Nutrition & Metabolism

RESEARCH

Open Access

Gender differences in the association between Life's essential 8 and cardiovascular disease: a U.S.-based cross-sectional analysis

Yi Tang[1*], Xiaojie Chen[1], Yifan Zhao[1], Jihong Sun[1] and Yaohui Jiang[1]

Abstract

Background This research aims to elucidate the gender differences in the association between cardiovascular disease (CVD) prevalence and Life's Essential 8 (LE8), a recently updated measure of cardiovascular health (CVH).

Methods This study included participants from the National Health and Nutrition Examination Survey (NHANES) between 2005 and 2018.The scores of LE8, health behavior, health factor and each metric based on diet, physical activity, nicotine exposure, sleep health, body mass index, blood lipid, blood glucose, and blood pressure were classified as low (0–49 points), moderate (50–79 points), and high (80–100 points). The scores of LE8, health behavior and health factor as continuous variables were also used for dose–response analysis. The main outcomes included the prevalence of CVD. The definition of CVD based on self-reported history of coronary heart disease or stroke.

Results A total of 23,307 individuals were included in this analysis. Participants with CVD had significantly lower LE8 scores compared to those without CVD, and females demonstrated higher CVH levels compared to males including total LE8 scores and the scores of diet, nicotine exposure, blood lipid, blood glucose, and blood pressure ($P < 0.05$). Moreover, the LE8 score demonstrated a non-linear association with CVD in both males and females (all *P*-values for non-linearity were < 0.001). Furthermore, compared to the low LE8 level, a high LE8 level was associated with a 78% decreased risk of CVD in males (HR: 0.22, 95% CI: 0.16–0.31) and an 83% decreased risk in females (HR: 0.17, 95% CI: 0.11–0.26). Consistently, compared to low levels of health behaviors and health factors, higher levels were significantly associated with a decreased risk of CVD in both males and females (All $P < 0.001$). Additionally, the area under the curve (AUC) for the total LE8 score in CVD discrimination was significantly higher in females than in males ($P < 0.001$).

Conclusion Higher CVH scores were associated with a lower risk of CVD, especially in females. These findings highlight the need for gender-specific preventive strategies in CVH promotion, with a particular focus on improving LE8 scores in high-risk populations.

Keywords Life's Essential 8, Cardiovascular health, Gender differences, Cardiovascular disease

Introduction

Cardiovascular disease (CVD), including coronary heart disease (CHD) and stroke, has consistently ranked as a top cause of mortality worldwide over the past century, accounting for 26.6% and 27.4% of fatalities among males and females, respectively [1]. In China, the rates are even higher, with CVD responsible for 38.9% of deaths in females and 35.5% in males [2]. The economic impact

*Correspondence:
Yi Tang
tangyizzu@126.com
[1] Department of Cardiology, the First Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan, China

of CVD is significant, costing an estimated average of US $363.4 billion annually between 2016 and 2017 [3]. Projections suggest that by 2030, CVD will lead to 20 million deaths worldwide [4]. It is imperative to effectively manage patients with CVD and prevent future CV events in high-risk individuals.

The concept of cardiovascular health (CVH) is widely known and acknowledged. However, there is a lack of tools for defining and measuring CVH levels in individuals and populations. To address this issue, the American Heart Association (AHA) put forth Life's Simple 7 (LS7) in 2010 for the evaluation and tracking of CVH, with the goal of improving the health of individuals and populations. LS7 comprises 7 metrics that can be modified, including physical activity (PA), diet, body mass index (BMI), smoking, blood pressure, blood glucose, and total cholesterol (TC) [5]. Research has indicated that the prevalence of ideal CVH is extremely low (< 1%) in all age groups [6], yet individuals with increased CVH levels experience significantly reduced risks of CV events and mortality [7, 8]. Despite the broad use of LS7 in forecasting health outcomes [9, 10], its limitations have become apparent, particularly regarding gender differences. LS7 fails to capture certain critical aspects of health, such as sleep health, and does not sufficiently account for variations among individuals, especially between genders. For instance, while smoking rates differ significantly between males and females, LS7's simplistic framework does not effectively reflect these differences. To address these shortcomings, Life's Essential 8 (LE8) score has been proposed. LE8 score enhances the evaluation of CVH by defining eight metrics on a scale from 0 to 100, enabling a more detailed and nuanced assessment of health behaviors and factors. Notably, LE8 score includes modifications that specifically address gender-related issues. For example, by incorporating sleep quality as a metric, LE8 score recognizes the significant impact of sleep on CVH—an aspect that predominantly affects females. Furthermore, LE8's structure enables a more sensitive detection of individual differences. This allows for a better understanding of how various lifestyle factors, including diet, PA, and smoking behaviors, differ between genders and influence CVH [11]. The latest research found that, compared with LS7, LE8 score showed superior ability in predicting coronary arteriosclerosis, stroke, and depression [12–14].

The LE8 score serves as a comprehensive indicator of CVH and overall health. It has been instrumental in predicting a wide range of health outcomes including mental health disorders [15], liver disease [16], gum disease [17], hyperuricemia [18], diabetes [19], hypertension, and metabolic diseases [20]. Additionally, LE8 score has shown strong predictive power for CV-related events and deaths [21, 22]. Although some studies have explored the relationship between LE8 score and the risk of CVD in young adults and diabetic populations [23, 24], its gender-specific predictive performance remains unexplored. Most existing diagnostic criteria for CVD overlook these gender differences. They fail to account for anatomical and physiological variations between males and females, as well as lifestyle choices that may differ by gender. We hypothesized that higher LE8 scores would be associated with a lower risk of CVD, with potential differences between males and females. Therefore, this study aims to bridge these gaps by analyzing data from a large public database to explore the associations between LE8 score, health behaviors and health factors, and the prevalence of CVD in the general population. Furthermore, it seeks to investigate potential gender-specific variations in these relationships to provide insight into gender-specific CVD prevention strategies or policy changes.

Materials and methods

Study population and design

The National Health and Nutrition Examination Survey (NHANES) is a continuous cross-sectional survey managed by the U.S. Centers for Disease Control and Prevention (CDC). It employs intricate multistage probability sampling to choose a representative sample of Americans, examining the health and nutritional status of both adults and children, offering important health statistics for the country. The research protocol of NHANES was sanctioned by the Ethical Review Board of the National Center for Health Statistics (NCHS), with all participants consenting in writing. The survey data involves six components, such as demographic details, dietary information, physical and laboratory tests, questionnaires, and data with restricted access. The majority of data, excluding private information like minors' substance use or infectious disease data, can be found on the NHANES official website (https://www.cdc.gov/nchs/nhanes/index.html). This specific study examined 70,190 individuals from 2005 to 2018, after excluding those under 20 years old ($n = 30,441$), individuals with incomplete CVH status ($n = 5,621$), or LE8-related questionnaires ($n = 10,821$). The final sample comprised 23,307 participants, with an equal distribution of males (49.2%) and females (50.8%).

Calculation of the LE8 score

The LE8 score is composed of eight different elements, which are diet, nicotine exposure, PA, sleep, BMI, blood glucose levels, blood lipid levels, and blood pressure. Each of these elements was evaluated on a scale ranging from 0 to 100, the LE8 score was calculated as the average value of the eight components [11]. Diet, nicotine exposure, PA, and sleep patterns were obtained through

standardized NHANES questionnaires. BMI, blood glucose, blood lipids, and blood pressure were determined through clinical/laboratory measurements. AHA categorized LE8 scores into three groups: low (0–49 points), moderate (50–79 points), and high (80–100 points) [11]. Additionally, a composite health score that includes both health behaviors and health factors was calculated. The health behavior score was the average of the scores for diet, nicotine exposure, PA, and sleep. The health factor score was the average of the scores for BMI, blood glucose levels, blood lipid levels, and blood pressure, all on a 0 to 100 scale. Moreover, these health behaviors and health factors were transformed into categorical variables with the same defined categories of low (0–49 points), moderate (50–79 points), and high (80–100 points). We have provided a detailed explanation of the calculation methods of LE8 and its eight sub-scores in Supplementary Table 1.

