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ORIGINAL RESEARCH

Adverse Trends in Premature Cardiometabolic Mortality in the United States, 1999 to 2018

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BACKGROUND: Life expectancy in the United States has recently declined, in part attributable to premature cardiometabolic mortality. We characterized national trends in premature cardiometabolic mortality, overall, and by race-sex groups.

METHODS AND RESULTS: Using death certificates from the Centers for Disease Control and Prevention's Wide-Ranging Online Data for Epidemiologic Research, we quantified premature deaths (<65 years of age) from heart disease, cerebrovascular disease, and diabetes mellitus from 1999 to 2018. We calculated age-adjusted mortality rates (AAMRs) and years of potential life lost (YPLL) from each cardiometabolic cause occurring at <65 years of age. We used Joinpoint regression to identify an inflection point in overall cardiometabolic AAMR trends. Average annual percent change in AAMRs and YPLL was quantified before and after the identified inflection point. From 1999 to 2018, annual premature deaths from heart disease (117 880 to 128 832), cerebrovascular disease (18 765 to 20 565), and diabetes mellitus (16 553 to 24 758) as an underlying cause of death increased. By 2018, 19.7% of all heart disease deaths, 13.9% of all cerebrovascular disease deaths, and 29.1% of all diabetes mellitus deaths were premature. AAMRs and YPLL from heart disease and cerebrovascular disease declined until the inflection point identified in 2011, then remained unchanged through 2018. Conversely, AAMRs and YPLL from diabetes mellitus did not change through 2011, then increased through 2018. Black men and women had higher AAMRs and greater YPLL for each cardiometabolic cause compared with White men and women, respectively.

CONCLUSIONS: Over one-fifth of cardiometabolic deaths occurred at <65 years of age. Recent stagnation in cardiometabolic AAMRs and YPLL are compounded by persistent racial disparities.

Key Words: cerebrovascular disease ■ diabetes mellitus ■ heart disease ■ mortality ■ premature

In 2005, a controversial forecast predicted that the growing prevalence of obesity and diabetes mellitus (DM) would reduce life expectancy in the United States after 2010.[1] In fact, life expectancy did indeed stall in 2010 and has fallen since 2014 in the United States.[2] This unprecedented decline after decades of increasing life expectancy has been largely attributed to an increase in premature mortality among younger adults (<65 years of age). Associated health disparities across race, sex, and geographic subgroups have also worsened over the past decade.[2,3] Accordingly, greater attention has turned to understanding the causes of premature mortality.[4,5] Cardiometabolic diseases, including heart disease (HD), cerebrovascular disease (CBD), and DM, remain the leading causes of premature death in the United States, yet are largely preventable.[6,7]

Premature mortality has broad economic and societal consequences, in terms of lost productivity and impact on family support units and communities.

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CLINICAL PERSPECTIVE

What Is New?

- Between 1999 and 2018, over one-fifth of cardiometabolic deaths in the United States occurred prematurely (<65 years of age) with persistent Black-White disparities; the proportion of cardiometabolic deaths occurring prematurely increased over time, with increases in mortality rates from premature cerebrovascular disease and diabetes mellitus.

What Are the Clinical Implications?

- The burden of premature mortality from heart disease, cerebrovascular disease, and diabetes mellitus is high in the United States and highlights the need for implementation of evidence-based management of clinical risk factors and public policy targeting high-burden groups to equitably reduce disparities in premature mortality.

Nonstandard Abbreviations and Acronyms

AAMR	age-adjusted mortality rate
CBD	cerebrovascular disease
CDC WONDER	Centers for Disease Control and Prevention's Wide-Ranging Online Data for Epidemiologic Research
DM	diabetes mellitus
HD	heart disease
LE	life expectancy
YPLL	years of potential life lost

The United Nations Sustainable Development Goals therefore outlined a global objective to reduce premature mortality from noncommunicable diseases, including cardiometabolic diseases, by one-third.[8] Such a target provides an important framework to develop and implement clinical and public health prevention strategies to equitably address premature mortality at the population, community, and individual level. To inform potential strategies, we quantified recent US trends in premature mortality from HD, CBD, and DM overall and in race-sex groups from 1999 to 2018.

METHODS

Premature Cardiometabolic Deaths

All data and materials are publicly available in the Centers for Disease Control and Prevention's Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER) database at https://wonder.cdc.gov. Premature cardiometabolic deaths were quantified using death certificate records from the CDC WONDER database.[9] *International Classification of Diseases, Tenth Revision* (*ICD-10*) codes were used to identify decedents <65 years of age at time of death from HD (I00–I09, I11, I13, I20–I51), CBD (I60–I69), or DM (E10–E14) as underlying cause of death. Premature mortality in the United States was defined as deaths at <65 years of age(versus <70 years of age, as defined in the United Nations Sustainable Development Goals[8]) to align with prior analyses of premature mortality in the United States that informed this analysis[2] as well as the fact that current life expectancy is <70 years of age for certain groups of the population. Secondary analysis evaluated mortality from DM as either an underlying or contributing cause of death in CDC WONDER multiple-cause-of-death files to more broadly quantify the burden of DM-related mortality, as DM also contributes to death from other underlying causes. The proportion of all deaths from cardiometabolic causes that occurred at <65 years of age, as well as the proportion of all deaths that occurred at <65 years of age that were attributable to cardiometabolic causes, was calculated.

Premature deaths were ascertained overall (all race groups) and separately in race-sex subgroups (Black and White women and men). Other race/ethnic groups (Asian Americans, Native Americans, Hispanic Americans) were not evaluated because of less reliable identification of these groups on death certificate records.[10–12] In secondary subgroup analyses, trends in age-adjusted mortality rate (AAMR) from premature cardiometabolic deaths was also evaluated by census region in the United States (Northeast, Midwest, South, and West) and by county-level urbanization (rural: micropolitan, noncore regions; urban: large central metro, large fringe metro, medium metro, small metro regions).[13]

Age-Adjusted Mortality Rates

AAMRs were calculated per 100 000 population for each cardiometabolic cause in each study year using the AAMR query embedded in CDC WONDER. AAMRs were adjusted to the 2000 US standard population. AAMR ratios were calculated by race to indicate the number of deaths in Black individuals for every 1 death in White individuals per 100 000 population. Temporal trends in AAMRs were characterized by fitting log-linear regression models with Joinpoint Regression Program version 4.7.0.0 (National Cancer Institute).[14] Joinpoint Regression identified an inflection point in cardiometabolic AAMR trends in 2011, consistent with prior reports of trends in overall cardiometabolic disease.[15,16] This inflection point was applied for all subgroups. To

evaluate trends in AAMRs, average annual percentage change in AAMRs was calculated before and after the inflection point, that is, from 1999 to 2011, and from 2011 to 2018.

