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Original Research

Sex differences in Life's Essential Eight and its Association with mortality among US adults without known cardiovascular disease

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ABSTRACT

Background: The American Heart Association's (AHA) Life's Essential 8 (LE8) score is a helpful tool to quantify cardiovascular health (CVH) metrics. We sought to assess sex differences in relation to LE8 and its components along with association with mortality.

Methods: The National Health and Nutrition Examination Survey (NHANES) between 2009 and 2018 was utilized to evaluate the prevalence of health metrics included in LE8 among adult participants > age 18, stratified by sex. We categorized overall CVH, health factors, and health behaviors into 3 levels (low: <50, moderate: 50 -79, high: ≥80) following the AHA's algorithm. Health metrics were further subdivided into health behaviors (diet, physical activity, nicotine exposure, and sleep) and health factors (body mass index, non–high density lipoprotein cholesterol, blood glucose, and blood pressure). LE8 scores were also evaluated based on age, race/ethnicity, and socioeconomic status. Cox proportional hazard models were used to evaluate the association between the levels of CVH and risk of all-cause and cardiovascular mortality, with adjustment for age group and race.

Results: Among 22,761 participants, 52 % were female. Overall CVH score was similar in both females and males (65.8 vs. 65.9). Females had higher health factors score (64.3 vs. 63.1, $p < 0.001$) and lower health behaviors score (67.2 vs 68.6, $p < 0.001$). Amongst individual metrics, blood pressure score was higher in females (73.2 vs. 67.7, $p < 0.001$) while males had higher physical activity score (70.6 vs. 54.9, $p < 0.001$). For individuals under 65 years of age, overall CVH and health factors scores were higher in females while in those age 65 or older, males had higher scores. The most prominent sex differences were noted in non-Hispanic Black females who had significantly lower CVH scores than Black males (62.6 vs. 74.7, respectively, $p < 0.001$. High LE8 scores vs. low LE8 scores demonstrated lower all-cause (HR 0.37 vs 0.35) and CV mortality (HR 0.35 vs. 0.36) in both males and females, respectively (p-interaction 0.21 and 0.28). High health behaviors scores also demonstrated a significant association with lower all-cause (0.34 vs. 0.24) and CV mortality (HR 0.47 vs. 0.26) in both males and females, respectively (p-interaction 0.20 and 0.11).

Conclusions: We demonstrate important sex differences in CVH metrics along with notable variations based on age and race/ethnicity. Furthermore, we highlight that CVH metrics including health factors and health behaviors are associated with mortality in both females and males. These findings underscore the importance of designing and implementing effective strategies for both sexes, aimed at targeting these specific factors.

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1. Introduction

Deaths attributable to cardiovascular disease (CVD) have increased over the last decade in the United States [1], highlighting the importance of primordial prevention and the need for implementation of upstream interventions targeting structural and social determinants of unhealthy behaviors and risk factors as well as interventions at the individual-level. The American Heart Association (AHA) has, therefore, expanded its focus to strategies promoting the health of the overall population and created an updated construct of cardiovascular health (CVH) from Life's Simple 7 to the new Life's Essential 8 (LE8) [2,3]. The components of LE8 include health behaviors (diet, physical activity, nicotine exposure, and sleep health) and health factors (body mass index, blood lipids, blood glucose, and blood pressure), with each metric having a scoring algorithm that allows for generation of a composite CVH score ranging from 0 to 100 points [3]. Higher composite CVH score has been shown to be inversely associated with all-cause and cardiovascular (CV) mortality [4,5]. Several past studies have demonstrated notable sex differences in the prevalence and impact of cardiovascular risk factors [1,6,7] including hypertension [8], obesity [9], and diabetes. However, sex differences related to LE8 have not been thoroughly investigated. In analyses by Ma et al. [10] and Sun et al. [4], there was no significant interaction between sex and LE8 on the risk of all-cause, CVD, and non-CVD mortality; however, further investigation into subgroups of health behaviors and health factors were not performed and are important to ascertain to guide future interventions to mitigate risk.

Significant sex disparities exist in the management of cardiovascular risk factors, with women being less likely than men to receive routine risk factor assessment [11], and, consequently, it is important to characterize sex differences in metrics of CVH to better implement solutions and optimize care. Furthermore, significant racial disparities are also present in CVD prevention; women of minority racial or ethnic backgrounds, particularly Black women, are at disproportionately higher risk of poor risk factor control [12]. We therefore utilized data from the National Health and Nutrition Examination Survey (NHANES) to evaluate sex differences in LE8 metrics overall and by age, race and ethnicity, and socioeconomic status. We also assessed sex differences in the association of CVH score and its subgroups with all-cause and CV mortality.

2. Methods

2.1. Study sample

The NHANES is a series of nationally representative, cross-sectional surveys designed to monitor the health of the U.S. population. Participants are selected from the U.S. noninstitutionalized, civilian population, with the data being publicly available [13].

This cross-sectional analysis used 12 years of data from the 2009 to 2018 NHANES cycles and data from the NHANES Linked Mortality File, which links participants of NHANES with death records in the National Death Index dataset through December 31, 2019. The total combined sample of NHANES 2009 through 2018 comprised 30,352 participants. We excluded individuals with a self-reported history of coronary heart disease, angina, heart attack, or stroke, and with incomplete information for all 8 CVH components.

2.2. Demographic and social characteristics

Demographic characteristics (age, self-reported sex, race and ethnicity, and annual household income) were queried during the home interview. Participants were stratified by sex. Household poverty as a measure of socioeconomic status (SES) was calculated as the ratio of monthly family income to poverty levels and categorized as low (≤1.30), low-middle (1.31–1.85), middle (1.86– 3.50), and high income (>3.50) [14].