Diagnosis of CVD

Participants diagnosed with CHD or who had a history of stroke were grouped under CVD. Diagnoses of CHD and stroke were established based on participants' self-reported medical histories. Participants responded to queries like 'Has a doctor ever informed you that you have CHD?' and 'Has a medical professional ever told you that you have angina?' Positive responses to any of these queries indicated that the participant had CHD. Likewise, if a participant confirmed that a medical professional had previously diagnosed them with a stroke, they were classified as having had a stroke.

Covariates assessment

In the study, various covariates were scrutinized to understand their potential impact. Education level was grouped by years of schooling, varying from less than high school to college education or higher. Diabetes was defined in various manners: self-reported history of diabetes, fasting blood glucose (FBG) $\geq$ 7.0 mmol/L, glycosylated hemoglobin, type A1C (HbA1c) $\geq$ 6.5%, or use of hypoglycemic drugs or insulin [25]. Smoking status was categorized into non-smokers, former smokers, and current smokers. Current smoker were defined as individuals who have smoked more than 100 cigarettes in their lifetime and are still smoking; former smokers as those who have smoked more than 100 cigarettes in their lifetime but have since quit; and non-smokers as those who have smoked fewer than 100 cigarettes in their lifetime [26]. Drinking status was classified into drinkers and non-drinkers. Drinkers were defined as individuals who consumed 12 or more alcoholic beverages in the past year, while those who consumed fewer than 12 were classified as non-drinkers [27]. Hypertension was defined as a self-reported history of hypertension, systolic blood pressure (SBP) $\geq$ 140 mmHg, diastolic blood pressure (DBP) $\geq$ 90 mmHg, or use of antihypertensive medications [28].

Statistical analyses

Participants who had missing independent and outcome variables were excluded during the data processing phase, while missing covariates were supplemented through multiple imputation techniques. To accommodate the multi-stage sampling design used in the NHANES, data were weighted according to official guidelines to mitigate errors resulting from complex sampling. According to the official NHANES documentation, since the LE8 score incorporates FBG data, participants with missing FBG data were excluded. Therefore, the weight used in this study is the fasting subsample weight (WTSAF2YR) divided by the number of cycles (7). This study aimed to investigate gender differences in CVH, with all analyses stratified by gender. Continuous variables were compared between CVD groups using independent sample t-tests, while categorical variables were analyzed using the chi-square test. Covariates with a between-group P-value < 0.1 were considered for inclusion in the multivariable logistic regression analysis. Subsequently, covariates related to LE8 score calculation, such as TC, HDL-C, FBG, HbA1c, PA, smoking status, hypertension, and diabetes, were further excluded to avoid multicollinearity (for details on LE8 score calculation, see Supplementary Table 1). Finally, multicollinearity was assessed, and covariates with a variance inflation factor (VIF) > 5 were iteratively removed until all included covariates showed no multicollinearity. A stacked column chart was utilized to graphically depict the distribution of LE8 scores across genders. A four-knot restricted cubic spline (RCS) regression model was implemented to assess potential nonlinear associations among LE8 scores, health behaviors, health factors, and CVD. Weighted multivariate logistic regression analyses were conducted to evaluate the relationship between LE8 scores, health behaviors, health factors, and the prevalence of CVD. Results were reported as odds ratios (ORs) with corresponding 95% confidence intervals (CIs). Model 1 didn't adjust; Model 2 additionally adjusted for covariates such as age, race, education, and ratio of family income to poverty (PIR) [29]; and Model 3 further accounted for potential confounders like aspartate aminotransferase (AST), alanine aminotransferase (ALT), TG, low-density lipoprotein (LDL-C), and alcohol consumption. The predictive capabilities of LE8 scores, health behaviors, and health factors for CVD were assessed using receiver operating characteristic (ROC) curve analysis. The DeLong test was used to statistically compare AUC values between males and

females. Statistical analyses were completed using R version 4.3.0, with a significance threshold set at $P < 0.05$.

Results

Baseline characteristics of study participants by CVH

The study meticulously examined data from 23,307 NHANES participants collected between 2005 and 2018 (Fig. 1). Among these participants, there were 11,468 males (49.2%) and 11,839 females (50.8%). Both males and females diagnosed with CVD were found to have lower income, education levels, and HDL-C, along with high levels of FBG, BMI, and higher prevalence of hypertension, and diabetes, in contrast to those without CVD ($P < 0.001$). Importantly, the CVD group exhibited significantly lower LE8 scores and 8 metric scores in comparison to the non-CVD group, independent of gender ($P < 0.001$) (Table 1).

Gender differences in CVH levels

Table 2 showed gender disparities in LE8 and eight metric scores. Overall, females demonstrated superior LE8 scores compared to males. More specifically, females achieved higher scores in health parameters such as diet, nicotine exposure, blood lipid, blood glucose, and blood pressure, while showing lower scores in PA and BMI relative to males ($P < 0.05$). Figure 2 graphically represented the differences in the eight metric levels between males and females, which were consistent with those in Table 2, indicating that females had a higher proportion of individuals with moderate and high levels of CVH in terms of diet, nicotine exposure, blood lipid, and blood glucose levels, while females have a lower percentage of moderate and high levels of CVH individuals in terms of PA and BMI.

RCS analysis

Figure 3 depicted the dose–response relationship among LE8 scores, health behavior scores, health factor scores, and the prevalence of CVD, separately for male and female cohorts. RCS analysis revealed that the LE8 scores, health factor scores, as well as health factor scores, all demonstrated a non-linear association with CVD in both males and females (all *P*-values for non-linearity were < 0.001).

Multivariate logistic regression

The associations between CVH, health behavior, health factor scores, and CVD risk were presented in Table 3. In the male cohort, after adjusting for potential confounders, a high CVH level was significantly associated with a 78% lower risk of CVD [OR (95% CI): 0.22 (0.16, 0.31)]. Similarly, compared with those with low health behavior and health factor levels, males with high levels exhibited a 61% [OR (95% CI): 0.39 (0.31, 0.50)] and 65% [OR (95% CI): 0.35 (0.24, 0.49)] reduction in CVD risk, respectively.

In females, similar associations were observed, with high CVH, health behavior, and health factor levels linked to a lower CVD risk. Notably, females with high CVH and health behavior levels had even greater risk reductions than men. After adjusting for confounders, high CVH level were associated with an 83% lower CVD risk [OR (95% CI): 0.17 (0.11, 0.27)]. Likewise,

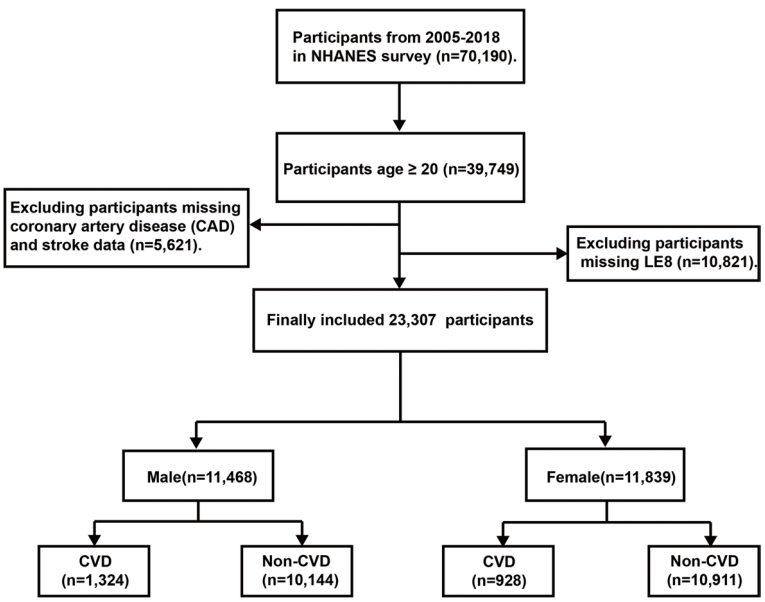

Fig. 1 Flowchart of the sample selection from National Health and Nutrition Examination Survey (NHANES) 2005–2018

