers of the trends and to explore research opportunities for interventions to reduce or eliminate the disadvantage.

Study Limitations

Our review has several limitations. First, we lacked access to subnational data, especially data from population subgroups and geographic locations. For example, data on race and/or ethnicity would have been invaluable [23,24]. Similarly, data for geographic location, such as the state or county level [25,26], made available through the GBD results tool, would also have been very informative. These additional data are likely to be available in future iterations of the GBD. Second, the analysis of blood diseases was limited by the categorical causes available in the GBD 2016 dataset. The disaggregation of "endocrine, metabolic, blood, and immune disorders" would have improved the analysis and likely shed more light on blood disease burden and trends. Third, sleep disorders are within the purview of NHLBI, yet the GBD 2016 study did not include any measures of sleep as a cause of death, DALYs, or as a risk factor. Adding sleep disorders to the GBD dataset as either risk factors or causes would improve the completeness of future measures. For example, insomnia, hypersomnia, and obstructive sleep apnea have ICD-10 codes and could be included as causes of disability or mortality in future GBD iterations. Finally, there were 51 pairs of risk outcomes in heart, lung, and blood diseases in the risk factor analysis. Additional heart, lung, and blood diseases risk-outcome pairs would also likely yield a more informative analysis.

CONCLUSIONS

Diseases of the heart remain the leading cause of death in the U.S. and collectively, heart, lung, and blood diseases contribute nearly one-third of all deaths and years of life lost prematurely. During the period of 1990 to 2016, the U.S. experienced substantial declines in the age-adjusted death rates from heart disease, although the magnitude of the decline was lower than seen in peer high-income countries, revealing a continuing U.S. health disadvantage. During that same period, mortality and disease burden declined only slightly for lung disease and increased for blood diseases in the U.S., while they remained unchanged or mildly improved in peer high-income countries. These are important differences that remain unexplained.

We believe the U.S. has a lot to gain from global health research that explores the principal drivers that underlie differences in health metrics for heart, lung, and blood diseases demonstrated between the U.S. and peer high-income countries. We hope that these findings will stimulate efforts to leverage the emerging science and capabilities of big data to improve U.S. burden of disease assessment through expanded and more granular

subnational data collection and analysis to guide research efforts. The ever-increasing granularity of health metrics analyses with each successive GBD study suggests that this task is feasible [18]. We also hope that these findings will galvanize global health research that leads to new knowledge discovery to help tackle the continuing health disadvantage in the U.S. observed for heart, lung, and blood diseases.

ACKNOWLEDGMENT

We thank our colleague, Dr. Gregory A. Roth of the Institute for Health Metrics and Evaluation and University of Washington, who provided constructive comments on an earlier version of this manuscript.

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