2.3. Quantification of CVH

The method for calculating LE8 scores using NHANES data has been previously described [15] (Table S1). We grouped the 4 health behaviors (diet, physical activity, nicotine exposure, and sleep) and 4 health factors (body mass index, non–high density lipoprotein cholesterol, blood glucose, and blood pressure) metrics. The overall CVH was calculated for everyone by averaging the scores for each of the 8 metrics; similarly,

Table 1
Characteristics of US Adults (Not Institutionalized) Without Cardiovascular Disease by Sex.

	Male	Female	P value
Number of participants	10,846	11,915	
% of weighted adults (Number, millions)	47.7 % (445)	52.3 % (488)	
Age, y, mean (SE)*	44.5 (0.001)	46.4 (0.001)	<0.001
Age strata, y*			
18–39	41.6 %	38.4 %	<0.001
40–64	45.6 %	45.0 %	
65–79	10.8 %	13.1 %	
80 and over	2.0 %	3.5 %	
Self-reported race and ethnicity*			
Mexican American	9.9 %	8.5 %	<0.001
Other Hispanic	6.1 %	6.2 %	
Non- Hispanic White	65.5 %	65.5 %	
Non- Hispanic Black	10.0 %	11.3 %	
Other race	8.4 %	8.4 %	
Ratio of family income to poverty levels*			
<1.31	20.2 %	22.9 %	<0.001
1.31–1.85	10.0 %	10.6 %	
1.86–3.5	24.0 %	24.5 %	
>3.5	45.8 %	43.5 %	
AHA Life's Essential 8 scores*			
Low LE8 Score (<50)	11.9 %	13.9 %	<0.001
Moderate LE8 Score (50–79)	72.6 %	67.9 %	
High LE8 Score (80 and above)	15.5 %	18.2 %	
Low Health Behaviors score (<50)	15.2 %	15.8 %	<0.001
Moderate Health Behaviors Score (50–79)	52.3 %	56.7 %	
High Health Behaviors Score (80 and above)	32.5 %	27.5 %	
Low Health Factors score (<50)	23.4 %	23.0 %	<0.001
Moderate Health Factors Score (50–79)	57.4 %	52.1 %	
High Health Factors Behaviors Score (80 and above)	19.2 %	24.9 %	
AHA Life's Essential 8 scores (100 possible points), mean (SE)*			
Total LE8 Score	65.9 (0.001)	65.8 (0.001)	<0.001
Health Behaviors score	68.6 (0.001)	67.2 (0.001)	<0.001
Tobacco or nicotine exposure score	69.8 (0.001)	77.7 (0.002)	<0.001
Diet Score	50.7 (0.001)	51.9 (0.001)	<0.001
Physical activity score	70.6 (0.002)	54.9 (0.002)	<0.001
Sleep health score	83.4 (0.001)	84.2 (0.001)	<0.001
Health factors score	63.1 (0.001)	64.3 (0.001)	<0.001
BMI score	60.8 (0.002)	60.4 (0.002)	<0.001
Blood lipids (non-HDL cholesterol) score	39.9 (0.001)	39.0 (0.001)	<0.001
Blood glucose score	84.2 (0.001)	84.7 (0.002)	<0.001
Blood pressure score	67.7 (0.001)	73.2 (0.001)	<0.001

Legend: LE8=AHA Life's Essential 8 scores.
LE8 Score: 100 possible points, with higher score reflecting greater positive health risk factors and health behaviors.
* weighted.

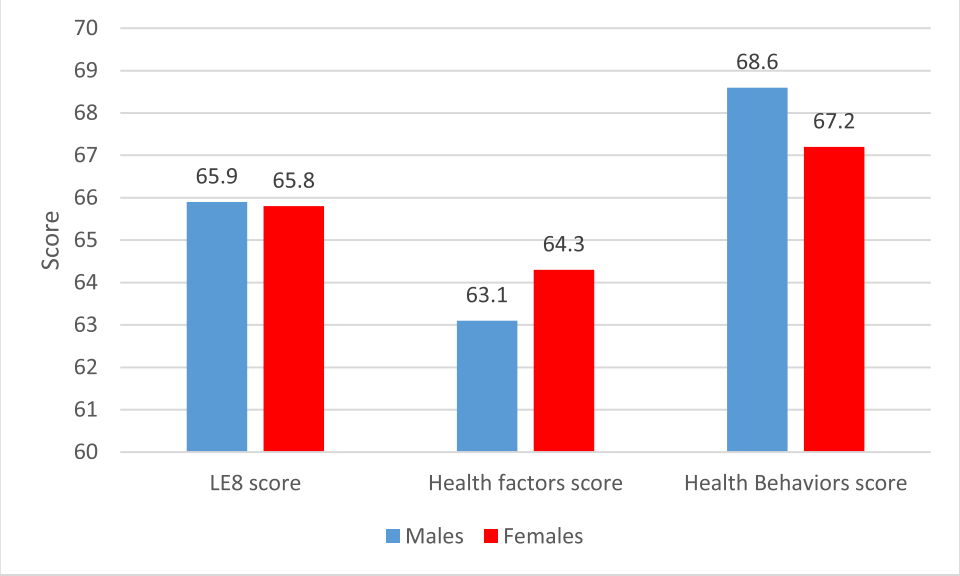


Fig. 1. Cardiovascular health scores, by sex.

we calculated the health behaviors and health factors scores using the relevant metrics to provide scores ranging from 0 to 100. We categorized overall CVH, health factors, and health behaviors into 3 levels (low: <50, moderate: 50 −79, high: ≥80) following the AHA's algorithm.

2.4. Assessment of mortality status

The mortality of each participant in NHANES was determined through a probabilistic record match to death certificate records from the National Death Index. Vital status was ascertained from additional sources, including information obtained from linkages with the U.S. Social Security Administration and/or by active follow-up of survey participants. Follow-up time for each outcome was counted from the baseline examination date until the registered date of death or the end of the study (December 31, 2019), whichever occurred first. The primary outcomes of interest in this study were mortality from all causes and CV mortality (codes I00-I09, I11, I13, and I20-I51) in compliance with the codes of ICD-10 (International Statistical Classification of Diseases, 10th revision). As follow up time was until any event of mortality, for cancer mortality, individuals were censored if they died of CVD and vice versa.