Years of Potential Life Lost

Years of potential life lost (YPLL) were calculated using standard methods previously described for various reference age points.[17,18] YPLL was calculated for premature deaths that occurred before 65 years of age (YPLL <65). For comparison, YPLL was secondarily calculated for deaths that occurred younger than overall life expectancy (LE) as well as race-sex subgroup-specific LE (YPLL<LE), as an estimate of actual years lost. For YPLL <65, age 65 was used as the reference age for YPLL calculations. For YPLL<LE, an average LE between 1999 and 2018 for the total US population, and individually for each race-sex subgroup, was calculated using US vital statistics reports.[19,20] This subgroup-specific average LE was used as the reference age for YPLL<LE calculations in each individual race-sex subgroup.[19,20] For each year of the study period, YPLL was calculated by multiplying the number of deaths from the respective cardiometabolic cause in each of a series of 5-year age groups decrementing from the reference age, by the difference between the reference age and the midpoint age of death within each 5-year age group. This result was divided by the total 5-year age group population, then multiplied by 100 000 to obtain YPLL per 100 000 population. YPLL was then age-standardized to the 2000 US standard population. The sum of YPLL from each 5-year age group of decedents within each study year provided YPLL per 100 000 in the total population and in race-sex subgroups for each year of analysis. Trends in YPLL were evaluated using Joinpoint Regression with the methods described above for AAMRs. Average annual percent change of YPLL was calculated from 1999 to 2011 and from 2011 to 2018. YPLL ratios were calculated by race to indicate the number of YPLL in Black individuals for every 1 year lost in White individuals per 100 000 population.

For tests of significance a 2-sided $P<0.05$ indicated statistical significance. Requirements for institutional review committee approval or informed consent were waived because deidentified publicly available data were used.

RESULTS

From 1999 to 2018, the number of premature deaths increased each year from HD (117 880 to 128 832), CBD (18 765 to 20 565), and DM (16553 to 24 758) (Table 1). Thus, by 2018, cardiometabolic deaths accounted for 23.5% (174 155/739 798) of all premature deaths, (HD, CBD, and DM accounting for 17.4% [128 832 deaths], 2.8% [20 565 deaths], and 3.3% [24 758 deaths],

Table 1. Number of Premature Cardiometabolic Deaths (<65 Years of Age) as a Percentage of All Cardiometabolic Deaths (All Ages), 1999 to 2018

	1999	2011	2018
Heart disease, No. deaths <65 y/No. deaths of all ages (%)			
Total	117 880/725 192 (16.3)	121 453/596 577 (20.4)	128 832/655 381 (19.7)
Black women	9195/40 998 (22.4)	9259/33 459 (27.7)	10 501/38 356 (27.4)
White women	25 908/327 533 (7.9)	26 446/248 105 (10.7)	27 685/253 786 (10.9)
Black men	14 876/37 576 (39.6)	15 894/34 913 (45.6)	18 431/43 713 (42.2)
White men	65 194/307 585 (21.2)	66 229/265 596 (24.9)	67 571/299 229 (22.6)
Cerebrovascular disease, No. deaths <65 y/No. deaths of all ages (%)			
Total	18 765/167 366 (11.2)	19 607/128 932 (15.2)	20 565/147 810 (13.9)
Black women	2364/10 990 (21.5)	2213/8814 (25.1)	2266/10 753 (21.1)
White women	5866/89 960 (6.5)	5849/65 278 (9.0)	5996/70 703 (8.5)
Black men	2674/7894 (33.9)	2905/7039 (41.3)	3027/8971 (33.7)
White men	7019/54 867 (12.8)	7579/43 264 (17.5)	8097/50 967 (15.9)
Diabetes mellitus, N deaths <65 y/N deaths of all ages (%)			
Total	16 553/68 399 (24.2)	21 429/73 831 (29.0)	24 758/84 946 (29.1)
Black women	2073/7168 (28.9)	2228/6847 (32.5)	2497/7562 (33.0)
White women	5028/29 054 (17.3)	5859/27 191 (21.5)	6283/27 805 (22.6)
Black men	2034/4759 (42.7)	2764/6048 (45.7)	3515/7935 (44.3)
White men	6866/25 545 (26.9)	9700/30 783 (31.5)	11 196/37 262 (30.0)

respectively, of 739 798 deaths total; Table S1). By 2018, premature HD deaths accounted for 19.7% (128 832/655 381) of all HD deaths, premature CBD deaths accounted for 13.9% (20 565/147 810) of all CBD deaths, and premature DM deaths accounted for 29.1% (24 758/84 946) of all DM deaths. Black men had the highest proportion of cardiometabolic deaths that occurred prematurely (42.2% of HD deaths [18 431/43 713], 33.7% of CBD deaths [3027/8971], and 44.3% of DM deaths [3515/7935]) compared with other race-sex groups.

Age-Adjusted Mortality Rates

AAMRs from premature cardiometabolic diseases are shown in Table 2 and Figure S1. From 1999 to 2011, overall AAMRs from premature HD declined 2.3% per year (95% CI, −2.4 to −2.1; $P<0.05$) from 49.4 to 37.5 deaths per 100 000. After 2011 through 2018, there was no change in AAMRs from premature HD. From 1999 to 2011, AAMRs from premature CBD declined 2.3% per year (95% CI, −2.5 to −2.1; $P<0.05$) from 7.9 to 6.0 deaths per 100 000, but did not change after 2011. AAMRs from premature DM remained unchanged from 1999 to 2011, then increased 1.7% per year (95% CI, 1.2–2.1) to 7.3 deaths per 100 000 in 2018.

Similar patterns were seen in all race-sex groups. AAMRs declined for HD and CBD in all race-sex groups through 2011. After 2011, HD AAMRs significantly increased in White women but remained unchanged for other groups. After 2011, CBD AAMRs declined at a slower rate in Black individuals compared with pre-2011, and stagnated in White individuals. For DM, AAMRs declined in Black and White women and remained unchanged in Black and White men before 2011. After 2011, AAMRs from DM increased for all groups except Black women, in whom AAMRs remained stagnant. For all cardiometabolic causes, Black individuals experienced ≈2-fold higher absolute AAMRs compared with White individuals. In 2018, HD AAMR ratio was 2.2 in women and 1.8 in men, CBD AAMR ratio was 2.2 in women and 2.5 in

Table 2. Age-Adjusted Mortality Rates From Premature Deaths (<65 Years of Age) Attributable to Each Cardiometabolic Disease Subtype as Underlying Cause of Death, 1999 to 2018

