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Relationship between cardiovascular health and osteoarthritis in middle-aged and elderly U.S. population: a cross-sectional NHANES study

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Abstract

Background Osteoarthritis (OA) is closely linked to cardiovascular diseases, mainly afflicting older adults. Our study aims to explore the association between Life's Essential 8 (LE8), a newly developed measurement of cardiovascular health (CVH), and OA in the middle-aged and elderly population.

Methods Our study utilized data from the National Health and Nutrition Examination Survey 2007–2018. OA was ascertained by self-reported data from questionnaires. The overall LE8 score is calculated as the mean of 8 individual metric scores ranging from 0 to 100 and is categorized into three CVH levels: low (0–49), moderate (50–79), and high (80–100). Multivariate logistic and restricted cubic spline regression models were performed to explore the associations between CVH and OA. Subgroup and sensitivity analyses were conducted to test the robustness of main results.

Results Our study included 10,231 participants aged ≥ 40 years from NHANES. The total age-adjusted prevalence of OA was 22.4%. After adjusting for the potential covariates, the adjusted odds ratio (AOR) of OA was significantly lower in participants with a moderate level (AOR = 0.687, 95% CI: 0.531, 0.889) or high CVH level (AOR = 0.430, 95% CI: 0.326, 0.567) compared to those with a low CVH level. Similar trends in the associations of the health behavior score and health factor score with OA were also observed.

Conclusions LE8-evaluated CVH levels were inversely associated with OA risks in the middle-aged and elderly U.S. population, indicating that maintaining the optimal CVH level may potentially contribute to the management of OA risks.

Keywords Life's essential 8, Osteoarthritis, Middle-aged and elderly people, NHANES

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Introduction

Osteoarthritis (OA), a degenerative disease of the articular cartilage with subchondral bone lesions, is the most common form of arthritis (AR) in adults [1]. OA can trigger joint damage and chronic pain, leading to functional impairment and diminished quality of life [2, 3]. In 2020, approximately 595 million people worldwide had OA, accounting for 7.6% of the global population, a 132.2% increase since 1990 [4]. OA accounted for an estimated $80 billion in healthcare expenditures in the United States in 2016 [5]. Notably, individuals with OA had more potential cardiovascular disease (CVD) risk factors, including obesity, hypertension, and high levels of low-density lipoprotein [6], and are associated with an increased risk of all-cause mortality, especially cardiovascular mortality, compared to the general population [7, 8].

In 2022, the American Heart Association (AHA) established a novel and measurable construct of cardiovascular health (CVH) called Life's Essential 8 (LE8) with 8 actionable components for individuals to monitor and improve CVH [9]. LE8 consisted of four health behaviors [diet, physical activity (PA), nicotine exposure, and sleep health] and four health factors [body mass index (BMI), total cholesterol, blood pressure (BP), and blood glucose]. Based on the assessment of LE8 scores, individuals' CVH is categorized into low, moderate, and high levels. Several relevant studies have demonstrated the protective effects of LE8 on all-cause, cardiovascular mortality, and chronic diseases, underscoring the importance of maintaining optimal CVH levels [10, 11]. Given the tight link between OA and CVD [12], promoting the CVH may serve as an appropriate prevention and management approach for diminishing the burden of OA.

Although some studies have discussed the relationships between CVD risk factors and OA, there are several limitations. First, most of these studies mainly focused on the impacts of a single CVD risk factor related to lifestyle on OA, including diet [13], PA [14], and blood lipids [15]. However, few studies explored the association of comprehensive indicators with OA. Secondly, researchers investigated the association of CVH status using Life's Simple 7 (LS7), the early version of LE8, with AR and rheumatoid arthritis, respectively [16, 17]. In contrast to LE8, the algorithm of LS7 is less sensitive to inter-individual differences and intra-individual changes, potentially constraining its capacity to comprehensively discern the full spectrum of health behaviors within the current context [9]. Lastly, previous studies have investigated the association between osteoporosis, OA and CVH [18, 19], but as the prevalence of OA increases with age [4], and given that ageing is induced and exacerbated by cardiovascular disease risk factors leading to geriatric syndromes [20]. Therefore, the presented study, based on the National Health and Nutrition Examination Survey (NHAENS) data, aimed to investigate the association between LE8 and OA in the in middle-aged and elderly population.

Methods

Study population

NHANES, is a national ongoing cross-sectional survey designed to collect information about nutritional status, health behaviors, and physical examination results of noninstitutionalized U.S. civilians utilizing a multistage probability sampling, performed by the National Centers for Disease Control and Prevention. The NHANES study protocol received approval from the ethics review board at the National Center for Health Statistics, and all participants signed informed consent [21]. More detailed NHANES information is available at https://www.cdc.gov/nchs/nhanes/index.htm.

