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Research article

The protective role of cardiovascular health against kidney stones: A study based on LE8 score

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ABSTRACT

Objectives: The American Heart Association recently released an updated algorithm for evaluating cardiovascular health (CVH)-Life's Essential 8 (LE8) score. Our objective was to investigate the correlation between levels of CVH, as determined by the LE8 score, and the risk of kidney stones among a representative sample of adults in the United States.

Methods: We included data from the National Health and Nutrition Examination Survey (NHANES) covering the years 2007–2016 for further analysis. The LE8 score, a comprehensive measurement ranging from 0 to 100, was used to evaluate overall CVH and classified into three categories: low (0–49), moderate (50–79), and high (80–100) CVH. Logistic regression was employed to assess the association between the LE8 score and kidney stones. Furthermore, sensitivity analysis was conducted to validate the findings, and the presence of a non-linear relationship was examined using restricted cubic spline (RCS) regression methods.

Results: A total of 19,988 participants were included in this study (weighted mean age, 47.99 years; 95 % confidence interval [CI]: 47.46–48.53 years), with 10,319 being female (weighted percentage, 51.98 %; 95 % CI: 51.26–52.71 %) and 1923 identified as having kidney stones (weighted percentage, 9.95 %; 95 % CI: 9.41–10.53 %). In the fully-adjusted multivariable model, higher LE8 scores were associated with prevalence of self-reported kidney stones (odds ratio [OR] for a 10-unit increase in score, 0.86; 95 % CI: 0.82–0.91), presenting a linear dose-response relationship. Compared to the low CVH group, participants in the moderate and high CVH groups exhibited a lower prevalence of kidney stones (OR = 0.80; 95 % CI: 0.69–0.92; OR = 0.54; 95 % CI: 0.43–0.69, respectively). Similar trends were observed when assessing the association between health behavior scores and kidney stones. Moreover, the negative correlation between the LE8 score and the prevalence of kidney stones was markedly more pronounced in various stratified analyses.

Conclusion: Our study suggests that a higher level of CVH, as assessed by the LE8 metrics, is independently associated with a lower prevalence of self-reported kidney stones in a linear relationship. Further research, particularly through longitudinal or intervention studies, is required to establish whether actively promoting optimal CVH levels can effectively reduce the incidence of kidney stones.

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1. Introduction

The increasing incidence of kidney stones, or renal calculi, poses significant health challenges, leading to discomfort, potential complications, and substantial societal economic burden [1–3]. These stones result from complex interactions among dietary, genetic, and environmental factors, with a notable recurrence rate of about 50 % over ten years [4,5]. Addressing these challenges requires an understanding of the multifaceted influences on kidney stone formation and the exploration of effective prevention strategies.

Introduced by the American Heart Association (AHA), the concept of cardiovascular health (CVH) has evolved from Life's Simple 7 (LS7) to the more comprehensive Life's Essential 8 (LE8) score, which now includes sleep health, reflecting its importance in overall well-being [6,7]. The LE8 suggests that lifestyle modifications along with these eight components could influence various health outcomes, including the risk of kidney stones. Despite known overlaps between CVH factors and kidney stone risk, a detailed examination of their relationship, particularly using the updated LE8 score, has not been conducted in the context of the U.S. adult population.

This study aims to investigate the association between the LE8 score and kidney stone prevalence, leveraging cross-sectional data from the National Health and Nutrition Examination Survey (NHANES).

2. Methods

2.1. Study population

The National Health and Nutrition Examination Survey (NHANES), which conducts a layered, sequential probability sampling of non-institutionalized US residents, functions as a sustained epidemiological study designed to collect vital data and gauge health conditions (https://wwwn.cdc.gov/nchs/nhanes/default.aspx). The comprehensive program has been approved by the Ethics Review Board of the National Center for Health Statistics (NCHS), and informed consent has been obtained from every individual involved. Information gathered in the cross-sectional study incorporates demographic details, dietary habits, physical health evaluations, and questionnaire responses. The NHANES process initiates with an in-home interview conducted by skilled interviewers, where questions are asked and automated data is obtained. Following this, all individuals involved visit a mobile health examination center, where professional staff acquire data on body dimensions and collect biological specimens.

Data for this cross-sectional study were sourced from the NHANES database, covering five consecutive cycles from 2007 to 2016, and included a total of 50,588 participants. We excluded individuals below the age of 20 years, pregnant individuals, and those lacking data on the LE8 metrics components. Furthermore, individuals not disclosing their kidney stone status were also excluded. Finally, we incorporated 19,988 participants with complete data into this study (Fig. 1).

