JACC: ADVANCES VOL. 3, NO. 8, 2024

ORIGINAL RESEARCH

Enhancing the Cardiovascular Health Construct With a Psychological Health Metric for Predicting Mortality Risk

Vanessa T. Dinh, MPH,[a] Rahul Hosalli, MPH,[a] Pricila H. Mullachery, PhD, MPH,[b] Brooke Aggarwal, EdD,[c] Charles A. German, MD,[d] Nour Makarem, PhD, MS[a]

ABSTRACT

BACKGROUND The American Heart Association's Life's Essential 8 (LE8) Presidential Advisory deemed psychological health foundational for cardiovascular health (CVH) but did not include it as a CVH metric.

OBJECTIVES The purpose of this study was to evaluate associations of a CVH construct enhanced with a ninth metric for psychological health based on readily administered depression screening with mortality risk in U.S. adults.

METHODS Participants were 21,183 adults (mean age: 48y, 51% female, 11% Black, 15% Hispanic, 65% White) from the 2011 to 2018 National Health and Nutrition Examination Survey. The LE8 algorithm was used to assess CVH. Two enhanced CVH constructs that include a ninth psychological health metric based on depression screening using the Patient Health Questionnaires (PHQ-2 and PHQ-9) were computed. Multivariable Cox proportional hazards models compared all-cause and cause-specific mortality risk across CVH score tertiles and a priori defined categories (high: 80-100, moderate: 50-79, low: 0-49) in the overall sample and by sex and race and ethnicity.

RESULTS There were 1,397 deaths (414 cardiovascular and 329 cancer deaths). High vs low CVH scores, enhanced with PHQ-2 and PHQ-9, were associated with 69% and 70% lower mortality risk, while a high vs low LE8 score was associated with 65% lower risk (p-trend<0.001). Higher LE8 and enhanced CVH scores predicted lower mortality risk in both sexes and in Black and White but not Hispanic adults and were also associated with lower cardiovascular and cancer mortality. Both enhanced CVH scores had excellent performance for predicting mortality, similar to the LE8 score (C-statistic = 0.843 vs 0.842, $P < 0.001$).

CONCLUSIONS A CVH construct enhanced with psychological health strongly predicts mortality. Inclusion of psychological health as a ninth CVH metric, with depression screening as a feasible proxy in clinical and public health settings, should be considered. (JACC Adv 2024;3:101112) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

From the [a]Department of Epidemiology, Mailman School of Public Health, Columbia University Irving Medical Center, New York, New York, USA; [b]Department of Health Services Administration and Policy, College of Public Health, Temple University, Philadelphia, Pennsylvania, USA; [c]Department of Medicine, Columbia University Irving Medical Center, New York, New York, USA; and the [d]Section of Cardiology, University of Chicago Pritzker School of Medicine, Chicago, Illinois, USA.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

Manuscript received November 17, 2023; revised manuscript received June 8, 2024, accepted June 9, 2024.

ISSN 2772-963X https://doi.org/10.1016/j.jacadv.2024.101112

ABBREVIATIONS AND ACRONYMS

AHA = American Heart Association

AUC = area under the curve

BMI = body mass index

BP = blood pressure

CVD = cardiovascular disease

CVH = cardiovascular health

HDL = high-density lipoprotein

LE8 = Life's Essential 8

LS7 = Life's Simple 7

NHANES = National Health and Nutrition Examination Survey

PA = physical activity

PHQ = Patient Health Questionnaire

Despite remarkable advances in life expectancy over the past century, progress in the United States has stalled in the past decade.[1-3] Cardiovascular disease (CVD) and cancer persist as the leading causes of mortality with CVD deaths currently rising, highlighting the need for immediate aon through targeted primordial prevention efforts.[3,4] In 2010, the American Heart Association (AHA) introduced Life's Simple 7 (LS7), a cardiovascular health (CVH) construct that included seven modifiable health factors and behaviors linked to lower CVD risk and healthy longevity when optimal.[5] In 2022, the AHA redefined CVH as Life's Essential 8 (LE8) by adding sleep as an eighth metric and updating definitions and quantification of the original metrics to better capture their entire spectrum, enhance sensitivity to intraindividual and interindividual differences, and optimize utility of the CVH construct for predicting various outcomes, including mortality.[6] Using the original LS7 framework, strong inverse associations were documented between ideal overall CVH or having a greater number of ideal CVH metrics and lower risk for mortality with evidence of a dose-response relationship.[7-12] Since the publication of the updated LE8 guidelines in 2022, a more favorable LE8 score has now also been linked to reduced mortality and longer healthspan.[13]

In their Presidential Advisory on Life's Essential 8, the AHA also deemed psychological health and well-being as foundational for CVH preservation but did not include it as a formal CVH metric.[6] Positive mental states such as optimism or having a sense of purpose have been linked to more favorable CVH,[14] while depression and poor mental health are risk factors for suboptimal CVH and CVD.[15,16] In addition, the presence of depression, even mild depressive symptoms, has been linked to greater risk of mortality in diverse populations and settings.[15,17] To determine whether the inclusion of a ninth metric for psychological health enhances the predictive value of the LE8 score over and above the original eight metrics, we investigated the association of a novel CVH score, consisting of the LE8 plus a measure for psychological health and wellbeing based on validated and feasible depression screening, with all-cause mortality (primary outcome) and cardiovascular and cancer mortality (secondary outcomes) in a nationally representative cohort of U.S. adults from the National Health and Nutrition Examination Survey (NHANES). In exploratory analyses, we examined potential differences in these associations by sex and by race and ethnicity.

METHODS

STUDY POPULATION. Participants were 21,183 adults, aged 20 to 79 years, from the 2011 to 2012, 2013 to 2014, 2015 to 2016, or 2017 to 2018 NHANES. NHANES data and guidance on analytical approaches are publicly and freely available from the U.S. Centers for Disease Control and Prevention's National Center for Health Statistics.[18] NHANES uses a complex, multistage probability sampling design to select a sample representative of the civilian, noninstitutionalized U.S. population.[18] Participants complete a home interview and mobile examination to provide sociodemographic, lifestyle, psychological status, anthropometric, and physiologic data. NHANES is approved by the National Center for Health Statistics Research Ethics Review Board. Participants provided written informed consent. This research is deemed exempt by the Columbia University Irving Medical Center Institutional Review Board given the deidentified nature of the data.

The total combined sample of 2011-2018 NHANES was comprised of 39,156 participants. For the present analysis, we excluded individuals aged <20 years, those who were pregnant or breastfeeding at the time of examination (due to CVH metrics not being representative of habitual health behaviors and factors), and those who were missing key data for addressing the research question. Our final analytic data set was comprised of 21,183 adults. A flowchart outlining the detailed application of the inclusion and exclusion criteria to create the analytic sample is shown in Supplemental Figure 1. We leveraged all available data for our analyses, excluding individuals only if relevant variables were missing for that particular analysis. For the main analysis assessing the relationship between the overall CVH score and all-cause mortality, we excluded participants who had incomplete data on any CVH component. However, for analyses investigating the individual CVH component scores in relation to mortality, we used data from all participants who had available data for that metric to maximize sample size. Individuals self-identifying as Asian and multiracial were included in all analyses except for those stratified by race and ethnicity given the limited sample size of these groups.

ASSESSMENT OF LIFE'S ESSENTIAL 8 CARDIOVASCULAR HEALTH METRICS. Adherence to a DASH (Dietary Approaches to Stop Hypertension)-style eating pattern was assessed from 24-hour dietary recalls.[19] Physical

activity (PA), nicotine exposure, and sleep duration were self-reported during the home interview. To estimate minutes per week of moderate (or greater) PA, data on the frequency and duration of recreational PA, such as exercise, sports, and physically active hobbies, at either a vigorous or a moderate level were used. Smoking status was ascertained using information regarding current smoking habits, lifetime smoking habits, and years since quitting as well as exposure to secondhand smoke for all persons living in the household, which was reported on the family household questionnaire. Sleep health was defined by average sleep duration, which was computed from the number of hours that participants reported they usually sleep on weekdays and weekends.

At the mobile examination visit, anthropometric measures were obtained and used to calculate body mass index (BMI). Blood samples were obtained and sent to central laboratories for the measurement of non-high-density lipoprotein (HDL) cholesterol, blood glucose, and hemoglobin A1c. In addition, blood pressure (BP) was measured after the participant had rested for 5 minutes. For participants with three measurements, the first reading was excluded and the second and third readings were averaged. Otherwise, the available reading was taken as the final BP record. Use of cholesterol, glucose, or BP medication usage was assessed during the home interview.