Table 1 Baseline characteristics of subjects stratified by CVD in both male and female population

Variables		Female		*P*		Male		*P*
	Overall	Non–CVD	CVD		Overall	Non–CVD	CVD	
Weighted number	80,169,900	74,439,781	5,730,119		75,121,127	68,270,118	6,851,009	
Unweighted number	11,839	10,911	928		11,468	10,144	1324	
Race (%)[a]				< 0.001				< 0.001
Mexican American	1791(15.1)	1711(15.7)	80(8.6)		1737(15.1)	1626(16.0)	111(8.4)	
Non-Hispanic White	5419(45.8)	4897(44.9)	522(56.2)		5433(47.4)	4622(45.6)	811(61.3)	
Non-Hispanic Black	2420(20.4)	2220(20.3)	200(21.6)		2279(19.9)	2037(20.1)	242(18.3)	
Other/multiracial	2209(18.7)	2083(19.1)	126(13.6)		2019(17.6)	1859(18.3)	160(12.1)	
Education (%)[a]				< 0.001				< 0.001
Less than high school	2590(21.9)	2303(21.1)	287(30.9)		2688(23.4)	2299(22.7)	389(29.4)	
Highschool graduate	2640(22.3)	2371(21.7)	269(29.0)		2744(23.9)	2421(23.9)	323(24.4)	
Some college or above	6609(55.8)	6237(57.2)	372(40.1)		6036(52.6)	5424(53.5)	612(46.2)	
Drinking (%)[a]	7251(61.2)	6749(61.9)	502(54.1)	< 0.001	9613(83.8)	8523(84.0)	1090(82.3)	
Smoke (%)[a]				< 0.001				< 0.001
Never smoker	7492(63.3)	7038(64.5)	454(48.9)		12,772 (54.8)	11,931(56.7)	841(37.3)	
Former smoker	2346(19.8)	2080(19.1)	266(28.7)		5884(25.2)	4969(23.6)	915(40.6)	
Current smoker	2001(16.9)	1793(16.4)	208(22.4)		4651(20.0)	4155(19.7)	496(22.0)	
Hypertension (%)[a]	5201(43.9)	4433(40.6)	768(82.8)	< 0.001	5147(44.9)	4108(40.5)	1039(78.5)	< 0.001
Diabetes (%)[a]	1675(14.1)	1344(12.3)	331(35.7)	< 0.001	1802(15.7)	1308(12.9)	494(37.3)	< 0.001
LE8 (%)[a]				< 0.001				< 0.001
low	1590(13.4)	1281(11.7)	309(33.3)		1435(12.5)	1093(10.8)	342(25.8)	
moderate	7596(64.2)	7021(64.3)	575(62.0)		8203(71.5)	7305(72.0)	898(67.8)	
high	2653(22.4)	2609(23.9)	44(4.7)		1830(16.0)	1746(17.2)	84(6.3)	
Age(years)[b]	50.0(17.5)	48.8(17.2)	64.8(13.5)	< 0.001	49.7(17.7)	47.44(17.1)	67.1(11.8)	< 0.001
PIR[b]	2.5(1.6)	2.6(1.6)	2.0 (1.4)	< 0.001	2.7(1.6)	2.7(1.6)	2.4(1.5)	< 0.001
BMI (kg/m2)[b]	29.6(7.6)	29.5(7.5)	31.0(7.9)	< 0.001	28.7(5.9)	28.6(5.9)	29.8(6.1)	< 0.001
HbA1c[b]	5.7(1.0)	5.6(0.9)	6.1(1.3)	< 0.001	5.7(1.0)	5.6(1.0)	6.2(1.3)	< 0.001
FBG (mg/dl)[b]	105.7(30.9)	104.5(28.6)	120.7(48.3)	< 0.001	109.9(33.3)	108.1(30.7)	123.4(46.4)	< 0.001
HDL-C(mg/dl)[b]	57.8(16.3)	58.0(16.2)	55.4(17.1)	< 0.001	48.2(14.4)	48.5(14.3)	46.6(14.4)	< 0.001
AST(u/l)[b]	21.4(13.5)	21.3(13.2)	21.9(16.4)	0.247	29.1(24.8)	29.5(20.8)	26.5(44.8)	< 0.001
ALT(u/l)[b]	23.8(12.0)	23.6(11.7)	25.3(14.5)	< 0.001	27.6(18.9)	27.7(18.5)	27.1(22.0)	0.253
TC (mg/dl)[b]	197.3 (41.2)	197.7(40.6)	192.3(46.7)	< 0.001	190.6(42.2)	193.1(41.3)	171.1(43.7)	< 0.001
LDL-C(mg/dl)[b]	114.6(35.1)	115.1(34.5)	108.6(40.5)	< 0.001	113.5(35.6)	115.7(34.8)	97.1(36.9)	< 0.001
CVH score[b]	65.7(13.7)	66.8(13.4)	59.1(13.9)	< 0.001	67.1(15.1)	68.0(14.8)	56.1(14.2)	< 0.001
Diet score[b]	37.9 (30.8)	37.6(30.6)	40.5(31.5)	0.001	41.8(31.8)	41.9(31.8)	39.9(31.7)	0.066
PA score[b]	72.4(41.2)	74.2(40.1)	58.0(46.3)	< 0.001	62.4(44.4)	64.0(43.9)	43.8(46.3)	< 0.001
Nicotine exposure score[b]	65.8(40.1)	66.2 (40.4)	62.3(37.0)	0.001	75.7(37.4)	76.4(37.1)	68.0(39.9)	< 0.001
Sleep score[b]	81.1(25.5)	81.4(25.2)	78.1(27.8)	< 0.001	81.3(25.7)	81.9(25.2	74.4(30.2)	< 0.001
BMI score[b]	61.4(31.4)	62.1(31.3)	56.1(31.5)	< 0.001	58.1(35.4)	58.8(35.4)	50.4(34.6)	< 0.001
Blood lipid score[b]	62.4(30.0)	62.1(30.5)	64.8(26.3)	0.002	65.7(30.4)	66.3(30.4)	59.2(30.3)	< 0.001
Blood glucose score[b]	81.6(26.7)	83.8(25.4)	64.7(30.1)	< 0.001	83.1(25.9)	84.5(24.9)	66.7(30.8)	< 0.001
Blood pressure score[b]	64.4(30.9)	66.4(30.3)	48.3(30.5)	< 0.001	68.5(33.0)	70.4(32.3)	46.2(32.4)	< 0.001

LE8 Life's Essential 8, *PIR* Ratio of family income to poverty, *BMI* Body mass index, *HbA1c* Glycosylated Hemoglobin, Type A1C, *FBG* Fasting blood glucose, *HDL-C* High-density lipoprotein cholesterol, *AST* Aspartate aminotransferase, *ALT* Alanine aminotransferase, *TC* Total cholesterol, *LDL-C* Low-density lipoprotein cholesterol, *CVH* Cardiovascular health, *CVD* Cardiovascular disease, *PA* Physical activity