2.2. Assessments of cardiovascular health

The evaluation of CVH was conducted using the LE8 score system. This scoring system includes eight distinct elements: diet, physical exertion, exposure to tobacco/nicotine, sleep duration, body mass index, non-HDL cholesterol, blood glucose levels, and blood pressure. The diet component within the LE8 score was assessed by calculating the Dietary Approaches to Stop Hypertension (DASH) diet score, using the average values from each dietary element gathered from two separate 24-h dietary recall sessions at the outset. Standardized questionnaires were employed to gather data on physical activity (self-reported minutes of intense or moderate

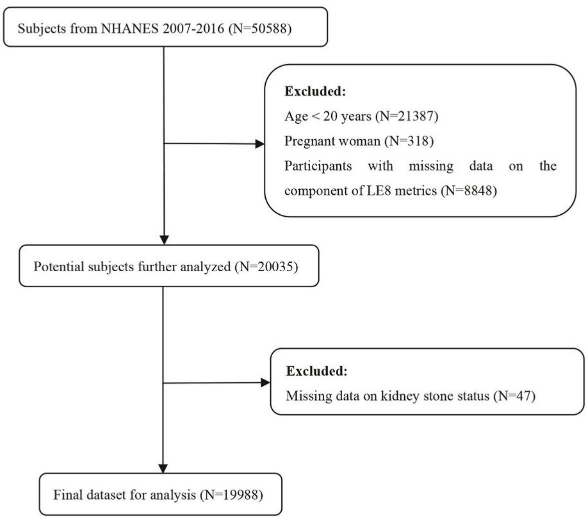

Fig. 1. Flow chart of the study population inclusion.

exercise weekly), exposure to tobacco/nicotine (usage of combustible tobacco and secondhand tobacco smoke exposure), sleep (sleep duration), and medication usage. Weight, height, blood glucose levels, and blood pressure were documented at mobile health examination centers, following standardized procedures. The body mass index (BMI) was computed by dividing the individual's weight in kilograms by the square of their height in meters. The mean value of all available blood pressure readings at the baseline was utilized to ascertain systolic and diastolic blood pressure. Serum cholesterol was determined enzymatically, while non-HDL cholesterol was calculated by subtracting HDL cholesterol from total cholesterol. Glycated hemoglobin (HbA1c) levels were measured utilizing high-performance liquid chromatography methods. The details and scoring algorithm for each CVH metric has been provided in previous studies [8,9]. To simplify references in clinical or research contexts, the eight measures constituting the updated CVH definition have been assembled into two primary categories: health behaviors (encompassing diet, physical activity, nicotine exposure, and sleep) and health factors (including body mass index, blood lipids, blood glucose, and blood pressure). Each individual CVH metric has a scale from 0 to 100 points. The cumulative CVH score was obtained by adding the points for the 8 measures, dividing the total by 8, and this too varies from 0 to 100 points. A superior score is indicative of better CVH. As per the AHA's guidelines, we classified the overall CVH into low (LE8 score less than 50), moderate (LE8 score equal to or above 50 but below 80), and high (LE8 score equal to or above 80) categories [7].

2.3. Outcome and exposure variables

The outcome was whether participants ever had kidney stones. The questionnaire results ascertain if the participant has a history of kidney stones. A positive response to the question "Have you ever had kidney stones?" leads us to presume that the participant has a past experience with kidney stones. The self-reported questionnaire has been validated and demonstrated a high level of accuracy, correctly identifying 97 % of individuals with clinically diagnosed kidney stones [10]. The exposure variable was the CVH, which was classified into, low, moderate, and high categories.

2.4. Variables

In order to increase accuracy and credibility, we included the following covariates: age, gender, race, marital status, education level, family poverty income ratio (PIR), BMI, smoking status, history of malignancy, history of diabetes, history of hypertension, history of congestive heart failure, history of coronary heart disease, history of angina, and history of stroke. The ages were categorized into four groups: 20–34, 35–49, 50–64, and 65 years and above. Race/ethnicity was categorized as on-Hispanic white, non-Hispanic black, Mexican-American, and others. Levels of educational attainment were classified into three levels: less than high school, high school or equivalent, and high school above. PIR was derived by dividing the monthly family income by the poverty levels, and it was classified into three categories: less than 1.3 (indicating low income), between 1.3 and 3.5 (representing middle income), and more than 3.5 (signifying high income). As for BMI, it's considered underweight if less than 18.5 kg/m^2, normal weight from 18.5 to 24.9 kg/m^2, overweight from 25 to 29.9 kg/m^2, and obese if 30 kg/m^2 or more. Marital status was categorized as unmarried and married. History of malignancy was obtained by questionnaire. Self-reported cardiovascular disease (CVD) included congestive heart failure, coronary artery disease, angina pectoris, heart failure, heart attacks, and strokes. According to two questions: "Smoked at least 100 cigarettes in your life" and "Do you smoke now", the smoking status was classified as never smoker, former smoker, and current smoker. Diabetes was classified through criteria such as a patient's self-reported diagnosis, a fasting plasma glucose (FPG) level of 7.0 mmol/L or greater, an HbA1c concentration of 6.5 % or higher, or the consumption of medication intended for blood glucose regulation. Hypertension, on the other hand, was characterized based on physician-diagnosed cases, intake of antihypertensive drugs, or instances wherein the average systolic blood pressure exceeded 140 mmHg or diastolic blood pressure was 90 mmHg or higher upon examination.