The study population was based on the six consecutive survey cycles of NHANES from 2007 to 2018. A total of 57,381 participants were involved at first for the present study. Missing data were addressed using listwise deletion in this study, where participants with missing necessary covariates on any analysis variable were excluded (Table S1). After the exclusion of 34,155 participants aged < 40 years old, 7,429 participants without LE8 information, 3,739 participants with missing data on OA, and 1,827 participants missing necessary demographic/health variables and covariates, 10,231 participants aged ≥ 40 years old were finally included in this analysis. Fig S1 shows the selection of study participants.

Assessment of CVH

The LE8, as a novel concept, is used to assess CVH, including four health behaviors (diet, PA, nicotine exposure, and sleep health) and four health factors (BMI, blood lipids, blood glucose, and BP). The elaborated description of the algorithm for LE8 using NHANSE data is available in Table S2. In short, the overall LE8 score was determined by calculating the unweighted average of all 8 metric scores, each ranging from 0 to 100 points. The unweighted average diet score, PA score, nicotine exposure score and sleep health score calculated health behavior score. Health factor score was calculated by the unweighted average of BMI score, blood lipids score, blood glucose score and BP score. According to the AHA's definition, the overall LE8 score of 80–100, 50–79, and 0–49 points were classified as a high CVH level, a moderate CVH level, and a low CVH level, respectively [9]. Diet metric was estimated using the Healthy Eating Index-2015 [22], with the components and scoring criteria summarized in Table S3. Information about PA, nicotine exposure, and sleep health was gathered through standardized questionnaires. Data on BP, height, and weight of participants were measured by professional

staff during the physical examination. BMI was calculated as weight (kg) divided by the height squared (m^2). Researchers collected blood samples and sent them to central laboratories to analyze blood lipids, plasma glucose, and hemoglobin A1c levels.

Ascertainment of OA

The OA was ascertained by questionnaires from NHANES. Previous studies have reported great consistency between self-reported OA and clinically confirmed OA [23]. Question MCQ160a (https://wwwn.cdc.gov/Nchs/Nhanes/2017-2018/P_MCQ.htm#MCQ160a): "Has a doctor or other health professionals ever told you that you had arthritis?". If participants answered "Yes", they were defined as AR. Then, they were asked the next question MCQ195 (https://wwwn.cdc.gov/Nchs/Nhanes/2017-2018/P_MCQ.htm#MCQ195): "Which type of arth ritis was it?". The participants whose answers indicated "Osteoarthritis or degenerative arthritis" were identified to have OA.

Assessment of covariates

We selected the following variables based on previous studies and the NHANES dataset [16, 24] as potentially confounding and modifying variables: gender (male and female), race or ethnicity [Non-Hispanic White, Non-Hispanic Black, Mexican American and Other races (including multiracial and other Hispanic)], education level (less than high school, high school and more high school), marital status (living alone and married or living with partner), poverty income ratio (PIR; PIR was determined by dividing the monthly income of a family by the poverty thresholds, we categorized into 3 levels: < 1.3, 1.3–3.5, and > 3.5), alcohol consumption (never, former, and current), calorie intake, hypertension (an average systolic pressure ≥ 140 mmHg and diastolic pressure ≥ 90 mmHg in 3 consecutive tests), diabetes mellitus (DM) (fasting plasma glucose ≥ 126 mg/dL, 2-h plasma glucose ≥ 200 mg/dL, hemoglobin A1c ≥ 6.5%, or self-reported diabetes diagnosed by a professional doctor), history of CVD (the presence of a self-reported history of coronary heart disease, angina, myocardial infarction, or stroke by a trained health professional before the survey) and history of fracture ("Yes" or "No").

Statistical analyses

Data were analyzed following the analytical guidelines and utilized survey weights (the wtmec2 year weights) recommended by NHANES to ensure nationally representative estimates [25]. Comparison of continuous variables with their mean (standard error, SE) was conducted using t-test analysis. The chi-squared test was used to analyze the counts and percentages of categorical variables. Survey-multivariable logistic regression models were used to estimate the adjusted odds ratio (AOR) and 95% confidence interval (CI) for the associations of the LE8 score, health behavior score, and health factor score with OA. The crude model was without adjustment. Model 1 was adjusted for age, gender, and race/ethnicity. Model 2 was further adjusted for education level, marital status, PIR, and alcohol consumption. When the association of each LE8 metric score with OA was evaluated, model 1 was unchanged and the remaining 7 LE8 components were further adjusted in model 2. Meanwhile, we tested for multicollinearity among potential covariates using the variance inflation factor (VIF), with a VIF > 5 indicating multicollinearity. Importantly, no significantly collinear covariates were detected in all models. Restricted cubic spline (RCS) models were used to explore the potential dose-response relationship between LE8 scores and the risks of OA. Additionally, subgroup analyses were implemented by different demographic/health characteristics (gender, race/ethnicity, education level, marital status, PIR, and alcohol consumption). All statistical analyses were performed using R language (X64 Version 4.4.2). R Foundation for Statistical Computing). The two-tailed P-value < 0.05 was assumed to be statistically significant.