[a] Categorical variables, presented as numbers (%)

[b] Continuous variables, presented as means (± SD)

Table 2 Gender differences in CVH and 8 component factors scores

	Overall (*n* = 23,307)	Male (*n* = 11,468)	Female (*n* = 11,839)	*P* value
CVH score	66.5(14.4)	65.9(13.7)	67.1(15.1)	< 0.001
Diet score	39.9 (31.3)	37.9(30.8)	41.8(31.8)	< 0.001
PA score	67.3(43.1)	72.4(41.2)	62.4(44.4)	< 0.001
Nicotine exposure score	70.8(39.1)	65.8(40.1)	75.7(37.4)	< 0.001
Sleep score	81.2(25.6)	81.1(25.5)	81.3(25.7)	0.498
BMI score	59.8(33.6)	61.4(31.4)	58.1(35.4)	< 0.001
Blood lipid score	64.1(30.3)	62.4(30.0)	65.7(30.4)	< 0.001
Blood glucose score	82.4(26.3)	81.6(26.7)	83.1(25.9)	< 0.001
Blood pressure score	66.5(32.0)	64.4(30.8)	68.5(33.0)	< 0.001

CVH cardiovascular health, *PA* Physical activity, *BMI* Body mass index

high health behavior and health factor levels were linked to 65% [OR (95% CI): 0.35 (0.26, 0.46)] and 60% [OR (95% CI): 0.40 (0.28, 0.58)] reductions in CVD risk, respectively (Table 3). Trend analysis further confirmed a dose–response relationship, with higher health scores correlating with progressively lower CVD risks in both genders.

This study also explored the relationship between the eight metric scores of LE8 and CVD risk in depth (Table 4). Following comprehensive adjustments for potential confounding variables, it was observed that higher levels of diet, PA, nicotine exposure, sleep, blood lipid, blood glucose and BMI sores continued to be linked with a reduced risk of CVD in both male and female participants ($P < 0.05$).

The diagnostic capability of LE8, health behavior, and health factor score in discriminating CVD

ROC curves were generated for LE8, health behavior, and health factor scores across different genders (Table 5). To compare the AUC between genders, the DeLong test was utilized. The AUC for total LE8 score, health behavior, and health factor scores in discriminating CVD among female participants was notably higher than that of male participants ($P < 0.001$) (Fig. 4).

Discussion

Using data from an extensive public database, this research demonstrated that high levels of LE8 scores were linked to a notably lower risk of CVD. A distinct negative correlation between health behaviors and health factors with CVD was also observed. This correlation persisted consistently even after accounting for various confounding variables. The research also found a dose–response relationship between LE8 scores and CVD risk. Additionally, the discriminating capacity of LE8 scores for CVD was stronger in females, who had higher CVH levels. In summary, these results highlight the critical role of achieving higher LE8 scores in preventing CVD.

The research conducted here is not the first to showcase the potential of the LE8 score in preventing CVD. Recent studies have delved into the relationship between the LE8 score and CVD occurrence based on a single assessment of CVH [23, 30]. These studies have unveiled that increases in the LE8 scores were tied to a notable decrease in CVD risk [31–33]. The results of this study further reinforced the proof that higher scores of the LE8, healthy behaviors and factors, were associated with a reduced risk of CVD. Upon closer examination of individual components, it was discovered that scores on diet, PA, smoking, sleep quality, BMI, non-HDL-C, and FBG were all linked to CVD risk. The heritability of CVD risk seems to be insignificant, implying that behavioral

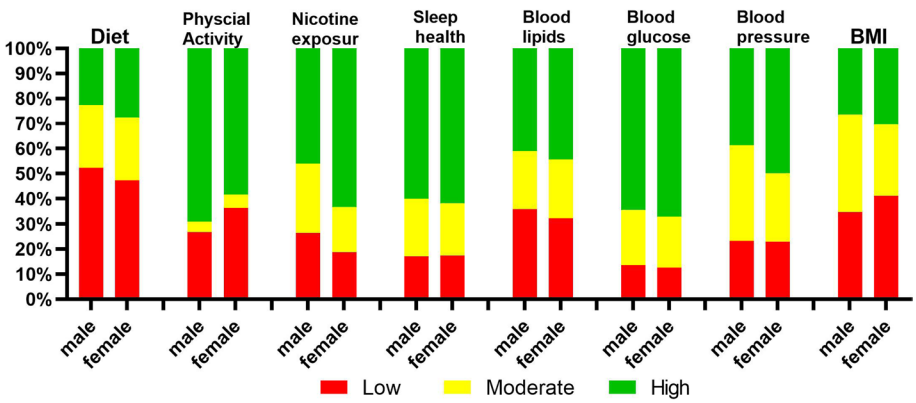

Fig. 2 Differences in the levels of eight health indexes between male and female

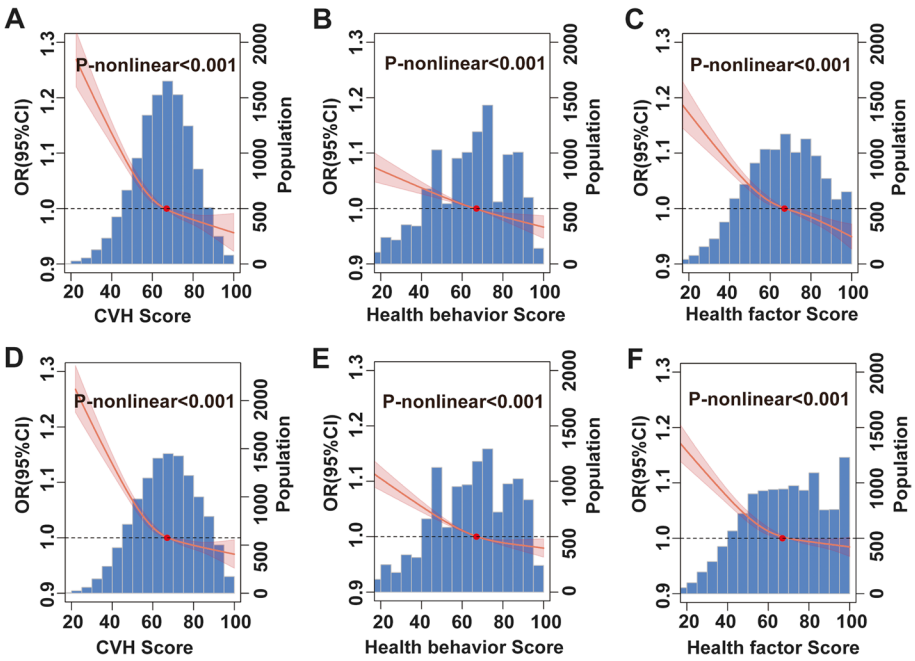

Fig. 3 RCS analysis. **A** The dose–response relationship between LE8 scores and CVD in males. **B** The dose–response relationship between health behavior scores and CVD in males. **C** The dose–response relationship between health factor scores and CVD in males. **D** The dose–response relationship between LE8 scores and CVD in females. **E** The dose–response relationship between health behavior scores and CVD in females. **F** The dose–response relationship between health factor scores and CVD in females

and environmental factors have a substantial impact on determining CVD risk [34]. Due to the fact that health behaviors positively influence health factors and the occurrence of CVD through a cause-and-effect pathway, improvements in health behaviors are likely to lead to higher LE8 scores. The detailed quantification of each metric provided by the LE8 allows individuals to better understand their CVH levels for each component and make timely adjustments to their health behaviors [35]. This preventative approach primarily focuses on averting the initial development of risk factors, rather than preventing the onset of a specific disease, as seen in primary prevention. Nevertheless, the initial LE8 score, which may be affected by lifestyle aspects, may not be effective in foreseeing mid- and long-term health outcomes [36]. It is vital to investigate how changes in LE8 scores over time impact CVD and health outcomes. To summarize, the LE8 score acts as a simple yet effective tool for assessing an individual's CVH and fostering healthy lifestyle habits.