	AAMR per 100 000			Average APC in AAMR	
	1999	2011	2018	1999–2011	2011–2018
Heart disease deaths <65 y					
Total	49.4	37.5	37.6	−2.3 (−2.4 to −2.1)*	0.0 (−0.2 to 0.2)
Black women	64.8	44.1	44.8	−3.1 (−4.0 to −2.3)*	0.3 (−0.4 to 1.0)
White women	25.1	19.7	20.0	−1.9 (−2.2 to −1.7)*	0.4 (0.1 to 0.8)*
AAMR ratio (women)	2.6	2.2	2.2		
Black men	125.7	87.7	90.7	−3.0 (−3.2 to −2.7)*	0.2 (−0.4 to 0.8)
White men	65.8	50.5	49.6	−2.2 (−2.3 to −2.1)*	−0.2 (−0.5 to 0.0)
AAMR ratio (men)	1.9	1.7	1.8		
Cerebrovascular disease deaths <65 y					
Total	7.9	6.1	6.0	−2.3 (−2.5 to −2.1)*	0.0 (−0.5 to 0.5)
Black women	16.6	10.6	9.6	−3.5 (−4.2 to −2.8)*	−1.6 (−2.6 to −0.7)*
White women	5.7	4.4	4.4	−2.4 (−2.6 to −2.1)*	0.1 (−0.6 to 0.8)
AAMR ratio (women)	2.9	2.4	2.2		
Black men	22.7	15.9	14.7	−3.1 (−3.9 to −2.3)*	−1.0 (−1.6 to −0.4)*
White men	7.1	5.8	6.0	−1.7 (−2.1 to −1.4)*	0.7 (0.0 to 1.4)
AAMR ratio (men)	3.2	2.7	2.5		
Diabetes mellitus deaths <65 y					
Total	6.9	6.6	7.3	−0.5 (−1.1 to 0.1)	1.7 (1.2 to 2.1)*
Black women	14.8	10.6	10.8	−3.0 (−4.6 to −1.3)*	0.7 (0.0 to 1.3)
White women	4.9	4.3	4.6	−1.4 (−2.4 to −0.5)*	1.5 (0.9 to 2.0)*
AAMR ratio (women)	3.0	2.5	2.3		
Black men	17.3	15.2	17.4	−1.1 (−2.9 to 0.8)	2.0 (0.5 to 3.4)*
White men	6.9	7.4	8.3	0.3 (−0.1 to 0.8)	2.2 (1.8 to 2.5)*
AAMR ratio (men)	2.5	2.1	2.1		

AAMR ratio indicates number of deaths in Black individuals for every 1 death in White individuals per 100 000 population. AAMR indicates age-adjusted mortality rate; and APC, annual percent change (95% CI).

*Indicates that the average APC is significantly different from zero; $P<0.05$.

men, and DM AAMR ratio was 2.3 in women and 2.1 in men.

Years of Potential Life Lost

Table 3 and the Figure show patterns in YPLL as a consequence of premature death from each underlying cardiometabolic cause of death. From 1999 to 2011, YPLL <65 from HD declined from 512.2 to 415.5 years per 100 000 (1.7% per year; 95% CI, –2.0 to –1.5; $P<0.05$), and thereafter remained relatively unchanged through 2018. YPLL <65 from CBD declined from 87.0 year per 100 000 in 1999 to 69.9 years per 100 000 in 2018 (–1.8% per year; 95% CI, –2.2 to –1.5; $P<0.05$), then did not change through 2018. YPLL <65 from DM remained unchanged from 1999 to 2011, then increased 2.4% per year (95% CI, 1.9–2.9; $P<0.05$) to 82.3 years lost per 100 000 in 2018.

Across all race-sex groups, YPLL <65 from HD and CBD significantly declined from 1999 to 2011 with fastest rate of decline in Black men and women. From 2011 to 2018, YPLL <65 from HD declined at a slower rate in White men but did not change in other groups. YPLL <65 from CBD decreased in Black men and women from 2011 to 2018. YPLL <65 from DM decreased in Black women and was unchanged in White women, Black men, and White men from 1999 to 2011. After 2011, YPLL <65 from DM increased for all race-sex groups. For all cardiometabolic causes, Black individuals experienced at least twice the number of YPLL per 100 000 compared with White individuals. In 2018, YPLL ratio for HD was 2.3 in women and 2.0 in men, for CBD was 2.3 in women and 2.4 in men, and for DM was 2.5 in women and 2.2 in men. YPLL <65 accounted for a large proportion of total YPLL<LE, which is shown in the Figure and Table S2. Comparison of YPLL<LE and YPLL <65 annual percent change CIs indicates that from 1999 to 2011, YPLL<LE from HD and CBD declined at a faster rate than their respective YPLL <65 trends, with no significant difference in YPLL<LE and YPLL <65 trend for DM. After 2011, annual percent change of YPLL<LE and YPLL <65 had

Table 3. Years of Potential Life Lost From Premature Deaths (<65 Years of Age) Attributable to Each Cardiometabolic Disease Subtype as Underlying Cause of Death, 1999 to 2018

	YPLL per 100 000			Average APC in YPLL	
	1999	2011	2018	1999–2011	2011–2018
Heart disease deaths <65 y					
Total	512.2	415.5	407.6	–1.7 (–2.0 to –1.5)*	–0.1 (–0.4 to 0.2)
Black women	716.7	518.2	516.9	–2.8 (–3.1 to –2.4)*	–0.2 (–1.0 to 0.7)
White women	253.5	219.1	220.5	–1.2 (–1.5 to –1.0)*	0.5 (0.0 to 1.0)
YPLL ratio (women)	2.8	2.4	2.3		
Black men	1350.0	987.0	1018.9	–2.5 (–3.1 to –1.9)*	0.3 (–0.4 to 0.9)
White men	663.1	542.1	513.1	–1.7 (–1.9 to –1.6)*	–0.7 (–1.1 to –0.3)*
YPLL ratio (men)	2.0	1.8	2.0		
Cerebrovascular disease deaths <65 y					
Total	87.0	69.9	67.9	–1.8 (–2.2 to –1.5)*	–0.5 (–2.2 to 1.3)
Black women	190.9	126.3	109.2	–3.6 (–4.4 to –2.8)*	–1.9 (–3.3 to –0.5)*
White women	62.1	49.4	47.2	–1.9 (–2.1 to –1.6)*	–0.4 (–1.2 to 0.4)
YPLL ratio (women)	3.1	2.6	2.3		
Black men	238.2	173.2	158.4	–2.8 (–3.7 to –1.8)*	–1.2 (–1.8 to –0.5)*
White men	75.6	64.6	65.6	–1.2 (–1.6 to –0.8)*	0.3 (–0.9 to 1.5)
YPLL ratio (men)	3.2	2.7	2.4		
Diabetes mellitus deaths <65 y					
Total	71.1	71.0	82.3	–0.2 (–0.8 to 0.4)	2.4 (1.9 to 2.9)*
Black women	143.3	117.0	131.7	–1.9 (–3.5 to –0.3)*	1.8 (1.1 to 2.4)*
White women	49.6	46.6	51.9	–0.7 (–1.5 to 0.1)	1.9 (1.4 to 2.4)*
YPLL ratio (women)	2.9	2.5	2.5		
Black men	178.8	161.1	200.5	–1.0 (–2.2 to 0.2)	3.1 (1.8 to 4.5)*
White men	71.8	78.3	89.8	0.5 (–0.1 to 1.1)	2.4 (1.9 to 2.9)*
YPLL ratio (men)	2.5	2.1	2.2		

YPLL ratio indicates number of years of potential life lost in Black individuals for every 1 year of potential life lost in White individuals per 100 000 population. APC indicates annual percent change (95% CI); and YPLL, years of potential life lost.