2.5. Statistical analysis

Within the NHANES, a sophisticated multistage sampling methodology was implemented, and relevant sampling weights were applied in the statistical evaluations. According to the method recommended on the NHANES website (https://www.cdc.gov/nchs/nhanes/index.htm), we merged the sample weights across five consecutive cycles using a weight suitable for the least frequently collected variable of interest. Categorical variables were presented as weighted percentages, and continuous variables as weighted means, with corresponding confidence intervals (CIs). We developed three logistic regression models to investigate the relationship between LE8 and kidney stones. The crude model was adjusted for no covariates. Model 1 was a minimally-adjusted model adjusted for age, gender, race/ethnicity, family PIR, BMI, marital status, and education level. Model 2 was further adjusted for smoke status, history of malignancy, history of diabetes, and history of hypertension. Subgroup analyses were also conducted to validate the association between LE8 and kidney stones among different subgroups, classified by attributes such as age, gender, race/ethnicity, BMI, marital status, level of education, smoking status, history of malignancy, history of diabetes, and history of hypertension. Interaction tests were also carried out to assess the individualized effects of LE8 on kidney stones across the subgroups. If the interaction *P*-value is not significant, then the results of the different strata are reliable; otherwise, there may be a specific population. Utilizing this more comprehensive model, a restricted cubic spline function was deployed to clarify the dose-response linkage between the levels of LE8 and the prevalence of kidney stones.

We also conducted additional sensitivity analyses to assess the robustness of our results. In our sensitivity analyses, we used E-values to quantify the potential impact of unmeasured confounding on the observed associations [11]. The E-value, defined as the minimum strength of association that an unmeasured confounder would need to have with both the exposure and outcome to fully explain away the observed association, was calculated for both the point estimate and the limit closest to the null of the 95 % confidence interval. Higher E-values suggest that the observed associations would be more difficult to explain away by an unmeasured confounder. Additionally, we excluded participants with self-reported histories of cardiovascular disease (including coronary heart disease, angina, heart attack, heart failure, and stroke) in order to evaluate the strength and consistency of our findings. Statistical significance was defined as $P < 0.05$ (two-sided). All statistical analyses were performed using R version 3.4.3 (http://www.R-project.org, The R Foundation), unless otherwise noted.

Table 1
Characteristics of study participants of adults from National Health and Nutrition Examination Survey 2007–2016 according to Life's Essential 8 (LE8) score, weighted.