MEASUREMENT OF DEPRESSION FOR PSYCHOLOGICAL HEALTH METRIC. Psychological health and well-being is multidimensional.[20,21] In NHANES, the Patient Health Questionnaire (PHQ) depression screener is the most reliable screening instrument for psychological health that has been consistently used across many cycles of this survey enabling the potential characterization as a CVH metric.[22] It is a self-administered depression screening tool which consists of nine questions inquiring about the frequency of depression symptoms over the past 2 weeks[23-26] such that 0 to 4 points is defined as none/minimal depression, 5 to 9 points is mild, 10 to 14 points is moderate, 15 to 19 is moderately severe, and 20 to 27 points is considered severe depression.[23-26] Traditionally, if a patient scores at least 10 points on the PHQ-9, they have a probable case of depression and should be evaluated further by a mental health care professional.[25] The PHQ-2 is a shortened version of PHQ-9, using only the first two questions to assess depression status.[23,27] Since PHQ-2 only has 2 questions, 0 points were defined as none/minimal depression, 1 to 2 points as mild, 3 points as moderate, 4 to 5 points as moderate/severe, and 6 points as severe depression. The advantage of the PHQ-2 is that it is a validated, readily administered, and low burden tool with broad application potential in public health and clinical settings.[24,27]

QUANTIFICATION OF CARDIOVASCULAR HEALTH. CVH was defined and operationalized using the LE8 scoring algorithm, as described in the 2022 AHA Presidential Advisory and the accompanying publication on CVH status using NHANES.[6,22] Briefly, participants received a score between 0 and 100 for each CVH metric. For the new psychological health component, participants received 100 points for none/minimal depression, 80 for mild, 40 for moderate, 20 for moderately severe, and 0 points for severe depression symptoms. The LE8 score and the enhanced CVH scores (enhanced CVH score 1 with PHQ-2 and enhanced CVH score 2 with PHQ-9) were then computed by averaging the scores of their eight and nine component scores, respectively. Scores ranged from 0 to 100 with higher scores representing more favorable CVH. We considered CVH scores of 80 to 100, 50 to 79, and 0 to 49 to be indicative of high, moderate, and low CVH, respectively.[6] A detailed description of the definitions, data collection methods, and scoring algorithm for each of the CVH metrics is shown in Supplemental Table 1.

MORTALITY STATUS. The National Death Index was used to determine mortality status through December 31, 2019.[28] The International Classification of Diseases-10th revision (ICD-10) codes were used to identify cardiovascular and cancer deaths.

ASSESSMENT OF COVARIATES. Sociodemographic characteristics including age, sex, race and ethnicity, marital status, education level, and family income were queried during the home interview. For self-reported race and ethnicity, Mexican American and other Hispanic were merged into a single Hispanic category.

STATISTICAL ANALYSIS. NHANES analytical guidelines for combining data across cycles and accounting for the complex multistage sampling design were followed.[18] The Kaplan-Meier method and Cox proportional hazards regression analysis were used to evaluate the LE8 score, the enhanced CVH scores (with PHQ-2 and PHQ-9), and their component scores in relation to all-cause, cardiovascular, and cancer mortality. Proportionality assumptions were assessed using Schoenfeld residuals and were met. For the overall CVH scores, we evaluated the predefined categories (low, moderate, high) and tertiles in relation to outcomes. For CVH component scores, tertiles were evaluated in relation to outcomes, except for

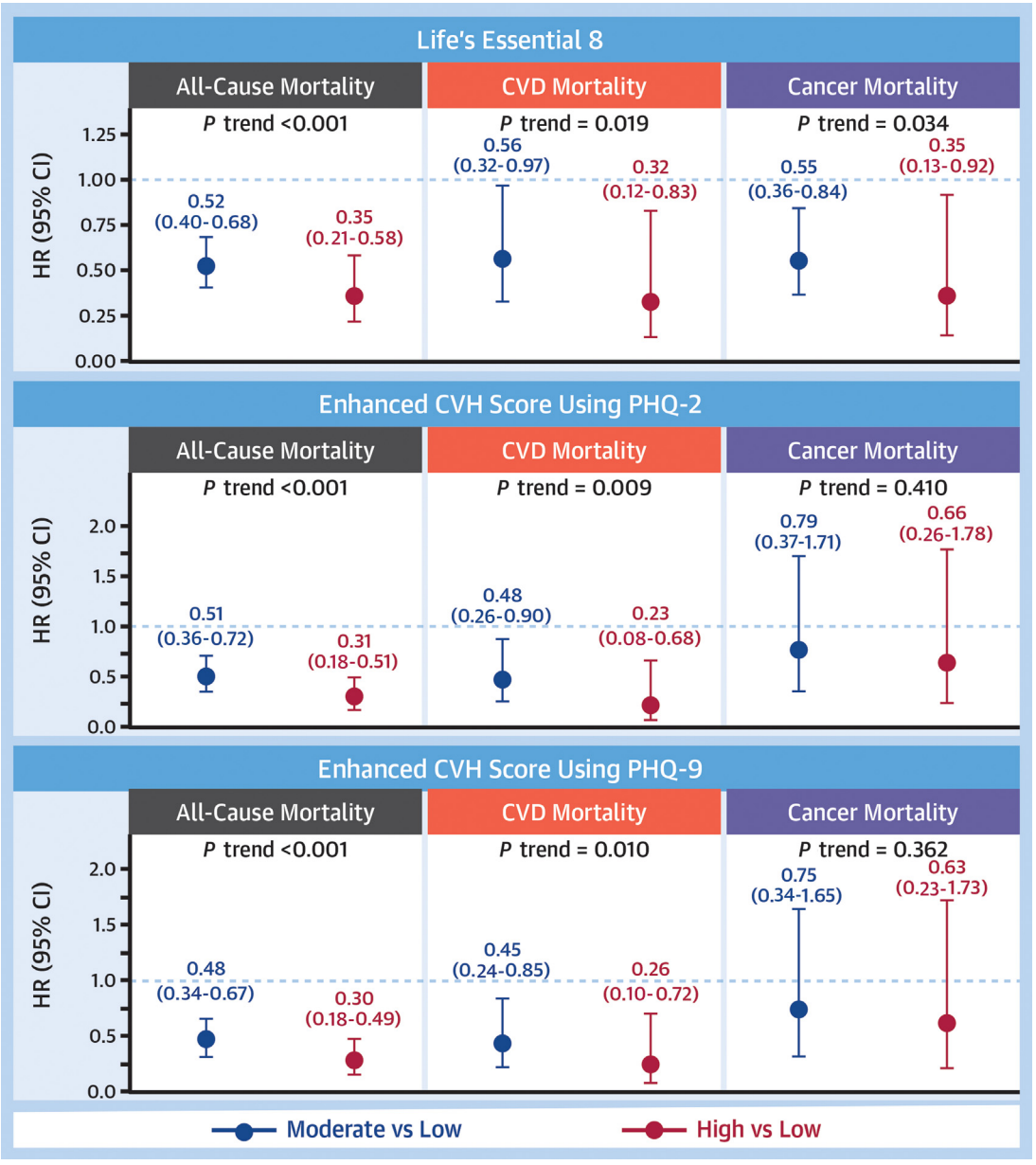
TABLE 1 Characteristics of the Analytic Sample and by Enhanced Cardiovascular Health Score Categories[a,b]