2.5. Statistical analysis

NHANES over-samples persons 60 and older, Blacks, and Hispanics. To ensure nationally representative estimates, sampling weights were considered in all analyses to account for oversampling of subgroups and complex sample design. Continuous variables are presented as a mean and standard error, and categorical data are presented as percentages and frequencies. Categorical variables were compared using the Pearson chi-square test, whereas continuous variables were compared using the Student's t-test or the Mann–Whitney U test. Cox proportional hazard models were used to evaluate the association between the levels of overall CVH, health factors, and health behaviors and risk of mortality, among males and females, and follow-up time was used as the underlying time metric. Follow-up time was calculated from date of interview or examination until date of death or the end of the study (December 31, 2019). We further tested the interaction between health metrics and sex on mortality. Models were adjusted for age group, race/ ethnicity, and were calculated according to sex. We ran an alternative model to estimate the association between 10-point increase in LE8 metrics and mortality. Proportionality (pH) assumptions for the Cox models were assessed based on Schoenfeld residual testing. In this method, correlation of time with the residuals between the observed and expected values of covariates in each failure time-point is examined. Significant correlation of residuals with time can be interpreted as a violation of the pH assumption; in our analysis, substantial deviations from proportionality were not observed. All analyses were performed using STATA SE version 17.0 (StataCorp) and SPSS version 26 (IBM).

3. Results

3.1. Sample characteristics

The analysis sample for the current report, after applying exclusion criteria, consisted of 22,761 participants (of which 52 % were females), representing 935.3 million US adults. A comparison of the characteristics and demographics of males and females are presented in Table 1. Female participants were older (mean age 46.4 vs 44.5, $p < 0.001$), less likely to be Mexican American (8.5% vs 9.9 %, $p < 0.001$), more likely to be non-Hispanic black (11.3% vs 10.0 %, $p < 0.001$), and to have lower family income.

3.2. CVH according to sex

Fig. 1 presents the mean CVH, health factors, and health behaviors scores in males and females. While the overall CVH score was similar in both sexes (65.9 in males, 65.8 in females), females had higher health factors score (64.3 vs 63.1 in males, $p < 0.001$) and lower health behaviors score (67.2 vs 68.6 in males, $p < 0.001$). Specific components of the CVH score are presented in Table 1. Of note, tobacco exposure scores and blood pressure scores were higher in females (77.7 vs 69.8 and 73.2 vs 67.7, respectively, both $p < 0.001$) and physical activity scores were higher for males (70.6 vs 54.9, $p < 0.001$).

Fig. 2 presents CVH stratified by age groups. Among both males and females, there was a decreasing trend in overall CVH and health factors score in the older age groups. The highest health behaviors score was observed in the 65–79 years old group in both sexes. Among individuals under 65 years old, overall CVH and health factors scores were higher in females, while in those older than age 65 years, males had higher overall CVH and health factors scores. Health behaviors scores were higher in males across all age groups.

Fig. 3 presents CVH scores across different ethnic and racial groups. While health behaviors scores were higher in males in all racial and ethnic groups, the most prominent difference was noted in non-Hispanic