Furthermore, considering (1) the evidence indicating potential associations between fracture, caloric intake, and OA [26, 27], and (2) the incorporation of covariates such as CVD, DM, and hypertension in regression models of previous studies examining the LS7 and OA relationship [28], we performed sensitivity analyses by including additional covariates (survey cycles, DM, hypertension, CVD, caloric intake, and fracture history) to control their potential influence and enhance the robustness of our primary findings.

Results

Baseline characteristics

In this study, a total of 10,231 participants aged ≥ 40 were enrolled from six NHANES cycles (2007–2018), representing the 73.6 million non-institutionalized U.S. population aged ≥ 40 (Fig S1). The baseline characteristics of the study population by OA status were summarized in Table 1. The average age (SE) of the participants was 56.99 (0.20) years old, of which 5,170 responders were females (52.3%). The average (SE) of LE8 scores was 67.51 (0.7), and there were 1,369 (10.5%), 7,150 (68.1%), and 1,712 (21.4%) participants with low (0–49), moderate (50–79), and high (80–100) CVH status, respectively. Participants with OA were more likely to be older, women, Non-Hispanic White, living alone, and those who had a history of drinking. Participants without OA exhibited significantly higher scores in LE8 metrics except the sleep health, and blood lipids scores compared to those with OA. Table

Table 1 Baseline characteristics of U.S. Adults aged ≥ 40 years with OA status

Demographic/health variables	Overall	OA status		*P*-value[a]
		No	Yes	
Total participants	10,231 (100.0)	8,118 (79.3)	2,113 (20.7)	-
Age	56.99 ± 0.20	55.15 ± 0.20	63.34 ± 0.29	**< 0.001**
40–59	5,520 (61.5)	4,894 (68.9)	626 (36.0)	**< 0.001**
60-	4,711 (38.5)	3,224 (31.1)	1,487 (64.0)	
Sex				
Male	5,061 (47.7)	4,324 (51.7)	7,37 (33.6)	**< 0.001**
Female	5,170 (52.3)	3,794 (48.3)	1,376 (66.4)	
Education level				
Less than high school	2,170 (12.5)	1,785 (12.8)	385 (11.4)	0.15
High school	2,296 (22.5)	1,827 (22.8)	469 (21.5)	
More than high school	5,765 (65.0)	4,506 (64.4)	1,259 (67.1)	
PIR	3.39 ± 0.04	3.41 ± 0.05	3.34 ± 0.06	0.23
< 1.3	2,512 (14.0)	2,005 (13.9)	507 (14.2)	0.44
1.3–3.5	3,895 (33.8)	3,069 (33.4)	826 (35.1)	
> 3.5	3,824 (52.3)	3,044 (52.7)	780 (50.7)	
Race/ethnicity				
Non-Hispanic White	4,984 (76.6)	3,617 (74.1)	1,367 (85.2)	**< 0.001**
Non-Hispanic Black	1,910 (8.2)	1,602 (8.9)	308 (5.6)	
Mexican American	1,345 (5.5)	1,183 (6.4)	162 (2.5)	
Other races	1,992 (9.7)	1,716 (10.6)	276 (6.7)	
Marital status				
Married/Living with partner	6,672 (70.6)	5,412 (71.7)	1,260 (66.5)	**< 0.001**
Living alone	3,559 (29.4)	2,706 (28.3)	853 (33.5)	
Alcohol consumption				
Never	1,382 (10.1)	1,106 (10.1)	276 (10.1)	**< 0.05**
Former	1,897 (15.0)	1,435 (14.1)	462 (18.0)	
Current	6,952 (75.0)	5,577 (75.8)	1375 (71.9)	
CVH levels				
Low	1,369 (10.5)	990 (9.5)	379 (13.8)	**< 0.001**
Moderate	7,150 (68.1)	5,661 (67.4)	1,489 (70.5)	
High	1,712 (21.4)	1,467 (23.1)	245 (15.7)	
Total LE8 score	67.51 ± 0.27	68.37 ± 0.29	64.53 ± 0.48	**< 0.001**
Health behavior score	68.88 ± 0.37	69.27 ± 0.35	67.52 ± 0.69	**< 0.05**
Diet score	44.18 ± 0.62	43.52 ± 0.60	46.46 ± 1.14	**< 0.05**
PA score	71.76 ± 0.62	74.00 ± 0.65	64.02 ± 1.20	**< 0.001**
Nicotine exposure score	74.57 ± 0.61	74.59 ± 0.61	74.51 ± 1.04	0.94
Sleep health score	85.00 ± 0.33	84.97 ± 0.35	85.11 ± 0.74	0.85
Health factor score	66.14 ± 0.30	67.48 ± 0.35	61.53 ± 0.54	**< 0.001**
BMI score	59.88 ± 0.51	61.97 ± 0.55	52.66 ± 0.96	**< 0.001**
Blood lipids score	59.56 ± 0.40	59.49 ± 0.41	59.79 ± 0.93	0.76
Blood glucose score	81.77 ± 0.41	83.01 ± 0.45	77.46 ± 0.77	**< 0.001**
Blood pressure score	63.37 ± 0.52	65.45 ± 0.61	56.19 ± 1.12	**< 0.001**