	Overall Sample With Complete Data for Enhanced CVH Score (Using PHQ-2) (n = 14,041, Weighted to 194,073,616 Adults)	Low Enhanced CVH Score (Using PHQ-2) (n = 1,908, Weighted to 21,270,791 Adults)	Moderate Enhanced CVH Score (Using PHQ-2) (n = 9,494, Weighted to 125,271,934)	High Enhanced CVH Score (Using PHQ-2) (n = 2,639, Weighted to 47,530,892)
Age, y	48.2 (47.5-48.9)	52.7 (51.6-53.8)	49.6 (48.9-50.4)	42.4 (41.1-43.7)
Age strata (%)				
20-29 y	18.3 (35,478,718)	6.1 (1,292,380)	16.6 (20,757,280)	28.3 (13,429,058)
30-39 y	16.9 (32,838,783)	13.9 (2,955,550)	15.5 (19,467,178)	21.9 (10,416,055)
40-49 y	16.6 (32,154,068)	16.7 (3,541,969)	16.5 (20,619,666)	16.8 (7,992,434)
50-59 y	20.1 (39,085,803)	31.7 (6,740,512)	19.9 (24,875,436)	15.7 (7,469,855)
60-69 y	15.3 (29,615,285)	20.4 (4,337,756)	16.4 (20,592,164)	9.9 (4,685,364)
70+ y	12.8 (24,900,960)	11.3 (2,402,623)	15.1 (18,960,210)	7.4 (3,538,126)
Sex (%)				
Male	49.8 (96,715,714)	52.0 (11,063,887)	52.1 (65,265,077)	42.9 (20,386,750)
Female	50.2 (97,357,903)	48.0 (10,206,904)	47.9 (60,006,857)	57.1 (27,144,142)
Self-reported race and ethnicity (%)				
Hispanic	14.7 (28,494,725)	12.7 (2,704,573)	16.0 (19,992,797)	12.2 (5,797,355)
Non-Hispanic White	66.2 (128,496,835)	63.3 (13,457,890)	64.3 (80,572,679)	72.5 (34,466,266)
Non-Hispanic Black	10.4 (20,197,136)	16.8 (3,574,705)	11.3 (14,119,101)	5.3 (2,503,330)
Non-Hispanic Asian	5.2 (10,186,784)	1.8 (383,756)	5.0 (6,287,483)	7.4 (3,515,545)
Other race, including multiracial	3.5 (6,698,136)	5.4 (1,149,867)	3.4 (4,299,873)	2.6 (1,248,396)
Marital status (%)				
Single/widowed/divorced	37.0 (71,837,183)	43.5 (9,261,856)	37.0 (46,393,449)	34.0 (16,181,877)
Married/living with partner	63.0 (122,228,853)	56.5 (12,008,935)	63.0 (78,870,904)	66.0 (31,349,015)
Education (%)				
High school/GED and below	34.9 (67,742,015)	57.4 (12,208,356)	38.3 (47,944,737)	16.0 (7,588,923)
Some college and above	65.1 (126,326,029)	42.6 (9,062,435)	61.7 (77,321,625)	84.0 (39,941,969)
Health insurance status (%)				
No	15.8 (30,580,609)	21.3 (4,520,945)	16.6 (20,838,778)	11.0 (5,220,885)
Yes	84.2 (163,360,997)	78.7 (16,749,846)	83.3 (104,324,486)	89.0 (42,286,665)
Family income (%)				
≥$45,000	57.2 (111,082,490)	37.8 (8,040,954)	55.5 (69,535,343)	70.5 (33,506,192)
<$45,000	39.2 (76,158,816)	59.3 (12,612,982)	40.8 (51,159,071)	26.1 (12,386,763)
Probable case of depression based on PHQ-2 (%)				
Probable case	8.9 (19,334,328)	34.1 (7,261,724)	7.1 (8,898,981)	1.9 (896,574)
Not a probable case	91.1 (197,891,992)	65.9 (14,009,067)	92.9 (116,372,952)	98.1 (46,634,318)
Probable case of depression based on PHQ-9 (%)				
Probable case	8.5 (18,388,770)	29.1 (6,184,670)	7.4 (9,257,904)	1.8 (831,903)
Not a probable case	91.5 (198,541,535)	70.6 (15,021,464)	92.5 (115,850,759)	98.2 (46,659,219)
Cardiovascular health metrics				
Total CVH score	68.5 (67.8-69.2)	42.5 (42.0-42.9)	65.8 (65.6-66.1)	87.0 (86.7-87.4)
Psychological health score (PHQ-2)	88.8 (88.1-89.5)	68.2 (65.6-70.8)	90.1 (89.5-90.7)	95.3 (94.6-95.9)
Diet	42.0 (40.5-43.5)	20.5 (18.3-22.7)	37.8 (36.4-39.1)	63.6 (61.6-65.6)
Physical activity	50.4 (48.5-52.3)	7.0 (5.3-8.8)	44.6 (42.8-46.4)	90.1 (88.5-91.7)
Nicotine use	70.9 (69.6-72.2)	35.6 (32.2-39.0)	68.9 (67.5-70.3)	91.6 (90.2-93.0)
Sleep health	83.7 (82.9-84.4)	65.9 (63.4-68.4)	83.9 (83.1-84.6)	92.7 (91.9-93.5)
BMI	58.3 (57.1-59.4)	31.7 (29.7-33.7)	54.1 (52.8-55.4)	82.1 (80.7-83.5)
Blood lipids	65.5 (64.5-66.5)	44.7 (41.6-47.8)	63.1 (61.9-64.3)	81.9 (80.2-83.6)
Blood glucose	83.6 (82.9-84.2)	60.7 (58.6-62.7)	83.0 (82.1-83.8)	96.8 (96.1-97.6)
Blood pressure	70.1 (69.3-70.9)	47.8 (45.4-50.1)	67.0 (65.8-68.1)	89.0 (87.8-90.3)

Values are mean (95% CI) or % (n). [a]Descriptive characteristics are shown for participants included in the main analysis of investigating the overall CVH scores (LE8 or enhanced CVH scores with PHQ-2 and PHQ-9) in relation to mortality outcomes, excluding participants with missing data for any of the CVH components. [b]NHANES data from 2011 to 2018 cycles were combined. Sample weights were constructed consistent with NHANES analytical guidelines for combining data across cycles and were used to estimate the number of individuals in the U.S. population overall and in each group. Sample weights and design were incorporated in calculating prevalence estimates and standard errors using standard survey procedures. Characteristics of the sample with weighted population numbers are presented. Estimates shown in this table are for participants with complete data for all CVH metrics.

BMI = body mass index; CVH = cardiovascular health; GED = General Education Development; PHQ = Patient Health Questionnaire.

CENTRAL ILLUSTRATION **Associations of AHA's Life's Essential 8 Score and Two Enhanced CVH Scores Including a Ninth Psychological Health Metric with Mortality Outcomes**



Dinh VT, et al. JACC Adv. 2024;3(8):101112.

HRs (95% CIs) comparing risk of all-cause, cardiovascular, and cancer mortality among participants with moderate vs low and high vs low LE8 scores (top panel), enhanced CVH scores with a ninth psychological health metric based on PHQ-2 (middle panel), and enhanced CVH scores with a ninth psychological health metric based PHQ-9 (bottom panel). All models were adjusted for age, sex, race and ethnicity, marital status, education, health insurance, and family income. The test for linear contrast was used to compute the p-trend for detection of a linear trend across the categories of CVH scores for all models. AHA = American Heart Association; CVD = cardiovascular disease; CVH = cardiovascular health; LE8 = Life's Essential 8; NHANES = National Health and Nutrition Examination Survey; PHQ = Patient Health Questionnaire.

TABLE 2 Associations of Life's Essential 8 and Enhanced Cardiovascular Health Scores Including a Ninth Psychological Health Metric With All-Cause Mortality

CVH Scores	N (n)[a]	Univariate Model[b,d]	Adjusted Model[b,c,d]
Total LE8 score	14,683 (852)		
Tertile 1 (<58.4)		1.00 (ref)	1.00 (ref)
Tertile 2 (58.4-73.5)		0.48 (0.35-0.65)	0.55 (0.41-0.74)
Tertile 3 (>73.5)		0.20 (0.15-0.28)	0.40 (0.28-0.58)
		P trend < 0.001	*P* trend < 0.001
Enhanced CVH score using PHQ-2	14,041 (796)		
Tertile 1 (<61.7)		1.00 (ref)	1.00 (ref)
Tertile 2 (61.7-75.6)		0.46 (0.33-0.62)	0.55 (0.40-0.76)
Tertile 3 (>75.6)		0.19 (0.14-0.27)	0.37 (0.25-0.54)
		P trend < 0.001	*P* trend < 0.001
Enhanced CVH score using PHQ-9	14,011 (790)		
Tertile 1 (<62.0)		1.00 (ref)	1.00 (ref)
Tertile 2 (62.0-75.9)		0.43 (0.31-0.60)	0.51 (0.37-0.70)
Tertile 3 (>75.9)		0.20 (0.14-0.28)	0.38 (0.26-0.54)
		P trend < 0.001	*P* trend < 0.001
Depression (PHQ-2)[e]	19,055 (1,195)		
0-40 (moderate/severe)		1.00 (ref)	1.00 (ref)
80 (mild)		0.51 (0.39-0.68)	0.56 (0.43-0.72)
100 (none)		0.43 (0.35-0.53)	0.48 (0.39-0.57)
		P trend < 0.001	*P* trend < 0.001
Depression (PHQ-9)[e]	19,000 (1,180)		
0-40 (moderate/severe)		1.00 (ref)	1.00 (ref)
80 (mild)		0.88 (0.65-1.20)	0.80 (0.60-1.07)
100 (none)		0.50 (0.38-0.66)	0.50 (0.39-0.63)
		P trend < 0.001	*P* trend < 0.001
Diet	16,772 (1,049)		
Tertile 1 (<12.0)		1.00 (ref)	1.00 (ref)
Tertile 2 (12.0-43.1)		1.03 (0.77-1.39)	0.86 (0.64-1.17)
Tertile 3 (>43.1)		0.95 (0.71-1.27)	0.72 (0.53-0.98)
		P trend = 0.718	*P* trend = 0.039
Physical activity	21,175 (1,397)		
Tertile 1 (0)		1.00 (ref)	1.00 (ref)
Tertile 2 (0-91.3)		0.31 (0.25-0.39)	0.45 (0.36-0.56)
Tertile 3 (>91.3)		0.27 (0.22-0.34)	0.45 (0.36-0.57)
		P trend < 0.001	*P* trend < 0.001
Nicotine exposure	21,103 (1,390)		
Tertile 1 (<61.7)		1.00 (ref)	1.00 (ref)
Tertile 2 (61.7-87.4)		1.51 (1.28-1.77)	0.63 (0.52-0.75)
Tertile 3 (>87.4)		0.62 (0.52-0.74)	0.50 (0.41-0.62)
		P trend < 0.001	*P* trend < 0.001
Sleep health	21,094 (1,384)		
Tertile 1 (<69.5)		1.00 (ref)	1.00 (ref)
Tertile 2 (69.5-94.2)		0.60 (0.48-0.75)	0.64 (0.52-0.79)
Tertile 3 (>94.2)		0.54 (0.44-0.65)	0.59 (0.49-0.70)
		P trend < 0.001	*P* trend < 0.001
BMI	20,881 (1,313)		
Tertile 1 (<28.6)		1.00 (ref)	1.00 (ref)
Tertile 2 (28.6-66.9)		0.89 (0.68-1.16)	0.76 (0.58-1.00)
Tertile 3 (>66.9)		0.89 (0.72-1.10)	0.80 (0.65-0.98)
		P trend = 0.286	*P* trend = 0.029