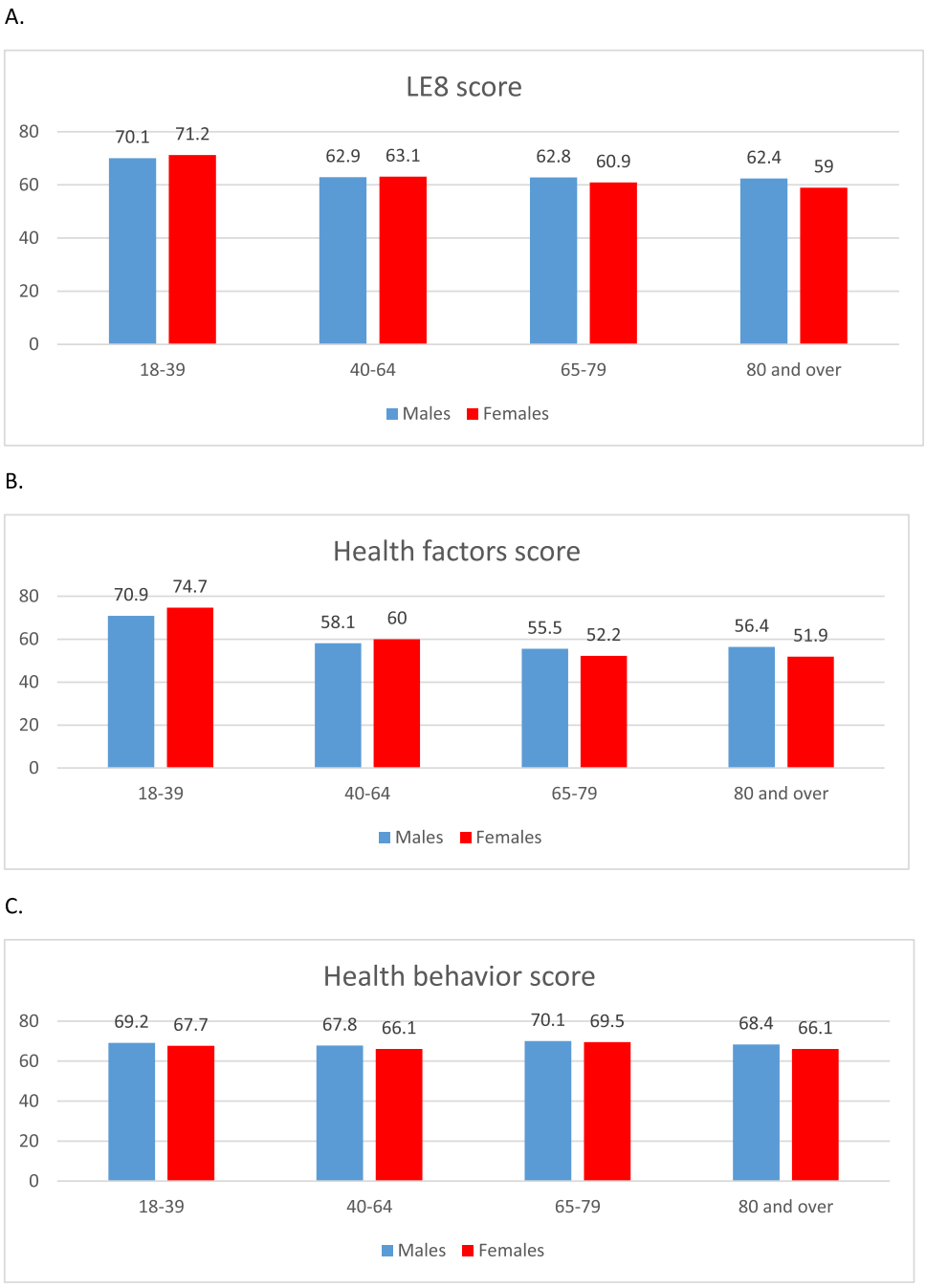


Fig. 2. Cardiovascular health scores, by sex and age groups. A. overall score; B. health factors score; C. health behavior score.

Black individuals (74.7 in males vs 62.6 in females, $p < 0.001$). Health factors scores were higher in females in most groups, but higher in males in non-Hispanic Black individuals (61.0 vs 58.4 non-Hispanic Black females, $p < 0.001$).

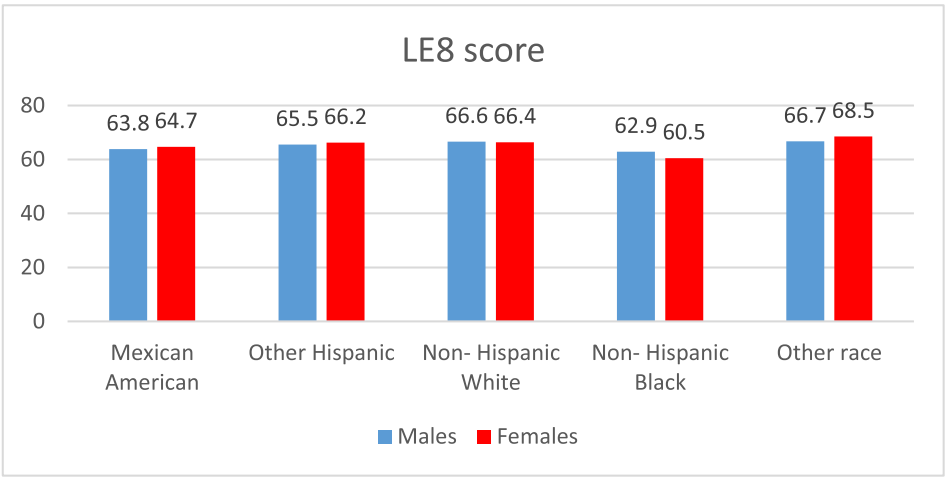
Fig. 4 presents CVH scores across ratio of family income to poverty levels. Generally, overall LE8 scores were higher in individuals with higher family income in both males and females. In the lower income groups, the overall LE8, health factors, and health behaviors scores were higher in males compared with females. In the highest income group (poverty index>3.5) the overall CVH score and health factors score was higher in females compared with males (69.0 vs 67.4, 66.0 vs 62.3 respectively, $p < 0.001$). Health behaviors scores were higher in males across all poverty index groups, compared with females.

3.3. CVH scores as predictors of mortality

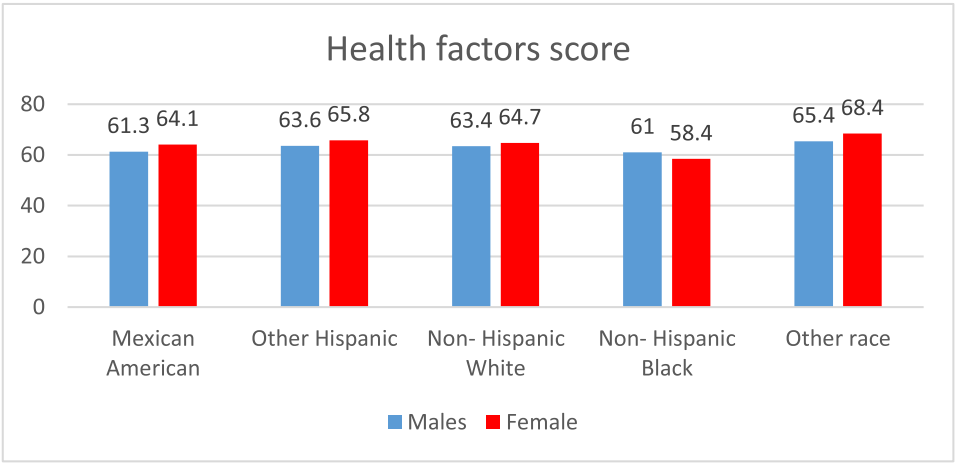
In analyses adjusted for age group, race/ethnicity, and poverty index, the overall cohort with high versus low LE8 scores demonstrated low risk for all-cause mortality [adjusted hazard ratio (aHR) 0.37; 95 % confidence interval (CI) 0.29–0.48, $p < 0.001$] and CV mortality (aHR 0.37, 95 % CI 0.21–0.63, $p < 0.001$) (Table 2). Compared to low LE8 scores, moderate LE8 scores were also associated with lower risk of all cause and CV mortality in both sexes.