*Indicates that the average APC is significantly different from zero; $P<0.05$.

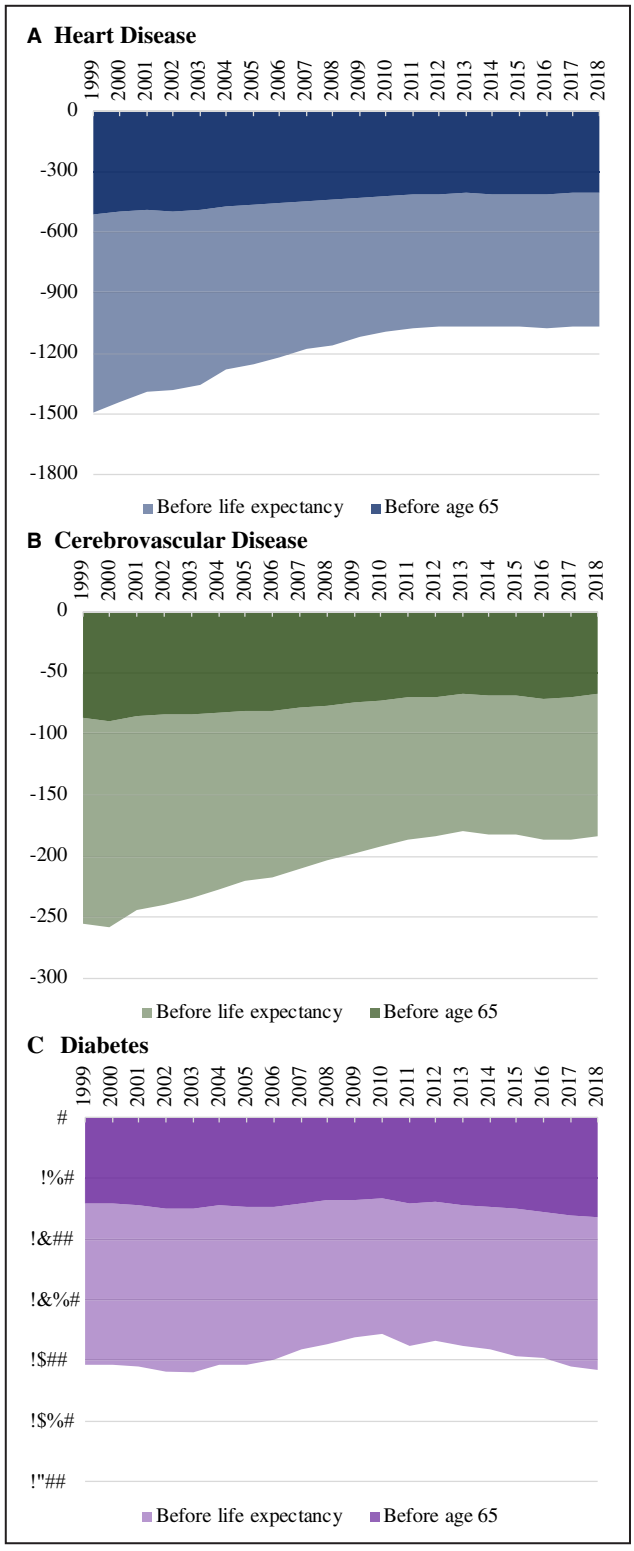

Figure 1. Years of potential life lost before age 65 (premature) and before life expectancy from each cardiometabolic cause of death, 1999 to 2018.
A, Heart disease, (**B**) cerebrovascular disease, (**C**) diabetes mellitus. YPLL indicates years of potential life lost.

overlapping CIs for HD, CBD, and DM, suggesting no significant difference in trend.

DM as Underlying or Contributing Cause

Secondary analyses evaluated DM as an underlying or contributing cause of death (see Tables S3 and S4). In 2018, there were 65 932 premature DM-related deaths, representing 23.9% of all DM-related deaths of any age, and 8.9% of all premature deaths. Overall YPLL <65 from DM as underlying or contributing cause was 193.8 years per 100 000 in 2018, and AAMR from DM-related deaths was 19.0 deaths per 100 000. Substantial disparities in YPLL and AAMRs from DM-related deaths were observed in race-sex groups.

Trends by Census Region and County-Level Urbanization

Secondary analyses also examined AAMRs from premature cardiometabolic deaths stratified by census region and by county-level urbanization (see Tables S5 and S6 and Figure S2). Patterns in AAMRs stratified by census region and by county-level urbanization were similar in comparison with overall trends. For HD and CBD, AAMR declines slowed or stagnated in all census regions and in both rural and urban counties after 2011. For DM, AAMRs either stagnated or increased in all census regions and in both rural and urban counties after 2011. AAMRs were consistently highest in the South compared with other regions, and higher in rural compared with urban counties, for all cardiometabolic causes.

DISCUSSION

Our analysis demonstrates increasing numbers of fatal cardiometabolic events in younger US adults <65 years of age. By 2018, approximately one-fifth of HD deaths, one-sixth of CBD deaths, and one-third of DM deaths occurred prematurely, which translated into ≈1.8 million YPLL to cardiometabolic disease in the United States. Compared with 1999, there were 9% more premature HD deaths, 10% more premature CBD deaths, and 50% more premature DM deaths in 2018. AAMRs and YPLL from HD and CB declined between 1999 and 2011, but were stagnant between 2011 and 2018. DM AAMRs and YPLL were stagnant between 1999 and 2011 and subsequently increased between 2011 and 2018. Similar trends across time were seen in each race-sex and geographic subgroup. However, Black individuals, the southern US census region, and rural counties consistently had the highest burdens of premature cardiometabolic mortality.

