



Contents lists available at ScienceDirect

The Journal of Prevention of Alzheimer's Disease

journal homepage: www.elsevier.com/locate/tjpad

Original Article

Association of the cumulative modified life's Essential 8 score with cognitive change: Results from two longitudinal cohorts

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ARTICLE INFO

Keywords:

Cardiovascular health
Life's Essential 8
Cumulative LE8
Cognitive change
Cohort study

ABSTRACT

INTRODUCTION: Although a higher baseline Life's Essential 8 (LE8) score is linked to better cognitive performance and slower decline, it remains unclear whether the cumulative LE8 score is associated with cognitive change in later life.**METHODS:** We included 1345 participants from the Health and Retirement Study (HRS) and 2865 participants from the English Longitudinal Study of Ageing (ELSA). A modified LE8 score was constructed based on sleep, physical activity, smoking, body mass index, blood lipids, blood glucose, and blood pressure. The cumulative modified LE8 score was calculated using 8 years of LE8 assessments. The association between cumulative modified LE8 score and cognitive change was examined using the linear mixed model.**RESULTS:** Results from the HRS and the ELSA demonstrated general consistency. Pooled analysis showed that a per SD increase in cumulative modified LE8 score was associated with a slower rate of decline in global cognition (pooled Beta=0.089 SD/year), executive function (pooled Beta=0.093 SD/year), memory (pooled Beta=0.050 SD/year), and orientation (pooled Beta=0.040 SD/year).**DISCUSSION:** A higher cumulative modified LE8 score was associated with better late-life cognition, highlighting the importance of maintaining long-term optimal cardiovascular health for preventing cognitive decline.

1. Introduction

Dementia is characterized by the progressive deterioration of cognitive functions, including memory and thinking [1,2]. With the increase in life expectancy, the prevalence of cognitive impairment has been rising [3]. It is estimated that the disability-adjusted life years of Alzheimer's disease and other dementia reached 113.5 million in 2022 and are projected to increase to 191.1 million by 2050, representing a substantial public health burden [4]. Given that no effective cure for dementia is available, identifying risk factors associated with cognitive decline is of critical importance [5].

Existing evidence indicates that vascular risk factors (VRFs) are

significant contributors to cognitive decline [6]. Previous studies have observed associations between individual VRFs, such as blood pressure, Hemoglobin A1c (HbA1c), blood lipids, and physical activity, and changes in cognitive function [7–10]. In 2010, the American Heart Association (AHA) introduced the Life's Simple 7 (LS7), a set of seven modifiable VRFs (smoking, diet, and physical activity [PA], body mass index [BMI], total cholesterol, blood pressure, and fasting plasma glucose), to promote ideal cardiovascular health (CVH) [11]. The LS7 was updated in 2022 to Life's Essential 8 (LE8), which incorporated sleep as the eighth component [12]. Numerous studies have demonstrated that both ideal LS7 and LE8 scores are associated with better cognitive performance and slower cognitive decline [13–16]. However,

List of abbreviations: AHA, American Heart Association; BMI, Body mass index; CI, Confidence interval; CVH, Cardiovascular health; ELSA, English Longitudinal Study of Ageing; HbA1c, Hemoglobin A1c; HRS, Health and Retirement Study; IQR, Interquartile range; LE8, Life's Essential 8; LS7, Life's Simple 7; MET, Metabolic equivalent of task; Non-HDL, Non-high-density lipoprotein cholesterol; PA, Physical activity; SD, Standard deviation; VRFs, Vascular risk factors.

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<https://doi.org/10.1016/j.tjpad.2026.100548>

Received 3 January 2026; Received in revised form 27 February 2026; Accepted 16 March 2026

Available online 26 March 2026

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these studies only focused on single-time-point measurements of CVH. Although two studies examined the association of changes in LS7 score, which occurred between baseline and another time point, with cognitive decline and incident dementia,[17,18] the relationship between long-term integration of LE8 exposure, or cumulative LE8, and cognitive change remains poorly understood. A recent study found that a higher cumulative LE8 score was associated with a lower risk of incident cardiovascular disease,[19] yet the association between cumulative LE8 and cognitive function has not been thoroughly investigated.

To address this gap, we aimed to examine the association of the cumulative LE8 score over 8 years with cognitive change among older adults from two nationally representative longitudinal cohorts. We hypothesized that a higher cumulative LE8 score would be associated with a slower rate of cognitive decline during follow-up. The results of the present study could enhance the understanding of how long-term maintenance of ideal CVH is associated with later-life cognitive change, thereby informing strategies for dementia prevention.

2. Methods

2.1. Study design and population

This cohort study used data from the Health and Retirement Study (HRS) and the English Longitudinal Study of Ageing (ELSA). These are two community-based, nationally representative longitudinal cohorts conducted in the USA and England, respectively. A detailed introduction of these two cohorts can be found elsewhere [20–22]. In brief, the HRS commenced in 1992 (wave 1) and followed up participants biennially until 2022 (wave 16), and the ELSA commenced in 2002 (wave 1) and followed up biennially until 2023 (wave 11). The HRS was approved by the Institutional Reviewing Board at the University of Michigan and the National Institute on Aging (HUM00061128), and the ELSA was approved by the London Multicenter Research Ethics Committee (MREC/01/2/91). Both cohorts were composed of people aged 50 and over and their partners, and collected extensive data across various domains, such as demographics, physical and psychosocial health, and cognitive function. All participants had provided written informed consent. This study followed the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) reporting guideline.

Fig. 1 presents the study timeline. We used wave 8 to wave 12 of the HRS and wave 2, wave 4, and wave 6 of the ELSA to calculate the

cumulative LE8 score. These waves were selected because they included blood sample collections for the assessment of biological markers relevant to the LE8 metric. Wave 12 of the HRS and wave 6 of the ELSA were defined as baseline. Using repeated measurements of cognition from all core interviews between baseline and the last follow-up, we investigated whether cumulative LE8 score predicted longitudinal cognitive change over the next 8 years in the HRS and 11 years in the ELSA.