Continued on the next page

blood glucose and depression. Given the distribution of the blood glucose and depression scores, it was not possible to generate tertiles. The following a priori defined categories were compared for the blood glucose component: 0 to 40 (includes type 2 diabetes), 60 (includes prediabetes), and 100 (referent group includes healthy blood glucose levels). For the depression component, the a priori defined categories

TABLE 2 Continued

CVH Scores	N (n)[a]	Univariate Model[b,d]	Adjusted Model[b,c,d]
Blood lipids	19,934 (1,256)		
Tertile 1 (<41.7)		1.00 (ref)	1.00 (ref)
Tertile 2 (41.7-80.6)		1.21 (1.04-1.42)	1.06 (0.89-1.25)
Tertile 3 (>80.6)		0.85 (0.71-1.02)	1.48 (1.21-1.80)
		P trend = 0.079	*P* trend < 0.001
Blood glucose[f]	20,214 (1,287)		
0-40 (diabetes)		1.00 (ref)	1.00 (ref)
60 (prediabetes)		0.53 (0.42-0.66)	0.60 (0.48-0.74)
100 (normal HbA1c)		0.26 (0.22-0.30)	0.63 (0.53-0.75)
		P trend < 0.001	*P* trend < 0.001
Blood pressure	19,398 (1,244)		
Tertile 1 (<46.4)		1.00 (ref)	1.00 (ref)
Tertile 2 (46.4-83.4)		0.38 (0.33-0.44)	0.68 (0.58-0.81)
Tertile 3 (>83.4)		0.15 (0.12-0.18)	0.58 (0.46-0.73)
		P trend < 0.001	*P* trend < 0.001

[a]N represents the analytic sample size, and n represents the total number of deaths. [b]Cox proportional hazards models were used to estimate HR (95%CI) for associations of tertiles of the overall CVH scores and their component scores with all-cause mortality risk. Tertile 1 was used as the referent category. [c]Multivariable models were adjusted for age (20-29 y, 30-39 y, 40-49 y, 50-59 y, 60-69 y, 70+ y), sex (male, female), race/ethnicity (NH Black, Hispanic, NH White, NH Asian, other race including multiracial), marital status (married/living with partner, single/widowed/divorced), education (>high school, ≤high school), health insurance (yes, no), and family income (≥$45,000, <$45,000). [d]The test for linear contrast was used to compute the *P* trend for detection of a linear trend across the categories of cardiovascular health for all models. [e]Given the distribution of the depression scores, the following a priori defined categories were compared: 0 to 40 (includes moderate to severe depressive symptoms), 80 (includes mild depressive symptoms), and 100 (referent group including no depressive symptoms). For the PHQ-2 score, there were 1,935 participants with moderate, moderately severe, or severe symptoms, 4,545 participants with mild depressive symptoms, and 12,575 participants with no/minimal depressive symptoms. For PHQ-9 score, there were 1,722 participants with moderate, moderately severe, and severe symptoms, 3,053 participants with mild symptoms, and 14,225 participants with no/minimal depressive symptoms. [f]Given the distribution of the blood glucose scores, the following a priori defined categories were compared: 0 to 40 (includes type 2 diabetes), 60 (includes prediabetes), and 100 (referent group includes healthy blood glucose levels). There were 3,560 participants with type 2 diabetes, 4,432 participants with prediabetes, and 12,222 with normal HbA1c.

AHA = American Heart Association; BMI = body mass index; CVH = cardiovascular health; LE8 = Life's Essential 8; PHQ = Patient Health Questionnaire.

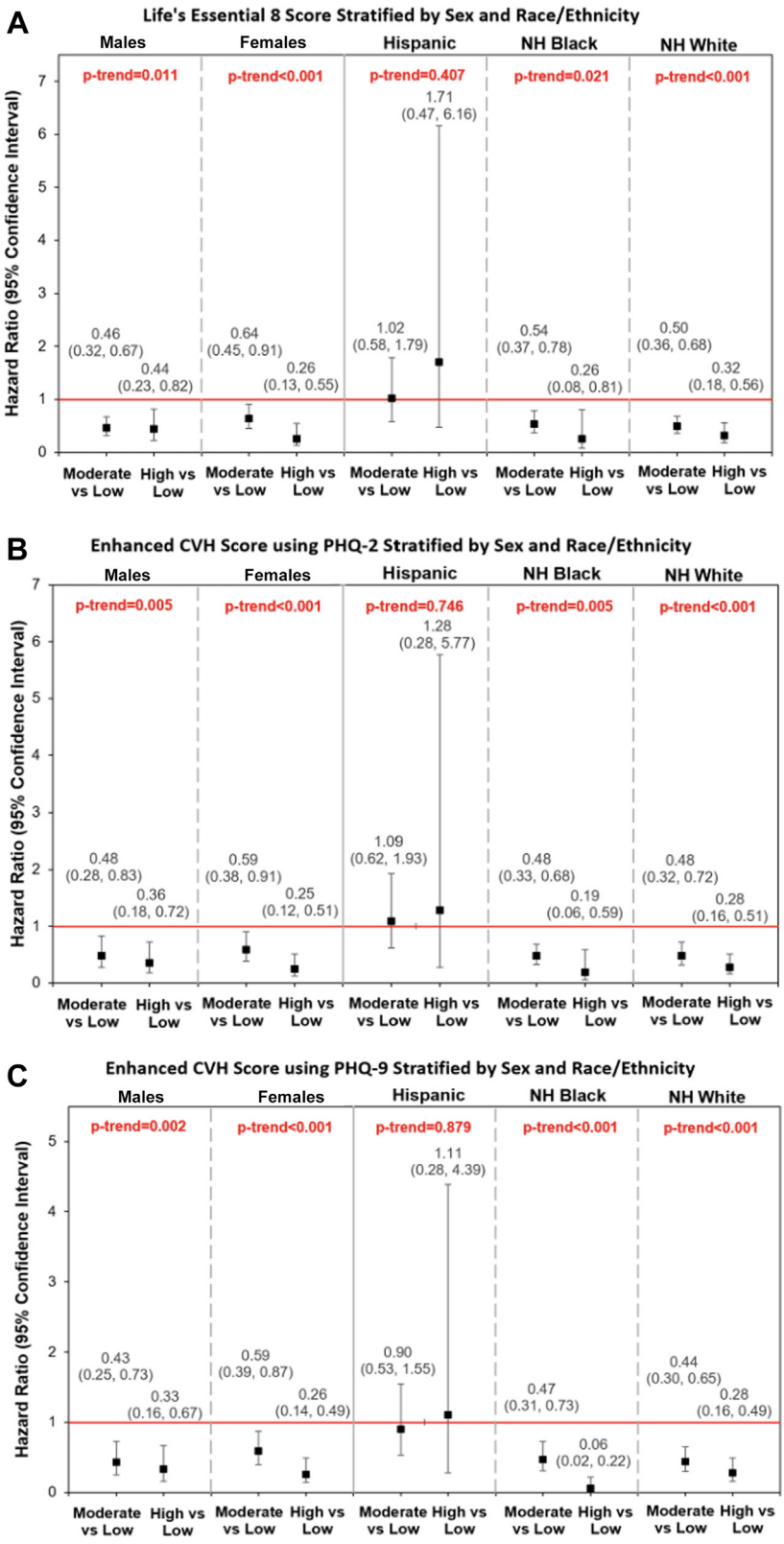
were as follows: 0 to 40 (includes moderate to severe depressive symptoms), 80 (includes mild depressive symptoms), and 100 (referent group including no depressive symptoms). Models were adjusted for age, sex, race and ethnicity, marital status, education, health insurance, and family income. The test for linear contrast was used for detection of a linear trend across CVH categories. Area under the curve (AUC) analysis was used to produce concordance statistics (C-statistic) to determine the discriminative performance of the LE8 score and the enhanced CVH scores for predicting mortality. In exploratory analyses, we examined interactions by sex and race and ethnicity for all-cause mortality, and stratified results were reported. Analyses were performed using SAS, version 9.4 (SAS Institute), and *P* values <0.05 were considered statistically significant.