Footnotes: Continuous variables are presented as mean ± SE, and categorical variables are presented as n (%)

[a] *P*-values were assessed by T-test (continuous variables) or by Chi-square test (categorical variables). *P*-values shown in bold were statistically significant

Abbreviations: BMI, Body mass index; CVH, Cardiovascular health; OA, Osteoarthritis; LE8, Life's Essential 8; NHANES, National Health and Nutrition Examination Survey; PA, Physical activity; PIR, Poverty income ratio; SE, Standard error

S4 presented the characteristics of U.S. adults aged ≥ 40 years by LE8-evaluated CVH levels.

OA prevalence trend

The total age-adjusted prevalence of OA was 22.4% (0.59) in our study population. As shown in Fig. 1, the age-adjusted prevalence of OA was stable at around 19% over 2007–2012, then rose to 25% and remained stable from 2013 to 2018. Fig S2 presented the age-adjusted prevalence of OA in different levels of LE8 score, health behavior score, and health factor score. In addition, we found that both participants with OA and participants

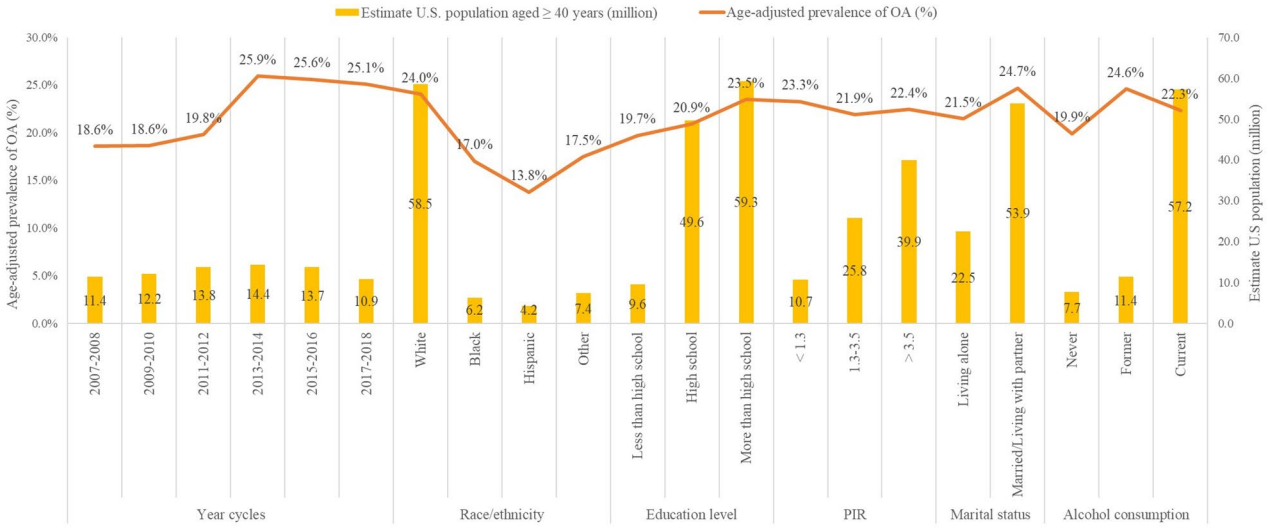

Fig. 1 Age-adjusted prevalence of OA and estimate U.S. population aged ≥ 40 years in NHANES 2007–2018

