



# Unfavorable social determinants of health and risk of mortality in adults with diabetes: findings from the National Health Interview Survey

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## ABSTRACT

**Introduction** Understanding the role of social determinants of health as predictors of mortality in adults with diabetes may help improve health outcomes in this high-risk population. Using population-based, nationally representative data, this study investigated the cumulative effect of unfavorable social determinants on all-cause mortality in adults with diabetes.

**Research design and methods** We used data from the 2013–2018 National Health Interview Survey, linked to the National Death Index through 2019, for mortality ascertainment. A total of 47 individual social determinants of health were used to categorize participants in quartiles denoting increasing levels of social disadvantage. Poisson regression was used to report age-adjusted mortality rates across increasing social burden. Multivariable Cox proportional hazards models were used to assess the association between cumulative social disadvantage and all-cause mortality in adults with diabetes, adjusting for traditional risk factors.

**Results** The final sample comprised 182 445 adults, of whom 20 079 had diabetes. In the diabetes population, mortality rate increased from 1052.7 per 100 000 person-years in the first quartile (Q1) to 2073.1 in the fourth quartile (Q4). In multivariable models, individuals in Q4 experienced up to twofold higher mortality risk relative to those in Q1. This effect was observed similarly across gender and racial/ethnic subgroups, although with a relatively stronger association for non-Hispanic white participants compared with non-Hispanic black and Hispanic subpopulations.

**Conclusions** Cumulative social disadvantage in individuals with diabetes is associated with over twofold higher risk of mortality, independent of established risk factors. Our findings call for action to screen for unfavorable social determinants and design novel interventions to mitigate the risk of mortality in this high-risk population.

## INTRODUCTION

Over 1 in 10 adults in the USA suffer from diabetes, a leading cause of morbidity and mortality globally.<sup>1 2</sup> Diabetes is an established risk factor for cardiovascular disease,

## WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Adverse social determinants of health (SDOH) are associated with increased risk of diabetes and mortality; however, it remains unknown how cumulative social burden affects mortality risk in people with diabetes.

## WHAT THIS STUDY ADDS

⇒ This study found that, in adults with diabetes, those experiencing the highest level of social disadvantage—assessed using 47 individual SDOH—had over twofold higher mortality risk, compared with those with the most favorable SDOH profiles.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings highlight SDOH as a robust predictor of mortality in adults with diabetes, independent of traditional risk factors, and demonstrate the need to improve SDOH screening in order to identify high-risk patient populations and inform efforts to address SDOH and mitigate persistent disparities in mortality.

chronic kidney disease, and vision disability, and often occurs alongside traditional risk factors including obesity and hypertension.<sup>3</sup> Diabetes, with its numerous complications, significantly increases a person's risk of morbidity and mortality and is among the top 10 leading causes of death in the USA.<sup>4</sup>

Increasing evidence points to social determinants of health (SDOH) as upstream drivers of persistent inequities in diabetes and associated cardiovascular events and all-cause mortality.<sup>5 6</sup> Multiple unfavorable SDOH, such as low income, poor access to healthcare, and food insecurity, among others, have been associated with diabetes and contribute to worse health outcomes.<sup>7 8</sup> However, existing approaches

**Table 1** Descriptive characteristics by diabetes status from the National Health Interview Survey 2013–2018

	No diabetes	Diabetes
Sample (n)	162 366	20 079
Weighted sample (weighted %)	215 015 330 (90.3)	23 211 567 (9.7)
Age category, n (weighted %)		
18–39	60 460 (42.0)	1303 (8.0)
40–64	66 007 (41.5)	8929 (49.5)
65+	35 899 (16.6)	9847 (42.4)
Sex, n (weighted %)		
Male	72 731 (47.9)	9384 (50.5)
Female	89 635 (52.1)	10 695 (49.5)
Race/ethnicity, n (weighted %)		
Non-Hispanic white	107 874 (65.9)	12 139 (61.5)
Non-Hispanic black	19 870 (11.7)	3612 (15.5)
Non-Hispanic Asian	9045 (5.9)	856 (5.0)
Hispanic	23 663 (15.6)	3049 (16.2)
Other	1914 (0.9)	423 (1.8)
CRF profile, n (weighted %)		
Optimal	71 763 (47.0)	2313 (12.5)
Average	61 328 (36.7)	7597 (38.5)
Poor	28 585 (16.3)	10 079 (49.0)
Comorbidities, n (weighted %)		
0	109 777 (71.6)	6473 (35.4)
1	37 350 (20.7)	7303 (35.7)
≥2	15 239 (7.7)	6303 (28.9)
SDOH quartile, n (weighted %)		
Q1	43 054 (28.9)	3833 (21.1)
Q2	43 787 (26.5)	4835 (23.8)
Q3	36 992 (22.5)	4864 (23.4)
Q4	38 533 (22.1)	6547 (31.7)

CRF, cardiovascular risk factor; SDOH, social determinants of health.

to assess mortality risk are predominantly based on “clinical” risk prediction algorithms which account for traditional measures of socioeconomic well-being, such as education or income, without a holistic assessment of cumulative social disadvantage across multiple SDOH domains.<sup>5</sup> Current frameworks to capture SDOH burden are either based on solitary measures of individual SDOH or indices that capture a limited number of social determinants without due attention to the interconnected nature of SDOH across established domains.<sup>6–9–10</sup> In addition, such indices have mostly been developed in subgroups without diabetes or in the general population,<sup>11</sup> and predict non-mortality endpoints.<sup>12</sup> To our knowledge, comprehensive SDOH indices have not been used to capture cumulative social

disadvantage and assess mortality risk in adults with diabetes.

SDOH do not exist in silos; rather, they interact with each other and impact distal health outcomes. Despite the known association between SDOH and diabetes, SDOH and mortality, and diabetes and mortality, the extent to which cumulative social disadvantage may explain variation in mortality risk in adults with diabetes has not been previously investigated. Similarly, racial/ethnic and gender disparities in both diabetes and mortality are well documented.<sup>13</sup> However, possible demographic disparities in the association between SDOH and mortality in adults with diabetes have not been studied to date.

In this population-based study, we sought to examine the impact of cumulative social disadvantage—measured using a comprehensive, validated SDOH framework—on all-cause mortality in a nationally representative sample of US adults with diabetes. We also assessed potential racial/ethnic and gender disparities in the SDOH-mortality association.

## METHODS

### Data source and study design

This study used data from the 2013–2018 National Health Interview Survey (NHIS), linked to the National Death Index (NDI) for adults ≥18 years. The NHIS, collected by the National Center for Health Statistics in the Centers for Disease Control and Prevention, comprises a series of annual cross-sectional national surveys, which feature complex, multistage sampling to provide estimates on the non-institutionalized US population.<sup>14–15</sup> The NHIS questionnaires collect information at the household, family, and personal levels, and are divided into four core components: household composition, family core, sample child core, and sample adult core.<sup>14</sup> Data from NHIS 2013–2018 were used due to the richness of SDOH information collected during this time, resulting in a comprehensive list of 47 SDOH variables.<sup>16–17</sup>

We used NDI data for mortality follow-up through 2019, which represent the most current data on mortality that are linkable to the NHIS.<sup>18</sup> With over 100 million death records, the NDI is the most complete source of mortality data in the USA, containing all death records for all 50 states and District of Columbia starting from 1979.<sup>19</sup> The NDI uses the following identifiers for linkage to NHIS: social security number, first name, last name, father’s surname, date of birth, sex, race, and state/country of birth and residence. In the NDI, participants are followed quarterly per year for mortality ascertainment. Participant eligibility for linkage and inclusion in the linked data set was contingent on the availability and completeness of all aforementioned identifiers.