Characteristic	Low (LE8 <50)	Moderate (50 ≤ LE8 <80)	High (LE8≥80)	*P*-value
Age (years)	54.42 (53.73–55.10)	49.18 (48.65–49.72)	42.02 (41.12–42.93)	<0.001
Sex				<0.001
Female	53.58 (50.87–56.27)	48.79 (47.87–49.71)	59.85 (57.85–61.83)	
Male	46.42 (43.73–49.13)	51.21 (50.29–52.13)	40.15 (38.17–42.15)	
Race				<0.001
Non-Hispanic white	7.10 (5.24–9.54)	8.36 (6.79–10.24)	7.11 (5.86–8.62)	
Non-Hispanic black	15.84 (13.00–19.16)	10.83 (9.30–12.57)	5.91 (4.96–7.02)	
Mexican-American	67.74 (63.19–71.98)	69.45 (66.06–72.63)	72.81 (69.74–75.67)	
Others	9.32 (7.59–11.39)	11.37 (10.05–12.83)	14.17 (12.39–16.16)	
Education level				<0.001
Less than high school	27.39 (24.69–30.26)	16.17 (14.73–17.72)	7.36 (6.32–8.55)	
High school or equivalent	30.21 (26.94–33.69)	24.40 (23.12–25.73)	12.16 (10.88–13.57)	
High school above	42.40 (39.25–45.62)	59.43 (57.19–61.64)	80.48 (78.36–82.44)	
Marital status				<0.001
Unmarried	40.32 (37.59–43.11)	35.27 (33.76–36.81)	33.21 (30.92–35.59)	
Married	59.68 (56.89–62.41)	64.73 (63.19–66.24)	66.79 (64.41–69.08)	
Poverty income ratio				<0.001
< 1.3	34.04 (30.89–37.34)	20.87 (19.17–22.69)	13.71 (11.89–15.75)	
1.3–1.5	40.32 (37.48–43.23)	37.05 (35.45–38.67)	30.31 (27.72–33.05)	
> 1.5	25.64 (22.08–29.55)	42.08 (39.62–44.58)	55.98 (52.52–59.38)	
BMI (kg/m^2)				<0.001
< 18.5	0.33 (0.15–0.72)	1.24 (1.04–1.48)	2.52 (1.97–3.22)	
18.5–24.9	6.46 (5.27–7.90)	20.97 (19.94–22.04)	58.07 (55.98–60.14)	
25–30	18.75 (16.80–20.88)	36.59 (35.46–37.75)	32.22 (30.40–34.11)	
≥ 30	74.45 (71.86–76.88)	41.20 (39.94–42.47)	7.18 (6.26–8.23)	
History of malignancy				<0.001
No	88.01 (86.37–89.48)	88.47 (87.76–89.14)	92.33 (91.25–93.28)	
Yes	11.99 (10.52–13.63)	11.53 (10.86–12.24)	7.67 (6.72–8.75)	
Smoke status				<0.001
Never	24.52 (22.25–26.93)	51.62 (50.06–53.19)	79.76 (77.52–81.83)	
Former	28.48 (26.39–30.66)	27.72 (26.47–29.01)	18.05 (16.24–20.00)	
Now	47.00 (44.51–49.51)	20.66 (19.55–21.81)	2.19 (1.59–3.01)	
History of CVD				<0.001
No	78.77 (76.39–80.97)	91.16 (90.48–91.80)	97.45 (96.76–97.99)	
Yes	21.23 (19.03–23.61)	8.84 (8.20–9.52)	2.55 (2.01–3.24)	
History of diabetes				<0.001
No	64.27 (61.69–66.78)	90.01 (89.37–90.61)	98.96 (98.46–99.29)	
Yes	35.73 (33.22–38.31)	9.99 (9.39–10.63)	1.04 (0.71–1.54)	
History of hypertension				<0.001
No	30.58 (28.48–32.77)	58.12 (56.82–59.40)	88.16 (86.80–89.40)	
Yes	69.42 (67.23–71.52)	41.88 (40.60–43.18)	11.84 (10.60–13.20)	
Total CVH score	42.14 (41.85–42.43)	66.18 (65.94–66.41)	86.78 (86.54–87.01)	<0.001
HEI diet score	19.93 (18.73–21.13)	35.68 (34.79–36.57)	59.69 (58.28–61.10)	<0.001
Physical activity score	26.10 (23.84–28.35)	72.36 (71.22–73.51)	95.44 (94.90–95.99)	<0.001
Tobacco/nicotine exposure score	41.55 (39.38–43.71)	69.28 (68.10–70.47)	91.68 (90.60–92.76)	<0.001
Sleep health score	66.00 (64.51–67.49)	82.78 (82.19–83.37)	92.69 (92.05–93.33)	<0.001
Body mass index score	32.57 (30.91–34.23)	56.76 (55.92–57.61)	85.02 (84.12–85.92)	<0.001
Blood lipids score	43.43 (41.80–45.07)	60.73 (59.97–61.48)	82.51 (81.53–83.50)	<0.001
Blood glucose score	61.09 (59.68–62.51)	85.39 (84.87–85.90)	97.58 (97.15–98.01)	<0.001
Blood pressure score	46.43 (44.93–47.92)	66.43 (65.57–67.29)	89.61 (88.80–90.42)	<0.001

For continuous variables: survey-weighted mean (95 % CI), *P*-value was by survey-weighted linear regression.
For categorical variables: survey-weighted percentage (95 % CI), *P*-value was by survey-weighted Chi-square test.

3. Results

3.1. Characteristics of the study population

After screening as required, a total of 19,988 participants were included in this study (weighted mean age, 47.99 years; 95 % CI: 47.46–48.53 years), with 10,319 being female (weighted percentage, 51.98 %; 95 % CI: 51.26–52.71 %) and 1923 identified as having kidney stones (weighted percentage, 9.95 %; 95 % CI: 9.41–10.53 %). Weighted demographic baseline characteristics of included participants are presented in Table 1. Overall, substantial differences were noticed in both baseline demographic and clinical characteristics between participants in three CVH categories (all $P < 0.001$).

3.2. LE8 score and kidney stones

The age-adjusted prevalence of kidney stones was significantly lower in participants with high CVH (6.14 %, 95 % CI: 5.25%–7.02 %) than in those with moderate (9.71 %, 95 % CI: 9.21%–10.2 %) and low CVH (13.8 %, 95 % CI: 12.42–15.19 %; Fig. 2). After adjusting for multiple potential confounding variables, compared with the low CVH group, the odds ratios (ORs) of kidney stones were 0.80 (95 % CI: 0.69–0.92) in the moderate CVH group and 0.54 (95%CI: 0.43–0.69) in the high CVH group, respectively. Every 10 scores increase in LE8 score was associated with an 14 % (95 % CI: 9%–18 %) decrease in the prevalence of kidney stones (Table 2). A linear association was observed between the LE8 score and kidney stones ($P = 0.5208$ for nonlinearity; Fig. 3A).

The age-adjusted prevalence of kidney stones diminished as health behaviors shifted from low and moderate to high categories. In the fully adjusted multivariable regression analysis, being in the moderate (OR = 0.75; 95 % CI: 0.66–0.86) and high (OR = 0.61; 95 % CI: 0.52–0.72) health behavior groups were significantly associated with lower odds of reporting kidney stones. Every 10-point increase in health behaviors score was associated with a 10 % (95 % CI: 8.7%–9.3 %) decrease in the odds of reporting kidney stones. A linear association was observed between the health behaviors score and kidney stones ($P = 0.3316$ for nonlinearity; Fig. 3B).