When the LE8 was further divided into health behaviors and health factors, the overall health behaviors metric demonstrated a significant association between high or moderate scores and lower risk of all-cause mortality (aHRs 0.31, 95 % CI 0.26–0.36 and 0.59, 95 % CI 0.54–0.65, $p < 0.001$) and CVD mortality (aHRs 0.40, 95 % CI 0.29–0.54, and 0.66, 95 % CI 0.57–0.84, $p < 0.001$). The reduction in mortality among

A.



B.



C.

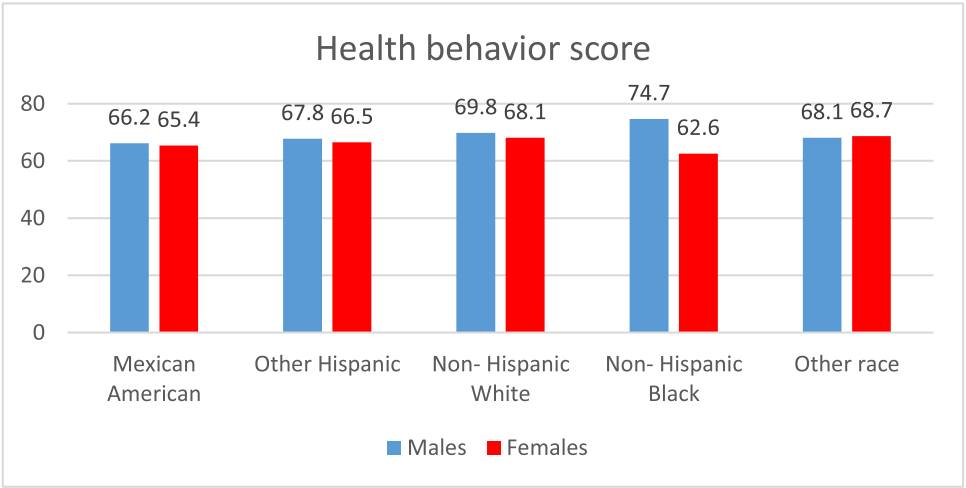


Fig. 3. Cardiovascular health scores, by sex and self reported race and ethnicity. A. overall score; B. health factors score; C. health behavior score.

females was consistent to that in males, for all cause mortality (aHR 0.24 vs. 0.34 for high scores and aHR 0.56 vs. 0.63 for moderate scores, respectively, p-interaction = 0.20) and CV mortality (0.26 vs. 0.47 for high scores and aHR 0.61 vs. 0.78 for moderate scores, respectively, p-interaction = 0.11).

Overall, high and moderate health factors scores had a significant association with lower risk of CVD mortality (aHR 0.68, 95 % CI 0.45–0.99, $p = 0.05$ and 0.80, 95 % CI 0.67–0.95, $p = 0.01$, respectively)