In this study, baseline was defined as the index quarter/year of survey participation for each NDI-linked NHIS participant, and October–December 2019 was used as the quarter/year of last follow-up. Additional methodological

**Table 2** Descriptive characteristics by SDOH quartiles in adults with diabetes from the National Health Interview Survey 2013–2018

	SDOH-Q1	SDOH-Q2	SDOH-Q3	SDOH-Q4
Sample (n)	3833	4835	4864	6547
Weighted sample (weighted %)	4 903 809 (21.1)	5 515 059 (23.8)	5 432 465 (23.4)	7 360 233 (31.7)
Age category, n (weighted %)				
18–39	192 (6.0)	212 (6.0)	331 (8.8)	568 (10.3)
40–64	1450 (43.1)	1598 (39.1)	2083 (48.4)	3798 (62.5)
65 and above	2191 (50.8)	3025 (54.9)	2450 (42.7)	2181 (27.2)
Sex, n (weighted %)				
Male	2185 (59.8)	2422 (53.4)	2193 (49.1)	2584 (43.1)
Female	1648 (40.2)	2413 (46.6)	2671 (50.9)	3963 (56.9)
Race/ethnicity, n (weighted %)				
Non-Hispanic white	2888 (76.6)	3387 (70.1)	2862 (59.4)	3002 (46.4)
Non-Hispanic black	459 (10.7)	743 (13.0)	920 (15.9)	1490 (20.3)
Non-Hispanic Asian	206 (5.6)	190 (4.4)	236 (6.1)	224 (4.1)
Non-Hispanic other	55 (1.1)	80 (1.6)	112 (1.9)	176 (2.3)
Hispanic	225 (5.9)	435 (10.8)	734 (16.7)	1655 (26.9)
CRF profile, n (weighted %)				
Optimal	591 (16.3)	648 (13.2)	535 (13.2)	539 (8.9)
Average	1534 (40.5)	2021 (42.0)	1869 (38.7)	2173 (34.3)
Poor	1663 (43.2)	2147 (44.8)	2446 (48.2)	3823 (56.7)
Comorbidities, n (weighted %)				
0	1387 (38.2)	1498 (33.7)	1620 (37.2)	1968 (33.4)
1	1431 (36.4)	1853 (37.8)	1716 (34.1)	2303 (34.8)
≥2	1015 (25.4)	1484 (28.4)	1528 (28.6)	2276 (31.8)

CRF, cardiovascular risk factor; SDOH, social determinants of health.

considerations for the NHIS-NDI data linkage have been reported in detail elsewhere.<sup>19–21</sup>

### Participants

This study included all 2013–2018 NHIS participants ≥18 years of age with available death record information in the NDI (n=190 113). Participants with an invalid response to the diabetes screening question, unavailable information on death status, or insufficient identifying data (n=7668) were not eligible for linkage to NHIS and were therefore excluded from the study population.

### Primary exposure

Social disadvantage, measured using quartiles of aggregate SDOH burden, was the primary exposure variable. We adapted the SDOH framework proposed by the Kaiser Family Foundation (KFF)<sup>22</sup> and Healthy People 2030 (HP2030),<sup>10</sup> organizing available SDOH information into six domains: (1) economic stability; (2) neighborhood, physical environment, and social cohesion; (3) community and social context; (4) food; (5) education; and (6) healthcare system. The KFF and HP2030 frameworks have been used and adapted widely in research and policy implementation settings to study disparities in

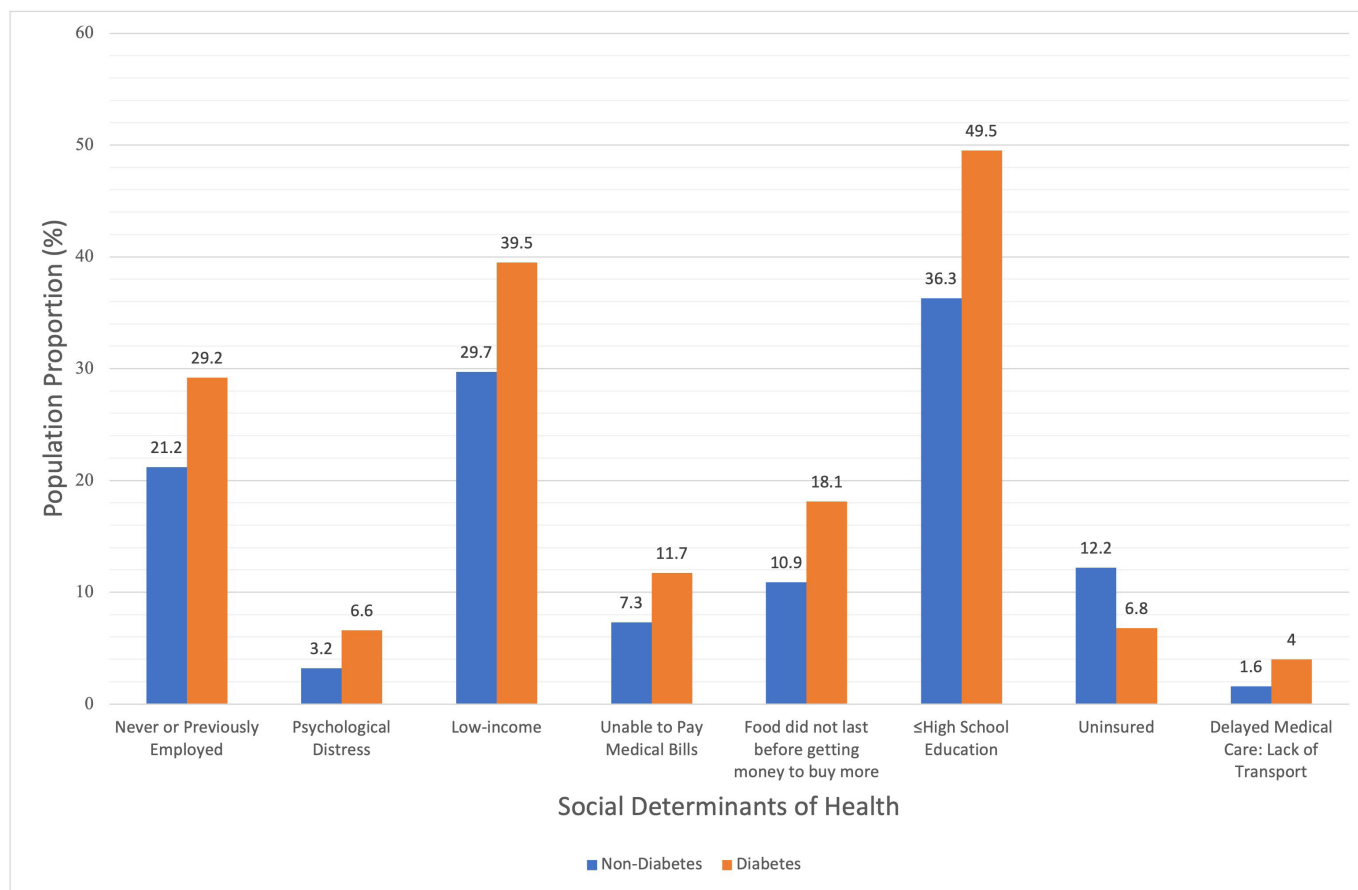
diverse health outcomes. A list of 47 individual SDOH was constructed across the six domains (online supplemental eTable 1). Each SDOH was classified as either favorable or unfavorable and assigned a value of 0 or 1, respectively (eg, “0” for middle/high-income and “1” for low-income). An aggregate SDOH index was created by combining the 47 individual SDOH and dividing the range of values of the resulting index into quartiles, with the most favorable (ie, lowest) SDOH scores in the first quartile (Q1) and the most unfavorable (ie, highest) scores in the fourth quartile (Q4).