Currently, a large number of studies have highlighted that the LS7 score was a reliable predictor on a variety of health outcomes including CVD, diabetes, stroke, overall deaths and CV deaths [37–40]. The LE8 score was introduced to improve the evaluation of CVH by integrating updated LS7 metrics and including sleep health as the eighth metric [11]. It has been shown that unhealthy sleeping patterns were linked to CV events, and incorporating sleep behaviors into the LE8 score has resulted in greater risk reductions than previously observed [41]. Our study also shows similar opinions. Additionally, the LE8 score redefines the other seven metrics, expanding the scope of each. For example, while the LS7 dietary score encompasses five aspects of diet such as fruit, vegetable, fish, fiber-rich whole grain, and sugary drink consumption, the LE8 dietary score is based on Dietary Approaches to Stop Hypertension (DASH) and Mediterranean-style diets. Non-HDL-C is preferred over total cholesterol for blood lipid metrics [42]. Moreover, the LS7 scores range from 0 to 2 points per metric, while LE8 scores span from 0 to 100 points, which gets more detailed quantification and captures more individual variability [5, 11]. A significant non-linear relationship between LE8 scores and CVD risk has been identified in the RCS analysis, which suggested a complex interaction between LE8 scores and CVD risk. It is essential to emphasize that these non-linear associations may indicate varying effects of LE8 scores at different levels. For instance, while modest increases in LE8 scores may significantly reduce CVD risk, further increases may yield diminishing returns or even plateau effects. Understanding these non-linear relationships is crucial for clinical practice. It suggests that healthcare providers should focus on not only encouraging individuals to

Table 3 The association between CVH, health behavior, health factor scores and CVD

	Model1		Model2		Model3	
	OR **(95%CI)**	***P*** **value**	***OR*** **(95%CI)**	***P*** **value**	***OR*** **(95%CI)**	***P*** **value**
Male						
CVH score						
low	Ref		Ref		Ref	
moderate	0.38(0.31, 0.46)	< 0.001	0.46(0.36, 0.59)	< 0.001	0.43(0.33, 0.56)	< 0.001
high	0.15(0.12, 0.20)	< 0.001	0.26(0.19, 0.35)	< 0.001	0.22(0.16, 0.31)	< 0.001
Behavior score						
low	Ref		Ref		Ref	
moderate	0.58(0.48, 0.70)	< 0.001	0.57(0.45, 0.71)	< 0.001	0.57(0.45, 0.72)	< 0.001
high	0.44(0.36, 0.54)	< 0.001	0.38(0.30, 0.48)	< 0.001	0.39(0.31, 0.50)	< 0.001
Factor score						
low	Ref		Ref		Ref	
moderate	0.53(0.44, 0.64)	< 0.001	0.66(0.53, 0.82)	< 0.001	0.64(0.50, 0.82)	< 0.001
high	0.19(0.15, 0.25)	< 0.001	0.43(0.31, 0.58)	< 0.001	0.35(0.24, 0.49)	< 0.001
Female						
CVH score						
low	Ref		Ref		Ref	
moderate	0.33(0.26, 0.41)	< 0.001	0.44(0.34, 0.57)	< 0.001	0.42(0.31, 0.55)	< 0.001
high	0.08(0.05, 0.12)	< 0.001	0.19(0.13, 0.30)	< 0.001	0.17(0.11, 0.27)	< 0.001
Behavior score						
low	Ref		Ref		Ref	
moderate	0.45(0.37, 0.54)	< 0.001	0.46(0.36, 0.58)	< 0.001	0.46(0.37, 0.58)	< 0.001
high	0.29(0.23, 0.38)	< 0.001	0.33(0.25, 0.44)	< 0.001	0.35(0.26, 0.46)	< 0.001
Factor score						
low	Ref		Ref		Ref	
moderate	0.42(0.34, 0.52)	< 0.001	0.60(0.47, 0.75)	< 0.001	0.58(0.44, 0.76)	< 0.001
high	0.16(0.12, 0.22)	< 0.001	0.49(0.35, 0.68)	< 0.001	0.40(0.28, 0.58)	< 0.001

Model 1 = CVH score/ Behavior score/ Factor score

Model 2 = Model1 + age, race, education, PIR;

Model 3 = Model2 + AST, ALT, TG, LDL-C, and alcohol consumption

CVH Cardiovascular health, *OR* Odds ratios, *CI* Confidence interval, *CVD* Cardiovascular disease, *Ref* Reference

achieve higher LE8 scores, but also on recognizing that the benefits of changes in LE8 score may vary depending on a patient's baseline CVH and lifestyle factors. As such, interventions may need to be tailored to individual patients, taking into account their unique starting points in LE8 metrics. Moreover, this non-linear relationship can guide public health strategies aimed at CVD prevention. Public health campaigns could emphasize the importance of incremental improvements in LE8 scores, especially at levels where significant risk reduction has been observed. This nuanced understanding of the data allows for a more strategic allocation of resources in promoting CVH.

The gender differences in CVD should be noted. This research is the first to explore potential gender disparities in the association between LE8 score and CVD. The findings of this study indicated that females had better CVH than male and the negative correlations between LE8 score and CVD were more pronounced in females. Interestingly, scores on LE8, diet, smoking, non-HDL-C, FBG, and blood pressure were all higher in females compared to males. However, only scores on diet, PA, smoking, and FBG showed greater protective effects for female. CVH metrics were distributed differently between males and females, and their impact was also different. Previous studies have also indicated that smoking, FBG, blood pressure, and non-HDL-C were linked to a higher risk of CVD in females [43]. Numerous clinical statistics suggested that females were less likely to develop CVD than males, but the severity and mortality rates following CVD events were generally higher in females [44]. This notable gender difference warrants a deeper exploration to understand the underlying mechanisms. Firstly, physiological factors may play a significant

