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Renal Disease

Association between Two Cardiovascular Health Algorithms and Kidney Stones: A Nationwide Cross-sectional Study

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Abstract

Background and objective: There is limited literature on the relationship between cardiovascular health (CVH) and kidney stones. This study aims to compare the association of Life's Simple 7 (LS7) and Life's Essential 8 (LE8) with kidney stone prevalence.
Methods: A cross-sectional analysis was conducted utilizing NHANES data (2007–2018). Participants aged $\geq$20 yr with a history of kidney stones and available LS7 and LE8 scores were included. Both LS7 and LE8 are scored such that higher scores indicate better CVH. Weighted proportions and multivariable logistic regression models assessed the relationship between CVH metrics and kidney stone prevalence, adjusting for confounders. The receiver operating characteristic (ROC) curve and the area under the ROC curve (AUC) were determined to distinguish between LS7 and LE8 in terms of their discriminative ability within the model associated with kidney stones.
Key findings and limitations: A total of 23 563 adults were included; the mean age was 48.1 yr (48.1% male). Kidney stone prevalence was 10.1%. The mean LS7 and LE8 scores were 8.4 and 68.6, respectively. A multivariate analysis and the restricted cubic spline model indicated a significant nonlinear negative correlation between these CVH measures and kidney stone prevalence. The LS7 ideal group showed a lower prevalence than the poor group (odds ratio [OR] = 0.53; 95% confidence interval [CI] 0.41–0.69). The high CVH group had a lower prevalence than the low CVH group (OR = 0.46; 95% CI 0.36–0.57). The AUCs for evaluating LS7 and kidney stones, as well as for LE8 and kidney stones were 0.676 and 0.677, respectively. Limitations were as follows: cross-sectional design limiting causal inference, recall bias from self-reported data, and potential residual confounding.
Conclusions and clinical implications: Both CVH algorithms show a significant nonlinear negative correlation with kidney stone prevalence. LS7 may be more accessible

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for broader implementation. Further high-quality prospective studies are needed to clarify this relationship.

Patient summary: In this study, we explored the connection between heart health and kidney stones using data from a large national survey. We found that better heart health, measured by two different scoring methods, is linked to a lower chance of having kidney stones. Our results suggest that promoting heart health could help reduce the risk of kidney stones in adults.

1. Introduction

Kidney stones represent a significant global public health burden, with their prevalence showing an increasing trend over the past five decades in numerous countries [1]. According to nationally representative cross-sectional surveys in the USA, the prevalence of kidney stones was reported to be 8.7% in 2007–2008 and increased to 10.1% in 2015–2016 [2]. Despite advances in treatment strategies, the post-treatment recurrence of kidney stones remains a challenge, with approximately 50% of individuals experiencing a second kidney stone episode within 10 yr [3]. Additionally, research suggests that recurrent stone disease is associated with a decline in renal function [4]. Therefore, it is crucial to explore both the risk and the protective factors for kidney stone formation.

In 2010, the American Heart Association (AHA) introduced the concept of the Life's Simple 7 (LS7) as a measure of cardiovascular health (CVH) [5]. LS7 encompasses diet quality, physical activity, cigarette smoking, body mass index (BMI), total cholesterol, blood pressure, and blood glucose levels [5]. While the introduction of this measure has been effective in promoting CVH, a report by the AHA in 2020 stated that the proportion of individuals with ideal CVH levels is low among the US population: only around 13% of US adults meet ideal levels in five categories, while just 5% have six ideal metrics; meeting all the seven criteria at ideal levels is virtually nonexistent [6]. Moreover, LS7 does not include sleep health, and its scoring system is relatively coarse, lacking sensitivity in explaining individual differences [7]. Considering these limitations, the AHA introduced a new enhanced method to assess CVH in 2022: Life's Essential 8 (LE8). LE8 has added sleep health as an additional component on top of the other seven factors and has updated the scoring methods for the existing components. Metrics such as diet quality [8], BMI, sleep health [9], hypertension [10,11], and blood glucose [12] are included as CVH indicators, with research suggesting a close association with kidney stones.

Despite the established link between these CVH metrics and kidney stones, a direct comparison of the associations of LS7 and LE8 with kidney stone prevalence remains sparse in the literature. Thus, this study aims to explore the relationship between these two CVH algorithms and the prevalence of kidney stones. This is a preliminary study evaluating the association between two CVH algorithms and kidney stones, intended to inspire further research into causal mechanisms if an association is identified.

2. Patients and methods

2.1. Study population

NHANES is a comprehensive program aimed at assessing the health and nutritional status of participants in the USA. We used data from six NHANES cycles (2007–2018) on kidney stones and LS7/LE8 components.

A total of 59 842 participants were included from 2007 to 2018. This cross-sectional study included only participants aged 20 yr or older (n = 34 770). Subsequently, pregnant participants (n = 372) and those with incomplete information on kidney stones or missing value of LE8 score (n = 10 835) were excluded. Ultimately, 23 563 participants were included for an analysis; the detailed criteria are shown in Supplementary Fig. 1.