Participants were excluded if they met any of the following criteria: (1) had fewer than 2 times of LE8 assessments (HRS: $N = 16,698$, ELSA: $N = 19,067$); (2) had no data on cognitive tests at baseline (HRS: $N = 446$, ELSA: $N = 423$); (3) had dementia at baseline (HRS: $N = 122$, ELSA: $N = 75$); (4) had fewer than 1 time of follow-up (HRS: $N = 136$, ELSA: $N = 277$); (5) had missing data on covariates (HRS: $N = 0$, ELSA: $N = 247$). We defined baseline dementia cases by using self-reported physician diagnosis or an alternative approach based on cognition and functionality scores. In the HRS, a composite score of ≤ 6 points for memory and executive function was used to define dementia; in the ELSA, dementia was defined as the coexistence of cognitive and functional impairment. Cognitive impairment was defined as a performance of 1.5 standard deviations below the education-stratified population mean. Functional impairment refers to reported difficulty with one or more basic activities of daily living, such as getting into and out of bed, walking across a room, bathing, dressing, and eating. These definitions have been validated using data from the HRS and ELSA cohorts, respectively [8]. The final analytical sample consisted of 4210 participants, including 1345 from the HRS and 2865 from the ELSA. Supplementary Figure S1 shows the flowchart of the participant selection process.

2.2. Measurements of the modified LE8 score

Because neither HRS nor ELSA collected diet information during core interviews, we constructed a modified LE8 score based on the remaining seven components: three health behaviors (sleep, PA, smoke) and four biological factors (BMI, blood lipids, blood glucose, and blood pressure) [12]. This approach is consistent with prior studies adapting the AHA's ideals CVH metrics to available cohort data [23]. The measurements of all seven variables were fully consistent between the HRS and ELSA cohorts. Sleep was assessed by asking participants about their average hours of sleep per night. PA was collected by asking participants "frequency of doing moderate or vigorous sports". Based on previous studies [24,25] the five response options- "never", "1 to 3 times per month",

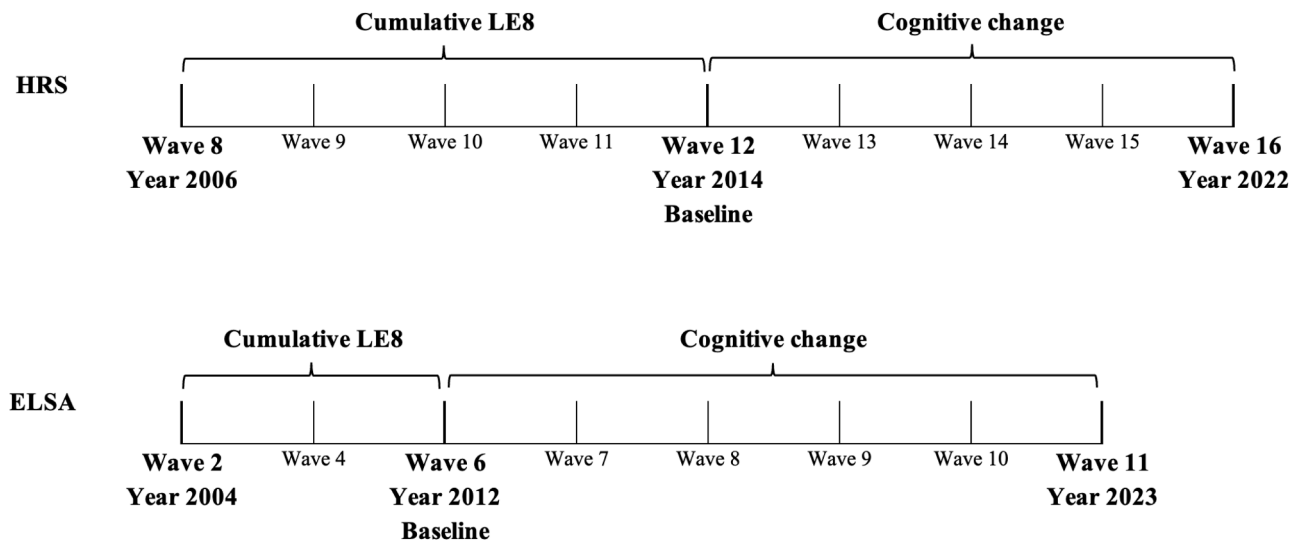


Fig. 1. Timeline of the study.

The vertical lines represent each separate survey for the HRS (Health and Retirement Study) and the ELSA (English Longitudinal Study of Ageing), with the length between lines indicating the interval between two consecutive surveys in years. We used wave 8 to wave 12 in the HRS and wave 2, wave 4, and wave 6 in the ELSA to calculate the cumulative LE8 score.

“once per week”, “more than once per week”, and “everyday”- were coded as 0 to 4, respectively. And the metabolic equivalent of task (MET) was calculated as the sum of moderate PA frequency multiplied by 1.4 and vigorous PA frequency multiplied by 1.8 [24,25]. Smoke was assessed based on participants’ responses to questions regarding “whether they had ever smoked” and “whether they currently smoke”. A diet score was unavailable because neither HRS nor ELSA collected diet information during core interviews. BMI was calculated as body weight (kilograms) divided by height (meters) squared. Blood samples were collected and sent to a central laboratory for measurement of non-high-density lipoprotein cholesterol (non-HDL) and HbA1c. Blood pressure was measured three times for each participant; the mean systolic and diastolic blood pressure values were calculated from the second and third measurements, or from all available valid measurements. Information on the use of antihypertensive medications, statins, or other cholesterol-lowering drugs, as well as insulin or other oral diabetes medications, was also obtained via questionnaires. Participants were considered to have diabetes if they had any of the following: elevated HbA1c levels ($\geq 6.5\%$), use of insulin or oral medications, and self-reported history of diabetes [26].