Table 2 Associations of LE8 with OA

	Crude model		Model 1		Model 2	
	COR (95% CI)	***P*-value**	**AOR (95% CI)**	***P*-value**	**AOR (95% CI)**	***P*-value**
LE8 score						
Low CVH (0–49)	Reference	-	Reference	-	Reference	-
Moderate CVH (50–79)	**0.719 (0.572, 0.903)**	**< 0.05**	**0.710 (0.549, 0.918)**	**< 0.05**	**0.687 (0.531, 0.889)**	**< 0.05**
High CVH (80–100)	**0.466 (0.364, 0.597)**	**< 0.001**	**0.469 (0.359, 0.613)**	**< 0.001**	**0.430 (0.326, 0.567)**	**< 0.001**
P for trend		**< 0.001**		**< 0.001**		**< 0.001**
Health behavior score						
Low level (0–49)	Reference	-	Reference	-	Reference	-
Moderate level (50–79)	0.832 (0.689, 1.004)	0.054	**0.810 (0.659, 0.995)**	**< 0.05**	**0.805 (0.652, 0.993)**	**< 0.05**
High level (80–100)	**0.831 (0.692, 0.999)**	**< 0.05**	**0.741 (0.610, 0.902)**	**< 0.05**	**0.718 (0.577, 0.895)**	**< 0.05**
P for trend		0.11		**< 0.05**		**< 0.05**
Health factor score						
Low level (0–49)	Reference	-	Reference	-	Reference	-
Moderate level (50–79)	**0.714 (0.596, 0.854)**	**< 0.001**	**0.744 (0.620, 0.892)**	**< 0.05**	**0.728 (0.606, 0.874)**	**< 0.001**
High level (80–100)	**0.416 (0.333, 0.520)**	**< 0.001**	**0.503 (0.398, 0.637)**	**< 0.001**	**0.482 (0.381, 0.610)**	**< 0.001**
P for trend		**< 0.001**		**< 0.001**		**< 0.001**

Footnotes: The crude model was unadjusted. Model 1 was adjusted for age, sex, and race/ethnicity. Model 2 was additionally adjusted for education level, marital status, PIR, and alcohol consumption. The results of COR (95% CI), AOR (95% CI), and *P*-value shown in bold were statistically significant. *P*-value < 0.05 or *P*-value < 0.001

Abbreviations: AOR, Adjusted odds ratio; CI, Confidence interval; COR, Crude odds ratio; CVH, Cardiovascular health; OA, Osteoarthritis; LE8, Life's Essential 8; NHANES, National Health and Nutrition Examination Survey; PIR, Poverty income ratio

with lower LE8 scores tended to be older, to live alone, and to have experienced alcohol consumption (Table 1; Table S4).

LE8 -evaluated CVH and OA

Compared to participants with low CVH, the risk of OA was significantly lower in participants with a moderate level (AOR = 0.687, 95% CI: 0.531, 0.889) or high CVH level (AOR = 0.430, 95% CI: 0.326, 0.567) in the fully adjusted model (Table 2). When participants with moderate CVH as the reference group, those with low CVH had a higher risk of OA of 1.455, (95% CI 1.125, 1.883), while the high CVH group had a lower risk of OA (AOR = 0.626, 95% CI: 0.500, 0.784) (Table S5). Additionally, an inverse dose-response relationship was identified between the LE8 score and the risk of OA (Fig. 2A; *P* for nonlinearity > 0.05). In addition, the reduced risk of OA was observed for participants with higher LE8 component scores of nicotine exposure and BMI (Table S6). Table S7 displayed the associations between all 8 LE8 metrics scores and OA when a moderate level as the reference.

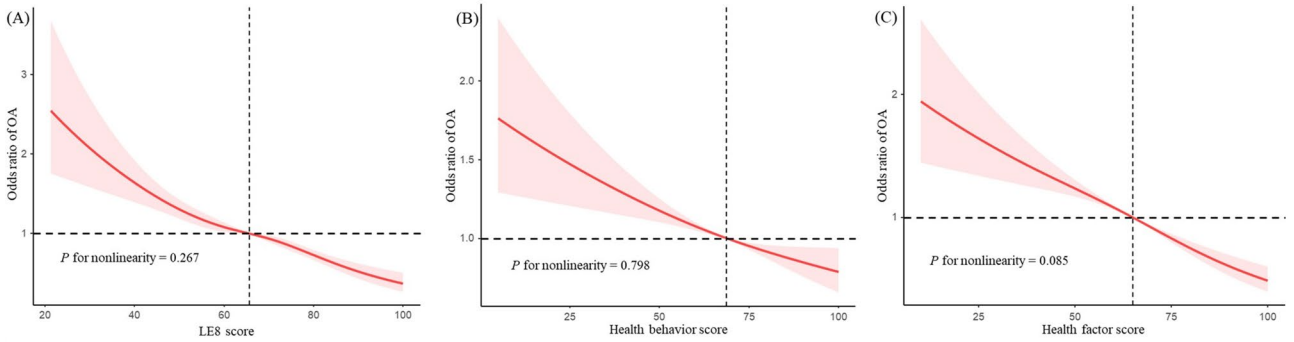

Fig. 2 Dose-response relationships between LE8 score (**A**), health behavior score (**B**), health factor score (**C**), and OA