The research ethics review board at the National Center for Health Statistics (NCHS) and all participants approved the study protocols for all NHANES investigations. This cross-sectional study adhered to the STROBE guidelines for reporting observational research findings [13].

2.2. Assessment of the prevalence of kidney stones

The primary outcome was whether participants ever had kidney stones. Kidney stone status was assessed through self-report. Within the NHANES questionnaire sections, individuals who responded "yes" to the question "have you/has the sample person (SP) ever had kidney stones?" were classified as having a history of kidney stones.

2.3. LS7 and LE8 assessment

The primary exposure factors were LS7 and LE8 scores for assessing CVH [7]. LS7 includes diet, physical activity, smoking, BMI, cholesterol, glucose, and blood pressure. LE8 consists of four health behaviors (diet, physical activity, nicotine use, and sleep) and four health factors (BMI, non–high-density lipoprotein cholesterol, glucose, and blood pressure).

Supplementary Tables 1 and 2 provide detailed algorithms for scoring LS7 and LE8, respectively. The dietary component is assessed using the Healthy Eating Index (HEI), with detailed calculation methods found in Supplementary Table 3 (HEI-2010 [14]) and Supplementary Table 4 (HEI-2015 [15]). Based on previous literature, the total LS7 score is further classified into three categories: poor (0–4), intermediate (5–9), and ideal (10–14) [16]. Similarly, LE8 is divided into three categories: low (0–49), moderate (50–79), and high (80–100) CVH [7].

2.4. Covariates

Covariates were selected based on their known or potential association with kidney stone risk as identified in previous literature, as well as some demographic variables. Several demographic covariates were taken into account during the adjustment process. These covariates included age (categorized into four groups: 20–34, 35–49, 50–64, and ≥65 yr), gender, race, marital status, education, poverty income ratio (PIR; categorized as ≤1.3, >1.3 and ≤3.5, >3.5), total plain water drank yesterday (including plain tap water, water from a drinking fountain, water from a water cooler, bottled water, and spring water), and daily total energy intake. Additionally, self-reported chronic conditions were included as binary variables (yes/no), including gout, stroke, cardiovascular disease (CVD; defined as the presence of at least one of the following heart diseases: coronary heart disease, angina, and congestive heart failure), and cancer. Year cycle was also included as a covariate. We adjusted for sleep duration (<7, 7–9, and >9 h) in analyzing LS7 and kidney stones. To handle missing values, dummy variables were utilized to indicate missing covariate values for variables with a missing rate exceeding 2%.

2.5. Statistical analysis

We applied complex sampling weights as recommended by the Centers for Disease Control and Prevention (CDC) in our analysis. To ensure the accuracy of our estimates, sample weights from six cycles were combined, as outlined in the NHANES website (https://www.cdc.gov/nchs/nhanes/index.htm). In the baseline characteristics table, continuous variables were presented as survey-weighted means with corresponding 95% confidence intervals (CIs), while categorical variables were reported as survey-weighted percentages along with their 95% CIs.

To investigate the relationship between the two CVH algorithms and kidney stones, three logistic regression models were performed. Model 1 was unadjusted; model 2 (minimally adjusted model) adjusted for age (category), gender, and race; and model 3 (fully adjusted model) added PIR (category), education, marital status, energy intake, gout, stroke, CVD, cancer, and year cycle. Model 3 also adjusted for sleep duration regarding LS7 and kidney stones. We conducted multivariable logistic regression with LS7 and LE8 scores as both continuous and categorical variables (LE8: low [0–49], moderate [50–79], and high [80–100]; LS7: poor [0–4], intermediate [5–9], and ideal [10–14]) [7,16]. The trends were evaluated by treating the LS7 and LE8 score categories as continuous variables. In addition, we used restricted cubic spline models with three knots (10th, 50th, and 90th percentiles) to explore potential nonlinear associations. The number of knots was determined based on the Akaike information criterion (AIC), with the optimal knot number corresponding to the minimum AIC value. Subgroup analyses were conducted using multivariable logistic regression to identify potential effect modifiers. Except for the variables used to define subgroups, all other covariates were adjusted for in the analyses. In addition, we employed the Pearson correlation coefficient to assess the linear correlation between LE8 and LS7.

To quantify the strength of associations between exposure variables and outcomes, we performed a receiver operating characteristic (ROC) curve analysis. The ROC curve plots the sensitivity (true positive rate) against 1 – specificity (false positive rate) at various threshold settings. The area under the ROC curve (AUC) was calculated as a measure of model discrimination, with values ranging from 0.5 (no discrimination) to 1.0 (perfect discrimination). While our study focused on associations rather than prediction, these metrics were used to evaluate the overall strength of relationships in our logistic regression models. We compared AUC values across different models using DeLong's test for correlated ROC curves.

All analyses were performed using R 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria) and EmpowerStats (http://www.empowerstats.com). A two-tailed p value of <0.05 was considered significant.