The age-adjusted prevalence of kidney stones diminished as health factors shifted from low and moderate to high categories. However, in the fully multivariable regression analysis, moderate (OR = 0.94; 95 % CI: 0.82–1.09) and high health behavior (OR = 0.87; 95 % CI: 0.70–1.08) groups were not significantly associated with kidney stones prevalence. Every 10 scores increase in health behaviors score was not associated with the prevalence of kidney stones (OR = 0.97; 95 % CI: 0.93–1.02). A linear association was observed between the health factors score and kidney stones ($P = 0.8546$ for nonlinearity; Fig. 3C).

3.3. Subgroup and sensitivity analysis

A subgroup analysis was conducted to explore the potential factors modifying the association between LE8 and kidney stones prevalence (Fig. 4). The association of LE8 with kidney stones was consistent across age, gender, race/ethnicity, BMI, marital status, level of education, smoking status, history of malignancy, and history of diabetes (all $P > 0.05$). The results of interaction analysis indicated that the presence of a hypertension history modulated the relationship between LE8 and kidney stones prevalence (P for interaction = 0.0306). Nevertheless, given the unchanged directionality of this association, these findings might not hold significant implications in a practical clinical context. Besides, the results are consistent with the main conclusions in sensitivity analyses after excluding participants with self-reported histories of CVD (Table 3). We further performed a sensitivity analysis designed to access unmeasured confounding factors related to the exposures and outcomes by calculating E-values. The E-value formula yielded a value of E = 1.37 for the estimate, indicating that for unmeasured confounders related to LE8 and kidney stones, an unmeasured confounder would need to be associated (controlling for measured covariates) with either the exposure or outcome with an odds ratio (OR) of at

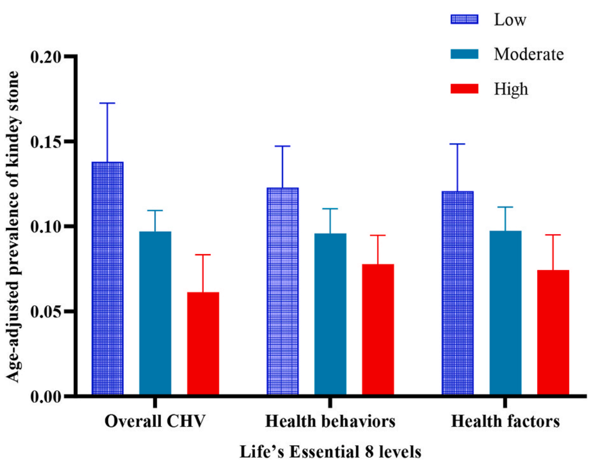

Fig. 2. Age-adjusted prevalence of kidney stones in three categories of Life's Essential 8 scores.

Table 2
Association of the Life's Essential 8 scores with the risk of kidney stones.

	Non-adjusted	Adjust I	Adjust II
Life's Essential 8 score			
Low (0–49)	1(Reference)	1(Reference)	1(Reference)
Moderate (50–79)	0.62 (0.54, 0.69) <0.001	0.69 (0.60, 0.78) <0.001	0.80 (0.69, 0.92) 0.0026
High (80–100)	0.30 (0.25, 0.35) <0.001	0.43 (0.35, 0.53) <0.001	0.54 (0.43, 0.69) <0.001
Per 10 points increase	0.78 (0.76, 0.81) <0.001	0.82 (0.79, 0.86) <0.001	0.86 (0.82, 0.91) <0.001
Health behaviors score			
Low (0–49)	1(Reference)	1(Reference)	1(Reference)
Moderate (50–79)	0.74 (0.66, 0.83) <0.001	0.74 (0.65, 0.83) <0.001	0.75 (0.66, 0.86) <0.001
High (80–100)	0.60 (0.52, 0.68) <0.001	0.59 (0.51, 0.68) <0.001	0.61 (0.52, 0.72) <0.001
Per 10 points increase	0.91 (0.89, 0.93) <0.001	0.90 (0.88, 0.93) <0.001	0.90 (0.87, 0.93) <0.001
Health factors score			
Low (0–49)	1(Reference)	1(Reference)	1(Reference)
Moderate (50–79)	0.69 (0.62, 0.77) <0.001	0.76 (0.67, 0.87) 0.0002	0.94 (0.82, 1.09) 0.4403
High (80–100)	0.38 (0.33, 0.43) <0.001	0.63 (0.52, 0.77) <0.001	0.87 (0.70, 1.08) 0.2112
Per 10 points increase	0.83 (0.81, 0.86) <0.001	0.90 (0.87, 0.93) <0.001	0.97 (0.93, 1.02) 0.2360

Non-adjusted model adjust for: none.
Adjust I model adjust for: sex, age, race, body mass index, marital status, and poverty income ratio.
Adjust II model adjust for: sex, age, race, body mass index, marital status, poverty income ratio, smoke status, history of malignancy, history of diabetes, and history of hypertension.