Each metric described above was scored from 0 to 100 points in accordance with the AHA’s recommendations,[12] and the modified LE8 score was calculated as the mean of these seven metric scores. A higher modified LE8 score indicates better CVH. More details and scoring algorithms are presented in Supplementary Table S1.

2.3. Definition of the cumulative LE8 score

Similar to previous studies, [27,28] the cumulative modified LE8 score over an 8-year period was quantified as the percentage of the maximum possible LE8 score achieved across wave 8 to wave 12 in the HRS and wave 2, wave 4, and wave 6 in the ELSA. First, the modified LE8 score was calculated at each visit. The original cumulative modified LE8 score was then derived as the area under the modified LE8 score-follow-up time curve over the 8-year period. Next, the maximum possible cumulative modified LE8 score over the 8-year period was computed. Finally, the cumulative modified LE8 score was calculated as a percentage by dividing the original cumulative modified LE8 score by the maximum possible cumulative modified LE8 score. A higher cumulative modified LE8 score over the 8-year period is indicative of a more favorable CVH profile sustained over time. An example illustrating the calculation of the cumulative modified LE8 score is provided in Supplementary Figure S2.

2.4. Assessment of cognitive function

Executive function, memory, and orientation were assessed in both cohorts. In the HRS, executive function was evaluated using the Serial Sevens Test and backward counting; in the ELSA, it was assessed via a verbal fluency task. Memory was measured using immediate and delayed word recall tests, and orientation was evaluated with a date naming task, both of which were consistent across the two cohorts. All cognitive tests demonstrated good validity and reliability, with higher scores indicating better cognitive performance [29–31]. Further details are available in previous studies [7,32].

To compare the rate of cognitive change across different domains, we computed standardized Z-scores for each of the three cognitive domains by subtracting the corresponding mean and dividing by the baseline standard deviation (SD) of the test scores. A global cognitive Z-score was then computed by averaging the three domain-specific Z-scores and re-standardized it using baseline values. Thus, a global cognitive Z-score of 1 at any follow-up wave indicated that the cognitive performance score was 1-SD above the baseline mean score. This method for generating standardized Z-scores is well-established and has been widely used among other studies [32–34].

2.5. Covariates

Based on previous literature, [35–37] the following covariates were included: age at baseline, sex (male or female), race/ethnicity (White or non-White), higher education (defined as attaining a college or university degree or other professional qualifications), current drinking (consumption of alcohol at least once per week), and stroke history (self-reported diagnosis at baseline). All covariates were assessed through questionnaires.

2.6. Statistical analysis

The baseline characteristics of participants in both cohorts were summarized using means and SD or the median and interquartile range (IQR) for continuous variables, and frequencies and percentages for categorical variables. We categorized all participants into four groups based on their distribution (quartile 1 to quartile 4). As appropriate, the comparison of baseline characteristics among the four groups was tested via ANOVA, Wilcoxon rank test, or χ^2 test.

The association of the cumulative modified LE8 score with cognitive change was investigated by using the linear mixed model, with the intercept and slope of time fitted as random effects at the participant level. Given that the linear mixed model could handle data missing at random (e.g., missing cognitive test scores in this study), no further imputation was performed [32]. A fully adjusted model was constructed to control for potential confounders, including age, sex, race/ethnicity, educational level, alcohol consumption, and stroke history. All results were presented as Beta coefficients along with their 95% confidence intervals (CIs).

For the primary analysis, we assessed the association between the cumulative modified LE8 score and the rate of cognitive change (SD per year) in both global cognition and specific cognitive domains within each cohort. The cumulative modified LE8 score was analyzed both as a quartile variable and as a continuous measure standardized by subtracting the mean and dividing by the SD. Then a meta-analysis was performed to pool results from the two cohorts using a random-effects model, with heterogeneity quantified by the I^2 statistic. To better interpret the clinical relevance, we contextualized the magnitude of the cumulative modified LE8 association by comparing it directly to that of aging within the same fully adjusted model.

Subgroup and sensitivity analyses were also performed. First, we conducted subgroup analyses to examine the association of a 1-SD increase in the cumulative modified LE8 score with the rate of cognitive change stratified by sex (female, male), age (<70 years, ≥ 70 years), ethnicity (White, non-White), higher level of education (yes, no), current drinking (yes, no), and stroke history (yes, no) to investigate potential modifying factors. Second, to examine whether the cumulative modified LE8 score was associated with the rate of cognitive change independently of a single-time-point LE8 score, we further adjusted for the modified LE8 score at wave 8 in the HRS and wave 2 in the ELSA in the models. Third, we repeated the primary analysis by treating the cumulative behavioral and biological scores separately. The cumulative behavioral score included sleep, PA, and smoking; and the cumulative biological score included BMI, blood lipids, blood glucose, and blood pressure.

All statistical analyses were conducted using SAS version 9.4 (SAS Institute). Analysis was two-sided, with a threshold of statistical significance set at 0.05. Data were analyzed from May to September 2025.

3. Results

3.1. Participant selection and characteristics

Supplementary Figure S1 demonstrates the flowchart of the participant selection process in this study. We excluded participants with less than 2 times of LE8 measurements (HRS: $N = 16,698$, ELSA: $N =$

19,067), those did not attend cognitive tests at baseline (HRS: $N = 446$, ELSA: $N = 423$), those had dementia at baseline (HRS: $N = 122$, ELSA: $N = 75$), those lost follow (HRS: $N = 136$, ELSA: $N = 277$), and those had missing data on covariates (HRS: $N = 0$, ELSA: $N = 247$). Finally, we included 1345 participants from the HRS and 2865 participants from the ELSA in the main analysis.