The patterns in premature cardiometabolic AAMR trends we observed are consistent with reports of stagnation or worsening in overall cardiometabolic AAMRs since 2011. However, we found that numbers of premature deaths from HD and CBD increased from 1999 to 2018, which contrasts with declining total deaths (all age groups) from these causes during this time.[21] There was also a smaller magnitude of decline in AAMR and YPLL between 1999 and 2011 in decedents <65 years of age as compared with overall population changes. Increases in highly preventable premature mortality from cardiometabolic causes have contributed a 3-fold greater absolute number of premature deaths compared with those from accidental drug overdose or suicide.[2,4,9] Additionally, recent modeling supports that stalling life expectancy in the United States since 2010 is predominantly attributable to cardiovascular diseases.[22] These findings suggest that reversal of the worrisome trends observed in premature cardiometabolic mortality may have the greatest effect in restoring LE growth.

Changing patterns in LE, consistent with prior forecasts from 2005,[1] are likely in large part attributable to the increasing prevalence of underlying cardiometabolic risk factors, including obesity,[23,24] DM,[23,25–27] inadequate physical activity,[28] and poor diet quality,[29] particularly among younger adults. Our findings quantifying the growing burden of premature cardiometabolic mortality highlight the large gaps that exist to achieve ambitious targets set by the United Nations Sustainable Development Goals program[8] to reduce premature mortality by one-third and by the American Heart Association to equitably improve health-adjusted LE by 2 to 3 years.[30] Anchoring the 2030 iteration of the American Heart Association impact goals on health-adjusted LE emphasizes broader health promotion earlier in the life course, and builds upon the cardiovascular health construct (dietary intake, smoking, physical activity, blood glucose, blood pressure, cholesterol, and weight) developed in 2010.[30] Multiple epidemiologic studies have since identified that trajectories of decline in cardiovascular health begin as early as childhood and adolescence.[31] Such patterns strongly suggest that health promotion and primordial cardiovascular disease prevention must be directed toward individuals earlier in the life course—not just in adults. Adolescence, childhood, infancy, in utero, and even preconception are each life stages during which cardiometabolic health must also be emphasized to reduce subsequent morbidity and mortality.[32–35]

We further show substantial and persistent race, sex, and geographic disparities in premature cardiometabolic mortality. In the United States, prevalence of cardiovascular risk factors and disease is higher, and rates of control and optimal medical treatment are lower in racial minority, socioeconomically disadvantaged, and lower education groups as well as in the southern states.[36–38] One barrier that may contribute to adverse outcomes in adults <65 years of age is lack of access to health care. Notably, implementation of the Affordable Care Act enacted in March 2010, which ostensibly broadened health insurance coverage including for younger adults, does not appear to have led to national reductions in premature cardiometabolic mortality rates. Yet a recent analysis demonstrated that counties in states that expanded Medicaid eligibility had a significantly smaller increase in premature HD AAMRs compared with counties in nonexpansion states.[39] These observations may suggest that having health insurance is necessary but not sufficient in improving access to care and improving health. Access to care comprises more than just health insurance; available services, timeliness of care, and prescription medication coverage are also important components that may vary across communities. As medication cost remains a significant barrier and may contribute to lower rates of adherence and risk factor control, alternative delivery strategies such as a polypill have been proposed and were recently demonstrated to lead to greater reduction in systolic blood pressure and cholesterol in a randomized controlled trial in low socioeconomic and minority communities in the southern United States.[40] Additionally, the suboptimal trends observed may have occurred in part because of health consequences related to the 2007 to 2009 economic recession in the United States and its consequent effects on employment, housing, access to health insurance, and other social determinants, which have been linked to increasing cardiovascular morbidity and a range of adverse health outcomes.[41]

Both evidence-based dissemination and implementation strategies and broader policy interventions can complement efforts at the individual, community, and population levels to close gaps in cardiometabolic mortality in those disproportionately affected.[42] Successful local health promotion program models that tailor to at-risk populations in diverse communities have been developed in partnership with community stakeholders and nonphysician health workers. One successful example is the program for hypertension management in Black men conducted in barbershops,[43] which leveraged the familiarity of barbers with their local communities in partnership with pharmacists, who prescribed antihypertensive medications, resulting in significantly better blood pressure compared with the study's control group. Appropriate and intensive blood pressure lowering is one of the most impactful targets for reducing premature mortality. In fact, global models integrating risk factor data and mortality projections demonstrate that increasing coverage of antihypertensive

medications to 70% might delay 39 million deaths. Dietary interventions reducing sodium intake by 30% and eliminating trans fatty acid intake could delay another 54 million deaths.[44] Policy interventions, such as taxation, may be a promising strategy to achieve these dietary goals, as preliminary data from the Sweetened Beverage Tax in Cook County, Illinois, demonstrated success in reduction of volume sold in response to taxation.[45]

Our analysis of premature cardiometabolic mortality has a number of limitations. First, we do not have data on individual-level risk factors. However, causal associations between traditional modifiable risk factors and premature mortality are already well established. Second, the absence of a national surveillance program in the United States limits our ability to estimate trends in health-adjusted LE. However, the use of YPLL is a particularly important metric of our analyses, because this measure uniquely captures the burden of premature mortality by placing greater weight on deaths that occur at younger ages. Third, our assessment of the US population is constrained by the limited race/ethnicity data available in the CDC WONDER database because of either a small number of decedents or lack of disaggregated ethnic data (especially for Hispanic and Asian Americans). Fourth, death certificate data may be subject to miscoding or misclassification. However, such changes are unlikely to substantially alter the major mortality trends we observed over 2 decades. Despite limitations, we present the most comprehensive available data to evaluate trends in premature cardiometabolic mortality in the United States.

Over one-fifth of cardiometabolic deaths are premature, occurring at <65 years of age. Recent stagnation in premature cardiometabolic AAMRs and YPLL, compounded by persistent disparities by race, sex, and region, reveal inadequate progress toward goals for cardiometabolic mortality reduction. This premature mortality is mostly preventable. Our findings inform the need for potential strategies focusing on cardiometabolic health promotion policies and health maintenance prioritizing younger populations to achieve goals for long-term, equitable health outcomes in all Americans.

ARTICLE INFORMATION

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Supplementary Material

Tables S1–S6
Figures S1–S2

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Supplemental Material

Table S1. Percent of all premature deaths (<65 years) that are cardiometabolic, 1999-2018.