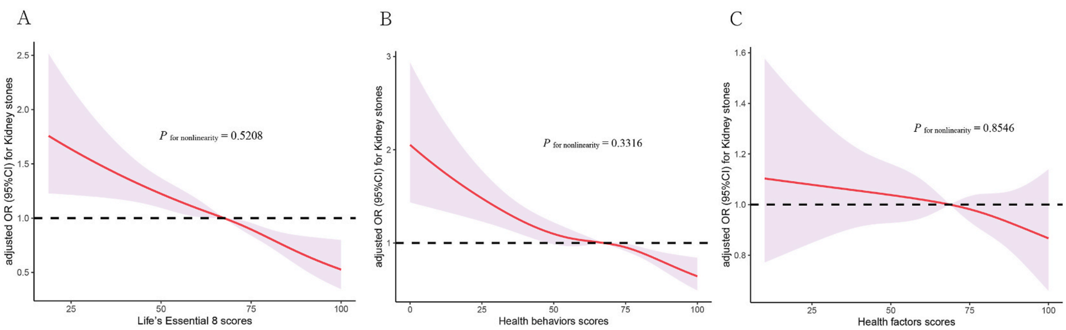

Fig. 3. Restricted cubic spline demonstrated the dose-response relationships between Life's Essential 8 scores (A), Health Behavior score (B), Health Factors Score(C), and kidney stones. ORs (red lines) and 95 % confidence levels (shaded areas) were adjusted for age, race/ethnicity, education level, sex, marital status, PIR, BMI, history of malignancy, history of diabetes, history of hypertension, and history of CVD. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

least 1.37 (e-value/high threshold), and with both the exposure and outcome with an OR of at least 1.27 (low threshold; Fig. 5). However, if the confounding is weaker, it would not have the same effect. Therefore, to some extent, the E-value supports the strength and reliability of this study.

4. Discussion

In a representative sample of US adults, the present study demonstrated that higher CVH-LE8 scores were associated with a lower prevalence of self-reported kidney stones after adjusting for multiple covariates, based on data from NHANES. Sensitivity analyses confirmed the robustness of the results. To our knowledge, this is the first cross-sectional study to investigate the associations of the new metric for evaluating CVH-LE8 score with kidney stones in US adults.

The population-based investigation has delineated a potent inverse relationship between LE8 score, a composite of CVH behaviors and health factors, and the prevalence of kidney stones. This finding substantially enhances the existing knowledge base by illuminating a potential protective impact of cardiovascular health promotion on renal health. Our findings thereby contribute to a growing body of evidence underscoring the benefits of adopting a comprehensive health promotion strategy to mitigate a diverse range of health risks [12]. Individuals with high CVH, as reflected by superior LE8 scores, demonstrated significantly reduced rates of kidney stone prevalence. This finding persisted even after adjustment for a multitude of potential confounders, suggesting that superior CVH could indeed serve as a protective factor against the development of kidney stones. This finding echoes the results of previous research, which have highlighted the presence of common risk factors and pathophysiological processes, such as hypertension, diabetes, and obesity, which exert deleterious effects on both the cardiovascular and renal systems [13,14].

The observation that a 10-point increment in the LE8 score was associated with decreased odds of reported kidney stone occurrence highlights the potential relationship between healthier lifestyles and the prevalence of kidney stones. This is in agreement with extant literature that supports the protective effect of certain dietary practices (e.g., high fluid intake, lower sodium intake, and moderate

Variables	OR(95%CI)	P for interaction
Gender		0.8709
Female	0.88 (0.82-0.94)	
Male	0.84 (0.78-0.90)	
Age (years)		0.3088
20-34	0.81 (0.69-0.94)	
35-49	0.83 (0.74-0.92)	
50-64	0.87 (0.80-0.94)	
≥65	0.89 (0.82-0.97)	
Race		0.5337
Mexican American	0.89 (0.77-1.02)	
Non-Hispanic Black	0.84 (0.73-0.96)	
Non-Hispanic White	0.88 (0.82-0.93)	
Other	0.82 (0.73-0.92)	
Education level		0.2776
Less than high school	0.92 (0.83-1.01)	
High school or equivalen	0.88 (0.80-0.98)	
High school above	0.83 (0.78-0.89)	
Marital status		0.4154
Unmarried	0.89 (0.82-0.96)	
Married	0.85 (0.80-0.90)	
BMI(kg/m^2)		0.2663
<18.5	1.06 (0.43-2.59)	
18.5-24.9	0.94 (0.84-1.06)	
25-30	0.88 (0.80-0.96)	
≥30	0.82 (0.76-0.88)	
History of malignancy		0.5403
No	0.86 (0.81-0.91)	
Yes	0.87 (0.76-0.99)	
Smoke status		0.8614
Never	0.86 (0.80-0.93)	
Former	0.84 (0.77-0.92)	
Now	0.92 (0.82-1.03)	
History of CVD		0.6067
No	0.86 (0.82-0.91)	
Yes	0.86 (0.77-0.97)	
History of diabetes		0.3347
No	0.87 (0.82-0.93)	
Yes	0.83 (0.75-0.92)	
History of hypertension		0.0306
No	0.84 (0.77-0.91)	
Yes	0.89 (0.83-0.95)	