Table 1 shows the baseline characteristics of included participants categorized by levels of cumulative modified LE8 score. In the HRS, the mean (SD) age was 75.5 (6.6) years, 549 (40.8%) were male, and the mean (SD) cumulative LE8 score was 67.5 (11.4). In the ELSA, the mean (SD) age was 69.5 (7.6) years, 1309 (45.7%) were male, and the mean (SD) cumulative modified LE8 score was 71.8 (10.8). Participants with higher cumulative modified LE8 scores had better memory and executive function, and were more likely to have a higher educational level and consume alcohol at least once per week. We also compared the characteristics of included participants between the HRS and the ELSA. Participants from the HRS were older, had a lower proportion of males and White individuals, a higher proportion of well-educated individuals, a lower prevalence of current drinking, and a higher prevalence of stroke

history (Supplementary Table S2).

3.2. Association of cumulative LE8 score with the rate of cognitive change

Table 2 presents the association of the cumulative modified LE8 score with the rate of cognitive change (SD/year) from the linear mixed models. After adjusting for age, sex, race/ethnicity, level of education, alcohol consumption, and stroke history, both separate and pooled results showed that a higher cumulative modified LE8 score was associated with slower cognitive decline in global cognition and executive function. For example, the quartile 4 group was associated with a slower rate of decline in global cognition in the HRS (Beta=0.277 SD/year, 95% CI: 0.115 to 0.440) and the ELSA (Beta=0.200 SD/year, 95% CI: 0.097 to 0.303), compared with the quartile 1 group. The pooled Beta was 0.222 SD/year (95% CI: 0.135 to 0.309, $I^2=0\%$). For memory and orientation, the results from two cohorts showed a slight difference. Still, the pooled results showed that a per-quartile increase in the cumulative modified LE8 was associated with a slower rate of memory decline (pooled Beta=0.045 SD/year, 95% CI: 0.020 to 0.070, $I^2=0\%$) and orientation

Table 1

Baseline characteristics of included participants according to cumulative modified LE8 score category from the HRS and the ELSA.

Characteristics	Total	Quartile 1	Quartile 2	Quartile 3	Quartile 4	P for difference
Health and Retirement Study (HRS)						
N	1345	342	316	356	331	
Age (years), mean (SD)	75.5 (6.6)	74.8 (5.9)	75.2 (6.4)	76.2 (7.1)	75.7 (6.8)	0.041
Sex, N (%)						0.547
Male	549 (40.8)	131 (38.3)	136 (43.0)	151 (42.4)	131 (39.6)	
Female	796 (59.2)	211 (61.7)	180 (57.0)	205 (57.6)	200 (60.4)	
Race/ethnicity, N (%)						0.001
White	1199 (89.1)	284 (83.0)	278 (88.0)	327 (91.8)	310 (93.7)	
Non-White	146 (10.9)	58 (17.0)	38 (12.0)	29 (8.2)	21 (6.3)	
Higher education, N (%)						<0.001
Yes	685 (50.9)	118 (34.5)	155 (49.1)	202 (56.7)	210 (63.4)	
No	660 (49.1)	224 (65.5)	161 (50.9)	154 (43.3)	121 (36.6)	
Current drinking, N (%)						<0.001
Yes	510 (37.9)	97 (28.4)	120 (38.0)	150 (42.1)	143 (43.2)	
No	835 (62.1)	245 (71.6)	196 (62.0)	206 (57.9)	188 (56.8)	
Stroke history, N (%)						0.552
Yes	113 (8.4)	35 (10.2)	24 (7.6)	29 (8.2)	25 (7.5)	
No	1232 (91.6)	307 (89.8)	292 (92.4)	327 (91.8)	306 (92.5)	
Cumulative LE8 score (%), mean (SD)	67.5 (11.4)	52.6 (6.4)	64.1 (2.1)	71.7 (2.4)	81.6 (4.4)	<0.001
Cumulative behavioral score (%), mean (SD)	69.4 (16.6)	53.5 (14.8)	66.2 (12.9)	73.2 (11.1)	84.7 (9.4)	<0.001
Cumulative biological score (%), mean (SD)	66.1 (13.8)	51.9 (10.7)	62.5 (9.6)	70.7 (8.5)	79.4 (8.2)	<0.001
Executive function, median (IQR)	6 (2)	6 (3)	6 (2)	6 (2)	6 (2)	<0.001
Memory, mean (SD)	9.8 (3.1)	9.3 (2.8)	9.9 (2.9)	9.8 (3.3)	10.2 (3.1)	0.001
Orientation, median (IQR)	4 (0)	4 (0)	4 (0)	4 (0)	4 (0)	0.171
English Longitudinal Study of Ageing (ELSA)						
N	2865	713	717	721	714	
Age (years), mean (SD)	69.5 (7.6)	68.5 (7.4)	69.8 (7.7)	70.1 (7.5)	69.4 (7.6)	0.001
Sex, N (%)						<0.001
Male	1309 (45.7)	288 (40.4)	300 (41.8)	373 (51.7)	348 (48.7)	
Female	1556 (54.3)	425 (59.6)	417 (58.2)	348 (48.3)	366 (51.3)	
Race/ethnicity, N (%)						0.650
White	2823 (98.5)	700 (98.2)	709 (98.9)	709 (98.3)	705 (98.7)	
Non-White	42 (1.5)	13 (1.8)	8 (1.1)	12 (1.7)	9 (1.3)	
Higher education, N (%)						<0.001
Yes	756 (26.4)	130 (18.2)	173 (24.1)	216 (30.0)	237 (33.2)	
No	2109 (73.6)	583 (81.8)	544 (75.9)	505 (70.0)	477 (66.8)	
Current drinking, N (%)						<0.001
Yes	1791 (62.5)	366 (51.3)	420 (58.6)	469 (65.1)	536 (75.1)	
No	1074 (37.5)	347 (48.7)	297 (41.4)	252 (34.9)	178 (24.9)	
Stroke history, N (%)						0.715
Yes	96 (3.3)	28 (3.9)	25 (3.5)	21 (2.9)	22 (3.1)	
No	2769 (96.7)	685 (96.1)	692 (96.5)	700 (97.1)	692 (96.9)	
Cumulative LE8 score (%), mean (SD)	71.8 (10.8)	57.5 (6.3)	68.7 (2.1)	75.9 (2.0)	84.9 (4.3)	<0.001
Cumulative behavioral score (%), mean (SD)	75.7 (16.2)	60.3 (17.7)	74.3 (12.0)	80.1 (10.5)	87.8 (8.9)	<0.001
Cumulative biological score (%), mean (SD)	69.1 (13.3)	55.6 (11.2)	65.0 (8.2)	73.0 (7.3)	82.8 (7.4)	<0.001
Executive function, mean (SD)	21.9 (6.1)	21.2 (5.9)	21.5 (6.2)	22.2 (6.2)	22.5 (6.1)	<0.001
Memory, mean (SD)	11.2 (3.2)	11.0 (3.2)	10.9 (3.3)	11.3 (3.2)	11.5 (3.2)	0.001
Orientation, median (IQR)	4 (0)	4 (0)	4 (0)	4 (0)	4 (0)	0.751