### Diabetes

Diabetes was assessed using the following question: “have you ever been told by a doctor or other health professional that you have diabetes (or sugar diabetes)?” Participants who responded “yes” were classified as having diabetes.

### Mortality

All-cause mortality, ascertained using death certificate records in the NDI, was the outcome event of interest. A participant was defined as dead if identified as “deceased” in the NDI during the study follow-up period. Cause of



**Figure 1** Distribution of individual SDOH characteristics by diabetes status. While people with diabetes were more likely to be insured than those without diabetes, they were also more likely to experience the other adverse conditions, such as limited transportation, food insecurity, and low-income status. All differences listed were statistically significant, with  $p$  values  $<0.001$ . Not all 47 SDOH are shown (see online supplemental eTable 1 for the full list). SDOH, social determinants of health.

death was determined using the International Classification of Diseases, Ninth and Tenth Revisions.

### Covariates

Relevant covariates included sex (male and female); race/ethnicity (non-Hispanic white (NHW), non-Hispanic black (NHB), non-Hispanic Asian, Hispanic, and other); cardiovascular risk factor (CRF) profile, including hypertension, diabetes mellitus, smoking, and obesity (body mass index  $\geq 30$  kg/m<sup>2</sup>); and comorbidity profile, including atherosclerotic cardiovascular disease (ASCVD), chronic obstructive pulmonary disease, cancer, and chronic kidney disease. ASCVD was defined as a composite of coronary heart disease, angina, myocardial infarction, and stroke. CRF conditions and comorbidities were constructed as binary (yes/no) variables and aggregated to create separate indices, categorized as 0 (optimal), 1–2 (average), or  $\geq 3$  (poor) for CRF and 0, 1, or  $\geq 2$  comorbidities. All covariates were self-reported and obtained from the NHIS Sample Adult Core Questionnaire.<sup>19 20</sup>

### Statistical analyses

Baseline participant characteristics were reported by diabetes status in the total population and by quartiles of

SDOH burden in adults with diabetes. We also reported the distribution of individual SDOH in adults with and without diabetes. Weighted proportions were generated to report nationally representative estimates. Statistically significant differences in participant characteristics were assessed using  $\chi^2$  tests. Poisson regression was used to generate age-adjusted mortality rates (AAMR) per 100 000 person-years (PYs) and 95% CI for each SDOH quartile, overall and by subgroups of interest, including sex, race/ethnicity, and comorbidity burden in adults with diabetes. For comparison, we also presented AAMR in the population without diabetes (online supplemental eTable 2).

Survival time was modeled as the number of years of follow-up from baseline (index quarter/year of survey participation) to death or end of study period (December 31, 2019), whichever came first, with a maximum follow-up time of 6 years. The proportional hazards assumption was checked by inspecting the log-log plots of survival (plots of  $\ln(-\ln[S(t)])$  [log(-log) survival function] against survival time) for the primary exposure variable (SDOH quartiles), adjusted for study covariates. Plots for each quartile were found to be approximately parallel, thus satisfying the assumption of proportionality.



Kaplan-Meier survival curves were generated to estimate survival probability by SDOH quartiles in the total population and in adults with and without diabetes (online supplemental eFigure 1). Multivariable Cox proportional hazards regression models were used to derive adjusted HR (aHR) and 95% CI for all-cause mortality, overall and by sex and race/ethnicity in adults with diabetes. Four models were tested: model 1 adjusted for age; model 2 adjusted for age, sex, and race/ethnicity; model 3 adjusted for age, sex, race/ethnicity, and CRFs; model 4 adjusted for age, sex, race/ethnicity, CRFs, and comorbidities.

## RESULTS

### Descriptive characteristics

The final analytical sample comprised 182 445 adults  $\geq 18$  years of age, of whom 20 079 (11%) had a diagnosis of diabetes. Table 1 highlights the relevant demographic and clinical characteristics of the study population. Participants with diabetes were older (mean age in years (SD): 61 (16.3) vs 46 (10.2); 42.4% over 65 vs 16.6%) and more likely to be male (50.5% vs 47.9%) and NHB (15.5% vs 11.7%) than their counterparts without diabetes. Similarly, those with diabetes had worse CRF profiles (poor CRF: 49.0% vs 16.3%) and higher comorbidity burden ( $\geq 2$  comorbidities: 28.9% vs 7.7%).

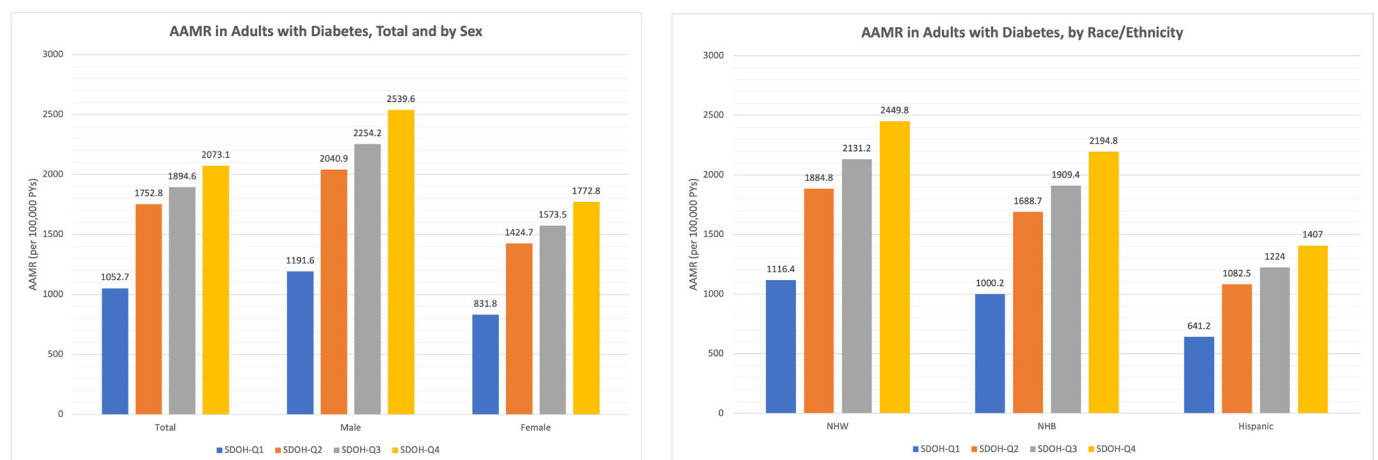
Among adults with diabetes, young and middle-aged, female, NHB, and Hispanic individuals were more likely to experience high levels of social disadvantage (SDOH-Q3/Q4), whereas NHW, male, and elderly individuals reported relatively favorable social profiles (SDOH-Q1/Q2) (table 2). Similarly, those with worse CRF profiles and higher comorbidity burden reported higher burden of unfavorable SDOH, relative to those with favorable clinical profiles.

The distribution of individual SDOH characteristics by diabetes status is presented in online supplemental eTable 1. Individuals with diabetes had a higher burden of unfavorable SDOH across nearly all domains. Adults with diabetes were more likely to experience lower educational attainment and household income, poor access to healthcare, food insecurity, and live in disadvantaged neighborhoods compared with those without diabetes (figure 1). Kaplan-Meier survival plots showed decreasing probability of survival with increasing levels of social disadvantage (online supplemental eFigure 1). Adults with diabetes had lower probability of survival than their counterparts without diabetes at all levels of SDOH burden.