	Percent of premature deaths (<65 years) that are CM, N (%)		
	1999	**2011**	**2018**
Deaths from all causes <65 years (denominator)			
Total	593,712	683,502	739,798
Black women	47,935	51,059	56,199
White women	169,582	200,201	211,004
Black men	73,444	75,335	86,838
White men	285,620	332,649	355,215
Heart disease deaths <65 years			
Total	117,880 (19.9)	121,453 (17.8)	128,832 (17.4)
Black women	9,195 (19.2)	9,259 (18.1)	10,501 (18.7)
White women	25,908 (15.3)	26,446 (13.2)	27,685 (13.1)
Black men	14,876 (20.3)	15,894 (21.1)	18,431 (21.2)
White men	65,194 (22.8)	66,229 (19.9)	67,571 (19.0)
Cerebrovascular disease deaths <65 years			
Total	18,765 (3.2)	19,607 (2.9)	20,565 (2.8)
Black women	2,364 (4.9)	2,213 (4.3)	2,266 (4.0)
White women	5,866 (3.5)	5,849 (2.9)	5,996 (2.8)
Black men	2,674 (3.6)	2,905 (3.9)	3,027 (3.5)
White men	7,019 (2.5)	7,579 (2.3)	8,097 (2.8)
Diabetes mellitus deaths <65 years			
Total	16,553 (2.8)	21,429 (3.1)	24,758 (3.3)
Black women	2,073 (4.3)	2,228 (4.4)	2,497 (4.4)
White women	5,028 (3.0)	5,859 (2.9)	6,283 (3.0)
Black men	2,034 (2.8)	2,764 (3.7)	3,515 (4.0)
White men	6,866 (2.4)	9,700 (2.9)	11,196 (3.2)

CM: Cardiometabolic. APC: annual percent change. *Indicates that the average APC is significantly different from zero, $p<0.05$. Cardiometabolic diseases are coded as underlying cause of death. Numerator (number of premature cardiometabolic deaths) is same as in Table 3.

Table S2. Years of potential life lost before life expectancy from each cardiometabolic disease subtype as underlying cause of death, 1999-2018.

	YPLL per 100,000			Average APC in YPLL	
	1999	**2011**	**2018**	**1999-2011**	**2011-2018**
Heart disease deaths <LE					
Total	1493.5	1079.7	1068.1	-2.7 (-2.9, -2.6)*	0.1 (-0.2, 0.4)
Black women	1823.8	1215.5	1208.1	-3.5 (-3.8, -3.3)*	-0.1 (-0.7, 0.6)
White women	1063.6	753.8	743.5	-2.8 (-3.0, -2.7)*	0.1 (-0.3, 0.6)
Black men	2182.7	1549.3	1601.8	-2.7 (-3.3, -2.2)*	0.3 (-0.3, 0.9)
White men	1677.2	1243.9	1205.1	-2.5 (-2.6, -2.3)*	-0.5 (-0.7, -0.2)*
Cerebrovascular disease deaths <LE					
Total	254.7	186.4	183.0	-2.7 (-2.9, -2.5)*	-0.2 (-0.6, 0.2)
Black women	465.1	295.0	267.5	-3.7 (-4.3, -3.0)*	-1.4 (-2.3, -0.5)*
White women	255.7	181.1	174.8	-3.0 (-3.2, -2.8)*	-0.3 (-0.8, 0.2)
Black men	389.7	276.6	257.7	-3.1 (-3.7, -2.5)*	-0.7 (-1.3, -0.1)*
White men	197.6	152.3	156.0	-2.1 (-2.4, -1.9)*	0.4 (-0.3, 1.0)
Diabetes mellitus deaths <LE					
Total	204.6	188.1	208.1	-0.9 (-1.4, -0.4)*	1.8 (1.4, 2.3)*
Black women	395.0	290.6	298.3	-2.9 (-4.4, -1.4)*	0.6 (0.0, 1.2)
White women	185.2	154.9	161.1	-1.7 (-2.3, -1.0)*	0.9 (0.5, 1.4)*
Black men	294.4	263.2	312.7	-0.8 (-2.5, 0.9)	2.3 (1.0, 3.7)*
White men	176.9	182.4	205.0	0.1 (-0.4, 0.6)	2.1 (1.7, 2.5)*

YPLL: Years of potential life lost. APC: annual percent change. *Indicates that the average APC is significantly different from zero, $p<0.05$.

Table S3. Premature deaths (before age 65) attributed to diabetes (as underlying or contributing cause) relative to all DM-related deaths and all premature deaths.

	1999	2011	2018
Number of DM deaths <65, N			
Total	43,808	58,530	65,932
Black women	5,181	5,704	6,324
White women	13,178	16,367	17,432
Black men	5,281	7,191	8,475
White men	18.703	26,791	30,419
Proportion of all DM deaths that are <65, %			
Total	20.9	24.5	23.9
Black women	27.5	29.9	30.4
White women	14.8	17.9	18.2
Black men	39.8	42.3	39.7
White men	22.5	26.1	24.4
Proportion of all <65 deaths that are DM-related, %			
Total	7.4	8.6	8.9
Black women	10.8	11.1	11.3
White women	7.8	8.2	8.3
Black men	7.2	9.5	9.8
White men	6.5	8.1	8.6

DM: Diabetes mellitus

Table S4. Years of potential life lost and age-adjusted mortality rates from premature mortality (before age 65) from diabetes (as underlying or contributing cause), 1999-2018.

				Average APC	
	1999	**2011**	**2018**	**1999-2011**	**2011-2018**
YPLL<65 per 100,000 from DM					
Total	170.0	173.8	193.8	0.2 (-0.2, 0.6)	1.5 (1.1, 2.0)*
Black women	344.9	274.5	296.6	-1.8 (-2.5, -1.0)*	0.8 (-0.1, 1.6)
White women	116.4	116.5	127.1	0.0 (-0.4, 0.4)	1.5 (1.0, 2.0)*
Black men	437.5	384.7	431.3	-1.0 (-1.6, -0.3)*	1.4 (0.6, 2.2)*
White men	172.3	192.0	215.7	0.8 (0.3, 1.3)*	1.7 (1.1, 2.2)*
AAMR<65 per 100,000 from DM					
Total	18.4	17.7	19.0	-0.4 (-0.7, 0.0)*	1.1 (0.7, 1.5)*
Black women	37.2	26.8	26.9	-2.6 (-3.2, -2.1)*	0.0 (-0.7, 0.6)
White women	12.7	11.8	12.4	-0.7 (-1.1, -0.3)*	0.8 (0.5, 1.2)*
Black men	45.5	39.3	41.3	-1.2 (-2.4, 0.0)*	0.7 (-0.3, 1.8)
White men	18.9	19.9	22.1	0.4 (0.0, 0.8)*	1.5 (1.1, 1.9)*

AAMR: age-adjusted mortality rate, APC: annual percent change, DM: diabetes mellitus, YPLL: years of potential life lost.

Table S5. Age-adjusted mortality rates from premature cardiometabolic mortality (before age 65) by region and by county-level urbanization, 1999-2018.