Health behavior score and OA

Compared to participants with a low level of health behavior score, the risk of OA was significantly lower in participants with a moderate (AOR = 0.805, 95% CI: 0.652, 0.993) or a high level of health behavior score (AOR = 0.718, 95% CI: 0.577, 0.895) in the fully adjusted model (Table 2). When participants with a moderate level of health behavior score as the reference, the relationship between health behavior scores and OA was not statistically significant (Table S5). In addition, the results of RCS models exhibited a negative dose-response relationship between health behavior scores and the risk of OA (Fig. 2B; *P* for nonlinearity > 0.05).

Health factor score and OA

Compared to participants with a low level of health factor score, the risk of OA was significantly lower in participants with a moderate (AOR = 0.728, 95% CI: 0.606, 0.874) or a high level of health factor score (AOR = 0.482, 95% CI: 0.381, 0.610) in the fully adjusted model (Table 2). When participants with a moderate level of health factor score as the reference group, those with a low level of health factor score had a higher risk of OA (AOR = 1.374, 95% CI: 1.144, 1.651), while those with a high level of health factor score had a lower risk of OA (AOR = 0.662, 95% CI: 0.557, 0.804) (Table S5). In addition, the results of RCS models exhibited a negative dose-response relationship between the health factor score and the risk of OA (Fig. 2C; *P* for nonlinearity > 0.05).

Subgroup and sensitivity analyses

The results of subgroup analyses are presented in Table 3. In all subgroups, LE8 scores exhibited a significant negative association with OA, except Mexican Americans, participants who were other races, and former drinkers. However, we did not find significant interactions across subgroups (All *P* for interaction > 0.05). In addition, the results of RCS models stratified by age, sex, and race/ethnicity indicated that the dose-exposure relationships were generally aligned with the main results across subgroups (Figure S3-S5). Notably, there were significant non-linear relationships between HBS (non-Hispanic Black), HFS (Other races) and OA (*P* for nonlinearity < 0.05).

The results of sensitivity analyses were unchanged significantly (Table S8-S10). Notably, the inverse associations of health behavior scores with OA were not significant, after further adjusted CVD (AOR = 0.824, 95% CI: 0.666, 1.020), DM (AOR = 0.814, 95% CI: 0.657, 1.008), and hypertension (AOR = 0.818, 95% CI: 0.662, 1.010), respectively. When the high CVH group as the reference (Table S11), individuals with a low CVH level increased 2.3 times higher OA risks (AOR = 2.324, 95% CI: 2.324, 3.064).

Discussion

In this work, we provide the extensive assessment the association between LE8 and OA, based on a nationally representative sample. Our study revealed that CVH, as measured by the LE8 score, was negatively associated with the prevalence of OA among middle-aged and elderly adults. These results remained unchanged even after subgroup analyses and sensitivity analyses were performed. Importantly, we found that more pronounced negative associations of the LE8-evaluated CVH with OA in participants aged > 60, at a lower education level, and those with lower PIR. Additionally, the racial disparities were observed in the non-linear relationships between LE8 and OA. These finding have never been reported in the previous literature.

Our study showed that, based on LE8 scores, participants who achieved a moderate CVH level or a high CVH level were associated with a lower risk of OA, compared with the low CVH group, which was consistent with previous similar LE8-related studies. A randomized controlled trial demonstrated that a 16-week "Plants for Joints" multidisciplinary lifestyle program, including a plant-based diet, physical activity, and stress management, improved weight, hemoglobin A1c, and fasting glucose in rheumatoid arthritis patients with low-moderate disease activity, compared to the controls [29]. Wang et al. based on NHANES (2011–2018) data to investigate the relationship between ideal cardiovascular