### Age-adjusted mortality rates

In individuals with diabetes, AAMR increased significantly with higher SDOH burden, from 1052.7 (95% CI 884.9, 1220.5) per 100 000 PYs in SDOH-Q1 to 2073.1 (95% CI 1827.2, 2319.0) per 100 000 PYs in SDOH-Q4. Similar patterns were observed across demographic and clinical subgroups (figure 2). Overall, mortality rates were higher for male, NHW participants, and those with poor CRF profiles or higher comorbidity burden, relative to female, Hispanic participants, and those with favorable CRF and comorbidity profiles, respectively. For nearly each sociodemographic and clinical subgroup, AAMR increased by 1.5-fold to 2-fold from SDOH-Q1 to SDOH-Q4.

In the supplementary analyses, we found that mortality rates were generally higher for participants with diabetes compared with those without diabetes, overall and across sociodemographic and clinical strata. Patterns of mortality across SDOH quartiles were observed similarly for both groups, with people with diabetes facing sharper



**Figure 2** Age-adjusted mortality rates in adults with diabetes. (A) AAMR, total and by sex in adults with diabetes. (B) AAMR by race/ethnicity in adults with diabetes. In individuals with diabetes, AAMR increased with higher SDOH burden, with significant differences between Q1 and Q4 for various demographics. (A) AAMR nearly doubled for both male and female participants in Q4 compared with their counterparts in Q1. (B) Differences in AAMR by race/ethnicity. While Hispanic and non-Hispanic black individuals had lower overall mortality rates, the association between higher SDOH burden and increased mortality risk was still present. AAMR, age-adjusted mortality rate; PY, person-years; Q1, first quartile; Q4, fourth quartile; SDOH, social determinants of health.

**Table 3** SDOH and risk of mortality in adults with diabetes from the National Health Interview Survey 2013–2018

		HR for all-cause mortality			
		Model 1*	Model 2†	Model 3‡	Model 4§
SDOH quartiles		HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Total (diabetes) population	Q1	Ref	Ref	Ref	Ref
	Q2	1.66 (1.37, 2.01)	1.73 (1.43, 2.10)	1.74 (1.43, 2.11)	1.70 (1.40, 2.06)
	Q3	1.79 (1.48, 2.17)	2.00 (1.66, 2.42)	2.00 (1.65, 2.42)	1.89 (1.56, 2.29)
	Q4	1.97 (1.62, 2.38)	2.37 (1.94, 2.90)	2.42 (1.98, 2.96)	2.11 (1.72, 2.58)
Subgroup analysis					
Sex					
Male	Q1	Ref	Ref	Ref	Ref
	Q2	1.69 (1.33, 2.14)	1.74 (1.37, 2.20)	1.75 (1.38, 2.23)	1.71 (1.35, 2.18)
	Q3	1.94 (1.52, 2.48)	2.09 (1.64, 2.66)	2.12 (1.66, 2.71)	2.01 (1.57, 2.57)
	Q4	2.32 (1.83, 2.93)	2.69 (2.11, 3.44)	2.80 (2.19, 3.59)	2.48 (1.94, 3.18)
Female	Q1	Ref	Ref	Ref	Ref
	Q2	1.72 (1.21, 2.43)	1.70 (1.20, 2.41)	1.70 (1.19, 2.42)	1.66 (1.17, 2.35)
	Q3	1.78 (1.25, 2.53)	1.85 (1.30, 2.63)	1.82 (1.27, 2.60)	1.70 (1.19, 2.44)
	Q4	1.91 (1.34, 2.72)	2.02 (1.40, 2.91)	2.01 (1.40, 2.91)	1.71 (1.18, 2.47)
Race					
Non-Hispanic white	Q1	Ref	Ref	Ref	Ref
	Q2	1.70 (1.37, 2.11)	1.76 (1.42, 2.19)	1.77 (1.42, 2.20)	1.74 (1.39, 2.18)
	Q3	1.98 (1.59, 2.47)	2.10 (1.68, 2.61)	2.11 (1.69, 2.64)	2.01 (1.60, 2.51)
	Q4	2.42 (1.90, 3.08)	2.64 (2.07, 3.36)	2.72 (2.13, 3.47)	2.42 (1.90, 3.08)
Non-Hispanic black	Q1	Ref	Ref	Ref	Ref
	Q2	1.08 (0.66, 1.77)	1.11 (0.68, 1.82)	1.09 (0.66, 1.78)	0.95 (0.58, 1.56)
	Q3	1.35 (0.83, 2.19)	1.40 (0.86, 2.28)	1.34 (0.81, 2.20)	1.19 (0.73, 1.96)
	Q4	1.36 (0.85, 2.18)	1.47 (0.91, 2.38)	1.43 (0.88, 2.32)	1.12 (0.69, 1.82)
Hispanic	Q1	Ref	Ref	Ref	Ref
	Q2	1.57 (0.63, 3.93)	1.57 (0.63, 3.90)	1.64 (0.64, 4.21)	1.71 (0.68, 4.29)
	Q3	1.23 (0.52, 2.92)	1.24 (0.52, 2.95)	1.26 (0.50, 3.13)	1.23 (0.50, 3.01)
	Q4	1.66 (0.76, 3.61)	1.68 (0.77, 3.65)	1.72 (0.75, 3.97)	1.58 (0.69, 3.63)

\*Adjusted for age.

†Adjusted for age, sex, and race/ethnicity.

‡Adjusted for age, sex, race/ethnicity, and cardiovascular risk factors.

§Adjusted for age, sex, race/ethnicity, cardiovascular risk factors, and comorbidities.

Ref, reference; SDOH, social determinants of health.

increases in mortality risk at higher levels of SDOH burden (online supplemental eTable 2).

### Multivariable regression

Cox proportional hazard regression models demonstrated a consistent association between SDOH burden and mortality risk, independent of demographic and clinical covariates (table 3). In adults with diabetes overall, individuals in SDOH-Q4 experienced up to twofold higher risk of mortality, relative to those in SDOH-Q1 (aHR, Q4=2.37, 95% CI 1.94, 2.90). While the observed association was somewhat attenuated by clinical risk factors (models 3 and 4), higher social disadvantage was consistently associated with higher mortality risk, with

risk increasing in a stepwise manner across increasing quartiles of SDOH burden.

Higher social disadvantage was associated with higher hazards of mortality for both male and female participants and for each racial/ethnic subgroup. Being in SDOH-Q4 was associated with 2-fold to nearly 2.5-fold higher risk of mortality for both male and female participants compared with those in Q1. Unfavorable SDOH burden was significantly associated with higher risk of mortality for only NHW participants. We found a significant interaction effect between race and SDOH ( $p$  for interaction=0.04); in models adjusted for age, sex, race/ethnicity, and CRFs (model 3), NHW individuals in SDOH-Q4 experienced

over 2.5-fold higher risk of mortality (aHR=2.72, 95% CI 2.13, 3.47), whereas NHB and Hispanic adults in the same quartile (Q4) experienced approximately 1.5-fold higher hazard of mortality, relative to those in Q1; however, the estimates for the latter did not achieve statistical significance (NHB: aHR=1.43, 95% CI 0.88, 2.32; Hispanic: aHR=1.72, 95% CI 0.75, 3.97).