RESULTS

CHARACTERISTICS OF THE STUDY POPULATION. The overall study sample consisted of 21,183 participants, representing 226,834,092 U.S. adults (51% female, mean age: 48 years, 65% aged ≥40 years). The racial and ethnic distribution was as follows: 6% Asian, 11% Black, 15% Hispanic, and 65% White. Overall, 21%, 63%, and 16% of participants had high, moderate, and low CVH, respectively, based on the LE8 algorithm. When the enhanced CVH scores were utilized, the distribution of high, moderate, and low CVH changed as follows 24%, 65%, and 11%, respectively. Detailed descriptive characteristics of the analytical sample with complete data for the CVH score components and by enhanced CVH score categories (using PHQ-2) are shown in **Table 1**.

CARDIOVASCULAR HEALTH AND ALL-CAUSE MORTALITY. During a median follow-up of 5 years, there were 1,397 deaths. A high vs low LE8 score was associated with 65% lower all-cause mortality risk, with evidence of a dose-response relation (*P* trend < 0.001) (**Central Illustration**, Supplemental Figure 2A); similar associations were observed when tertiles of the LE8 score were compared. Having a high vs low enhanced CVH score, with the psychological health metric based on PHQ-2 depression screening, was associated with a 69% reduction in risk for all-cause mortality (*P* trend < 0.001) (**Central Illustration** and Supplemental Figure 2B). Being in the high vs low category for the enhanced CVH score using PHQ-9 for depression screening was associated with 70% lower

FIGURE 1 Association of AHA's Life's Essential 8 and the Enhanced Cardiovascular Health Scores with All-Cause Mortality Stratified by Sex and by Race and Ethnicity



Continued on the next page

mortality risk (P trend $<$ 0.001) (**Central Illustration** and Supplemental Figure 2C). Similar associations were observed when tertiles of the enhanced CVH scores were compared (**Table 2**). An AUC analysis showed that the LE8 score and CVH scores enhanced with PHQ-2 or PHQ-9 all demonstrated excellent discriminative performance for predicting mortality (LE8 C-statistic = 0.842 vs enhanced CVH scores C-statistic = 0.843, P $<$ 0.001). When CVH score components were evaluated, being in the highest vs lowest category of the new psychological health component based on PHQ-2 and PHQ-9 was associated with 52% and 50% lower mortality risk, respectively (p-trend<0.001). Similarly, higher diet, PA, nicotine exposure, sleep health, BMI, glucose, and BP scores predicted 20% to 55% reduced all-cause mortality risk (**Table 2**).

DIFFERENCES BY SEX, RACE, AND ETHNICITY. Having a high vs low LE8 or enhanced CVH score predicted lower all-cause mortality risk in both sexes with stronger associations in females vs males (**Figures 1A to 1C**) (P interaction $<$ 0.05). A high vs low CVH score predicted 68% to 94% lower all-cause mortality risk in White and Black adults but null associations were observed in Hispanic adults (**Figures 1A to 1C**) (p-interaction<0.001). Notably, effect sizes were strongest among Black adults for all scores, particularly the CVH score enhanced with PHQ-9, for which being in the high vs low category was associated with ∼2-fold lower risk of mortality. Differential associations were observed between individual CVH metrics and mortality in stratified analyses (Supplemental Tables 2 and 3). For the novel psychological health metric, being in the highest vs lowest category predicted up to 69% lower all-cause mortality risk in both sexes and among Black and White adults; the strongest associations were among Black adults and null results were observed for Hispanic adults.

CARDIOVASCULAR HEALTH AND CAUSE-SPECIFIC MORTALITY. There were 414 and 329 CVD and cancer deaths, respectively. Having a high vs low LE8 score was associated with 68% lower cardiovascular mortality risk and 65% lower cancer mortality risk (P trend $<$ 0.001) (**Central Illustration**, Supplemental Figure 3). A high vs low CVH score enhanced with PHQ-2 and PHQ-9 predicted 77% and 74% lower risk of cardiovascular mortality (P trend $\leq$ 0.01), but there was no association with cancer mortality (**Central Illustration**, Supplemental Figure 3). However, in analyses using tertiles, being in the highest vs lowest tertile for the CVH score enhanced with PHQ-9 predicted 52% lower cancer mortality risk (P trend = 0.04); the CVH score enhanced with PHQ-2 tended to be associated with 50% cancer mortality, but the association was not statistically significant (P trend = 0.053) (**Table 3**).

When CVH score components were evaluated, being in the highest vs lowest category of PA, sleep health, BMI, glucose, and BP scores predicted 36% to 53% lower cardiovascular mortality risk (P trend $<$ 0.05) (**Table 3**). Higher nicotine exposure and sleep health scores predicted 55% and 35% lower cancer mortality risk (P trend $<$ 0.05), respectively, while higher non-HDL cholesterol scores predicted 52% higher risk (P trend = 0.017). For the new psychological health metric, being in the highest vs lowest category was associated with 38% and 39% lower cardiovascular mortality based on PHQ-2 and PHQ-9, respectively, but there was no association with cancer mortality.

DISCUSSION

In U.S. adults, higher CVH, defined by the original LE8 and two iterations of an enhanced CVH score that encompasses an additional ninth metric for psychological health, predicted lower all-cause and cause-specific mortality risk. The observed effect size was stronger for the enhanced CVH scores, and a gradient in risk was detected for all associations suggesting that substantial gains in longevity may be feasible with improvement in overall and individual metrics of CVH, including psychological health. AUC analysis demonstrated that all scores had excellent

FIGURE 1 Continued

(A) HRs (95% CIs) comparing risk of all-cause mortality among participants with moderate vs low and high vs low LE8 scores, stratified by sex (P interaction $<$ 0.05) and by race and ethnicity (P interaction $<$ 0.001). (B and C) HRs (95% CIs) for associations between an enhanced CVH score, with a ninth psychological health metric based on PHQ-2 and PHQ-9, respectively, and mortality, stratified by sex and by race and ethnicity. Sex-stratified models were adjusted for age, race and ethnicity, marital status, education, health insurance, and family income. Models stratified by race and ethnicity were adjusted for age, sex, marital status, education, health insurance, and family income. The test for linear contrast was used to compute the p-trend for detection of a linear trend across the categories of cardiovascular health for all models. AHA = American Heart Association; CVD = cardiovascular disease; CVH = cardiovascular health; LE8 = Life's Essential 8; NHANES = National Health and Nutrition Examination Survey; PHQ = Patient Health Questionnaire.

TABLE 3 Associations of Life's Essential 8 and Enhanced Cardiovascular Health Scores Including a Ninth Psychological Health Metric With Cardiovascular and Cancer Mortality