Table 3 Subgroup analysis of the associations of LE8 with OA

Subgroups	Cases/Participants	LE8 score					*P* for trend	*P* for interaction
		Low CVH	Moderate CVH		High CVH			
			AOR (95% CI)	*P*-value	AOR (95% CI)	*P*-value		
Age								
40–59	626/5,520	Reference	0.742 (0.544, 1.012)	0.059	**0.538 (0.380, 0.762)**	**< 0.001**	**< 0.001**	0.063
60-	1,487/4,711	Reference	**0.682 (0.497, 0.937)**	**< 0.05**	**0.384 (0.248, 0.594)**	**< 0.001**	**< 0.001**	
Sex								
Female	1,376/5,170	Reference	0.735 (0.509, 1.060)	0.098	**0.570 (0.363, 0.895)**	**< 0.05**	**< 0.05**	0.109
Male	737/5,061	Reference	**0.641 (0.467, 0.878)**	**< 0.05**	**0.372 (0.264, 0.523)**	**< 0.001**	**< 0.001**	
Race/ethnicity								
Non-Hispanic White	1,367/4,984	Reference	**0.682 (0.501, 0.926)**	**< 0.05**	**0.432 (0.312, 0.597)**	**< 0.001**	**< 0.001**	0.96
Non-Hispanic Black	308/1,910	Reference	0.749 (0.536, 1.047)	0.090	**0.367 (0.206, 0.653)**	**< 0.001**	**< 0.001**	
Mexican American	162/1,345	Reference	0.969 (0.544, 1.727)	0.915	0.547 (0.172, 1.741)	0.301	0.287	
Other races	276/1,992	Reference	0.668 (0.354, 1.261)	0.210	0.443 (0.174, 1.130)	0.088	0.097	
Education level								
Less than high school	385/2,170	Reference	**0.504 (0.336, 0.755)**	**< 0.05**	**0.243 (0.079, 0.743)**	**< 0.05**	**< 0.001**	0.589
High school	469/2,296	Reference	0.783 (0.502, 1.221)	0.277	**0.412 (0.219, 0.778)**	**< 0.05**	**< 0.05**	
More than high school	1,259/5,765	Reference	0.730 (0.527, 1.012)	0.059	**0.486 (0.348, 0.678)**	**< 0.001**	**< 0.001**	
Marital status								
Married/Living with partner	1,260/6,672	Reference	**0.655 (0.478, 0.896)**	**< 0.05**	**0.398 (0.275, 0.576)**	**< 0.001**	**< 0.001**	0.707
Living alone	853/3,559	Reference	0.743 (0.528, 1.047)	0.089	**0.536 (0.344, 0.835)**	**< 0.05**	**< 0.05**	
PIR								
< 1.3	507/2,512	Reference	**0.643 (0.465, 0.888)**	**< 0.05**	**0.375 (0.184, 0.768)**	**< 0.05**	**< 0.05**	0.586
1.3–3.5	826/3,895	Reference	**0.600 (0.426, 0.845)**	**< 0.05**	**0.404 (0.262, 0.622)**	**< 0.001**	**< 0.001**	
> 3.5	780/3,824	Reference	0.892 (0.527, 1.509)	0.666	**0.559 (0.329, 0.951)**	**< 0.05**	**< 0.001**	
Alcohol consumption								
Never	276/1,382	Reference	0.896 (0.534, 1.503)	0.673	0.471 (0.215, 1.036)	0.061	**< 0.05**	0.237
Former	462/1,897	Reference	**0.700 (0.497, 0.986)**	**< 0.05**	0.673 (0.348, 1.300)	0.234	0.143	
Current	1,375/6,952	Reference	**0.653 (0.475, 0.898)**	**< 0.05**	**0.396 (0.277, 0.565)**	**< 0.001**	**< 0.001**	

Footnotes: The multivariable logistic regression model was adjusted for age, sex, race/ethnicity, education level, marital status, PIR, and alcohol consumption. The results of AOR (95% CI), *P* for trend, *P*-interaction, and *P*-value shown in bold were statistically significant. *P*-value < 0.05 or *P*-value < 0.001

Abbreviations: AOR, Adjusted odds ratio; CI, Confidence interval; CVH, Cardiovascular health; OA, Osteoarthritis; LE8, Life's Essential 8; NHANES, National Health and Nutrition Examination Survey; PIR, Poverty income ratio

health metrics (ICVHM) and OA concluded that higher ICVHM scores were inversely correlated with the prevalence of OA. In addition, compared to the "≤ 1" score, the odd ratios of arthritis in participants with 2, 3, 4, and ≥ 5 were 0.586, 0.472, 0.259, and 0.130, respectively [16]. An additional cross-sectional NHANES study of 23,213 participants aged ≥ 20 years revealed that a higher LE8 score was associated with reduced AR risks in U.S. general adults [19].