Abbreviations: SD, standard deviation; LE8, Life's Essential 8.

Note: ANOVA, Wilcoxon rank test, or χ^2 test was used to test the differences among the four groups.

Table 2
Association of the cumulative modified LE8 score with cognitive change rate (SD/year).

Cumulative modified LE8 score, %	HRS (N = 1345)		ELSA (N = 2865)		Pooled analysis (N = 4210)			
	Beta (95% CI) ^a	P value	Beta (95% CI) ^a	P value	Pooled Beta (95% CI)	P value ^b	I ² statistic, %	P value ^c
Global cognition								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.125 (-0.035 to 0.284)	0.125	0.082 (-0.019 to 0.184)	0.113	0.094 (0.009 to 0.180)	0.030	0	0.66
Quartile 3	0.166 (0.008 to 0.324)	0.040	0.227 (0.125 to 0.329)	<0.001	0.209 (0.123 to 0.295)	<0.001	0	0.52
Quartile 4	0.277 (0.115 to 0.440)	0.001	0.200 (0.097 to 0.303)	<0.001	0.222 (0.135 to 0.309)	<0.001	0	0.43
Per quartile increment	0.087 (0.035 to 0.138)	0.001	0.074 (0.042 to 0.107)	<0.001	0.078 (0.050 to 0.105)	<0.001	0	0.68
Per SD increment	0.107 (0.050 to 0.164)	<0.001	0.082 (0.045 to 0.118)	<0.001	0.089 (0.059 to 0.120)	<0.001	0	0.47
Executive function								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.038 (-0.109 to 0.184)	0.614	0.128 (0.030 to 0.227)	0.011	0.100 (0.018 to 0.182)	0.020	0	0.32
Quartile 3	0.133 (-0.012 to 0.278)	0.073	0.219 (0.121 to 0.318)	<0.001	0.192 (0.110 to 0.273)	<0.001	0	0.34
Quartile 4	0.216 (0.066 to 0.365)	0.005	0.250 (0.151 to 0.350)	<0.001	0.240 (0.157 to 0.322)	<0.001	0	0.71
Per quartile increment	0.074 (0.027 to 0.121)	0.002	0.084 (0.053 to 0.116)	<0.001	0.081 (0.055 to 0.107)	<0.001	0	0.73
Per SD increment	0.090 (0.037 to 0.142)	0.001	0.094 (0.058 to 0.129)	<0.001	0.093 (0.063 to 0.122)	<0.001	0	0.90
Memory								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.113 (-0.027 to 0.252)	0.112	-0.002 (-0.097 to 0.092)	0.966	0.044 (-0.067 to 0.154)	0.440	44	0.18
Quartile 3	0.115 (-0.023 to 0.253)	0.103	0.146 (0.051 to 0.241)	0.003	0.136 (0.058 to 0.214)	0.001	0	0.72
Quartile 4	0.138 (-0.004 to 0.279)	0.057	0.106 (0.010 to 0.201)	0.030	0.116 (0.037 to 0.195)	0.004	0	0.71
Per quartile increment	0.041 (-0.004 to 0.086)	0.073	0.047 (0.016 to 0.077)	0.003	0.045 (0.020 to 0.070)	0.001	0	0.83
Per SD increment	0.051 (0.001 to 0.101)	0.047	0.050 (0.016 to 0.084)	0.004	0.050 (0.022 to 0.078)	0.001	0	0.97
Orientation								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.090 (-0.065 to 0.245)	0.253	0.053 (-0.052 to 0.157)	0.325	0.065 (-0.022 to 0.151)	0.140	0	0.70
Quartile 3	0.068 (-0.085 to 0.222)	0.383	0.124 (0.019 to 0.229)	0.020	0.106 (0.020 to 0.193)	0.020	0	0.56
Quartile 4	0.177 (0.020 to 0.335)	0.027	0.061 (-0.044 to 0.166)	0.257	0.104 (-0.006 to 0.213)	0.060	31	0.23
Per quartile increment	0.051 (0.001 to 0.100)	0.047	0.025 (-0.008 to 0.059)	0.136	0.033 (0.005 to 0.061)	0.020	0	0.39
Per SD increment	0.064 (0.008 to 0.119)	0.025	0.028 (-0.010 to 0.065)	0.144	0.040 (0.007 to 0.073)	0.020	10	0.29

Abbreviations: LE8, Life's Essential 8; HRS, Health and Retirement Study; ELSA, English Longitudinal Study of Ageing; CI, confidence interval; SD, standard deviation.

^a Beta coefficients were estimated using a linear mixed model. Adjusted for age, sex, race/ethnicity, level of education, alcohol consumption, and stroke history.