3. Results

3.1. Characteristics of population, outcome, and exposure factors

Supplementary Fig. 1 describes the inclusion and exclusion criteria. A total of 34 770 participants aged 20 yr or older were enrolled in this study. We excluded 372 pregnant individuals and 10 835 cases with incomplete information regarding kidney stones or missing values for LE8 scores; 23 563 eligible individuals remained for subsequent analyses.

Table 1 presents the baseline population characteristics according to the categories of LE8 scores. The weighted mean age (95% CI) of all included individuals was 48.1 (47.6, 48.6) yr, with 48.1% (47.4%, 48.9%) being males. The proportion of individuals being "college graduate or above" was significantly higher in the high CVH group at 52.3% (49.4%, 55.1%), compared with 11.8% (9.9%, 14.1%) in the low CVH group and 27.0% (25.0%, 29.1%) in the moderate CVH group. Furthermore, the proportion of individuals with PIR >3.5 in the high CVH group was higher than that in the other two groups, at 52.0% (49.2%, 54.8%). Notably, the proportions of stroke, CVD, gout, and cancer were lower in the high CVH group, with respective values of 0.8% (0.5%, 1.1%), 2.8% (2.2%, 3.6%), 1.6% (1.0%, 2.4%), and 7.4% (6.5%, 8.4%). The unweighted number of missing PIR data cases was 1775, accounting for an unweighted proportion of 8.35%.

The overall prevalence of kidney stones was 10.1% (95% CI 9.6–10.7%). The mean LS7 score was 8.4 (95% CI 8.3–8.5), while the mean LE8 score was 68.6 (95% CI 68.1–69.1). In the low, moderate, and high CVH groups, the corresponding LS7 scores were 4.6 (95% CI 4.5–4.7), 8.0 (95% CI 8.0–8.0), and 11.2 (95% CI 11.2–11.3), respectively. The corresponding LE8 scores were 42.3 (95% CI 42.0–42.7), 66.2 (95% CI 65.9–66.4), and 86.9 (95% CI 86.6–87.1), respectively. The LS7 ideal group accounted for 34.2% (95% CI 32.8–35.7) of the total population. The prevalence of kidney

Table 1 – Characteristics of participants by categories of Life's Essential 8 scores: NHANES 2007–2018[a]