Although the mechanism between LE8 and OA remains unclear to date, growing evidence showed that OA was closely linked to lifestyle and metabolic syndrome (MetS) [30], which were intrinsic health behavior and health factor metrics of LE8. These findings provided a potential perspective to explain the mechanism between LE8 and OA among middle-aged and elderly people. For the health behavior aspect, first, healthy eating patterns, such as a Mediterranean diet, may mitigate inflammation

status and improve antioxidant capacity, which is beneficial to the prevention of OA [13]. Second, PA has the potential to induce the expression and secretion of irisin in muscle tissue, leading to the inhibition of chondrocyte apoptosis through the reduction of inflammatory factors and matrix metalloproteinases in chondrocytes [31, 32]. Furthermore, due to the OA causing activity limitations, OA patients were generally less active, had more sedentary behavior time, and had more barriers to PA than the general population [7, 33, 34]. Third, smoking may reduce antioxidant enzymes and enhance the degree of pain and loss of cartilage in older adults [35]. Lastly, sleep disturbance was closely correlated with the production of melatonin [36], which in turn plays an important role in the onset of OA by modulating the secretion of pro-inflammatory cytokines, cartilage-degrading enzymes, and inflammatory mediators [37]. Moreover, OA-related joint pain can lead to fatigue and poor sleep, which places a huge burden on an individual's daily functioning and quality of life [3].

For the health factor aspect, MetS is a risk factor for OA [37], and its components including overweight, dyslipidemia, hypertension, and impaired glucose tolerance are significantly associated with increased risk of OA [38, 39]. Obesity is a significant factor in the elevation of mechanical stress on weight-bearing joints, which can result in misalignment and adverse joint mechanics [40]. This heightened mechanical stress, in turn, can lead to cartilage degradation and the development of OA [41]. Meanwhile, OA is often considered a contributing factor in weight gain because joint pain limits an individual's activity and thus reduces caloric expenditure [42]. MetS and OA are linked to an increase in oxidative stress [37]. In the presence of interleukin-1β, elevated glucose levels, or increased fatty acid concentrations, chondrocytes, osteoblasts, and synovial cells overproduce reactive oxygen species [43, 44], which subsequently induce the oxidation of various proteins, lipids, and nucleic acids, ultimately resulting in alterations to their structure and function. Additionally, CVD prevention requires adherence to a healthy lifestyle [45] (regular PA, healthy eating patterns, adequate sleep, etc.) to reduce body weight and improve BP, blood sugar, and cholesterol levels. The improvement of these physiological indicators plays an important role in managing OA risks [46]. Furthermore, the development of both CVD and OA is closely linked to inflammation [47, 48]. Therefore, by protecting against CVD, the inflammatory activity can be mitigated, thus potentially inhibiting the inflammatory response associated with OA and slowing its progression. This may explain the relationship between LE8-evaluated CVH and OA among middle-aged and elderly people. In addition, the stratified results showed a stronger protective impact of the LE8-evaluated CVH on OA in participants aged > 60, at a lower education level, and those with lower PIR. These findings may be largely related to baseline differences in CVH status (Table S4; $P < 0.001$), and thus the marginal benefit from following the LE8 guidelines may be stronger for them. However, the mechanisms of these findings need to be further investigated.

To the best of our knowledge, this is the first study to examine the association of CVH measured by LE8 scores with OA among the middle-aged and elderly population, utilizing a national representative sample from NHANES. Additionally, we also performed RCS models to explore the dose-response relationships between LE8 and OA across various subgroups, including age, gender, and race/ethnicity. However, several limitations to this study need to be considered. First, due to the cross-sectional study design, we are unable to determine the causality and temporality of LE8 and OA. Second, the ascertainment of OA was based on self-report data, which may cause measurement errors and recall bias. This shortcoming in the diagnostic criteria may lead to biased estimates of OA. Third, due to the limitations of the NHANES dataset in acquiring detailed information regarding the specific location of OA, we are unable to categorize the type of OA (e.g., hip, knee, spine). Finally, our study is unable to completely eliminate residual or unknown confounding, which may arise from measurement errors and unmeasured variables (i.e., psychosocial stress or genetic susceptibility).

Conclusions

LE8-evaluated CVH levels were inversely associated with OA risks in the middle-aged and elderly U.S. population, indicating that maintaining the optimal CVH level may potentially contribute to the management of OA risks.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12891-025-08781-y.

Supplementary Material 1

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Author contributions

DM: Conceptualization, Software, Data curation, Formal analysis, Visualization, Writing - original draft & editing.; YHL: Software, Data curation, Formal analysis, Visualization, Writing - original draft & editing. SYG: Methodology, Formal analysis, Writing - Review & editing; PZ: Conceptualization, Writing - Review & editing. All authors read and approved the final manuscript.

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Data availability
The datasets generated and analyzed during the present study are available from the NHANES databases (Available from https://www.cdc.gov/nchs/nhanes/participant.htm).

Declarations

Ethics approval and consent to participate
The ethics review board of the National Center for Health Statistics approved all NHANES protocols and written informed consent was obtained from all participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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