## DISCUSSION

In this nationally representative study, we found that adults with diabetes generally experience greater burden of unfavorable SDOH compared with their counterparts without diabetes, and that higher SDOH burden is an independent risk factor for all-cause mortality in this population. Despite the known association between diabetes and mortality, as well as increasing evidence of the role of SDOH in explaining disparities in diabetes, relatively little is known about the effect of SDOH on all-cause mortality in the diabetes population.<sup>8</sup> This is the first large-scale, nationally representative study, to our knowledge, to examine the role of cumulative social disadvantage—experienced across multiple SDOH domains—in determining mortality risk in adults with diabetes.<sup>23</sup>

Previous research has reported the association between adverse SDOH and diabetes risk, while protective factors such as social support have been shown to mitigate this risk somewhat.<sup>24</sup> Diabetes is also linked with low socioeconomic status, environmental risk factors, poor access to healthcare, and food insecurity.<sup>8</sup> However, prior studies have not assessed the association between cumulative social disadvantage and mortality in a national sample of adults with diabetes in the USA. Furthermore, prior work assessing aggregate SDOH burden and clinical outcomes is primarily based on a relatively small number of SDOH, is focused on the general population or defined clinical subgroups other than diabetes, or assesses non-mortality outcomes.<sup>25 26</sup> A comprehensive SDOH index, as used in this study, may inform future development of holistic social risk assessment approaches and evidence-based, individualized social support interventions.<sup>27</sup> In contrast to prior reports, ours is the first nationally representative study to comprehensively describe the burden of social disadvantage experienced by adults with diabetes and the extent to which it predicts mortality in this population. We found that, at each SDOH quartile, people with diabetes faced 1.5-fold to 2-fold higher AAMR than people without diabetes. Furthermore, higher SDOH burden was associated with over twofold increased risk of mortality in adults with diabetes, with the highest risk attributable to the highest degree of social disadvantage (SDOH-Q4). This pattern was observed similarly across race and sex, although with a stronger association for male and NHW adults.

Various pathways may explain the association between SDOH and diabetes observed in this study. Limited green space and exposure to environmental risk

factors can increase the risk of diabetes and subsequent mortality.<sup>8</sup> It is thought that low health literacy, which is often associated with low educational attainment, may further contribute to the link between low socioeconomic status and poor diabetes outcomes.<sup>28</sup> Low income status and limited availability of nutritious food can also promote food insecurity, which is a significant risk factor for developing diabetes and experiencing associated complications like hypertension and cardiovascular disease.<sup>29</sup> Additionally, low socioeconomic status is associated with poor glycemic control, which may further contribute to the observed link between adverse SDOH and increased mortality risk among people with diabetes.<sup>30</sup> Future work can elucidate how various SDOH influence risk of diabetes, subsequent mortality, or both.

We found a relatively weaker SDOH effect on mortality for Hispanic and non-Hispanic black participants, which merits additional study. This finding may be explained by the higher burden of diabetes in Hispanic and NHB participants (relative to NHW participants), potentially attenuating the SDOH effect on mortality to a greater extent for Hispanic and NHB subgroups, relative to NHW subgroups. The weaker association for Hispanic individuals may also be attributed to lower overall all-cause mortality rates in this population, possibly contributing to relatively lower power for mortality assessment, especially given that mortality was assessed across four separate SDOH levels (Q1–Q4).<sup>31</sup> While prior studies have pointed to potential health benefits of community support systems in this population, additional study is needed to fully understand potential racial/ethnic variation in community support systems, social networks, and neighborhood-level factors, with implications for coping with adverse SDOH and affecting downstream mortality risk.<sup>32</sup> We also found a relatively stronger SDOH–mortality association for male compared with female individuals, which may be attributable to the higher overall mortality rate and higher prevalence of diagnosed and undiagnosed diabetes in the former.<sup>33</sup> Additional research is warranted to fully understand the correlates and potential mediators of the “SDOH effect” on mortality in diverse gender and racial/ethnic subgroups.

While SDOH play large roles in determining the risk of diabetes, the reverse relationship is also worth noting. Indeed, individuals with diabetes are more likely to experience financial toxicity—defined as the negative financial consequences associated with disease—due to increased medical costs from clinical visits, medication, and treatment equipment.<sup>34 35</sup> This bidirectional relationship may explain the greater burden of adverse SDOH on people with diabetes. Thus, our study underscores the importance of addressing socioeconomic barriers to diabetes prevention and treatment, whether it is through promotion of affordable insulin programs or reduction of insulin costs.<sup>36</sup>



### Strengths and limitations

This study's strengths lie in its large, nationally representative sample size and the application of a comprehensive SDOH framework comprising over 40 SDOH variables across six established domains to capture social disadvantage. Additionally, use of data from the NHIS and NDI—the principal sources of health and mortality information in the USA—enables generalizability of our findings to the adult US population with diabetes. We used multiple multivariate models to adjust for traditional risk factors of diabetes and/or cardiovascular disease, as well as established clinical predictors of mortality (such as cancer and ASCVD), in order to account for their potential confounding effect on the SDOH–mortality association. However, NHIS data are cross-sectional, which precludes assessment of potential temporal variation or change in SDOH burden. Future studies should consider replicating our methodology in longitudinal data sets to potentially capture temporal variation in SDOH. Furthermore, non-Hispanic Asian and American Indian/other subpopulations were not included in this study due to low sample size, which when divided among SDOH quartiles for mortality assessment would have yielded potentially unstable estimates due to low power. Another potential limitation lies in the self-reported nature of NHIS data, including diabetes, as well as lack of information about diabetes type. While prior reports have shown good correlation between NHIS data and clinically ascertained measures,<sup>37</sup> the latter may reduce potential biases associated with self-report. Increased efforts should be made to enable cross-talks between survey-based and clinically measured data. Similar efforts should be made to capture diabetes type in population-based survey data, given prior evidence showing that patients with type 1 versus type 2 diabetes may have different SDOH profiles, with implications for downstream mortality risk.<sup>38</sup> Uncovering these incompletely understood differences and the extent to which they affect the diabetes–mortality association could inform risk stratification and care pathways for adults with type 1 or type 2 diabetes.

### Implications

Our work may provide further impetus to develop robust polysocial risk scores for mortality prediction in individuals with diabetes, as we reported previously for the ASCVD population.<sup>39</sup> Contemporary risk prediction models are primarily reliant on clinical predictors and often ignore SDOH or consider a small subset of socioeconomic factors.<sup>40</sup> Available population health databases provide unique opportunities to develop such indices and assess the effects of SDOH burden on mortality risk in patients with varying cardiovascular risk profiles. While assessing over 40 SDOH such as in this study may not always be feasible, particularly in clinical settings, polysocial risk scores provide a parsimonious prediction model which may lower the burden of screening. Similarly, there are increasing opportunities to integrate available validated indices such as the Social Vulnerability Index and

the PRAPARE (Protocol for Responding to and Assessing Patients' Assets, Risks, and Experiences) screening tool into clinical workflows via geocodes and electronic health record plug-ins.

In turn, screening patients for adverse socioeconomic conditions that may impact the risk of diabetes as well as mortality can help improve risk stratification and guide clinical care. For instance, efficient SDOH screening may highlight important barriers to diabetes care, such as food insecurity, pharmacy deserts, transportation barriers, or prohibitively high prescription costs.<sup>41</sup> This may help develop critical partnerships between health-care systems and community stakeholders to address unfavorable SDOH and mitigate their burden on adults with diabetes,<sup>42</sup> with the goal of improving life expectancy and reducing mortality in this high-risk population.

### CONCLUSIONS

The results of this national study suggest that US adults with diabetes experience high burden of unfavorable SDOH, which is associated with significantly elevated risk of all-cause mortality independent of established clinical predictors. Our findings highlight the importance of carefully screening for unfavorable SDOH and finding novel solutions to addressing SDOH to mitigate mortality risk in this clinically high-risk population.