	Cardiovascular Mortality			Cancer Mortality		
CVH Scores	N (n)[a]	Univariate Model[b,d]	Adjusted Model[b,c,d]	N (n)[a]	Univariate Model[b,d]	Adjusted Model[b,c,d]
Total LE8 score	14,683 (251)			14,683 (200)		
Tertile 1 (<58.4)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (58.4-73.5)		0.46 (0.24-0.88)	0.55 (0.30-1.04)		0.56 (0.35-0.89)	0.62 (0.38-1.02)
Tertile 3 (>73.5)		0.20 (0.10-0.39)	0.46 (0.22-0.97)		0.24 (0.13-0.45)	0.44 (0.23-0.84)
		P trend < 0.001	*P* trend = 0.041		*P* trend < 0.001	*P* trend = 0.014
Enhanced CVH score using PHQ-2	14,041 (236)			14,041 (192)		
Tertile 1 (<61.7)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (61.7-75.6)		0.47 (0.25-0.89)	0.61 (0.32-1.16)		0.45 (0.29-0.72)	0.52 (0.32-0.83)
Tertile 3 (>75.6)		0.20 (0.10-0.38)	0.44 (0.21-0.90)		0.29 (0.15-0.55)	0.50 (0.25-1.01)
		P trend < 0.001	*P* trend = 0.026		*P* trend < 0.001	*P* trend = 0.053
Enhanced CVH score using PHQ-9	14,011 (234)			14,011 (190)		
Tertile 1 (<62.0)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (62.0-75.9)		0.46 (0.25-0.87)	0.58 (0.32-1.06)		0.47 (0.29-0.75)	0.52 (0.31-0.87)
Tertile 3 (>75.9)		0.20 (0.10-0.40)	0.45 (0.21-0.96)		0.28 (0.14-0.54)	0.48 (0.24-0.96)
		P trend < 0.001	*P* trend = 0.038		*P* trend < 0.001	*P* trend = 0.040
Depression (PHQ-2)[e]	19,055 (354)			19,055 (289)		
0-40 (moderate/severe)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
80 (mild)		0.64 (0.41-0.99)	0.76 (0.50-1.16)		0.90 (0.50-1.61)	0.89 (0.49-1.62)
100 (none)		0.53 (0.36-0.76)	0.62 (0.42-0.91)		0.83 (0.50-1.37)	0.83 (0.50-1.38)
		P trend < 0.001	*P* trend = 0.016		*P* trend = 0.454	*P* trend = 0.467
Depression (PHQ-9)[e]	19,000 (351)			19,000 (283)		
0-40 (moderate/severe)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
80 (mild)		0.92 (0.63-1.36)	0.90 (0.61-1.32)		1.74 (0.89-3.40)	1.67 (0.88-3.19)
100 (none)		0.59 (0.39-0.87)	0.61 (0.42-0.88)		1.06 (0.58-1.94)	1.05 (0.59-1.86)
		P trend = 0.009	*P* trend = 0.009		*P* trend = 0.842	*P* trend = 0.880
Diet	16,772 (304)			16,772 (253)		
Tertile 1 (<12.0)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (12.0-43.1)		1.32 (0.83-2.10)	1.08 (0.65-1.79)		1.18 (0.64-2.15)	0.94 (0.50-1.76)
Tertile 3 (>43.1)		1.19 (0.77-1.84)	0.93 (0.55-1.54)		0.90 (0.50-1.62)	0.61 (0.35-1.08)
		P trend = 0.428	*P* trend = 0.761		*P* trend = 0.722	*P* trend = 0.090
Physical activity	21,175 (414)			21,175 (329)		
Tertile 1 (0)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (0-91.3)		0.29 (0.19-0.46)	0.45 (0.28-0.73)		0.43 (0.27-0.70)	0.57 (0.35-0.93)
Tertile 3 (>91.3)		0.27 (0.19-0.39)	0.52 (0.36-0.76)		0.46 (0.31-0.68)	0.71 (0.47-1.07)
		P trend < 0.001	*P* trend = 0.001		*P* trend < 0.001	*P* trend = 0.097
Nicotine exposure	21,103 (412)			21,103 (329)		
Tertile 1 (<61.7)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (61.7-87.4)		1.86 (1.23-2.81)	0.72 (0.48-1.10)		1.48 (1.05-2.09)	0.56 (0.39-0.81)
Tertile 3 (>87.4)		0.96 (0.64-1.44)	0.80 (0.53-1.19)		0.60 (0.42-0.85)	0.45 (0.31-0.66)
		P trend = 0.827	*P* trend = 0.254		*P* trend = 0.005	*P* trend < 0.001
Sleep health	21,094 (409)			21,094 (325)		
Tertile 1 (<69.5)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (69.5-94.2)		0.63 (0.44-0.90)	0.70 (0.49-0.99)		0.72 (0.52-1.00)	0.71 (0.51-0.99)
Tertile 3 (>94.2)		0.56 (0.41-0.78)	0.64 (0.46-0.87)		0.65 (0.46-0.92)	0.65 (0.46-0.92)
		P trend < 0.001	*P* trend = 0.005		*P* trend = 0.015	*P* trend = 0.016
BMI	20,881 (381)			20,881 (320)		
Tertile 1 (<28.6)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (28.6-66.9)		0.78 (0.50-1.22)	0.64 (0.38-1.06)		1.71 (1.04-2.81)	1.38 (0.87-2.19)
Tertile 3 (>66.9)		0.71 (0.47-1.06)	0.58 (0.39-0.87)		1.50 (0.98-2.28)	1.31 (0.86-1.99)
		P trend = 0.091	*P* trend = 0.010		*P* trend = 0.059	*P* trend = 0.204

Continued on the next page

TABLE 3 Continued

CVH Scores	Cardiovascular Mortality			Cancer Mortality		
	N (n)[a]	Univariate Model[b,d]	Adjusted Model[b,c,d]	N (n)[a]	Univariate Model[b,d]	Adjusted Model[b,c,d]
Blood lipids	19,934 (387)			19,934 (279)		
Tertile 1 (<41.7)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (41.7-80.6)		1.29 (0.92-1.81)	1.08 (0.78-1.48)		1.15 (0.83-1.57)	0.99 (0.71-1.37)
Tertile 3 (>80.6)		0.71 (0.51-0.99)	1.27 (0.92-1.75)		0.83 (0.61-1.14)	1.52 (1.08-2.14)
		P trend = 0.042	*P* trend = 0.149		*P* trend = 0.249	*P* trend = 0.017
Blood glucose[f]	20,214 (396)			20,214 (287)		
0-40 (diabetes)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
60 (prediabetes)		0.52 (0.35-0.75)	0.60 (0.40-0.90)		0.85 (0.55-1.32)	1.01 (0.66-1.55)
100 (normal HbA1c)		0.18 (0.14-0.23)	0.53 (0.40-0.68)		0.35 (0.24-0.52)	0.91 (0.61-1.36)
		P trend < 0.001	*P* trend < 0.001		*P* trend < 0.001	*P* trend = 0.642
Blood pressure	19,398 (368)			19,398 (297)		
Tertile 1 (<46.4)		1.00 (ref)	1.00 (ref)		1.00 (ref)	1.00 (ref)
Tertile 2 (46.4-83.4)		0.39 (0.29-0.52)	0.79 (0.58-1.08)		0.44 (0.31-0.62)	0.81 (0.55-1.18)
Tertile 3 (>83.4)		0.09 (0.06-0.14)	0.47 (0.31-0.70)		0.17 (0.11-0.25)	0.73 (0.43-1.24)
		P trend < 0.001	*P* trend < 0.001		*P* trend < 0.001	*P* trend = 0.236

[a]N represents the analytic sample size, and n represents the total number of deaths. [b]Cox proportional hazards models were used to estimate HR (95% CI) for associations of tertiles of the overall CVH scores and their component scores with all-cause mortality risk. Tertile 1 was used as the referent category. [c]Multivariable models were adjusted for age (20-29 y, 30-39 y, 40-49 y, 50-59 y, 60-69 y, 70+ y), sex (male, female), race/ethnicity (NH Black, Hispanic, NH White, NH Asian, other race including multiracial), marital status (married/living with partner, single/widowed/divorced), education (>high school, ≤high school), health insurance (yes, no), and family income (≥$45,000, <$45,000). [d]The test for linear contrast was used to compute the p-trend for detection of a linear trend across the categories of cardiovascular health for all models. [e]Given the distribution of the depression scores, the following a priori defined categories were compared: 0 to 40 (includes moderate to severe depressive symptoms), 80 (includes mild depressive symptoms), and 100 (referent group including no depressive symptoms). For the PHQ-2 score, there were 1,935 participants with moderate, moderately severe, or severe symptoms, 4,545 participants with mild depressive symptoms, and 12,575 participants with no/minimal depressive symptoms. For PHQ-9 score, there were 1,722 participants with moderate, moderately severe, and severe symptoms, 3,053 participants with mild symptoms, and 14,225 participants with no/minimal depressive symptoms. [f]Given the distribution of the blood glucose scores, the following a priori defined categories were compared: 0 to 40 (includes type 2 diabetes), 60 (includes prediabetes), and 100 (referent group includes healthy blood glucose levels). There were 3,560 participants with type 2 diabetes, 4,432 participants with prediabetes, and 12,222 with normal HbA1c.