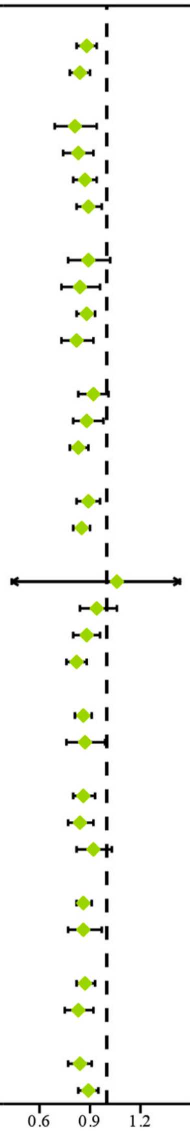

Fig. 4. Subgroup analysis of the association of Life's Essential 8 scores and the risk of kidney stones.

protein intake) against stone formation [15,16]. Similarly, regular engagement in physical activity has been identified as a protective factor against kidney stones, possibly mediated by resultant metabolic changes and modifications in body mass index [17].

However, our analysis revealed that health factors, when considered independently, were not significantly associated with kidney stone prevalence. This somewhat counterintuitive finding highlights the complexities of the underlying pathophysiology, underscoring the importance of considering the cumulative impact of a range of CVH factors, rather than considering them in isolation [18]. Further examination of our data via subgroup analysis revealed a consistent association across a variety of demographic and clinical variables. However, the presence of hypertension history emerged as a potential modifier of the relationship between LE8 scores and kidney stone prevalence, suggesting a complex interplay between hypertension, CVH, and kidney stone formation [19].

The possible link between CVH and kidney stones can be attributed to shared risk factors and underlying mechanisms. Metabolic syndrome components such as hypertension and diabetes, prevalent in poor CVH, can alter urinary composition, promoting stone formation. Additionally, cardiovascular dysfunction can lead to reduced renal blood flow, concentrating urinary solutes. The interplay of oxidative stress and systemic inflammation, common in suboptimal CVH, may further disrupt renal function and facilitate crystal aggregation. Furthermore, lifestyle elements integral to CVH, like diet and hydration, directly impact kidney stone risk. Thus, the association between CVH and kidney stones is supported by overlapping metabolic, hemodynamic, and inflammatory pathways, highlighting the need for integrated health management approaches.

Our research highlights the significance of the AHA's 2030 strategic objectives not just in relation to cardiovascular health, but

Table 3
Association of the Life's Essential 8 scores with the risk of kidney stones among adults from National Health and Nutrition Examination Survey 2007–2016 in different models after excluded individuals with cardiovascular disease.

	Non-adjusted	Adjust I	Adjust II
Life's Essential 8 score			
Low (0–49)	1(Reference)	1(Reference)	1(Reference)
Moderate (50–79)	0.64 (0.55, 0.74) <0.001	0.71 (0.60, 0.83) <0.001	0.79 (0.67, 0.94) 0.0073
High (80–100)	0.31 (0.26, 0.38) <0.001	0.44 (0.34, 0.55) <0.001	0.52 (0.40, 0.68) <0.001
Per 10 points increase	0.79 (0.77, 0.82) <0.001	0.84 (0.80, 0.88) <0.001	0.86 (0.82, 0.91) <0.001
Health behaviors score			
Low (0–49)	1(Reference)	1(Reference)	1(Reference)
Moderate (50–79)	0.77 (0.67, 0.87) <0.001	0.75 (0.65, 0.86) <0.001	0.74 (0.64, 0.86) 0.001
High (80–100)	0.62 (0.53, 0.72) <0.001	0.60 (0.51, 0.70) <0.001	0.59 (0.49, 0.72) <0.001
Per 10 points increase	0.91 (0.89, 0.94) <0.001	0.91 (0.88, 0.93) <0.001	0.90 (0.86, 0.93) <0.001
Health factors score			
Low (0–49)	1(Reference)	1(Reference)	1(Reference)
Moderate (50–79)	0.72 (0.63, 0.82) <0.001	0.78 (0.67, 0.91) 0.0014	0.96 (0.82, 1.14) 0.6528
High (80–100)	0.41 (0.35, 0.48) <0.001	0.66 (0.53, 0.82) 0.0002	0.90 (0.71, 1.14) 0.3861
Per 10 points increase	0.85 (0.83, 0.87) <0.001	0.91 (0.88, 0.95) <0.001	0.99 (0.94, 1.04) 0.6378

Non-adjusted model adjust for: none.
Adjust I model adjust for: sex, age, race, body mass index, marital status, and poverty income ratio.
Adjust II model adjust for: sex, age, race, body mass index, marital status, poverty income ratio, smoke status, history of malignancy, history of diabetes, and history of hypertension.