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#### ORCID iDs

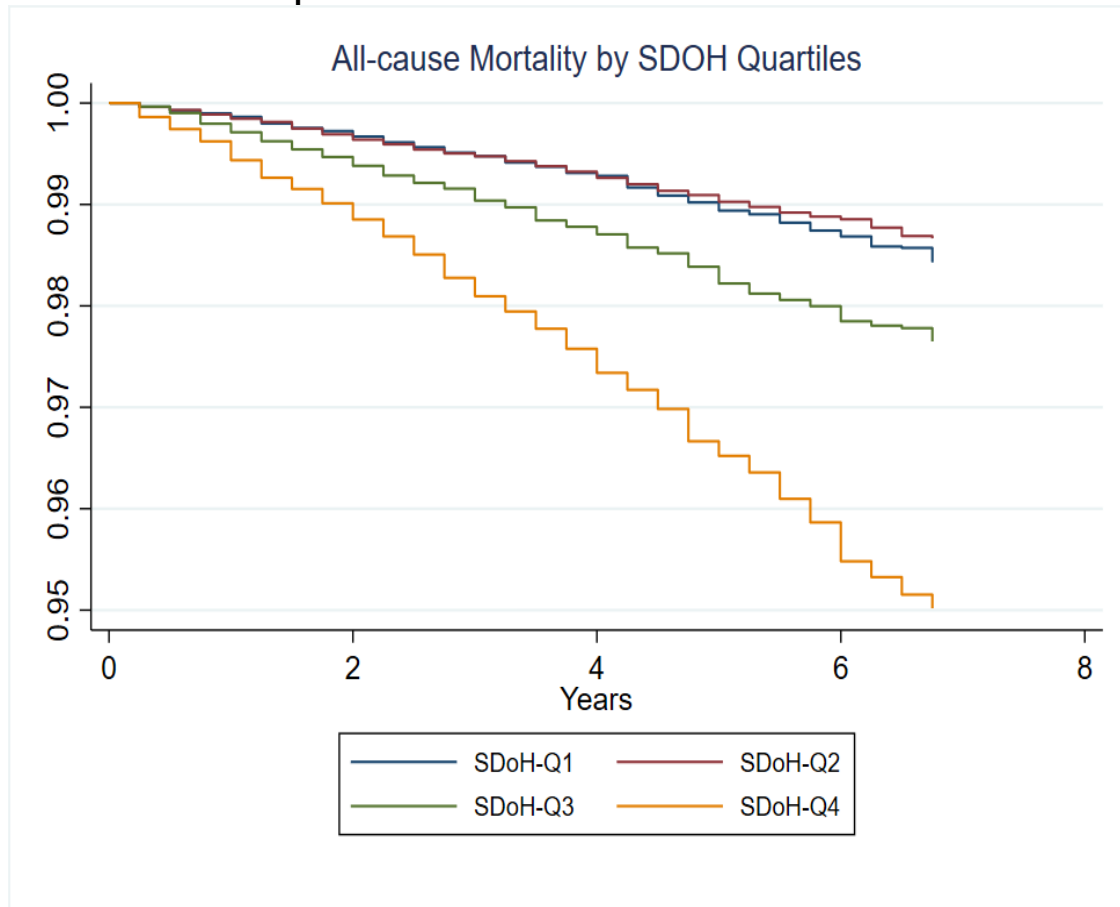
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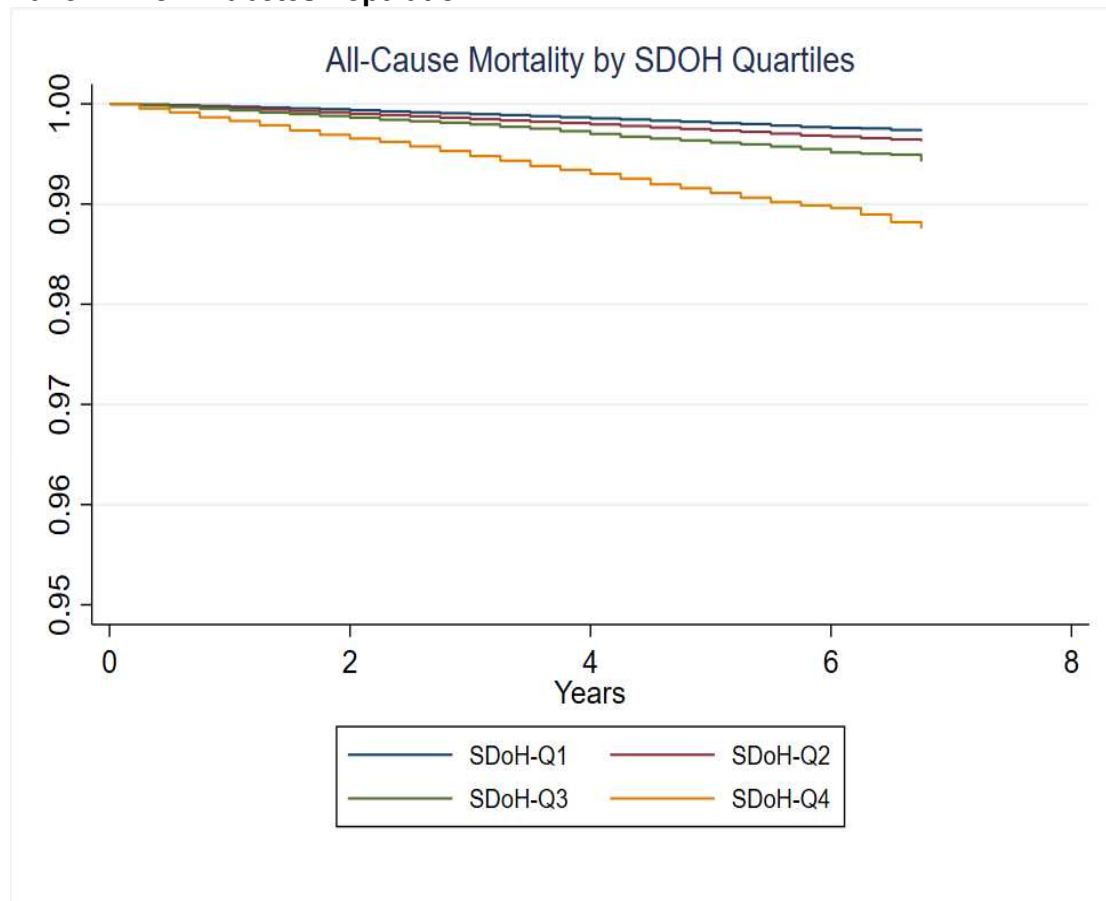
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**SUPPLEMENTARY MATERIAL**

**eFigure 1. Kaplan-Meier Survival Curves, by Diabetes Status and SDOH Quartiles.****Panel A. Diabetes Population**

**Panel B. Non-Diabetes Population**

Compared to individuals without diabetes, diabetes patients experienced a greater decrease in survival rate at each quartile of SDOH burden.