Characteristic	All mean (95% CI)	Low CVH (0–49)	Moderate CVH (50–79)	High CVH (80–100)
Age (yr)	48.1 (47.6, 48.6)	55.0 (54.3, 55.6)	49.3 (48.8, 49.9)	41.8 (41.0, 42.7)
Age category (%)				
20–34	25.8 (24.6, 27.1)	10.1 (8.9, 11.4)	23.1 (21.8, 24.4)	40.4 (37.7, 43.1)
35–49	27.4 (26.39, 28.36)	25.0 (23.0, 27.2)	27.3 (26.2, 28.4)	28.5 (26.4, 30.7)
50–64	27.7 (26.7, 28.8)	38.6 (35.8, 41.6)	28.6 (27.5, 29.8)	20.5 (18.6, 22.4)
≥65	19.1 (18.2, 20.0)	26.3 (24.2, 28.5)	21.0 (19.9, 22.1)	10.7 (9.3, 12.2)
Female (%)	51.9 (51.1, 52.6)	53.7 (51.1, 56.3)	48.8 (47.9, 49.7)	59.4 (57.5, 61.3)
Race/ethnicity (%)				
Mexican American	7.9 (6.6, 9.4)	7.0 (5.4, 9.1)	8.2 (6.8, 9.8)	7.4 (6.2, 8.9)
Other Hispanic	5.5 (4.6, 6.5)	5.0 (3.8, 6.5)	5.5 (4.6, 6.6)	5.7 (4.7, 6.8)
Non-Hispanic White	69.3 (66.6, 72.0)	67.0 (62.9, 70.8)	69.0 (66.0, 71.7)	71.4 (68.6, 74.1)
Non-Hispanic Black	10.2 (9.0, 11.7)	15.7 (13.2, 18.5)	10.9 (9.5, 12.5)	6.0 (5.10, 7.0)
Other races	7.1 (6.4, 7.8)	5.3 (4.3, 6.7)	6.4 (5.8, 7.2)	9.5 (8.3, 10.9)
Education (%)				
<9th grade	4.5 (4.0, 5.0)	8.4 (7.0, 10.1)	4.5 (4.0, 5.1)	2.6 (2.1, 3.2)
9–11th grade	9.7 (8.9, 10.6)	17.2 (15.3, 19.2)	10.4 (9.5, 11.3)	4.6 (3.9, 5.4)
High school graduate	22.9 (21.8, 24.1)	31.2 (28.4, 34.1)	25.2 (24.0, 26.5)	13.0 (11.7, 14.3)
Some college	31.5 (30.4, 32.7)	31.5 (29.3, 33.7)	32.9 (31.7, 34.2)	27.6 (25.2, 30.1)
College graduate or above	31.4 (29.4, 33.5)	11.8 (9.9, 14.1)	27.0 (25.0, 29.1)	52.3 (49.4, 55.1)
Marital (%)				
Married	56.6 (55.1, 58.1)	50.6 (48.0, 53.1)	56.7 (55.2, 58.3)	58.9 (56.3, 61.5)
Widowed	5.5 (5.2, 5.9)	9.4 (8.2, 10.7)	6.1 (5.7, 6.6)	2.3 (1.9, 2.8)
Divorced	10.3 (9.7, 10.9)	15.4 (13.8, 17.3)	10.9 (10.2, 11.6)	6.4 (5.5, 7.5)
Separated	2.2 (2.0, 2.5)	2.9 (2.3, 3.6)	2.5 (2.3, 2.8)	1.1 (0.8, 1.6)
Never married	17.5 (16.3, 18.7)	12.7 (11.1, 14.5)	15.8 (14.6, 17.1)	24.2 (22.1, 26.4)
Living with partner	7.9 (7.3, 8.5)	9.0 (7.8, 10.4)	8.0 (7.2, 8.7)	7.1 (6.2, 8.1)
PIR category (%)				
≤1.3	18.9 (17.7, 20.2)	30.5 (28.0, 33.3)	18.9 (17.6, 20.4)	13.6 (12.1, 15.2)
>1.3 and ≤3.5	33.2 (31.9, 34.6)	38.4 (36.0, 40.9)	34.1 (32.7, 35.6)	28.5 (26.3, 30.8)
>3.5	41.1 (39.1, 43.2)	23.7 (20.7, 26.9)	40.0 (37.9, 42.1)	52.0 (49.2, 54.8)
Missing	6.7 (6.1, 7.4)	7.4 (6.0, 9.0)	6.9 (6.3, 7.7)	5.9 (5.1, 6.9)
Energy (kcal)	2169 (2151, 2188)	2065 (2010, 2120)	2193 (2170, 2215)	2152 (2119, 2184)
Plain water intake (g)	1160 (1129, 1191)	1016 (955, 1078)	1123 (1088, 1159)	1324 (1278, 1371)
Stroke (%)	3.0 (2.3.2)	8.1 (6.99.4)	2.9 (2.6.3)	0.8 (0.51.1)
CVD (%)	8.8 (8.2, 9.3)	21.8 (19.7, 24.0)	8.8 (8.2, 9.5)	2.8 (2.2, 3.6)
Gout (%)	4.1 (3.7, 4.5)	8.5 (7.2, 9.9)	4.3 (3.9, 4.8)	1.6 (1.0, 2.4)
Cancer (%)	10.7 (10.2, 11.3)	12.5 (11.0, 14.2)	11.7 (11.0, 12.4)	7.4 (6.5, 8.4)
Kidney stones (%)	10.1 (9.6, 10.7)	15.3 (13.5, 17.2)	10.9 (10.3, 11.6)	5.8 (4.9, 6.7)
Life's Simple 7 and ideal Life's Simple 7 component count				
Life's Simple 7 score	8.4 (8.3, 8.5)	4.6 (4.5, 4.7)	8.0 (8.0, 8.0)	11.2 (11.2, 11.3)
Life's Simple 7 score category (%)				
Poor (0–4)	5.5 (5.1, 5.9)	46.2 (43.8, 48.6)	1.0 (0.8, 1.2)	0.0 (0.0, 0.0)
Intermediate (5–9)	60.3 (58.8, 61.7)	53.8 (51.4, 56.2)	80.4 (79.3, 81.4)	7.7 (6.7, 8.8)
Ideal (10–14)	34.2 (32.8, 35.7)	0.0 (0.0, 0.0)	18.6 (17.6, 19.6)	92.3 (91.2, 93.3)
Life's Simple 7 ideal component count (%)				
0 ideal component	4.2 (3.9, 4.5)	26.3 (24.4, 28.3)	2.2 (1.9, 2.6)	0.0 (0.0, 0.1)
1 ideal component	13.2 (12.6, 13.8)	44.2 (41.7, 46.7)	12.8 (12.1, 13.6)	0.5 (0.3, 0.8)
2 ideal components	20.6 (19.8, 21.5)	24.2 (22.3, 26.2)	26.6 (25.6, 27.6)	2.8 (2.2, 3.6)
3 ideal components	23.3 (22.4, 24.1)	5.2 (4.3, 6.3)	30.9 (29.9, 32.0)	10.2 (9.0, 11.4)
4 ideal components	20.4 (19.8, 21.1)	0.2 (0.1, 0.4)	21.0 (20.0, 22.0)	27.7 (26.2, 29.3)
5 ideal components	12.8 (12.2, 13.5)	0.0 (0.0, 0.0)	6.4 (5.8, 7.0)	36.3 (34.7, 37.9)
6 ideal components	5.1 (4.6, 5.7)	0.0 (0.0, 0.0)	0.1 (0.1, 0.2)	21.2 (19.6, 22.9)
7 ideal components	0.3 (0.2, 0.5)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	1.3 (0.9, 1.9)
Life's Essential 8 and its component scores (out of 100 possible points)				
Life's Essential 8 score	68.6 (68.1, 69.1)	42.3 (42.0, 42.7)	66.2 (65.9, 66.4)	86.9 (86.6, 87.1)
HEI-2015 score	39.6 (38.7, 40.5)	20.7 (19.6, 21.9)	35.4 (34.5, 36.2)	59.7 (58.5, 60.9)
Physical activity score	73.7 (72.7, 74.6)	27.6 (25.3, 29.9)	73.2 (72.2, 74.3)	95.3 (94.7, 95.8)
Nicotine exposure score	72.2 (71.2, 73.2)	42.9 (40.9, 45.0)	69.7 (68.6, 70.8)	91.9 (91.0, 92.9)
Sleep health score	83.5 (82.9, 84.1)	66.3 (64.7, 67.8)	82.9 (82.4, 83.5)	92.6 (92.0, 93.2)
Body mass index score	60.2 (59.4, 61.1)	31.5 (30.0, 32.9)	55.9 (55.0, 56.8)	85.0 (84.2, 85.8)
Blood lipid score	64.7 (64.0, 65.4)	44.4 (42.9, 45.9)	61.3 (60.5, 62.1)	83.2 (82.1, 84.2)
Blood glucose score	85.4 (84.9, 85.9)	60.3 (58.9, 61.7)	85.0 (84.4, 85.5)	97.6 (97.2, 98.0)
Blood pressure score	69.4 (68.7, 70.1)	45.1 (43.6, 46.5)	65.9 (65.1, 66.8)	89.7 (88.9, 90.4)