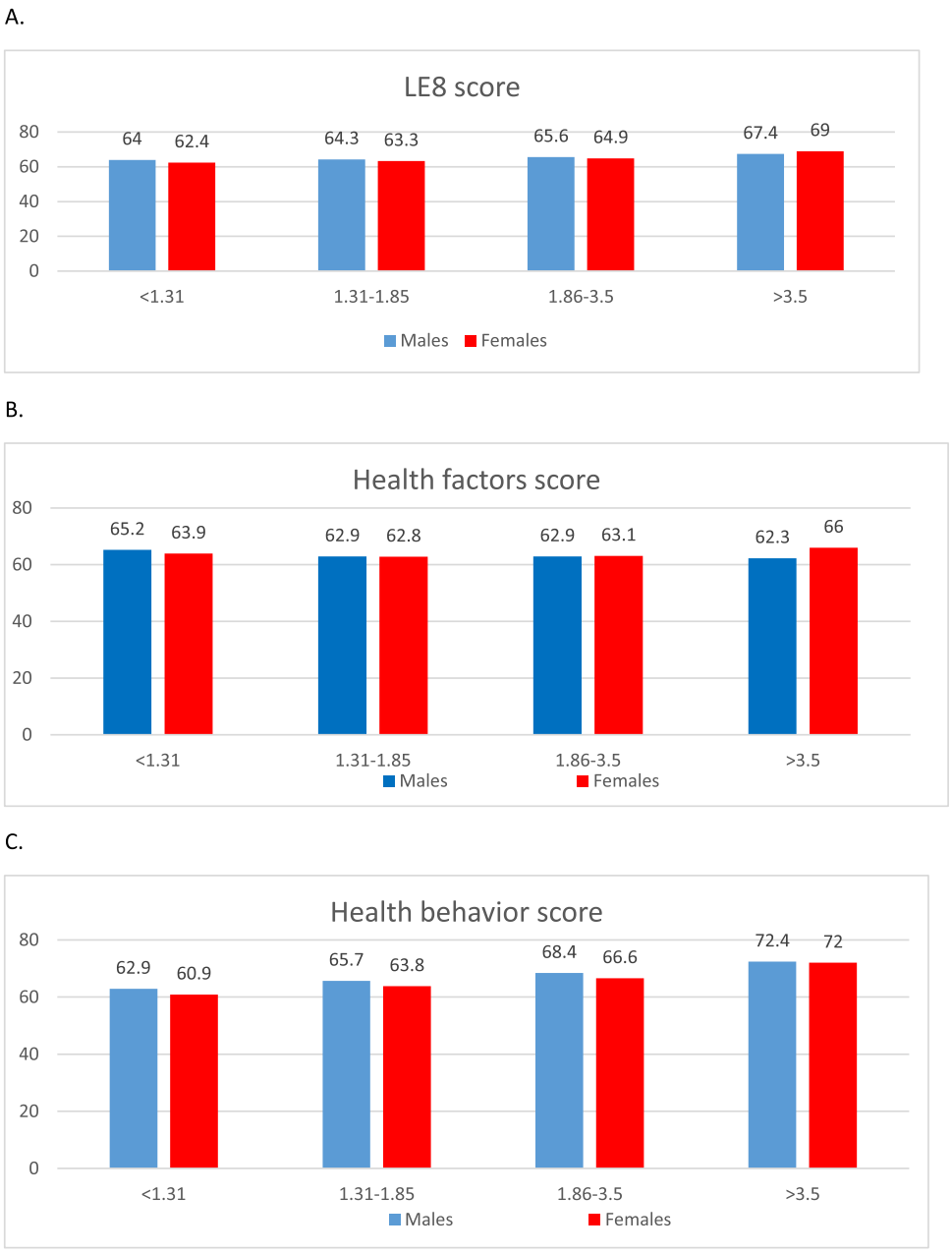


Fig. 4. Cardiovascular health scores, by sex and poverty index (y-axis). A. overall score; B. health factors score; C. health behavior score.

but not all-cause mortality. Compared to low score group, moderate health factors score was significantly associated with lower risk of CV mortality (aHR 0.70, 95 % CI 0.56–0.88, $p < 0.001$) in males, but not in females.

In the alternative model, with LE8 scores as continuous variables (Table 3), for every 10-point increase in LE8 score, there was a 24 % decrease in CV mortality (aHR 0.76, 95 % CI 0.71–0.82, $p < 0.001$) and 21 % decrease in all-cause mortality (aHR 0.79, 95 % CI 0.77–0.82, $p < 0.001$), without any difference by sex. An increase by 10 points in health factors score was associated with lower CV mortality among males and females respectively (aHRs of 0.85, 95 % CI 0.79–0.91, $p < 0.001$ and 0.91, 95 % CI 0.84–0.99, $p = 0.03$). It was also associated with a small but statistically significant decrease in all-cause mortality among females (aHR 0.95, 95 % CI 0.92–0.99, $p = 0.02$). Improved health behaviors score was associated with lower CV and all-cause mortality in the overall cohort, with a non-significant trend toward greater reduction in all-cause mortality among females.

4. Discussion

In this nationally representative study of health behaviors and health factors that comprise the LE8, results suggest: 1) that whilst the overall CVH score is similar between the sexes, females have higher health factors scores (driven primarily by higher blood pressure score), yet lower health behaviors scores (driven primarily by lower physical activity score) compared to males; 2) when stratified by race/ethnicity, the biggest difference in LE8 scores by sex was seen in the non-Hispanic Black group with Black females having the poorest CVH scores, and 3) LE8 score was inversely associated with all-cause and CV mortality among both sexes (Central Illustration). Overall, these results demonstrate notable sex differences in specific CVH metrics and underscore the importance of sex specific, targeted efforts to improve CVH, on both an individual and population level.

Whilst overall CVH scores were similar in both females and males, significant sex differences exist. Health behaviors scores were lower in

Table 2
Adjusted* HR of overall and CV mortality by Overall CVH, health factors, and health behaviors score categories. * adjusted for age group, race, and poverty index.

		Overall HR (95 % CI)	Male HR (95 % CI)	Female HR (95 % CI)	P for interaction
Overall CV health	**All cause mortality***				
	Moderate LE8 Score	0.67 (0.61–0.73) $p < 0.001$	0.60 (0.53—0.68) $p < 0.001$	0.69 (0.60–0.79) $p < 0.001$	0.21
	High LE8 Score	0.37 (0.29–0.48) $p < 0.001$	0.37 (0.27–0.51) $p < 0.001$	0.35 (0.23–0.53) $p < 0.001$	
	CV mortality*				
	Moderate LE8 Score	0.64 (0.54–0.77) $p < 0.001$	0.54 (0.42–0.68) $p < 0.001$	0.74 (0.56–0.97) $p = 0.03$	0.28
	High LE8 Score	0.37 (0.21–0.63) $p < 0.001$	0.35 (0.18–0.68) $p = 0.002$	0.36 (0.15–0.89) $p = 0.02$	
Health factors	**All cause mortality***				
	Moderate Health Factors Score	0.95 (0.87–1.04) $p = 0.27$	0.89 (0.79–1.01) $p = 0.08$	0.92 (0.80–1.06) $p = 0.25$	0.19
	High Health Factors Score	1.09 (0.91–1.29) $p = 0.34$	1.17 (0.94–1.44) $P = 0.16$	0.89 (0.67–1.19) $P = 0.44$	
	CV mortality*				
	Moderate Health Factors Score	0.80 (0.67–0.95) $p = 0.01$	0.70 (0.56–0.88) $p = 0.002$	0.83 (0.63–1.10) $p = 0.20$	0.42
	High Health Factors Score	0.68 (0.45–0.99) $p = 0.05$	0.59 (0.35–0.99) $p = 0.05$	0.79 (0.40–1.54) $p = 0.48$	
Health behaviors	**All cause mortality***				
	Moderate Health Behaviors Score	0.59 (0.54–0.65) $p < 0.001$	0.63 (0.55–0.71) $p < 0.001$	0.56 (0.49–0.65) $p < 0.001$	0.20
	High Health Behaviors Score	0.31 (0.26–0.36) $p < 0.001$	0.34 (0.28–0.41) $p < 0.001$	0.24 (0.19–0.32) $p < 0.001$	
	CV mortality*				
	Moderate Health Behaviors Score	0.66 (0.57–0.84) $p < 0.001$	0.78 (0.60–1.01) $p = 0.06$	0.61 (0.45–0.82) $p = 0.001$	0.11
	High Health Behaviors Score	0.40 (0.29–0.54) $p < 0.001$	0.47 (0.33 −0.68) $p < 0.001$	0.26 (0.15–0.45) $p < 0.001$	

* Reference – Low Score Groups
Legend: Low Score defined as LE8<50; Moderate Score = LE8 score of 50–79; High Score= LE8≥80 for LE8 Score, Health Factors and Health Behaviours.