**eTable 1. SDOH Characteristics of the Study Population, by Diabetes Status, from the National Health Interview Survey 2013-18.**

	No DM	DM	<i>p value</i>
Sample (N)	162,366	20,079	
Weighted sample, (weighted %)	215,015,330 (90.3)	23,211,567 (9.7)	
Employment, n (weighted %)			<0.001
Employed or Retired	128,962 (78.8)	14,152 (70.8)	
Never or Previously Employed	33,284 (21.2)	5,921 (29.2)	
Sick Leave, n (weighted %)			0.23
Paid sick leave at current/most recent job	84,757 (55.7)	10,398 (56.4)	
No paid sick leave	67,658 (44.3)	8,182 (43.6)	
Family Income, n (weighted %)			<0.001
Middle/High-income	98,999 (70.3)	10,191 (60.5)	
Low-income	52,218 (29.7)	8,406 (39.5)	
Difficulty Paying Medical Bills, n (weighted %)			<0.001
No DPMB	122,829 (79.8)	13,874 (75.8)	
DPMB	28,168 (20.2)	3,954 (24.2)	
Unable to Pay Medical Bills, n (weighted %)			<0.001
No DPMB	150,997 (92.7)	17,828 (88.3)	
Unable to Pay Med Bills	11,369 (7.3)	2,251 (11.7)	
Worried about money for retirement, n (weighted %)			<0.001
Not too worried/Not at all	87,637 (55.1)	10,381 (50.6)	
Mod/Very Worried about money for retirement	70,633 (44.9)	9,191 (49.4)	
Worried about med costs of illness/accident, n (weighted %)			<0.001
Not too worried/Not at all	91,983 (57.8)	11,092 (54.5)	
Mod/Very Worried about med costs of illness/accident	66,345 (42.2)	8,498 (45.5)	
Worried about maintaining std of living, n (weighted %)			<0.001
Not too worried/Not at all	99,753 (62.8)	11,290 (56.2)	
Mod/Very Worried about maintaining std of living	58,552 (37.2)	8,299 (43.8)	
Worried about medical costs of normal healthcare, n (weighted %)			<0.001
Not too worried/Not at all	113,971 (71.7)	13,243 (65.4)	
Mod/Very Worried about medical costs of normal healthcare	44,373 (28.3)	6,355 (34.6)	
Worried about paying monthly bills, n (weighted %)			<0.001
Not too worried/Not at all	114,353 (72.5)	12,731 (63.9)	
Mod/Very Worried about paying monthly bills	44,012 (27.5)	6,866 (36.1)	
Worried about paying rent/mortgage/housing costs, n (weighted %)			<0.001
Not too worried/Not at all	123,259 (78.1)	14,330 (71.8)	
Mod/Very Worried about paying rent/mortgage/housing costs	35,090 (21.9)	5,266 (28.2)	
Foregone/Delayed Care due to Cost, n (weighted %)			<0.001
No Delay Medical Care due to Cost	143,769 (90.1)	17,365 (87.1)	

Foregone/Delayed Medical Care due to Cost	18,597 (9.9)	2,714 (12.9)	
House Tenure, n (weighted %)			<0.001
Own or being bought	98,175 (65.3)	12,825 (68.8)	
Rent/Other arrangement	63,915 (34.7)	7,228 (31.2)	
Agree: People in neighborhood help each other, n (weighted %)			<0.001
Yes	127,102 (83.0)	15,106 (79.2)	
No	26,826 (17.0)	3,960 (20.8)	
Agree: There are people I can count on in neighborhood, n (weighted %)			<0.001
Yes	127,036 (82.4)	15,449 (80.4)	
No	27,609 (17.6)	3,723 (19.6)	
Agree: People in neighborhood can be trusted, n (weighted %)			<0.001
Yes	127,580 (83.8)	15,262 (80.9)	
No	26,056 (16.2)	3,707 (19.1)	
Agree: This is a close-knit neighborhood, n (weighted %)			<0.001
Yes	99,257 (64.7)	12,029 (62.5)	
No	55,104 (35.3)	7,098 (37.5)	
≥ 3 days did not eat, n (weighted %)			<0.001
No	160,654 (99.1)	19,746 (98.7)	
Yes	1,712 (0.9)	333 (1.3)	
Kessler K6 Scale, n (weighted %)			<0.001
No Psychological Distress	152,006 (96.8)	18,143 (93.4)	
Psychological Distress	5,429 (3.2)	1,333 (6.6)	
Marital status, n (weighted %)			<0.001
Never married/living with partner	49,955 (31.7)	3,337 (15.8)	
Married	71,686 (52.5)	8,557 (55.2)	
Previously married	40,437 (15.8)	8,148 (29.0)	
Hungry but did not eat because not enough money, n (weighted %)			<0.001
No	156,879 (97.0)	18,949 (94.9)	
Yes	5,487 (3.0)	1,130 (5.1)	
Eat less than felt should because not enough money, n (weighted %)			<0.001
No	153,337 (94.9)	18,134 (91.3)	
Yes	9,029 (5.1)	1,945 (8.7)	
Cut size or skipped meals because not enough money, n (weighted %)			<0.001
No	152,507 (94.6)	18,033 (90.9)	
Yes	9,859 (5.4)	2,046 (9.1)	
≥ 3 days cut size or skipped meals, n (weighted %)			<0.001
No	154,358 (95.6)	18,351 (92.3)	
Yes	8,008 (4.4)	1,728 (7.7)	
Could not afford to eat balanced meals, n (weighted %)			<0.001
No	145,255 (90.3)	16,418 (83.3)	

Yes	17,111 (9.7)	3,661 (16.7)	
Worried food would run out before getting money to buy more, n (weighted %)			<0.001
No	139,936 (87.0)	15,766 (79.9)	
Yes	22,430 (13.0)	4,313 (20.1)	
Food did not last before getting money to get more, n (weighted %)			<0.001
No	143,299 (89.1)	16,142 (81.9)	
Yes	19,067 (10.9)	3,937 (18.1)	
Lose weight because not enough money for food, n (weighted %)			<0.001
No	159,102 (98.2)	19,289 (96.6)	
Yes	3,264 (1.8)	790 (3.4)	
Not eat for a whole day because not enough money for food, n (weighted %)			<0.001
No	159,890 (98.7)	19,588 (98.0)	
Yes	2,476 (1.3)	491 (2.0)	
English Language, n (weighted %)			<0.001
Well/Very well	140,468 (94.7)	16,995 (91.7)	
Not well/Not at all	7,547 (5.3)	1,400 (8.3)	
Education, n (weighted %)			<0.001
≥ Some college	102,089 (63.7)	9,831 (50.5)	
≤ High School	59,685 (36.3)	10,146 (49.5)	
Looked up health info on Internet in past 12 m, n (weighted %)			<0.001
Yes	79,649 (51.9)	7,076 (39.2)	
No	80,483 (48.1)	12,736 (60.8)	
Filled a prescription on Internet in past 12 m, n (weighted %)			<0.001
Yes	12,995 (8.7)	2,114 (12.3)	
No	147,195 (91.3)	17,700 (87.7)	
Scheduled medical appointment on Internet in past 12 m, n (weighted %)			<0.001
Yes	15,811 (11.3)	1,494 (9.4)	
No	144,358 (88.7)	18,320 (90.6)	
Communicated with health care provider by email in past 12 m, n (weighted %)			0.51
Yes	17,140 (11.7)	2,033 (11.9)	
No	143,025 (88.3)	17,777 (88.1)	
Insurance Status, n (weighted %)			<0.001
Insured	141,049 (87.8)	18,730 (93.2)	
Uninsured	19,622 (12.2)	1,177 (6.8)	
Usual Source of Care, n (weighted %)			<0.001
Usual source of care	137,624 (85.0)	19,256 (96.1)	
No usual source of care	23,652 (15.0)	697 (3.9)	
Citizenship Status, n (weighted %)			<0.001
US Citizens	149,252 (91.6)	19,028 (93.7)	
Non-Citizens	12,908 (8.4)	1,037 (6.3)	

Delayed Medical Care: Couldn't get through on phone, n (weighted %)			<0.001
No	157,183 (97.7)	19,234 (96.5)	
Yes: Couldn't get through on phone	3,894 (2.3)	690 (3.5)	
Delayed Medical Care: Couldn't get appt soon enough, n (weighted %)			<0.001
No	151,440 (94.1)	18,292 (91.3)	
Yes: Couldn't get appt soon enough	9,615 (5.9)	1,632 (8.7)	
Delayed Medical Care: Wait too long at MD's office, n (weighted %)			<0.001
No	154,732 (96.2)	18,714 (93.6)	
Yes: Wait too long at MD's office	6,307 (3.8)	1,209 (6.4)	
Delayed Medical Care: Not open when you could go, n (weighted %)			<0.001
No	156,478 (97.2)	19,228 (96.3)	
Yes: Not open when you could go	4,561 (2.8)	692 (3.7)	
Delayed Medical Care: Transport, n (weighted %)			<0.001
No	157,854 (98.4)	18,985 (96.0)	
Yes	3,198 (1.6)	939 (4.0)	
Quality of Care (Satisfaction), n (weighted %)			<0.001
Somewhat/Very Satisfied	132,217 (83.1)	18,006 (91.0)	
Somewhat/Very Dissatisfied	26,640 (16.9)	1,644 (9.0)	



eTable 2.