	AAMR per 100,000			Average APC	
	1999	**2011**	**2018**	**1999-2011**	**2011-2018**
Region					
Heart disease					
Northeast	45.4	31.8	31.1	-3.0 (-3.3, -2.7)*	-0.3 (-0.7, 0.1)
Midwest	50.6	39.1	39.5	-2.1 (-2.3, -1.9)*	0.0 (-0.2, 0.3)
South	56.6	44.4	45.3	-2.0 (-2.4, -1.5)*	0.3 (0.1, 0.6)*
West	39.6	29.5	28.4	-2.5 (-2.8, -2.2)*	-0.3 (-1.1, 0.4)
Cerebrovascular Disease					
Northeast	6.2	4.5	4.2	-2.8 (-3.2, -2.4)*	-0.7 (-1.7, 0.2)
Midwest	7.2	5.7	5.8	-2.3 (-2.6, -1.9)*	0.3 (-0.5, 1.1)
South	9.6	7.5	7.4	-2.1 (-2.2, -1.9)*	0.0 (-0.5, 0.5)
West	7.2	5.4	5.4	-2.5 (-2.8, -2.2)*	0.2 (-0.8, 1.2)
Diabetes mellitus					
Northeast	6.0	5.2	5.5	-1.9 (-2.4, -1.4)*	1.1 (0.0, 2.1)*
Midwest	6.7	6.4	7.3	-0.6 (-0.9, -0.3)*	2.2 (1.5, 2.9)*
South	8.1	7.7	8.7	-0.6 (-1.1, -0.1)	2.0 (1.6, 2.4)*
West	6.1	6	6.6	-0.2 (-1.5, 1.2)	2.3 (1.6, 3.1)*
Rurality					
Heart disease					
Urban	47.9	35.6	35.5	-2.4 (-2.5, -2.3)*	-0.1 (-0.3, 0.1)
Rural	56.5	48.2	50.3	-1.4 (-1.6, -1.2)*	0.8 (0.5, 1.1)*
Cerebrovascular disease					
Urban	7.7	5.9	5.8	-2.3 (-2.6, -2.1)*	-0.1 (-0.7, 0.4)
Rural	8.5	7.1	7.5	-1.6 (-1.9, -1.3)*	1.1 (0.4, 1.8)*
Diabetes mellitus					
Urban	6.8	6.2	6.9	-1.0 (-1.9, -0.1)*	1.7 (1.4, 2.1)*
Rural	7.5	8.5	10.1	0.7 (-0.3, 1.8)	3.1 (2.4, 3.8)*

AAMR: age-adjusted mortality rate, APC: annual percent change

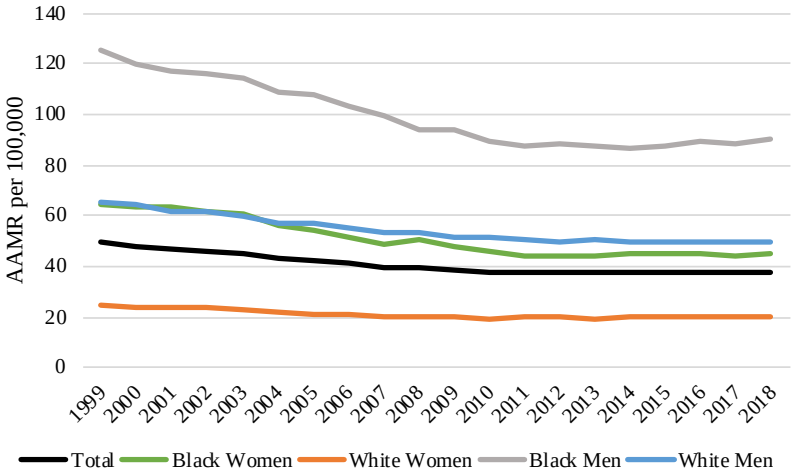
Table S6. Age-adjusted mortality rates from premature cardiometabolic mortality (before age 65) by region and county-level urbanization, 1999-2018.

	AAMR per 100,000			Average APC	
	1999	**2011**	**2018**	**1999-2011**	**2011-2018**
Heart disease					
Northeast					
Urban	45.2	31.3	30.6	-3.0 (-3.2, -2.7)*	-0.4 (-0.8, 0.0)*
Rural	47.2	36.8	36.8	-2.4 (-3.0, -1.9)*	0.7 (-0.1, 1.5)
Midwest					
Urban	51.1	38.7	38.7	-2.2 (-2.5, -2.0)*	-0.2 (-0.5, 0.1)
Rural	48.9	40.6	42.3	-1.6 (-1.8, -1.4)*	0.9 (0.5, 1.2)*
South					
Urban	53.1	40.6	41.5	-2.3 (-2.4, -2.1)*	0.4 (0.0, 0.8)*
Rural	70.5	62.1	65.5	-1.1 (-1.3, -0.8)*	0.9 (0.6, 1.3)*
West					
Urban	39.7	29.1	27.8	-2.6 (-2.9, -2.2)*	-0.4 (-1.3, 0.4)
Rural	39.0	33.1	33.8	-1.5 (-1.9, -1.1)*	0.5 (-0.5, 1.4)
Cerebrovascular Disease					
Northeast					
Urban	6.2	4.5	4.2	-2.8 (-3.2, -2.5)*	-0.9 (-1.7, 0.0)*
Rural	5.7	4.5	4.5	-1.2 (-1.5, -0.8)*	1.2 (-1.5, -0.8)*
Midwest					
Urban	7.4	5.8	5.7	-2.5 (-2.8, -2.1)*	0.0 (-0.8, 0.9)
Rural	6.8	5.5	5.9	-1.6 (-2.2, -1.0)*	0.5 (-0.2, 1.2)
South					
Urban	9.1	7.0	6.9	-2.3 (-2.8, -1.7)*	0.0 (-0.4, 0.5)
Rural	11.3	9.7	10.0	-1.4 (-1.6, -1.1)*	1.1 (0.2, 1.9)*
West					
Urban	7.3	5.4	5.4	-2.6 (-2.9, -2.3)*	0.1 (-0.9, 1.2)
Rural	6.6	5.1	6.0	-2.2 (-3.1, -1.3)*	2.6 (0.3, 0.5)*
Diabetes mellitus					
Northeast					
Urban	6	5.1	5.4	-1.9 (-3.5, -0.2)*	1.1 (0.5, 1.8)*
Rural	5.8	6.5	6.5	0.1 (-0.6, 0.7)	0.1 (-0.6, 0.7)
Midwest					
Urban	6.8	6.3	6.8	-0.9 (-1.3, -0.6)*	1.7 (0.7, 2.6)*
Rural	6.5	7	8.8	0.2 (-0.3, 0.7)	3.6 (2.3, 5.0)*
South					
Urban	7.9	7.1	7.9	-1.1 (-1.6, -0.5)*	1.6 (1.1, 2.1)*
Rural	8.9	10.8	13.0	1.4 (0.2, 2.6)*	3.1 (2.5, 3.7)*
West					
Urban	6.1	5.9	6.5	-0.3 (-1.6, 1.0)	2.2 (1.5, 2.9)*
Rural	6.6	6.7	7.3	1.0 (0.3, 1.7)*	.0 (0.3, 1.7)*