CI = confidence interval; CVD = cardiovascular disease; CVH = cardiovascular health; HEI = Healthy Eating Index; PIR = poverty income ratio.
[a] For continuous variables: survey-weighted mean (95% CI); for categorical variables: survey-weighted percentage (95% CI).

stones in these three groups was 15.3% (13.5%, 17.2%), 10.9% (10.3%, 11.6%), and 5.8% (4.9%, 6.7%), respectively. Concurrently, it was observed that higher LE8 score groups corresponded to higher component scores, with similar findings noted for LS7 as well.

3.2. *Associations of the two CVH algorithms with kidney stones*

Table 2 demonstrates a consistent negative association between LS7 and LE8 scores and the prevalence of kidney stones across all three models. Specifically, higher LS7 and

Table 2 – Association between LE8 and LS7 scores with kidney stones

Exposure	OR (95%CI)		
	Model 1 [a]	Model 2 [b]	Model 3 [c]
LS7 score category [d]			
Poor (0–4)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Intermediate (5–9)	0.65 (0.53, 0.80)	0.70 (0.56, 0.87)	0.77 (0.61, 0.98)
Ideal (10–14)	0.34 (0.27, 0.43)	0.45 (0.36, 0.57)	0.53 (0.41, 0.69)
	All p values for trend <0.001		
LS7 score (continuous) [d]	0.86 (0.84, 0.88)	0.89 (0.87, 0.91)	0.91 (0.88, 0.93)
LE8 score category			
Low CVH (0–49)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Moderate CVH (50–79)	0.68 (0.58, 0.80)	0.72 (0.61, 0.86)	0.77 (0.65, 0.92)
High CVH (80–100)	0.34 (0.28, 0.42)	0.41 (0.34, 0.51)	0.46 (0.36, 0.57)
	All p values for trend <0.001		
LE8 score (continuous, per 10 score)	0.78 (0.76, 0.81)	0.81 (0.78, 0.84)	0.82 (0.79, 0.86)

CVD = cardiovascular disease; CVH = cardiovascular health; LE8 = Life's Essential 8; LS7 = Life's Simple 7; PIR = poverty income ratio; Ref = reference.
[a] Nonadjusted model: adjusted for none.
[b] Minimally adjusted model: adjusted for gender, age, and race.
[c] Fully adjusted model: adjusted for gender, age, race, PIR, education, marital status, energy, gout, stroke, CVD, cancer, plain water intake, and year cycle.
[d] Fully adjusted model: adjusted for gender, age, race, PIR, education, marital status, energy, gout, stroke, CVD, cancer, plain water intake, year cycle, and sleep duration.

LE8 scores were associated with a lower prevalence of kidney stones. The ideal group exhibited a significantly lower kidney stone prevalence than the poor group in model 1 (odds ratio [OR] = 0.34; 95% CI 0.27–0.43), model 2 (OR = 0.45; 95% CI 0.36–0.57), and model 3 (OR = 0.53; 95% CI 0.41–0.69). The high CVH group showed a significantly lower kidney stone prevalence than the low CVH group in model 1 (OR = 0.34; 95% CI 0.28–0.42), model 2 (OR = 0.41; 95% CI 0.34–0.51), and model 3 (OR = 0.46; 95% CI 0.36–0.57). A trend analysis revealed a statistically significant trend with a p value of <0.001 in all three models. Higher LS7 and LE8 scores were associated with a lower prevalence of kidney stones across all models. In the fully adjusted model, the ORs were 0.91 for LS7 per score and 0.82 for LE8 per 10 score, both with p values being <0.001. Additionally, Supplementary Figs. 2A and 2B demonstrate a significant nonlinear association ($p < 0.01$ for nonlinearity) between LS7 and LE8 scores, and the prevalence of kidney stones.