Table 4 The association between eight metric scores of LE8 and CVD

		Model1		Model2		Model3	
		***OR* (95%CI)**	***P* value**	***OR* (95%CI)**	***P* value**	***OR* (95%CI)**	***P* value**
Diet score	Male						
	low	Ref		Ref		Ref	
	moderate	1.34(1.11, 1.61)	0.002	1.08(0.87, 1.33)	0.5	1.1(0.89, 1.37)	0.4
	high	1.23(1.03, 1.47)	0.024	0.76(0.61, 0.95)	0.016	0.76(0.60, 0.95)	0.015
	Female						
	low	Ref		Ref		Ref	
	moderate	0.92(0.73, 1.16)	0.5	0.72(0.56, 0.92)	0.01	0.72(0.56, 0.93)	0.012
	high	0.86(0.71, 1.04)	0.11	0.66(0.54, 0.81)	< 0.001	0.66(0.54, 0.81)	< 0.001
PA score	Male						
	low	Ref		Ref		Ref	
	moderate	0.29(0.18, 0.45)	< 0.001	0.39(0.25, 0.64)	< 0.001	0.43(0.26, 0.70)	< 0.001
	high	0.44(0.37, 0.53)	< 0.001	0.70(0.56, 0.86)	0.001	0.73(0.59, 0.90)	0.003
	Female						
	low	Ref		Ref		Ref	
	moderate	0.52(0.33, 0.83)	0.006	0.77(0.47, 1.26)	0.3	0.77(0.48, 1.25)	0.3
	high	0.43(0.35, 0.53)	< 0.001	0.67(0.54, 0.85)	< 0.001	0.7(0.55, 0.88)	0.003
Nicotine exposure score	Male						
	low	Ref		Ref		Ref	
	moderate	1.91(1.57, 2.32)	< 0.001	0.77(0.60, 0.97)	0.028	0.73(0.57, 0.93)	0.01
	high	0.56(0.46, 0.69)	< 0.001	0.49(0.38, 0.62)	< 0.001	0.47(0.37, 0.60)	< 0.001
	Female						
	low	Ref		Ref		Ref	
	moderate	0.99(0.77, 1.27)	> 0.9	0.57(0.43, 0.75)	< 0.001	0.54(0.41, 0.70)	< 0.001
	high	0.53(0.42, 0.66)	< 0.001	0.42(0.32, 0.54)	< 0.001	0.39(0.30, 0.52)	< 0.001
Sleep score	Male						
	low	Ref		Ref		Ref	
	moderate	0.55(0.44, 0.70)	< 0.001	0.63(0.48, 0.83)	< 0.001	0.62(0.48, 0.82)	< 0.001
	high	0.62(0.51, 0.76)	< 0.001	0.55(0.44, 0.69)	< 0.001	0.56(0.45, 0.71)	< 0.001
	Female						
	low	Ref		Ref		Ref	
	moderate	0.59(0.46, 0.76)	< 0.001	0.66(0.50, 0.88)	0.004	0.66(0.49, 0.88)	0.005
	high	0.49(0.40, 0.60)	< 0.001	0.55(0.44, 0.68)	< 0.001	0.56(0.44, 0.70)	< 0.001
Blood lipid score	Male						
	low	Ref		Ref		Ref	
	moderate	0.49(0.35, 0.68)	< 0.001	0.63(0.44, 0.90)	0.011	0.46(0.32, 0.66)	< 0.001
	high	1.87(1.53, 2.28)	< 0.001	1.66(1.30, 2.11)	< 0.001	0.53(0.37, 0.76)	< 0.001
	Female						
	low	Ref		Ref		Ref	
	moderate	0.41(0.31, 0.55)	< 0.001	0.63(0.47, 0.86)	0.003	0.47(0.35, 0.64)	< 0.001
	high	0.9(0.73, 1.09)	0.3	1.4(1.13, 1.74)	0.002	0.58(0.42, 0.80)	0.001
Blood glucose score	Male						
	low	Ref		Ref		Ref	
	moderate	0.5(0.39, 0.63)	< 0.001	0.56(0.42, 0.76)	< 0.001	0.93(0.67, 1.29)	0.7
	high	0.15(0.12, 0.18)	< 0.001	0.34(0.26, 0.43)	< 0.001	0.59(0.42, 0.83)	0.003
	Female						
	low	Ref		Ref		Ref	
	moderate	0.38(0.32, 0.47)	< 0.001	0.42(0.34, 0.52)	< 0.001	0.49(0.39, 0.63)	< 0.001
	high	0.16(0.12, 0.20)	< 0.001	0.33(0.25, 0.44)	< 0.001	0.4(0.29, 0.55)	< 0.001

Table 4 (continued)

		Model1		Model2		Model3	
		OR (95%CI)	*P* value	*OR* (95%CI)	*P* value	*OR* (95%CI)	*P* value
Blood pressure score	Male						
	low	Ref		Ref		Ref	
	moderate	0.26(0.21, 0.33)	< 0.001	0.54(0.42, 0.69)	< 0.001	0.59(0.46, 0.75)	< 0.001
	high	0.37(0.30, 0.45)	< 0.001	0.94(0.74, 1.20)	0.6	0.91(0.71, 1.17)	0.5
	Female						
	low	Ref		Ref		Ref	
	moderate	0.34(0.27, 0.44)	< 0.001	0.66(0.51, 0.85)	0.002	0.7(0.54, 0.90)	0.007
	high	0.23(0.18, 0.28)	< 0.001	0.76(0.59, 0.98)	0.037	0.79(0.60, 1.02)	0.072
BMI score	Male						
	low	Ref		Ref		Ref	
	moderate	0.77(0.65, 0.92)	0.004	0.63(0.52, 0.76)	< 0.001	0.73(0.59, 0.90)	0.004
	high	0.57(0.47, 0.68)	< 0.001	0.52(0.42, 0.65)	< 0.001	0.59(0.48, 0.73)	< 0.001
	Female						
	low	Ref		Ref		Ref	
	moderate	0.77(0.62, 0.95)	0.018	0.71(0.56, 0.90)	0.004	0.81(0.64, 1.02)	0.072
	high	0.54(0.41, 0.72)	< 0.001	0.65(0.49, 0.85)	0.002	0.71(0.54, 0.92)	0.011

Model 1 = CVH score/ Behavior score/ Factor score

Model 2 = Model1 + age, race, education, PIR;

Model 3 = Model2 + AST, ALT, TG, LDL-C, and alcohol consumption

CVH Cardiovascular health, *OR* Odds ratios, *CI* Confidence interval, *CVD* Cardiovascular disease, *Ref* Reference

Table 5 AUCs of CVH, health behavior, health factor scores for discriminating CVD by gender

Variables	AUC (95%CI)	Cut-off value	Youden's index	Sensitivity (%)	Specificity (%)
Male					
CVD					
CVH score	0.653(0.638,0.669)	65.9	0.2	68.4	54.2
Health behavior scores	0.572(0.556,0.589)	70.6	0.1	68.6	42.5
Health factor scores	0.656(0.641,0.671)	74.4	0.2	82.6	39.5
Female					
CVD					
CVH score	0.719(0.703,0.735)	66.6	0.3	77.7	55.1
Health behavior scores	0.632(0.613,0.651)	59.4	0.2	54.9	65.0
Health factor scores	0.701(0.684,0.718)	60.6	0.3	63.9	66.8

CVH Cardiovascular health, *OR* Odds ratios, *CI* Confidence interval, *CVD* Cardiovascular disease, *Ref* Reference

role in this phenomenon. Estrogen is known to have protective effects on CVD, as it enhances vascular function and promotes lipid metabolism, thereby reducing CVD risk. Research indicates that females possess a greater innate cardiovascular protective mechanism, which may partially explain their higher LE8 scores and the stronger negative correlation with CVD risk [45]. Secondly, behavioral and lifestyle factors are also critical contributors to these observed gender differences. Females generally tend to engage in healthier lifestyle choices, including a higher intake of fruits and vegetables, reduced consumption of high-fat foods, and lower smoking rates. These healthful behaviors significantly enhance their LE8 scores, contributing to a lower risk of CVD [46]. Additionally, psychosocial factors should not be overlooked. Social and cultural influences can differently impact health behaviors between genders. Females are often more likely to have access to support and resources that

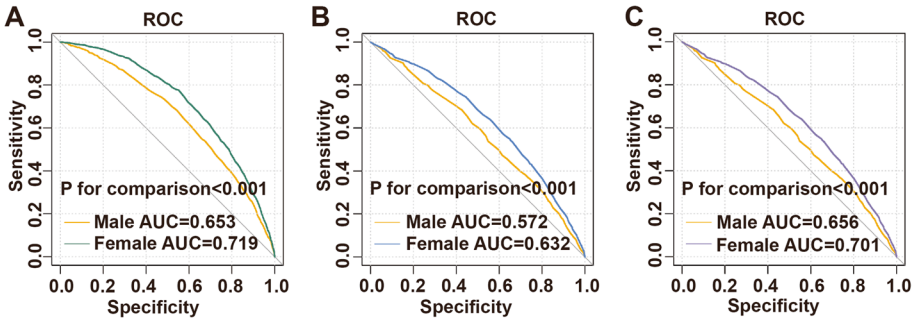

Fig. 4 Receiver operating characteristic (ROC) curve. **A** The diagnostic capability of LE8 scores in discriminating CVD across different genders. **B** The diagnostic capability of health behavior scores in discriminating CVD across different genders. **C** The diagnostic capability of health factor scores in discriminating CVD across different genders

encourage health maintenance, including participation in health education programs and the availability of emotional support networks. These elements may play a crucial role in fostering behaviors that improve their health status [47]. In summary, addressing gender differences is essential for the development of targeted interventions in CVH. Such an approach will help to form personalized public health strategies that aim to enhance the overall health of both males and females, thereby reducing the incidence of CVD.