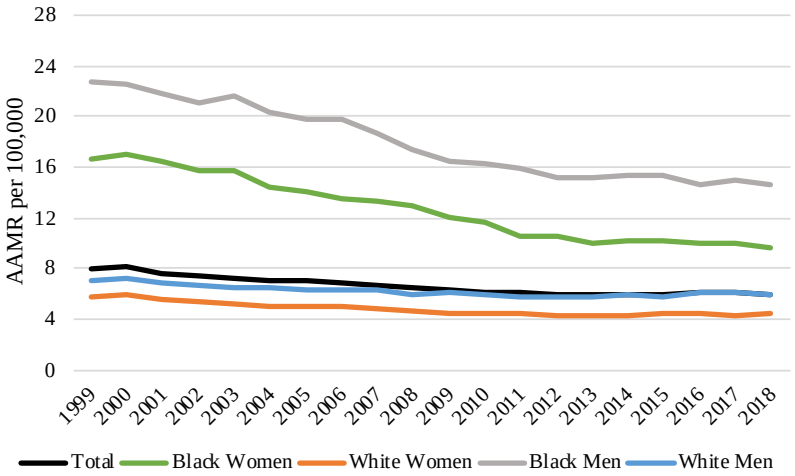
AAMR: age-adjusted mortality rate, APC: annual percent change

Figure S1. Age adjusted mortality rates from premature cardiometabolic mortality before age 65, 1999-2018.

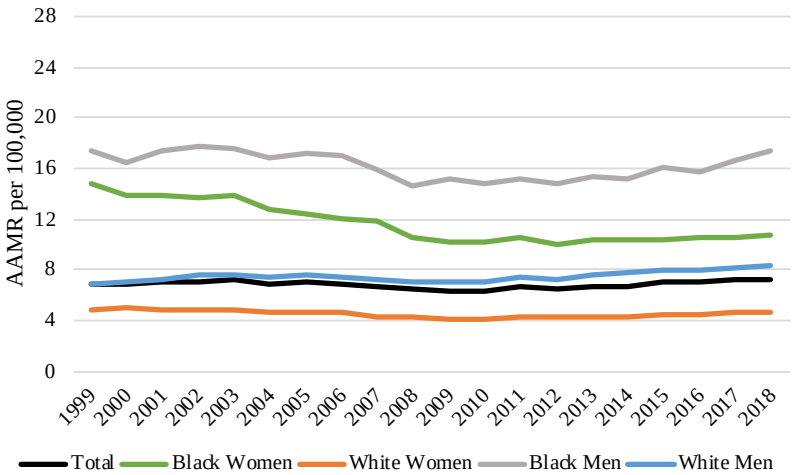
A. Heart disease



B. Cerebrovascular disease

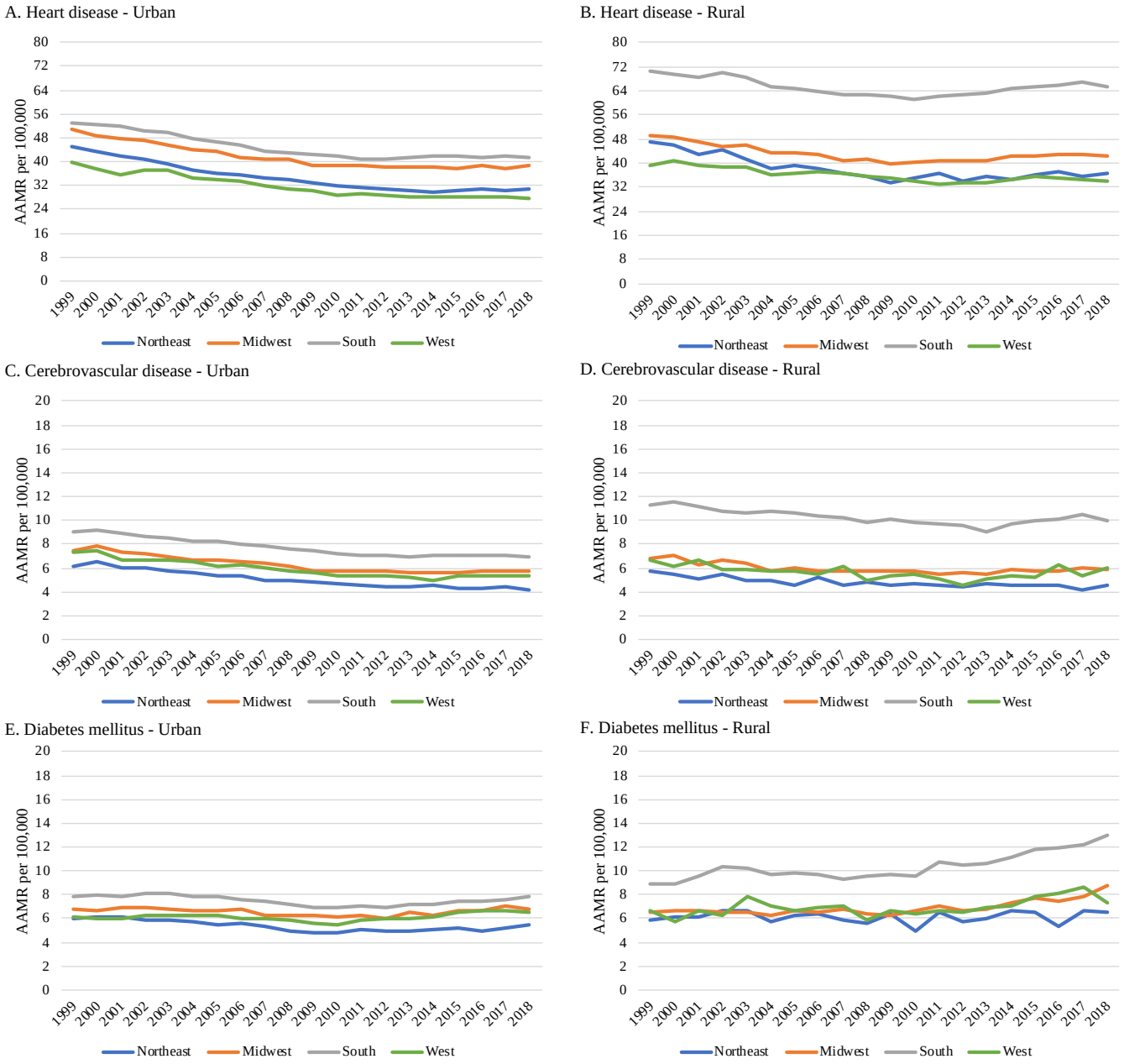


C. Diabetes mellitus



AAMR: Age-adjusted mortality rates.

Figure S2. Age adjusted mortality rates from premature cardiometabolic mortality by region and county-level urbanization, 1999-2018.



AAMR: Age-adjusted mortality rates.