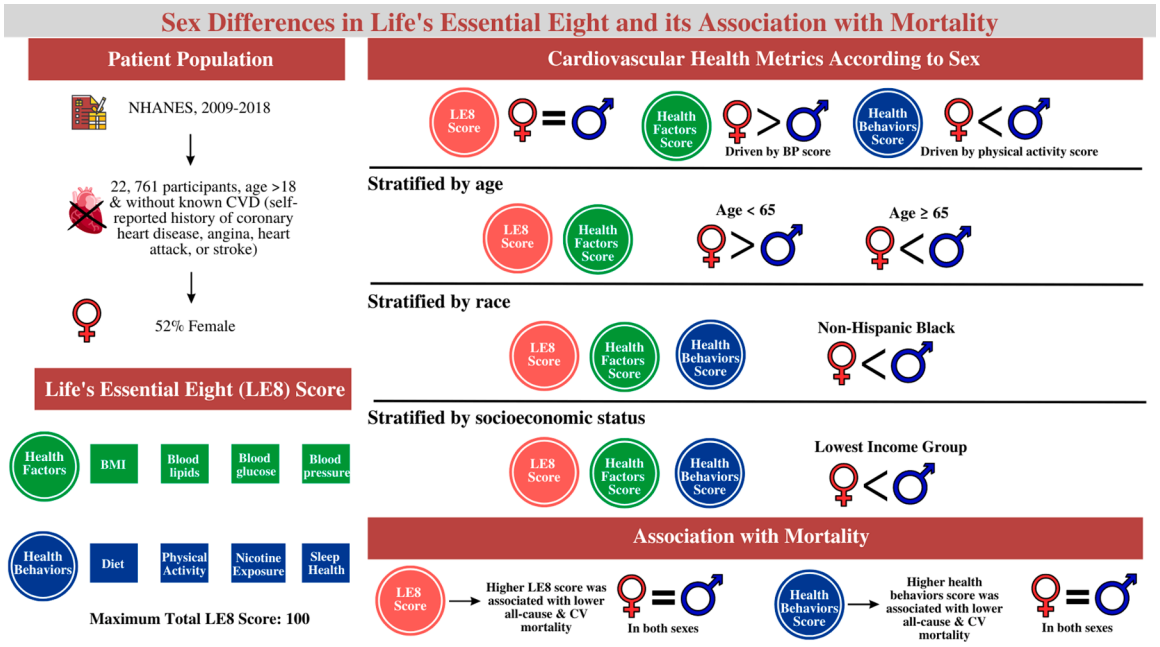
Table 3
Adjusted* HR of overall and CV mortality by Overall CVH, health factors, and health behaviors scores as continuous variable (per 10 points improvement).

	Overall HR (95 % CI)	Male HR (95 % CI)	Female HR (95 % CI)	P for interaction HR (95 % CI)
All cause mortality				
Overall CV health	0.79 (0.77–0.82) $P < 0.001$	0.78 (0.75–0.81) $P < 0.001$	0.77 (0.74–0.82) $P < 0.001$	0.82
Health factors	0.98 (0.93–1.01) $P = 0.07$	0.97 (0.94–1.01) $P = 0.1$	0.95 (0.92–0.99) $P = 0.02$	0.42
Health behaviors	0.80 (0.78–0.82) $P < 0.001$	0.80 (0.78–0.83) $P < 0.001$	0.79 (0.76–0.82) $P < 0.001$	0.64
CV mortality				
Overall CV health	0.76 (0.71–0.82) $P < 0.001$	0.75 (0.68–0.82) $P < 0.001$	0.74 (0.67–0.83) $P < 0.001$	0.77
Health factors	0.90 (0.85–0.94) $P < 0.001$	0.85 (0.79–0.91) $P < 0.001$	0.91 (0.84–0.99) $P = 0.03$	0.22
Health behaviors	0.83 (0.77–0.89) $P < 0.001$	0.85 (0.80–0.91) $P=<0.001$	0.78 (0.72–0.85) $P < 0.001$	0.08

* adjusted for age group, race, and poverty index.

females compared with males, and this was primarily driven by lower physical activity scores in females. Lower levels of physical activity have been demonstrated in females compared with males across the life span [16-19]. These patterns are concerning given the well-established inverse association between physical activity and cardiovascular disease and mortality [20-22]. Our analysis observed that lower health behaviors score was seen in females as compared to males for all age groups and mostly all socioeconomic statuses. It is plausible to speculate whether sex differences in health behaviors such as physical activity become ingrained into society from an early age, beginning even in childhood and adolescence, and therefore interventions must be targeted as early on in life as possible. When assessing afterschool and weekend physical activity in adolescents, boys have been shown to spend more time in moderate to vigorous physical activity than girls [23]. Lifestyle behavioral factors such as physical activity, diet, nicotine exposure, and sleep are important contributors to CVH, but may not be routinely emphasized to the same extent as risk factors. The significant sex differences noted in our analysis with females having lower behavior scores highlight the importance of physicians counseling women regarding these metrics with greater public health interventions targeted towards women. It is also important to note that males had worse nicotine exposure scores than females underscoring the importance of smoking cessation initiatives. Effective implementation of behavioral counseling interventions is needed at the individual patient-provider level and also engagement of communities at-large to optimize behaviors across the lifespan through school-based programs, faith communities, and other public health awareness campaigns. Shetty et al. demonstrated that there has been improvement in physical activity scores in females over time when comparing 2007–2010 NHANES data to 2015–2018 data [24], but further work is still needed.

In our study, females had higher health factors scores compared with males, primarily driven by differences in blood pressure score (73.2 vs. 67.7). This is consistent with the hypertension prevalence in the U.S., reported in 2017–2020 NHANES data as 50 % in males and 43 % in females [1]. However, it is important to observe that when our analysis was stratified by age, females greater than age 65 did not have better health factors scores than males. This correlates to the increased risk of



Central Illustration. Summary of Findings.