3.3. Subgroup analyses

Subgroup analyses (Fig. 1A) indicated no significant interaction effects in the relationship between LS7 and kidney stones. Additionally, after adjusting for other covariates, subgroup analyses (Fig. 1B) revealed that age served as an effect modifier in the relationship between LE8 scores and kidney stones.

3.4. Pearson correlation

A further correlation analysis revealed a Pearson correlation coefficient of 0.91 ($p < 0.001$), indicating a very strong positive correlation between LS7 and LE8 (Supplementary Fig. 3).

3.5. Model performance

The AUC value of the model assessing the association between LS7 and kidney stones was 0.676 (95% CI 0.665–0.687), while the AUC value of the model for LE8 and kidney stones was 0.677 (95% CI 0.665–0.688). The p value for the comparison between the two models was 0.67. The ROC curves and AUCs are shown in Fig. 2.

4. Discussion

The findings of this cross-sectional study revealed a statistically significant nonlinear inverse association between the two CVH algorithms and the prevalence of kidney stones, even after adjusting for potential confounders. Based on the ROC and AUC results, both LS7 and LE8 exhibit comparable performance in evaluating their association with kidney stone prevalence.

Previous literature has indicated a close association between LS7 and LE8 components and kidney stones. In terms of diet, studies have shown a negative association between dietary quality measured by the HEI-2015 score and the incidence of kidney stones [8]. A cross-sectional study conducted on the NHANES population revealed a negative association between physical activity and the incidence of kidney stones [17]. Additionally, a sleep duration of 7–9 h has been linked to a lower prevalence of kidney stones than shorter sleep durations of <7 h [9]. Furthermore, other research has demonstrated an association between BMI [12,18], smoking [19], blood lipids [20], blood glucose [12], blood pressure [10,11], and a higher incidence of kidney stones. Therefore, it is not surprising that LS7 and LE8 scores—incorporating several of these indicators—correlate with the kidney stone prevalence. These findings underscore the importance of lifestyle modifications and improvements in the aforementioned indicators for the prevention and management of kidney stones. However, most prior research has focused on individual factors associated with kidney stones, lacking comprehensive lifestyle recommendations specifically targeted at individuals with kidney stones. Currently, LS7 and LE8 are comprehensive and easily applicable assessment tools in clinical settings. Our study expands the scope of beneficial health outcomes associated with ideal CVH indicators beyond CVDs and indicates that