AHA = American Heart Association; BMI = body mass index; CVH = cardiovascular health; LE8 = Life's Essential 8; PHQ = Patient Health Questionnaire.

discriminative ability for predicting mortality outcomes. However, the improvement in the C-statistic for the enhanced CVH scores, although statistically significant, was minimal, which is expected given that the baseline model had a C-statistic >0.75.[29] Furthermore, the inclusion of a ninth psychological health metric based on depression screening did not substantially alter the percentage of participants classified as having high, moderate, and low CVH. Importantly, we observed similar associations and effect sizes for both iterations of the enhanced CVH scores underscoring the utility of the PHQ-2, due to its simplicity compared to the PHQ-9, for in-clinic assessments of psychological health among patients at risk for CVD and in public health or low resource settings where comprehensive assessments may not be feasible.[6]

Our findings are consistent with the strong inverse dose-response association detected between ideal CVH, defined by the LS7 framework, and mortality outcomes in prior work.[7-12] A 2016 meta-analysis of prospective studies showed that having the highest number of ideal CVH metrics was associated with 45% and 75% lower all-cause and CVD mortality risk, respectively.[7] Our results also align with findings from the UK Biobank showing that higher CVH, based on the LE8 algorithm, is associated with longer life expectancy free of major chronic diseases, including CVD and cancer.[13] Indeed, poor CVH has been linked to chronic diseases representing the leading causes of mortality[6,30-32] via mechanisms related to inflammation, endothelial dysfunction, atherosclerosis, cardiac stress and remodeling, hemostatic factors, and accelerated epigenetic aging among others.[33-36]

Higher scores for the new psychological health metric based on depression screening were associated with lower all-cause and cardiovascular but not cancer mortality. In U.S. adults, depression is related to ~80% higher odds of having suboptimal CVH, and a graded positive association between the number of poor mental health days and CVD odds has been reported.[16] Furthermore, major depression is associated with 52% and >2-fold higher risk of all-cause and cardiovascular mortality, respectively.[37] Although psychological distress and depression have been linked to cancer mortality in prior studies,[38,39] we only observed significant associations for the CVH score enhanced with PHQ-9 in tertile analyses. Predictors of cancer outcomes may vary by site, so it is possible that associations of depression with site-

specific cancer deaths were diluted by the use of a composite cancer mortality outcome in our analyses. Alternatively, the full psychological profile contributing to cancer mortality may not be captured by the PHQ-2 or may be distinct from other types of mortality. Specifically, the PHQ-2 asks about finding little pleasure in life and feeling hopeless, and individuals with cancer, the majority of whom survive ≥5 years after initial diagnosis, report unique perspectives of gratitude and appreciation for life as positive aspects of having cancer.[40] Notably, sleep health, the novel 8th metric, was the only health behavior related to all mortality outcomes, which extends our prior work showing that the inclusion of sleep as a CVH metric enhances the CVH construct over and above the original seven metrics.[41] Given the strong bidirectional association between sleep and wellbeing, it is also possible that sleep serves a proxy for aspects of psychological health more strongly related to cancer mortality.

In sex-stratified analyses, high CVH predicted lower all-cause mortality in both sexes, with stronger associations in females. This stronger effect size may be explained by differences in health behaviors and the higher depression rates typically reported among females.[42,43] Diet quality was associated with mortality in females only. Furthermore, although sleep health score tertiles were not associated with mortality in females, in sensitivity analyses, we found that sleeping <6 h or ≥10 h vs ≥7 h and <9 h is associated with 30% higher mortality risk (data not shown). In analyses stratified by race and ethnicity, the association of CVH with mortality in both Black and White adults is consistent with prior research.[11] There was a remarkable increase in effect size when the CVH score was enhanced with a measure of psychological health, particularly PHQ-9, among Black adults. Previous research has found that Black populations tend to have worse CVH[44] as well as higher rates of depression compared to other racial and ethnic groups in the United States.[43] Therefore, screening for and addressing psychological health as well as structural factors that increase depression risk are important targets for promoting CVH equity in this population. We did not observe an association between overall CVH and mortality in Hispanic adults; this finding adds to the literature documenting the Hispanic mortality paradox.[45,46] However, recent data suggest that disaggregating data by demographics may reveal differential results in the U.S. Hispanic population.[47] Therefore, factors that confer resilience and differences by Hispanic/Latina/o/x background and age group within the heterogeneous Hispanic population warrant further investigation.

STUDY STRENGTHS AND LIMITATIONS. Strengths of our study include the use of standardized data from a large representative cohort of U.S. adults, the rigorous survey planning, data collection, and data processing procedures of NHANES. The carefully adjusted models for relevant potential confounding factors, stratification of results by relevant demographic factors, and sensitivity analyses represent additional strengths of our analytic approach. Importantly, the use of the LE8 algorithm in conjunction with a measure of psychological health and wellbeing represents an enhanced and updated approach to prior studies on CVH and mortality and is a notable strength of this work.

Our findings should be considered in light of several limitations. First, the follow-up of our cohort was of limited duration. Second, we had only a single measurement for CVH and depression status; thus, were unable to account for changes in CVH metrics and depressive symptoms during the follow-up period, years living with depression, or the timing of depression diagnosis and their association with mortality across adulthood. We were also not able to adjust for emergent health complications and drug use during follow-up. Third, health behaviors and depression status were self-reported and prone to recall bias. Fourth, the measure of psychological health that we used is based solely on depression symptoms, without accounting for anxiety, stress, pessimism or measures of positive psychological wellbeing (eg, gratitude, optimism, mindfulness, sense of purpose) that are known to interact with and shape CVH.[6,21] Fifth, there is potential misclassification of the scoring approach; we also cannot rule out misclassification error of underlying and contributing causes of death and the possibility of residual confounding. Finally, we had limited statistical power to conduct stratified analyses for CVH in relation to cause-specific mortality.

CONCLUSIONS

A new enhanced CVH score that includes a ninth metric for psychological health, based on feasible depression screening, was a strong predictor of all-cause and cause-specific mortality in U.S. adults, with evidence of a dose-response relationship. Our data support a possible future update to the LE8 guidelines to encompass a ninth metric for psychological health and wellbeing (eg, “Life’s Necessary

9"), and suggest that screening for and addressing depression, as a key CVD risk factor, with psychotherapy, behavioral, and pharmacological interventions as part of primordial prevention efforts may have a far-reaching effect for population-level reductions in mortality. Long-term population studies are needed to investigate associations of enhanced CVH scores, that utilize a more comprehensive but pragmatic psychological health construct, with mortality and other health outcomes and to compare the predictive value of LE8 to other enhanced scoring algorithms.

FUNDING SUPPORT AND AUTHOR DISCLOSURES

Dr Makarem is supported by NHLBI Grant #HL148511, American Heart Association Grant #855050, and NIMHD Grant #P50MD017341 (subproject ID: 8126). The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication. The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

ADDRESS FOR CORRESPONDENCE: Dr Nour Makarem, Mailman School of Public Health, Columbia University Irving Medical Center, 722 West 168th street, New York, New York 10032, USA. E-mail: nm2968@cumc.columbia.edu. X handle: @DrNMakarem.

PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: A CVH construct enhanced with a ninth psychological health metric, based on validated feasible depression screening, strongly predicted all-cause and cardiovascular mortality in U.S. adults and demonstrated excellent predictive value compared to the LE8 score. Associations of the enhanced CVH score with mortality were stronger than those observed for the LE8 score, particularly among Black and female populations, while null associations were observed among Hispanic populations.

TRANSLATIONAL OUTLOOK 1: The incorporation of depression screening within health care delivery systems and risk algorithms and addressing psychological health and wellbeing with psychotherapy, behavioral, and pharmacological interventions as part of primordial prevention efforts may have far-reaching effects for CVH equity promotion and population-level reductions in mortality.

TRANSLATIONAL OUTLOOK 2: Additional research is warranted to investigate the association of enhanced CVH scores, that utilize different and more comprehensive definitions of psychological health and wellbeing, with mortality and other health outcomes and to compare the predictive value of the LE8 score to other enhanced scoring algorithms.

REFERENCES

1. National Academies of Sciences Engineering and Medicine. Division of behavioral and social Sciences and education, Committee on national statistics, Committee on population Committee on rising Midlife mortality rates and Socioeconomic Disparities. In: Becker T, Majmundar MK, Harris KM, eds. *High and rising mortality rates among Working-age adults*. National Academies Press (US); 2021.

2. Schöley J, Aburto JM, Kashnitsky I, et al. Life expectancy changes since COVID-19. *Nat Hum Behav*. 2022;6(12):1649-1659.

3. Xu JQ, Murphy SL, Kochanek KD, Arias E. *Mortality in the United States, 2021*. NCHS Data Brief, no 456. Hyattsville, MD: National Center for Health Statistics; 2022.

4. Roth GA, Mensah GA, Johnson CO, et al. Global burden of cardiovascular diseases and risk factors, 1990-2019: update from the GBD 2019 study. *J Am Coll Cardiol*. 2020;76(25):2982-3021.

5. Lloyd-Jones DM, Hong Y, Labarthe D, et al. Defining and setting national Goals for cardiovascular health promotion and disease reduction. *Circulation*. 2010;121(4):586-613.

6. Lloyd-Jones DM, Allen NB, Anderson CAM, et al. Life's Essential 8: updating and enhancing the American Heart Association's construct of cardiovascular health: a Presidential Advisory from the American Heart association. *Circulation*. 2022;146(5):e18-e43.

7. Fang N, Jiang M, Fan Y. Ideal cardiovascular health metrics and risk of cardiovascular disease or mortality: a meta-analysis. *Int J Cardiol*. 2016;214:279-283.

8. Ford ES, Greenlund KJ, Hong Y. Ideal cardiovascular health and mortality from all causes and diseases of the Circulatory system among adults in the United States. *Circulation*. 2012;125(8):987-995.