^b For the pooled Beta.

^c For the I² statistics.

(pooled Beta=0.033 SD/year, 95% CI: 0.005 to 0.061, I²=0%) after full adjustment. Importantly, a per SD increase in the cumulative modified LE8 score was associated with significantly decelerated declines in global cognition (pooled Beta=0.089 SD/year, 95% CI: 0.059 to 0.120, I²=0%), executive function (pooled Beta=0.093 SD/year, 95% CI: 0.063 to 0.122, I²=0%), memory (pooled Beta=0.050 SD/year, 95% CI: 0.022 to 0.078, I²=0%), and orientation (pooled Beta=0.040 SD/year, 95% CI: 0.007 to 0.073, I²=10%). The level of heterogeneity between the two cohorts was consistently small and non-significant (P value>0.05). Within the same adjusted model, each year of older age was associated with a decline in global cognition of -0.063 SD/year (95% CI: -0.066 to -0.059) (Supplementary Table S3). The absolute magnitude of the protective association with LE8 was 1.41 times (calculated as 0.089/0.063) of the absolute magnitude of the detrimental association with normal annual aging.

3.3. Subgroup and sensitivity analysis

We observed no interaction between the cumulative modified LE8 score and age, sex, race/ethnicity, educational level, alcohol consumption, and stroke history (Supplementary Tables S4-S7). When further adjusted for single-time-point LE8 score, the results remained largely consistent with the primary analyses (Supplementary Table S8). When treating the cumulative behavioral and biological scores separately, we found that a higher cumulative behavioral score was associated with a slower rate of decline in global cognition, executive function, memory, and orientation (Table 3). However, we observed no association between the cumulative biological score and global cognition or any specific cognitive domains (Table 4). Pooled results showed that a per SD increment in the cumulative PA score was associated with significantly decelerated declines in global cognition (pooled Beta=0.107 SD/year,

Table 3
Association of the cumulative behavioral score with cognitive change rate (SD/year).

Cumulative behavior score, %	HRS (N = 1345)		ELSA (N = 2865)		Pooled analysis (N = 4210)			
	Beta (95% CI) ^a	P value	Beta (95% CI) ^a	P value	Pooled Beta (95% CI)	P value ^b	I ² statistic, %	P value ^c
Global cognition								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.234 (0.078 to 0.390)	0.003	0.160 (0.059 to 0.261)	0.002	0.182 (0.097 to 0.266)	<0.001	0	0.43
Quartile 3	0.344 (0.192 to 0.496)	<0.001	0.200 (0.097 to 0.303)	<0.001	0.261 (0.122 to 0.400)	<0.001	58	0.12
Quartile 4	0.378 (0.218 to 0.538)	<0.001	0.280 (0.175 to 0.385)	<0.001	0.309 (0.221 to 0.398)	<0.001	1	0.31
Per quartile increment	0.127 (0.076 to 0.177)	<0.001	0.088 (0.054 to 0.121)	<0.001	0.102 (0.065 to 0.140)	<0.001	38	0.20
Per SD increment	0.174 (0.118 to 0.230)	<0.001	0.114 (0.077 to 0.150)	<0.001	0.140 (0.081 to 0.198)	<0.001	68	0.08
Executive function								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.235 (0.091 to 0.378)	0.001	0.122 (0.024 to 0.219)	0.015	0.166 (0.057 to 0.274)	0.003	39	0.20
Quartile 3	0.352 (0.212 to 0.491)	<0.001	0.161 (0.061 to 0.260)	0.002	0.250 (0.063 to 0.436)	0.009	79	0.03
Quartile 4	0.420 (0.273 to 0.566)	<0.001	0.284 (0.183 to 0.386)	<0.001	0.341 (0.211 to 0.472)	<0.001	55	0.14
Per quartile increment	0.139 (0.093 to 0.186)	<0.001	0.089 (0.057 to 0.121)	<0.001	0.111 (0.062 to 0.160)	<0.001	68	0.08
Per SD increment	0.178 (0.126 to 0.230)	<0.001	0.116 (0.081 to 0.151)	<0.001	0.144 (0.084 to 0.204)	<0.001	73	0.05
Memory								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.187 (0.050 to 0.324)	0.008	0.087 (-0.007 to 0.181)	0.071	0.124 (0.029 to 0.219)	0.010	29	0.24
Quartile 3	0.185 (0.052 to 0.319)	0.007	0.152 (0.056 to 0.248)	0.002	0.163 (0.086 to 0.241)	<0.001	0	0.69
Quartile 4	0.207 (0.067 to 0.348)	0.004	0.179 (0.082 to 0.277)	<0.001	0.189 (0.108 to 0.269)	<0.001	0	0.75
Per quartile increment	0.064 (0.020 to 0.108)	0.005	0.060 (0.029 to 0.091)	<0.001	0.061 (0.036 to 0.087)	<0.001	0	0.90
Per SD increment	0.091 (0.042 to 0.140)	<0.001	0.072 (0.038 to 0.107)	<0.001	0.078 (0.050 to 0.106)	<0.001	0	0.55
Orientation								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.025 (-0.128 to 0.178)	0.750	0.147 (0.043 to 0.251)	0.006	0.099 (-0.017 to 0.216)	0.090	40	0.20
Quartile 3	0.125 (-0.024 to 0.273)	0.101	0.133 (0.027 to 0.239)	0.014	0.130 (0.044 to 0.216)	0.003	0	0.93
Quartile 4	0.098 (-0.059 to 0.255)	0.220	0.144 (0.037 to 0.252)	0.008	0.130 (0.041 to 0.218)	0.004	0	0.63
Per quartile increment	0.040 (-0.009 to 0.090)	0.108	0.041 (0.008 to 0.075)	0.017	0.041 (0.013 to 0.069)	0.004	0	0.97
Per SD increment	0.065 (0.010 to 0.120)	0.021	0.059 (0.022 to 0.097)	0.002	0.061 (0.030 to 0.092)	<0.001	0	0.87

Abbreviations: HRS, Health and Retirement Study; ELSA, English Longitudinal Study of Ageing; CI, confidence interval; SD, standard deviation.