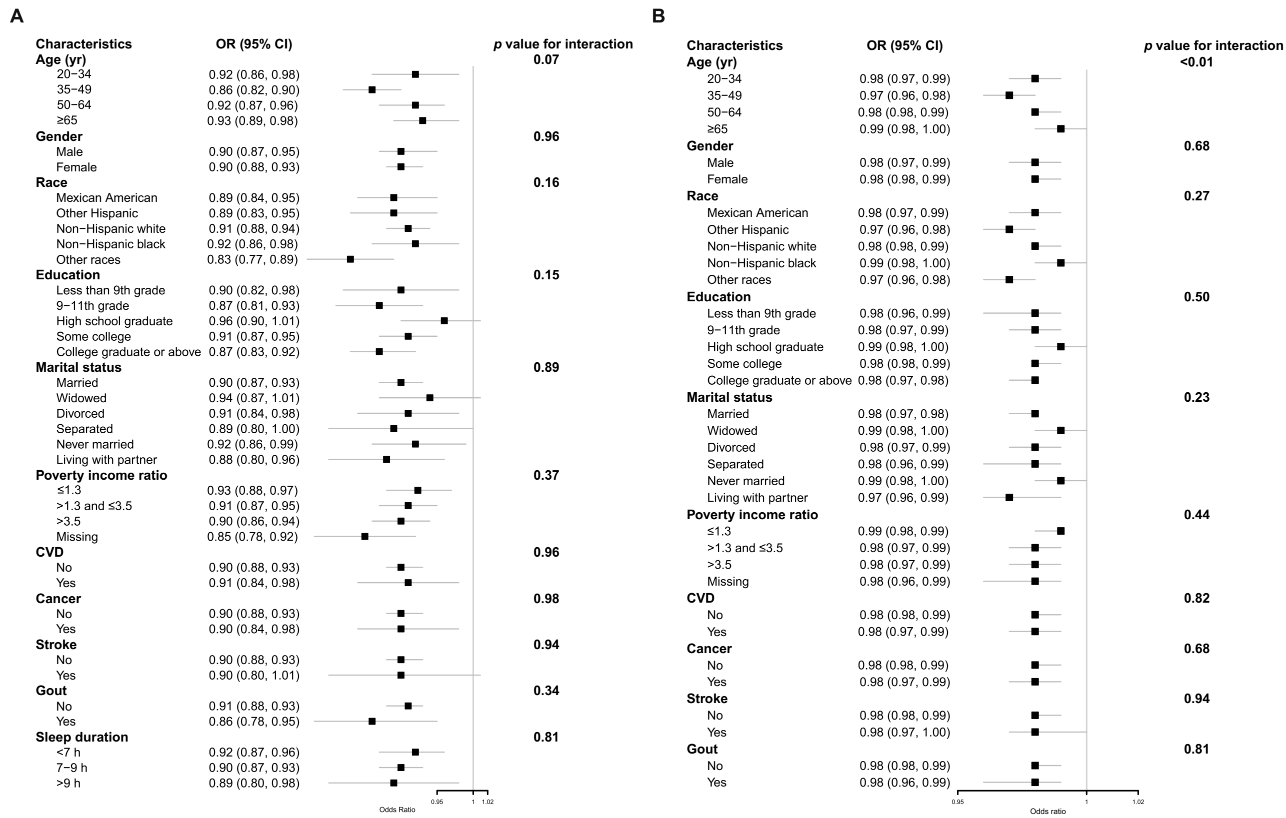

Fig. 1 – Subgroup analysis of the association of Life's Simple 7 and Life's Essential 8 with kidney stones. (A) Subgroup analysis of the link between Life's Simple 7 and the prevalence of kidney stones. (B) Subgroup analysis of the association between Life's Essential 8 and the prevalence of kidney stones. CI = confidence interval; CVD = cardiovascular disease; OR = odds ratio.

adhering to ideal CVH indicators may be an appropriate preventive and management strategy for alleviating the burden of kidney stones and other chronic conditions, including nonalcoholic fatty liver disease [21], chronic kidney disease [22], and CVD [23].

There are currently no studies directly comparing the associations of LS7 and LE8 with kidney stones; however, previous research examining their links to various diseases has yielded differing conclusions [24–27]. For instance, Li and Dai [27] conducted a study using the NHANES database, revealing that the association between LE8 and depression was stronger and more practical than that of LS7. Similarly, Herraiz-Adillo et al [25] found that while predictive capacities for coronary computed tomographic angiography stenosis were comparable between LE8 and LS7, LE8 exhibited slightly higher predictive capacity for any stenosis. Another study involving 11 609 participants indicated that both LS7 and LE8 were associated with the incidence of CVD, with minimal distinction between the two metrics. LS7, being simpler, may be more favorable among the general population and clinical practitioners [26]. Conversely, Gao et al [24] found that LE8 outperformed LS7 in predicting the risk of future major adverse cardiac events. Howard et al [26] suggested that discrepancies between their findings and those of Gao et al [24] could stem from substantial differences in populations and outcomes, complicating comparisons between studies. In our study, we observed that LS7 and LE8 exhibited comparable associations with kidney stones. Given the lack of direct comparisons in existing literature, we cannot draw further distinctions. Based on our findings of ROC and AUC, both LS7 and LE8 demonstrate similar performance; however, the greater accessibility of LS7 may facilitate its broader application and dissemination. Considering the substantial overlap between the components of LS7 and LE8, we conducted a correlation analysis, which revealed significant linear correlations between the two indicators, providing additional evidence for their comparability. Importantly, while the direction of effect sizes remained consistent across age groups, subgroup analyses indicated that age modulates the relationship between LE8 and kidney stones. Therefore, we believe that future research exploring individual and intraindividual variations in CVH scores in relation to kidney stones would be insightful and meaningful.

Our findings demonstrate a significant association between CVH metrics and kidney stone prevalence, although the relationship appears to be complex and potentially bidirectional. Poor CVH may contribute to kidney stone formation; however, Bhattacharyya et al [28] reported that kidney stone patients have an increased 10-yr risk for major cardiovascular events, suggesting that reverse causation is also plausible. Several mechanisms could explain this bidirectional relationship: kidney stones and their treatments may influence CVH through changes