This cohort study aimed to investigate the gender-specific relationship between total and specific CVH metrics measured by LE8 and CVD risk on a national scale. The research also examined gender disparities in CVH by LE8 score between males and females. The study revealed a dose–response relationship between CVH scores and CVD risk, indicating that higher CVH scores were associated with reduced CVD risk. Notably, the analysis meticulously adjusted for important confounding variables, including education level, race, and PIR. However, the study has some limitations that should be noted. The cross-sectional design limits the ability to establish causal relationships. Moreover, CVD diagnoses, diet, PA, smoking, and sleep are self-reported, and these data are prone to recall bias and social desirability bias, which may result in underreporting or overreporting of behaviors. We should explicitly acknowledge this limitation, and we agree that future studies incorporating clinical validation of self-reported data would further strengthen the reliability of such data. Additionally, the observational nature of the study makes it challenging to completely account for all potential confounders, both measured and unmeasured. The study's focus on baseline LE8 score may overlook the impact of changes in LE8 scores over time on CVD and health outcomes. Furthermore, the findings, which are based on American adults, may not be generalizable to other populations like those in China, requiring cautious interpretation. Lastly, the lack of data on the use of medications that affect CVH, such as lipid-lowering, antihypertensive, and antidiabetic drugs, is a significant limitation.

Conclusion

This study found that higher levels of CVH were significantly associated with a reduced risk of CVD, with this association being particularly pronounced among females. These findings underscored the importance of enhancing CVH, especially considering gender-specific factors. Additionally, a deeper analysis of the socioeconomic factors and lifestyle differences affecting CVH will provide valuable insights for developing more effective public health policies and preventive strategies, ultimately contributing to efforts to reduce the incidence of CVD.

Abbreviations

CVD	Cardiovascular disease
LE8	Life's Essential 8
CVH	Cardiovascular health
CHD	Coronary heart disease
AHA	American Heart Association
LS7	Life's Simple 7
PA	Physical activity
BMI	Body mass index
NHANES	National Health and Nutrition Examination Survey
FBG	Fasting blood glucose
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
RCS	Restricted cubic spline
OR	Odds ratio
CI	Confidence interval
HbA1c	Glycosylated hemoglobin, type A1C
AST	Aspartate aminotransferase
ALT	Alanine aminotransferase
TC	Total cholesterol
LDL-C	Low-density lipoprotein cholesterol
ROC	Receiver operating characteristic
AUC	Area under the curve
DASH	Dietary Approaches to Stop Hypertension (DASH)
HDL-C	High-density lipoprotein cholesterol

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12986-025-00929-w.

Supplementary Material 1.

Authors' contributions

YZ. was responsible for data collection and organization, XC. was responsible for statistical analysis and visualization. Both TY., XC. and YZ. co-authored the first draft of the manuscript. TY., YJ., and JS. proposed the methodology, supervised, reviewed, and edited the article. All authors read and approved the final manuscript.

Funding

No fundings.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

All authors have reviewed and approved the final version of the manuscript.

Competing interests

The authors declare no competing interests.

Received: 20 August 2024 Accepted: 22 April 2025
Published online: 07 May 2025

References

1. Virani SS, Alonso A, Aparicio HJ, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, Chamberlain AM, Cheng S, Delling FN. Heart disease and stroke statistics-2021 update: a report from the American Heart Association. Circulation. 2021;143:e254-743.
2. Kerr AJ, Broad J, Wells S, Riddell T, Jackson R. Should the first priority in cardiovascular risk management be those with prior cardiovascular disease? Heart. 2009;95:125–9.
3. Hackam DG, Spence JD. Combining multiple approaches for the secondary prevention of vascular events after stroke: a quantitative modeling study. Stroke. 2007;38:1881–5.
4. Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. PLoS Med. 2006;3:e442.
5. Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, Greenlund K, Daniels S, Nichol G, Tomaselli GF. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. Circulation. 2010;121:586–613.
6. Virani SS, Alonso A, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, Chamberlain AM, Chang AR, Cheng S, Delling FN. Heart disease and stroke statistics-2020 update: a report from the American Heart Association. Circulation. 2020;141:e139-596.
7. Ogunmoroti O, Allen NB, Cushman M, Michos ED, Rundek T, Rana JS, Blankstein R, Blumenthal RS, Blaha MJ, Veledar E. Association between Life's Simple 7 and noncardiovascular disease: the multi-ethnic study of atherosclerosis. J Am Heart Assoc. 2016;5:e003954.
8. Perak AM, Ning H, Khan SS, Bundy JD, Allen NB, Lewis CE, Jacobs DJ, Van Horn LV, Lloyd-Jones DM. Associations of late adolescent or young adult cardiovascular health with premature cardiovascular disease and mortality. J Am Coll Cardiol. 2020;76:2695–707.
9. Han L, You D, Ma W, Astell-Burt T, Feng X, Duan S, Qi L. 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:e1913131.
10. Fretts AM, Howard BV, McKnight B, Duncan GE, Beresford SA, Mete M, Zhang Y, Siscovick DS. Life's Simple 7 and incidence of diabetes among American Indians: the strong heart family study. Diabetes Care. 2014;37:2240–5.
11. Lloyd-Jones DM, Allen NB, Anderson C, Black T, Brewer LC, Foraker RE, Grandner MA, Lavretsky H, Perak AM, Sharma G. 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:e18-43.
12. Herraiz-Adillo A, Higueras-Fresnillo S, Ahlqvist VH, Berglind D, Syrjala MB, Daka B, Lenander C, Sundstrom J, Ortega FB, Ostgren CJ. Life's Essential 8 and Life's Simple 7 in relation to coronary atherosclerosis: results from the population-based SCAPIS project. Mayo Clin Proc. 2024;99:69–80.
13. Yuan Y, Tian P, Li L, Qu Q. Comparison of the associations between life's essential 8 and life's simple 7 with stroke: NHANES 1999–2018. J Stroke Cerebrovasc Dis. 2025;34:108238.
14. Li L, Dai F. Comparison of the associations between Life's Essential 8 and Life's Simple 7 with depression, as well as the mediating role of oxidative stress factors and inflammation: NHANES 2005–2018. J Affect Disord. 2024;351:31–9.
15. Zeng G, Lin Y, Lin J, He Y, Wei J. Association of cardiovascular health using Life's Essential 8 with depression: Findings from NHANES 2007–2018. Gen Hosp Psychiatry. 2024;87:60–7.
16. Wang L, Yi J, Guo X, Ren X. Associations between life's essential 8 and non-alcoholic fatty liver disease among US adults. J Transl Med. 2022;20:616.
17. Chen X, Sun J, Zeng C, Jin F, Ma S, Song J, Chen Z. Association between life's essential 8 and periodontitis: a population-based study. BMC Oral Health. 2024;24:19.
18. Wang Y, Meng Q, Zhang X, Baima K, Chen L, Dai Y, Yang T, Feng Y, Mi F, Zhou J. Life's Essential 8, Life's Simple 7 and the odds of hyperuricaemia: results from the China Multi-Ethnic Cohort Study. Rheumatol Adv Pract. 2024;8:e9.
19. Ueno K, Kaneko H, Okada A, Suzuki Y, Matsuoka S, Fujiu K, Michihata N, Jo T, Takeda N, Morita H. Association of four health behaviors in Life's Essential 8 with the incidence of hypertension and diabetes mellitus. Prev Med. 2023;175:107685.
20. Gou R, Xiong S, Liang X, Wu H, Qin S, Li B, Luo C, Chen J. Relationship between Life's Essential 8 and metabolic syndrome among older Americans (NHANES, 2007–2010): navigating biological aging and inflammation. Front Med (Lausanne). 2024;11:1380464.
21. Hernandez-Martinez A, Duarte-Junior MA, Sotos-Prieto M, Ortola R, Banegas JR, Rodriguez-Artalejo F, Soriano-Maldonado A, Martinez-Gomez D. Cardiovascular health in Spain based on the Life's Essential 8 and its association with all-cause and cardiovascular mortality: the ENRICA cohort. Rev Esp Cardiol (Engl Ed). 2024;77:372–80.
22. He L, Zhang M, Zhao Y, Li W, Zhang Y. Association between new Life's Essential 8 and the risk of all-cause and cardiovascular mortality in patients with hypertension: a cohort study. BMC Public Health. 2024;24:1730.
23. Xing A, Tian X, Wang Y, Chen S, Xu Q, Xia X, Zhang Y, Zhang X, Wang A, Wu S. "Life's Essential 8" cardiovascular health with premature cardiovascular disease and all-cause mortality in young adults: the Kailuan prospective cohort study. Eur J Prev Cardiol. 2023;30(7):593–600.
24. Wu H, Wei J, Wang S, Chen W, Chen L, Zhang J, Wang N, Tan X. Life's Essential 8 and risks of cardiovascular morbidity and mortality among individuals with type 2 diabetes: A cohort study. Diabetes Metab Syndr. 2024;18:103066.
25. Qiu Z, Geng T, Wan Z, Lu Q, Guo J, Liu L, Pan A, Liu G. Serum selenium concentrations and risk of all-cause and heart disease mortality among individuals with type 2 diabetes. Am J Clin Nutr. 2022;115:53–60.
26. Alavi TG, Mohammadifard N, Rafiee H, Nouri F, Maghami MA, Najafian J, Sadeghi M, Boshtam M, Roohafza H, Haghighatdoost F. Association of the triglyceride glucose index with all-cause and cardiovascular mortality in a general population of Iranian adults. Cardiovasc Diabetol. 2024;23:66.
27. Shen Y, Wu Y, Luo P, Fu M, Zhu K, Wang J. Association between weight-adjusted-waist index and depression in US adults: a cross-sectional study. J Affect Disord. 2024;355:299–307.