^a Beta coefficients were estimated using a linear mixed model. Adjusted for age, sex, race/ethnicity, level of education, alcohol consumption, and stroke history.

^b For the pooled Beta.

^c For the I² statistics.

95% CI: 0.076 to 0.138, I²=0%), executive function (pooled Beta=0.107 SD/year, 95% CI: 0.057 to 0.156, I²=60%), memory (pooled Beta=0.077 SD/year, 95% CI: 0.049 to 0.105, I²=0%), and orientation (pooled Beta=0.033 SD/year, 95% CI: 0.001 to 0.064, I²=0%). A higher cumulative smoke score was associated with a slower decline in global cognition, executive function, and orientation. In contrast, the cumulative sleep score was only associated with memory. Consistent with our findings on biological factors, the cumulative scores of blood glucose, blood pressure, BMI, and blood lipid were not associated with any of the cognitive outcomes (Supplementary Tables S9-S12).

4. Discussion

In this pooled study of 1345 participants from the HRS and 2865 participants from the ELSA, two longitudinal community-based cohorts,

we found that a higher cumulative modified LE8 score over 8 years was associated with a slower rate of decline in global cognition, executive function, memory, and orientation during long-term follow-up. This association was independent of age, sex, race/ethnicity, educational level, alcohol consumption, stroke history, and single-time-point LE8 score. The higher cumulative behavioral score, but not the cumulative biological score, was associated with decelerated declines in global cognition and separate cognitive domains. To our best knowledge, this is the first study to explore the association of cumulative modified LE8 score with long-term cognitive change.

The relationship between VRFs and cognition or dementia has been widely investigated. The CVH, which was proposed by the AHA and assessed by LS7 or LE8, has been an important concept in the study of dementia prevention. Extensive research has investigated the association between single-time-point CVH and cognitive change or dementia

Table 4
Association of the cumulative biological score with cognitive change rate (SD/year).

Cumulative biological score, %	HRS (N = 1345)		ELSA (N = 2865)		Pooled analysis (N = 4210)			
	Beta (95% CI) ^a	P value	Beta (95% CI) ^a	P value	Pooled Beta (95% CI)	P value ^b	I2 statistic, %	P value ^c
Global cognition								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	-0.028 (-0.184 to 0.128)	0.724	0.052 (-0.047 to 0.152)	0.302	0.029 (-0.055 to 0.113)	0.500	0	0.39
Quartile 3	0.022 (-0.135 to 0.179)	0.782	0.089 (-0.015 to 0.194)	0.094	0.069 (-0.018 to 0.156)	0.120	0	0.48
Quartile 4	0.006 (-0.156 to 0.169)	0.939	0.048 (-0.054 to 0.150)	0.354	0.036 (-0.050 to 0.122)	0.410	0	0.67
Per quartile increment	0.007 (-0.044 to 0.058)	0.788	0.018 (-0.015 to 0.050)	0.283	0.015 (-0.013 to 0.042)	0.290	0	0.73
Per SD increment	-0.005 (-0.062 to 0.052)	0.868	0.021 (-0.015 to 0.057)	0.264	0.013 (-0.017 to 0.044)	0.390	0	0.46
Executive function								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.010 (-0.134 to 0.153)	0.895	0.070 (-0.026 to 0.166)	0.155	0.051 (-0.029 to 0.131)	0.210	0	0.49
Quartile 3	-0.013 (-0.157 to 0.131)	0.862	0.101 (-0.001 to 0.202)	0.051	0.056 (-0.053 to 0.165)	0.310	38	0.21
Quartile 4	-0.053 (-0.202 to 0.095)	0.481	0.091 (-0.008 to 0.189)	0.070	0.030 (-0.110 to 0.169)	0.670	60	0.11
Per quartile increment	-0.018 (-0.065 to 0.029)	0.448	0.030 (-0.001 to 0.061)	0.059	0.009 (-0.037 to 0.056)	0.700	64	0.09
Per SD increment	-0.033 (-0.085 to 0.019)	0.218	0.035 (0.000 to 0.070)	0.049	0.004 (-0.062 to 0.070)	0.910	78	0.03
Memory								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	0.006 (-0.131 to 0.142)	0.936	0.037 (-0.055 to 0.130)	0.427	0.027 (-0.049 to 0.104)	0.480	0	0.70
Quartile 3	0.082 (-0.055 to 0.219)	0.239	0.056 (-0.041 to 0.153)	0.261	0.065 (-0.015 to 0.144)	0.110	0	0.76
Quartile 4	-0.013 (-0.155 to 0.128)	0.853	0.025 (-0.069 to 0.119)	0.605	0.013 (-0.065 to 0.092)	0.740	0	0.66
Per quartile increment	0.005 (-0.040 to 0.049)	0.833	0.009 (-0.021 to 0.039)	0.558	0.008 (-0.017 to 0.032)	0.550	0	0.88
Per SD increment	-0.011 (-0.060 to 0.039)	0.677	0.011 (-0.023 to 0.044)	0.524	0.004 (-0.024 to 0.032)	0.770	0	0.48
Orientation								
Quartile 1	Reference	/	Reference	/	Reference	/	Reference	/
Quartile 2	-0.072 (-0.224 to 0.079)	0.351	-0.017 (-0.119 to 0.085)	0.747	-0.034 (-0.119 to 0.051)	0.430	0	0.55
Quartile 3	-0.031 (-0.184 to 0.121)	0.688	0.036 (-0.072 to 0.143)	0.514	0.014 (-0.074 to 0.101)	0.760	0	0.48
Quartile 4	0.074 (-0.083 to 0.231)	0.358	-0.026 (-0.130 to 0.078)	0.625	0.006 (-0.085 to 0.097)	0.900	7	0.30
Per quartile increment	0.025 (-0.024 to 0.075)	0.320	-0.003 (-0.036 to 0.030)	0.866	0.006 (-0.022 to 0.033)	0.680	0	0.36
Per SD increment	0.032 (-0.023 to 0.087)	0.257	-0.009 (-0.046 to 0.028)	0.638	0.006 (-0.032 to 0.045)	0.750	31	0.23

Abbreviations: HRS, Health and Retirement Study; ELSA, English Longitudinal Study of Ageing; CI, confidence interval; SD, standard deviation.