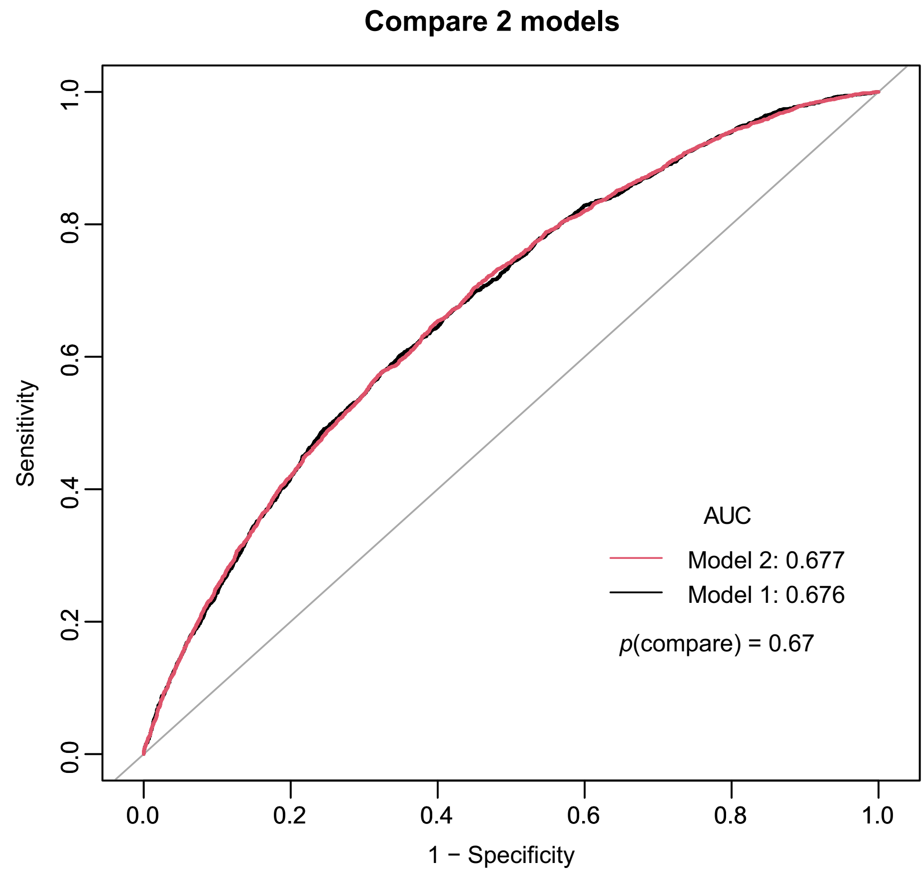

Fig. 2 – ROC curves and the area under the curves (AUC) for the two models. Model 1: fully adjusted multivariable logistic regression model evaluating the association between Life's Simple 7 and kidney stones. Model 2: fully adjusted multivariable logistic regression model evaluating the association between Life's Essential 8 and kidney stones.

in dietary habits, physical activity levels, sleep patterns, or treatment-related effects, while CVH factors may, in turn, influence kidney stone formation. Given the cross-sectional design of our study, we are unable to definitively determine the temporal sequence or causal direction of these associations. This complexity emphasizes both the need for longitudinal studies to establish temporal relationships and potential causal pathways, and the importance of considering a holistic approach to patient care that addresses both CVH and kidney health simultaneously. The potential for reverse causation has several implications for our analysis. First, the observed associations between CVH metrics and kidney stones may reflect complex bidirectional relationships rather than simple unidirectional effects, as discussed above. This means that our reported ORs should be interpreted as measures of association rather than causal effects. Second, the temporal ambiguity inherent in our cross-sectional design makes it impossible to determine whether changes in CVH preceded or followed kidney stone development. Finally, this bidirectional relationship could influence the magnitude of our observed associations, potentially leading to an over- or underestimation of the true relationship between CVH and kidney stones.

4.1. *Strengths and limitations*

This study has several strengths. First, it uses a large-scale nationally representative analysis to explore the relationship between LS7, LE8, and kidney stone prevalence. Although cross-sectional, the representative sample enhances generalizability. Second, it considers various potential confounders, enhancing result reliability. This is the first comparison of LS7 and LE8 concerning kidney stones, providing valuable insights for clinical practice.

However, limitations remain. The cross-sectional design restricts causal inference. Future longitudinal studies would be valuable to investigate whether poorer CVH is associated with increased recurrence of kidney stone episodes over time. A recall bias may influence self-reported data from NHANES; the timing between kidney stone events and the completion of the CVH questionnaires was not established, which could introduce a potential recall bias or changes in lifestyle between these time points. In addition, residual confounding from unknown variables may persist. This study relied on self-reported history of kidney stones, which may be subject to a recall bias and lacks clinical confirmation. Future studies using medical records or imaging confirmation of kidney stones would be valuable to validate our findings. Additionally, the NHANES database lacks information on kidney stone composition, such as calcium oxalate or uric acid stones. This limitation may obscure or dilute associations that are specific to certain types of kidney stones.

5. Conclusions

This study demonstrates a significant nonlinear negative correlation between LS7 and LE8 scores and kidney stone prevalence. While both algorithms exhibit comparable associations, the greater accessibility of LS7 may enhance its feasibility for a broader application. Further high-quality prospective studies are required to investigate the causality and underlying mechanisms of this association.

***Author contributions*:** Shan Yin had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Critical revision of the manuscript for important intellectual content: Yin, Z. Yang, Zhu, X. Yang, Yu, Tang, Borné.
Statistical analysis: Yin, Z. Yang, Zhu, X. Yang, Yu, Tang.
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***Data sharing*:** The data presented in this study are available on the NHANES website (https://www.cdc.gov/nchs/nhanes/index.htm).

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.euros.2025.01.003.

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