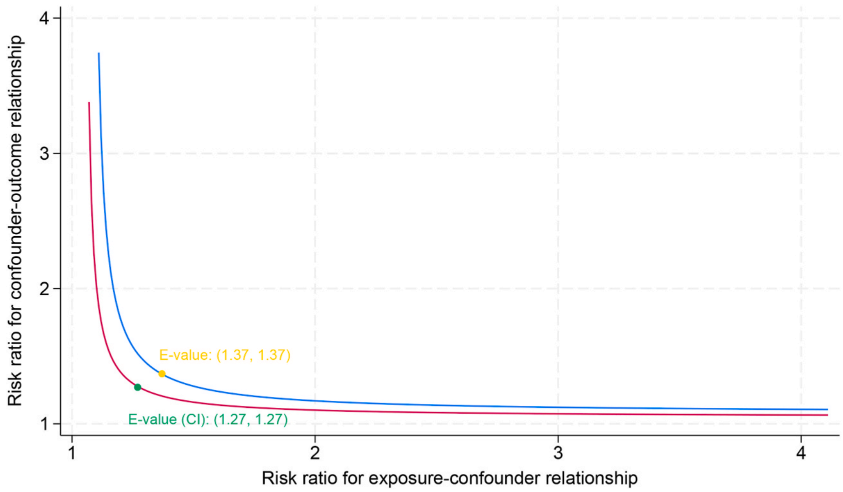

Fig. 5. This value signifies the lowest combined strength of association on the odds ratio scale that a not yet identified confounder must maintain with both the exposure and the outcome in order to completely account for the observed LE8-kidney stones odds ratio.

more broadly. It also advocates for the use of the LE8 in evaluating the prevalence of kidney stones and promoting kidney health. While our study brings new insights, it also has certain limitations that need to be addressed. One such limitation is the potential for unmeasured confounding variables. We attempted to ameliorate this by using E-value calculations to estimate the minimum strength of association that an unmeasured confounder would require to negate our observed associations. Encouragingly, the E-value obtained lends further credence to the reliability and robustness of our study findings. Thus, our findings emphasize the potential benefits of placing a high priority on optimal cardiovascular health in order to reduce the risk of kidney stones. Inherent differences among the groups defined by LE8 scores present a potential source of bias in our analysis. While we have endeavored to adjust for known confounders, the possibility of residual confounding remains. It's crucial to acknowledge that despite our rigorous statistical adjustments, unmeasured or unknown factors might still influence the observed associations. The cross-sectional design limits our ability to establish causality between cardiovascular health and kidney stone risk. While this design is effective for identifying associations, it limits our ability to infer causality. Longitudinal studies are needed to establish the temporal sequence of events and better ascertain causal relationships between cardiovascular health and kidney stone risk. Besides, another limitation of our study is the reliance on self-reported data for kidney stone history. Specifically, asymptomatic kidney stones that did not require medical intervention might not be reported, potentially leading to an underestimation of the true prevalence of kidney stones in our study population. Despite its limitations, this approach provides a valuable insight into the prevalence and relationships at the population level, especially when utilizing extensive datasets like NHANES. Future research is warranted to decipher the specific mechanisms underpinning this association and to explore how strategies to improve CVH can be effectively employed to prevent the onset of kidney stones.

5. Conclusions

Our study suggests a significant association between adherence to a high CVH level, as measured by the LE8 score, and a reduced prevalence of kidney stones. These findings highlight the potential link between cardiovascular health and kidney stone prevalence, underscoring the importance of CVH in overall health discussions. Moreover, our study highlights the potential benefits of utilizing the LE8 score as a practical and effective approach for enhancing kidney health. Longitudinal studies or intervention trials are needed to determine whether improving CVH levels can directly contribute to a reduction in the incidence of kidney stones.

Ethics approval and consent to participate

The research adhered to the ethical guidelines of the Declaration of Helsinki. The protocol for data collection was vetted and greenlit by the Research Ethics Review Board of the National Center for Health Statistics. Informed consent in writing was secured from every participant before undertaking the NHANES, and all information was anonymized by the NCHS before it was made accessible to the public (https://www.cdc.gov/nchs/nhanes/irba98.htm).

Consent for publication

Not applicable.

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Data availability statement

Publicly available dataset was analyzed in this study. The National Health and Nutrition Examination Survey dataset are publicly available at https://www.cdc.gov/nchs/nhanes/index.htm.

CRediT authorship contribution statement

Xingye Wang: Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hang Xie:** Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Xuegang Xie:** Writing – original draft, Visualization, Software, Resources, Investigation, Formal analysis, Data curation. **Yushun Zhang:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors 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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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e32497.

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