## Panel A. Age-Adjusted Mortality Rates, Diabetes Population

	SDOH-Q1	SDOH-Q2	SDOH-Q3	SDOH-Q4
<b>Total Population</b>	1052.7 (884.9, 1220.5)	1752.8 (1542.0, 1963.6)	1894.6 (1665.4, 2123.7)	2073.1 (1827.2, 2319.0)
<b>Sub-group Analysis</b>				
Age Category				
18-39	225.8 (92.8, 358.8)	376.0 (158.3, 593.6)	406.4 (167.2, 645.6)	444.7 (188.0, 701.3)
40-64	852.8 (688.3, 1017.2)	1419.9 (1178.2, 1661.6)	1534.8 (1296.3, 1773.2)	1679.4 (1433.1, 1925.7)
65+	3168.3 (2669.3, 3667.3)	5275.4 (4689.2, 5861.5)	5702.0 (5030.5, 6373.5)	6239.3 (5440.8, 7037.9)
Sex				
Male	1191.6 (996.5, 1386.7)	2040.9 (1771.9, 2309.9)	2254.2 (1955.5, 2552.8)	2539.6 (2191.1, 2888.2)
Female	831.8 (682.1, 981.4)	1424.7 (1228.0, 1621.4)	1573.5 (1355.7, 1791.3)	1772.8 (1542.4, 2003.1)
Race/Ethnicity				
Non-Hispanic White	1116.4 (933.8, 1299.0)	1884.8 (1646.6, 2123.1)	2131.2 (1860.5, 2401.9)	2449.8 (2111.6, 2788.0)
Non-Hispanic Black	1000.2 (794.4, 1206.0)	1688.7 (1404.2, 1973.2)	1909.4 (1582.0, 2236.8)	2194.8 (1848.2, 2541.5)
Non-Hispanic Asian	677.0 (392.8, 961.2)	1143.0 (659.9, 1626.1)	1292.4 (742.5, 1842.3)	1485.6 (846.6, 2124.6)
Hispanic	641.2 (485.9, 796.4)	1082.5 (843.7, 1321.4)	1224.0 (966.0, 1482.0)	1407.0 (1140.1, 1673.8)
CRF Profile				
Optimal	902.7 (683.8, 1121.6)	1503.9 (1161.1, 1846.7)	1618.2 (1265.3, 1971.0)	1788.0 (1388.9, 2187.1)
Average	1137.4 (932.4, 1342.4)	1894.9 (1639.1, 2150.6)	2038.9 (1749.3, 2328.4)	2252.9 (1945.5, 2560.2)
Poor	1012.2 (838.0, 1186.4)	1686.3 (1448.8, 1923.9)	1814.5 (1563.2, 2065.7)	2004.9 (1731.4, 2278.4)
Comorbidities				
0	651.5 (520.6, 782.4)	1061.8 (878.0, 1245.7)	1120.0 (917.2, 1322.8)	1143.5 (946.7, 1340.4)

1	961.9 (772.8, 1151.0)	1567.8 (1316.7, 1818.9)	1653.6 (1379.7, 1927.6)	1688.4 (1417.4, 1959.4)
≥ 2	1859.0 (1514.9, 2203.1)	3029.8 (2554.9, 3504.8)	3195.8 (2714.4, 3677.2)	3262.9 (2787.4, 3738.5)

**Panel B. Age-Adjusted Mortality Rates, Non-Diabetes Population**

	SDOH-Q1	SDOH-Q2	SDOH-Q3	SDOH-Q4
<b>Total Population</b>	562.2 (518.7, 605.6)	1064.8 (997.5, 1132.1)	1093.1 (1007.2, 1179.0)	1428.5 (1311.1, 1545.9)
<b>Sub-group Analysis</b>				
<b>Age Category</b>				
<i>18-39</i>	53.1 (43.2, 63.1)	100.6 (81.5, 119.8)	103.3 (83.4, 123.2)	135.0 (108.5, 161.5)
<i>40-64</i>	283.6 (253.1, 314.1)	537.2 (483.8, 590.6)	551.4 (493.1, 609.8)	720.7 (644.2, 797.2)
<i>65+</i>	2104.1 (1935.9, 2272.3)	3985.3 (3727.8, 4242.8)	4091.2 (3757.5, 4424.8)	5346.6 (4888.6, 5804.6)
<b>Sex</b>				
<i>Male</i>	667.6 (611.6, 723.6)	1298.2 (1205.6, 1390.8)	1338.7 (1221.5, 1455.9)	1769.8 (1609.4, 1930.3)
<i>Female</i>	460.9 (420.9, 500.8)	896.2 (830.1, 962.3)	924.2 (844.8, 1003.5)	1221.8 (1113.6, 1330.0)
<b>Race/Ethnicity</b>				
<i>Non-Hispanic White</i>	582.0 (536.4, 627.7)	1113.4 (1040.3, 1186.4)	1187.2 (1088.8, 1285.7)	1645.0 (1494.2, 1795.9)
<i>Non-Hispanic Black</i>	609.2 (528.9, 689.5)	1165.4 (1028.1, 1302.6)	1242.7 (1090.0, 1395.4)	1721.9 (1508.0, 1935.8)
<i>Non-Hispanic Asian</i>	338.0 (251.7, 424.3)	646.5 (482.4, 810.6)	689.4 (520.6, 858.2)	955.2 (711.1, 1199.3)
<i>Hispanic</i>	303.2 (243.3, 363.1)	579.9 (468.8, 691.0)	618.4 (494.6, 742.2)	856.8 (702.6, 1011.1)
<b>CRF Profile</b>				
<i>Optimal</i>	430.8 (385.9, 475.7)	802.7 (728.7, 876.7)	809.5 (720.9, 898.1)	1021.6 (903.0, 1140.1)

<i>Average</i>	635.3 (580.7, 690.0)	1183.9 (1096.3, 1271.5)	1193.9 (1091.0, 1296.8)	1506.7 (1369.8, 1643.6)
<i>Poor</i>	670.3 (599.3, 741.2)	1249.0 (1132.8, 1365.3)	1259.6 (1133.6, 1385.6)	1589.6 (1428.7, 1750.5)
Comorbidities				
<i>0</i>	350.5 (315.7, 385.4)	660.7 (604.0, 717.4)	665.8 (597.5, 734.1)	816.0 (730.2, 901.8)
<i>1</i>	584.4 (530.9, 638.0)	1101.5 (1006.4, 1196.7)	1110.0 (1008.0, 1211.9)	1360.5 (1229.3, 1491.7)
$\geq 2$	1090.6 (985.4, 1195.9)	2055.6 (1880.0, 2231.2)	2071.4 (1871.1, 2271.7)	2538.8 (2284.9, 2792.7)