9. Gaye B, Canonico M, Perier MC, et al. Ideal cardiovascular health, mortality, and Vascular Events in Elderly Subjects: the three-City study. *J Am Coll Cardiol*. 2017;69(25):3015-3026.

10. Aneni EC, Crippa A, Osondu CU, et al. Estimates of mortality Benefit from ideal cardiovascular health metrics: a dose response meta-analysis. *J Am Heart Assoc*. 2017;6(12):e006904.

11. Han L, You D, Ma W, et al. National trends in American Heart association revised Life's Simple 7 metrics associated with risk of mortality among US adults. *JAMA Netw Open*. 2019;2(10):e1913131.

12. Gaye B, Tajeu GS, Vasan RS, et al. Association of changes in cardiovascular health metrics and risk of Subsequent cardiovascular disease and mortality. *J Am Heart Assoc*. 2020;9(19):e017458.

13. Wang X, Ma H, Li X, et al. Association of cardiovascular health with life expectancy free of cardiovascular disease, diabetes, cancer, and dementia in UK adults. *JAMA Intern Med*. 2023;183(4):340-349.

14. Kubzansky LD, Huffman JC, Boehm JK, et al. Positive psychological well-being and cardiovascular disease: JACC health promotion Series. *J Am Coll Cardiol*. 2018;72(12):1382-1396.

15. Rajan S, McKee M, Rangarajan S, et al. Association of symptoms of depression with cardiovascular disease and mortality in low-, Middle-, and high-income Countries. *JAMA Psychiatr*. 2020;77(10):1052-1063.

16. Kwapong YA, Boakye E, Khan SS, et al. Association of depression and poor mental health with cardiovascular disease and Suboptimal cardiovascular health among Young adults in the United States. *J Am Heart Assoc*. 2023;12(3):e028332.

17. Penninx BWJH, Geerlings SW, Deeg DJH, van Eijk JTM, van Tilburg W, Beekman ATF. Minor and major depression and the risk of death in Older persons. *Arch Gen Psychiatry*. 1999;56(10):889-895.

18. Centers for Disease Control and Prevention; National Center for Health Statistics. National health and Nutrition examination survey. Accessed

January 19, 2023. https://www.cdc.gov/nchs/nhanes/index.htm

19. Mellen PB, Gao SK, Vitolins MZ, Goff DC Jr. Deteriorating dietary habits among adults with hypertension: DASH dietary accordance, NHANES 1988-1994 and 1999-2004. *Arch Intern Med*. 2008;168(3):308–314.

20. Everson-Rose SA, Lewis TT. Psychosocial factors and cardiovascular diseases. *Annu Rev Public Health*. 2005;26(1):469–500.

21. Levine GN, Cohen BE, Commodore-Mensah Y, et al. Psychological health, well-being, and the Mind-Heart-body Connection: a Scientific Statement from the American Heart association. *Circulation*. 2021;143(10):e763–e783.

22. Lloyd-Jones DM, Ning H, Labarthe D, et al. Status of cardiovascular health in US adults and Children using the American Heart Association's new "Life's Essential 8" metrics: prevalence estimates from the national health and Nutrition examination survey (NHANES), 2013 through 2018. *Circulation*. 2022;146(11):822–835.

23. Carey M, Boyes A, Noble N, Waller A, Inder K. Validation of the PHQ-2 against the PHQ-9 for detecting depression in a large sample of Australian general practice patients. *Aust J Prim Health*. 2016;22(3):262–266.

24. Levis B, Sun Y, He C, et al. Accuracy of the PHQ-2 Alone and in Combination with the PHQ-9 for screening to Detect major depression: systematic review and meta-analysis. *JAMA*. 2020;323(22):2290–2300.

25. Kroenke K, Spitzer RL. The PHQ-9: a new depression diagnostic and severity measure. *Psychiatric Ann*. 2002;32(9):509–515.

26. Gilbody S, Richards D, Brealey S, Hewitt C. Screening for depression in medical settings with the patient health Questionnaire (PHQ): a diagnostic meta-analysis. *J Gen Intern Med*. 2007;22(11):1596–1602.

27. Kroenke K, Spitzer RL, Williams JB. The Patient Health Questionnaire-2: validity of a two-item depression screener. *Med Care*. 2003;41(11):1284–1292.

28. Centers for Disease Control and Prevention. NCHS data linked to NDI mortality Files. Accessed January 19, 2023. https://www.cdc.gov/nchs/data-linkage/mortality.htm

29. Pencina MJ, D'Agostino RB, Vasan RS. Statistical methods for assessment of added usefulness of new biomarkers. *Clin Chem Lab Med*. 2010;48(12):1703–1711.

30. Tsao CW, Aday AW, Almarzooq ZI, et al. Heart disease and Stroke statistics-2023 update: a report from the American Heart association. *Circulation*. 2023;147(8):e93–e621.

31. Rasmussen-Torvik LJ, Shay CM, Abramson JG, et al. Ideal cardiovascular health is inversely associated with incident cancer: the Atherosclerosis Risk in Communities study. *Circulation*. 2013;127(12):1270–1275.

32. Wu J, Xiong Y, Xia X, et al. Can dementia risk be reduced by following the American Heart Association's Life's Simple 7? A systematic review and dose-response meta-analysis. *Ageing Res Rev*. 2023;83:101788.

33. Polonsky TS, Ning H, Daviglus ML, et al. Association of cardiovascular health with subclinical disease and incident Events: the Multi-ethnic study of atherosclerosis. *J Am Heart Assoc*. 2017;6(3):e004894.

34. Xanthakis V, Enserro DM, Murabito JM, et al. Ideal cardiovascular health: associations with biomarkers and subclinical disease and impact on incidence of cardiovascular disease in the Framingham Offspring Study. *Circulation*. 2014;130(19):1676–1683.

35. Joyce BT, Gao T, Zheng Y, et al. Epigenetic age acceleration Reflects Long-term cardiovascular health. *Circ Res*. 2021;129(8):770–781.

36. Gaye B, Tafflet M, Arveiler D, et al. Ideal cardiovascular health and incident cardiovascular disease: Heterogeneity across event Subtypes and Mediating effect of blood biomarkers: the PRIME study. *J Am Heart Assoc*. 2017;6(10):e006389.

37. Wei J, Lu Y, Li K, Goodman M, Xu H. The associations of late-life depression with all-cause and cardiovascular mortality: the NHANES 2005–2014. *J Affect Disord*. 2022;300:189–194.

38. Wang Y-H, Li J-Q, Shi J-F, et al. Depression and anxiety in relation to cancer incidence and mortality: a systematic review and meta-analysis of cohort studies. *Mol Psychiatry*. 2020;25(7):1487–1499.

39. Pinquart M, Duberstein PR. Depression and cancer mortality: a meta-analysis. *Psychol Med*. 2010;40(11):1797–1810.

40. Adorno G, Lopez E, Burg MA, et al. Positive aspects of having had cancer: a mixed-methods analysis of responses from the American Cancer Society Study of Cancer Survivors-II (SCS-II). *Psycho Oncol*. 2018;27(5):1412–1425.

41. Makarem N, Castro-Diehl C, St-Onge MP, et al. Redefining cardiovascular health to include sleep: prospective associations with cardiovascular disease in the MESA sleep study. *J Am Heart Assoc*. 2022;11(21):e025252.

42. Yu B, Zhang X, Wang C, Sun M, Jin L, Liu X. Trends in depression among Adults in the United States, NHANES 2005-2016. *J Affect Disord*. 2020;263:609–620.

43. Brody DJ, Pratt LA, Hughes J. *Prevalence of depression among adults aged 20 and over: United States, 2013 -2016*. NCHS Data Brief, no 303. Hyattsville, MD: National Center for Health Statistics; 2018.

44. Bucholz EM, Butala NM, Allen NB, Moran AE, de Ferranti SD. Age, sex, race/ethnicity, and income patterns in ideal cardiovascular health among Adolescents and adults in the U.S. *Am J Prev Med*. 2022;62(4):586–595.

45. Abraído-Lanza AF, Mendoza-Grey S, Flórez KR. A Commentary on the Latin American paradox. *JAMA Netw Open*. 2020;3(2):e1921165.

46. Ruiz JM, Steffen P, Smith TB. Hispanic mortality paradox: a systematic review and meta-analysis of the longitudinal literature. *Am J Public Health*. 2013;103(3):e52–e60.

47. Khan SU, Lone AN, Yedlapati SH, et al. Cardiovascular disease mortality among Hispanic versus non-Hispanic white adults in the United States, 1999 to 2018. *J Am Heart Assoc*. 2022;11(7):e022857.

KEY WORDS cardiovascular health, depression, Life's Essential 8, mortality, primordial prevention, psychological health

APPENDIX For supplemental tables and figures, please see the online version of this paper.