CV disease in females after the menopause transition, which is also associated with cardiometabolic health changes (including lipids, body mass index, blood pressure, blood glucose) as consistently shown across several cohort studies [25,26]. Also, NHANES data from 2013 to 2016 has revealed that while a higher percentage of males have hypertension before 65 years of age, a higher percentage of females have hypertension after 65 years [27]. This underscores the importance of aggressive risk factor modification in women, who may inaccurately be perceived to be at lower risk of CVD [28,29]. In addition, in our analysis, for those in the lowest income group, males had significantly higher health factors score than females. A prior large-scale meta-analysis demonstrated that while indices of socioeconomic status were inversely related with cardiovascular risk in both sexes, the association with CV disease was stronger in females [30]. This may be due to worse control of health factors in females vs. males of lower socioeconomic status, as shown in our analysis, and may stem from aspects such as lack of health insurance, transportation or childcare barriers to attend appointments, poor health care literacy, and underlying bias regarding treatment of risk factors. Our analysis should serve as a call to action for implementation of strategies to improve risk factor control in low-income females. Potential strategies may include optimizing health care delivery through digital health technology, telemedicine, and remote monitoring programs as well as ensuring initiatives are tailored towards diverse health literacy levels.

Our analysis highlights important racial disparities, with Non-Hispanic Black females having the lowest LE8 score, health factors score, and health behaviors score as compared with any other sex or race group. The worse health behaviors score is consistent with prior observations revealing that Black females had lower prevalence of regular physical activity compared with males [31]. The worse health factors score in Black females is also consistent with prior NHANES data that has shown that Black women are more likely to have inadequate blood pressure control. Significant mediators in racial differences in blood pressure control include social determinants of health such as financial hardship and neighborhood quality and also behavioral risk factors, as shown in the REGARDS (Reasons for Geographic and Racial Differences in Stroke) cohort [32]. There are likely multiple factors that play a role, including increased family responsibilities, caregiver status, social determinants of health, in addition to chronic stress due to institutional and structural racism which disproportionately affects Black females and can further intensify behavioral risk factors – such as diet, physical activity, nicotine exposure, and sleep – due to unhealthy coping mechanisms [33,34]. As such, it is important to employ community-based interventions, such as increasing access to healthy foods and safe areas for physical activity, to eliminate these disparities. Prior data has shown that Black individuals had fewer ideal Life's Simple 7 components, the earlier version of LE8, as compared to their White counterparts [35]. Our analysis is the first study to show that Black females had the worst LE8 scores compared to all other groups, and therefore, represent a particularly vulnerable population who should be a focus for future community-designed interventions.

While prior global data from the Prospective Urban Rural Epidemiological (PURE) study has demonstrated similar association of risk factors with cardiovascular disease in both women and men [36] and other analyses investigating the association of the LE8 score and mortality have shown no significant sex differences [4,10], our analysis was the first one to consider the differences when the CVH metrics are divided into health behaviors and health factors. The reduction in all-cause and CV mortality was similar among females and males when assessing health factors and health behaviors scores separately. While there are biological sex differences in associated pathways such as inflammation, endothelial function, atherosclerosis, cardiac remodeling, and epigenetics which are affected by health behaviors and health factors and associated with CVD risk and subsequent CV mortality [3,37], our results collectively emphasize the importance of focusing on modification of both health behaviors and factors in females and males alike. While addressing traditional risk factors for CVD, such as obesity, cholesterol levels, blood glucose, and blood pressure, are often at the forefront of attention for prevention efforts, our results demonstrate that targeting health behaviors through concerted interventions is also equally important in women.

Important limitations to consider for this analysis include that data are collected from a national U.S. dataset that is reliant on accurate patient recollection of health habits, and misreporting could be differential by sex. Furthermore, exclusion of participants known to have cardiovascular disease was self-reported and, therefore, participants included in the study may have undiagnosed coronary heart disease. Also, our sample may not be representative of CVH metrics in populations outside of the U.S and stratification by race and ethnicity is limited with subdivisions such as "other race" comprising a diverse population which includes South Asians, East Asians, American Indian

or Alaska Native, and Pacific Islander, and different health behaviors may be influenced by cultural differences. Furthermore, participants were excluded if there was incomplete information for all 8 CVH components and, thus, missing data may have led to a bias in results. Finally, given limitations of the dataset, we were not able to classify specific causes of CV and non-CV related mortality.

5. Conclusions

We identify important sex differences in LE8 CVH metrics, with females having higher health factors scores and males having higher health behaviors scores. However, females older than age 65 no longer demonstrated better health factors score than males. In addition, non-Hispanic Black females had worse LE8 scores across all metrics, associated with the worst health outcomes. We also demonstrate that LE8 score was inversely associated with all-cause and CV mortality amongst both sexes. These findings are a call to action for future primary prevention strategies focused on addressing these factors, both health factors and health behaviors, to improve the health of women.

Author declaration

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

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Disclosures

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CRediT authorship contribution statement

Gurleen Kaur: Writing – review & editing, Writing – original draft. **Ofer Kobo:** Writing – original draft, Formal analysis, Data curation, Conceptualization. **Purvi Parwani:** Writing – review & editing. **Alaide Chieffo:** Writing – review & editing. **Martha Gulati:** Writing – review & editing, Supervision. **Mamas A. Mamas:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Martha Gulati reports a relationship with Esperion Therapeutics Inc that includes: consulting or advisory. Martha Gulati reports a relationship with Novartis that includes: consulting or advisory. MG- Receives funding from the Department of Defense for the Women's IschemiA TRial to Reduce Events In Non-ObstRuctive CAD (WARRIOR) (Award Number: W81XWH-17–2–0030). If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajpc.2024.100685.

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