28. Muntner P, Krousel-Wood M, Hyre AD, Stanley E, Cushman WC, Cutler JA, Piller LB, Goforth GA, Whelton PK. Antihypertensive prescriptions for newly treated patients before and after the main antihypertensive and lipid-lowering treatment to prevent heart attack trial results and seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure guidelines. Hypertension. 2009;53:617–23.
29. Huang D, Zhong S, Yan H, Lai S, Lam M, Jia Y. Association between serum zinc levels and suicidal ideation in US adults: A population-based cross-sectional study. J Affect Disord. 2023;329:359–68.
30. Huang L, Wang A, Wu Z, Chen S, Zheng Y, Wu S, Gao X. Life's essential 8 and risk of all-cause mortality in individuals with cardiovascular diseases: A prospective community-based study. Clin Cardiol. 2024;47:e24119.
31. Xia X, Chen S, Tian X, Xu Q, Zhang Y, Zhang X, Wang P, Wu S, Lin L, Wang A. Association of cardiovascular health assessed by the new Life's Essential 8 Metrics with years lived without cardiovascular disease. J Am Heart Assoc. 2023;12(11):e029241.
32. Ning H, Perak AM, Siddique J, Wilkins JT, Lloyd-Jones DM, Allen NB. Association between Life's Essential 8 cardiovascular health metrics with cardiovascular events in the cardiovascular disease lifetime risk pooling project. Circ Cardiovasc Qual Outcomes. 2024;17(5):68.
33. Sun J, Li Y, Zhao M, Yu X, Zhang C, Magnussen CG, Xi B. Association of the American Heart Association's new "Life's Essential 8" with all-cause and cardiovascular disease-specific mortality: prospective cohort study. BMC Med. 2023;21(1):116.
34. Tun B, Ehrbar R, Short M, Cheng S, Vasan RS, Xanthakis V. Association of exhaled carbon monoxide with ideal cardiovascular health, circulating biomarkers, and incidence of heart failure in the Framingham offspring study. J Am Heart Assoc. 2020;9(21):e016762.
35. Kurl S, Antero LJ. Life's Essential 8 and ideal cardiovascular health. Int J Cardiol. 2024;409:132143.
36. Li W, Xing A, Lamballais S, Xu W, Chen S, Zhou S, Wu S, Chen Z. Changes in Life's Essential 8 and risk of cardiovascular disease in Chinese people. Eur J Public Health. 2024;34:766–73.
37. Wu J, Xiong Y, Xia X, Orsini N, Qiu C, Kivipelto M, Rizzuto D, Wang R. 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.
38. Elgazzar R, Nolan TS, Joseph JJ, Aboagye-Mensah EB, Azap RA, Gray DN. Community-engaged and community-based participatory research to promote American Heart Association Life's Simple 7 among African American adults: a systematic review. PLoS ONE. 2020;15:e238374.
39. Wang L, Song L, Li D, Zhou Z, Chen S, Yang Y, Hu Y, Wang Y, Wu S, Tian Y. Ideal cardiovascular health metric and its change with lifetime risk of cardiovascular diseases: a prospective cohort study. J Am Heart Assoc. 2021;10:e22502.
40. Yang X, Wang A, Liu X, An S, Chen S, Wang Y, Wang Y, Wu S. Positive changes in ideal CVH metrics reduce the incidence of stroke. Sci Rep. 2016;6:19673.
41. Cappuccio FP, Cooper D, D'Elia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. Eur Heart J. 2011;32:1484–92.
42. Vairaperumal T, Tsai ZY, Liu PY. Emerging predictors by Non-HDL-C/HDL-C ratio and novel biomarkers for coronary slow flow phenomenon. Acta Cardiol Sin. 2024;40:367–72.
43. Walli-Attaei M, Rosengren A, Rangarajan S, Breet Y, Abdul-Razak S, Sharief WA, Alhabib KF, Avezum A, Chifamba J, Diaz R. Metabolic, behavioural, and psychosocial risk factors and cardiovascular disease in women compared with men in 21 high-income, middle-income, and low-income countries: an analysis of the PURE study. Lancet. 2022;400:811–21.
44. Xia S, Du X, Guo L, Du J, Arnott C, Lam C, Huffman MD, Arima H, Yuan Y, Zheng Y. Sex differences in primary and secondary prevention of cardiovascular disease in China. Circulation. 2020;141:530–9.
45. Mosca L, Barrett-Connor E, Wenger NK. Sex/gender differences in cardiovascular disease prevention: what a difference a decade makes. Circulation. 2011;124:2145–54.
46. Khamis RY, Ammari T, Mikhail GW. Gender differences in coronary heart disease. Heart. 2016;102:1142–9.
47. Rosano GM, Vitale C, Tulli A. Managing cardiovascular risk in menopausal women. Climacteric. 2006;9(Suppl 1):19–27.

Publisher's Note