^a Beta coefficients were estimated using a linear mixed model. Adjusted for age, sex, race/ethnicity, level of education, alcohol consumption, and stroke history.

^b For the pooled Beta.

^c For the I² statistics.

incidence. A cross-sectional study analyzed 2585 older adults in the National Health and Nutrition Examination Survey 2011 to 2014, and found that one-point increase in baseline LS7 score was associated with higher Z-score for global cognition (Beta=0.05, 95% CI: 0.02 to 0.07), memory (Beta=0.03, 95% CI: 0.004 to 0.05), and executive function (Beta=0.05, 95% CI: 0.02 to 0.07) [38]. A longitudinal cohort study consisted of 3224 participants observed that the poor LE8 group (0 to 49 points) was twice as likely to have an accelerated decline of more than 1-SD in the cognitive composite score over 10 years (odds ratio=2.11, 95% CI:1.20 to 3.72) compared to the ideal group (80 to 100 points) [16]. A systematic review and dose-response meta-analysis, which included fourteen publications with longitudinal design and resulted in a final sample of 311,654 participants, found that elevating one point in the single-time-point LS7 score was associated with a 6% decrease in the risk of incident dementia [39].

Our study extends the existing knowledge in the relationship between CVH and cognition by concentrating on the cumulative LE8 score, which reflects the long-term maintenance of CVH. The pooled results of the HRS and ELSA in our study showed that a higher cumulative modified LE8 score over 8 years was associated with a slower rate of decline in global cognition and separate cognitive domains, namely executive function, memory, and orientation, during 8 to 11 years of follow-up. What's more, the magnitude of cognitive preservation associated with per SD increment in the cumulative modified LE8 score was substantial, corresponding to a slowing of cognitive aging by roughly 1.4 years. This suggests that maintaining a favorable cumulative LE8 score may counteract a meaningful portion of the cognitive toll imposed by natural aging. Most previous studies focused on single-time-point assessment of CVH, with very few studies investigating its long-term accumulation. A study including 1022 participants aged ≥ 60 years

analyzed the relationship of change in LS7, which was calculated as the difference between baseline and 6-year reassessment, and categorized as worse, stable, or improved, with the rate of cognitive decline [17]. This study found that a deterioration in the LS7 score was related to faster cognitive decline compared to the stable group. Other studies also found that improvement of the LS7 score within midlife was associated with a lower risk of dementia and a lower prevalence of cerebrovascular disease markers [18,40]. However, two-time-point assessments cannot fully represent the comprehensive variation of CVH during a long period, and these studies that assessed CVH using LS7, did not consider the role of sleep. Considering that ideal CVH is reported to be low-prevalent worldwide and declines with age, [41,42] our results may suggest that maintaining ideal CVH during the long term is crucial to preventing cognitive decline.

Notably, the association between cumulative modified LE8 score and cognitive change was independent of the single-time-point LE8 score at the beginning of the cumulative period (wave 8 in the HRS and wave 2 in the ELSA). This indicates that anyone can benefit from taking actions to improve their CVH, regardless of their starting LE8 level. Since dementia is characterized by the progressive deterioration of cognitive functions, [1,2] and the accumulation of VRFs plays a crucial role in the cognitive decline, [8] the cumulative LE8 score may be a useful tool for screening high-risk older adults and arranging them for primordial and primary prevention.

Our results showed that the cumulative behavioral score, but not the cumulative biological score, was associated with global cognition and cognitive domains. Specifically, cumulative PA score was associated with global cognition and separate cognitive domains, including executive function, memory, and orientation. The cumulative smoke score was associated with global cognition, executive function, and orientation. In contrast, the cumulative sleep score was only associated with memory. However, the cumulative scores of blood glucose, blood pressure, BMI, and blood lipid were not associated with any of the cognitive outcomes. In accordance with our present findings, two cross-sectional analyses comprised of participants with a mean age of 69 and 65 years, respectively, and a longitudinal cohort study comprised of 928 participants with a mean age of 74 years, found that the behavioral score was associated with cognition and dementia incidence, but the biological score was not [13,43,44]. However, another cohort study, which included 11,390 participants with a mean age of 51 years, observed that the single-time-point behavioral score was only associated with executive function, and the single-time-point biological score was associated with global cognition, memory, verbal fluency, and executive function [14]. This discrepancy could be attributed to the variation of participants' characteristics, such as age, or more importantly, the study design focusing on a single-time assessment, as the single-time assessment of CVH cannot reflect the long-term variation of CVH. A dose-response meta-analysis of single-time-point LS7 showed that the hazard of incident dementia was decreased significantly by maintaining intermediate levels of both behavioral and biological components (PA, blood glucose, blood lipids, and smoking) [39]. Two studies investigating the single-time-point LE8 conducted in the UK Biobank found that both the behavioral and biological components were both associated with all-cause dementia and vascular dementia [23,45]. Regarding the individual health behavior components, a study conducted in the UKB found that a per 10-point increase in the baseline scores for sleep, diet, smoking, and physical activity was associated with a 8%, 5%, 4%, and 2% lower risk of dementia, respectively [37]. Given that the behavioral components can lead to changes in biological factors [27] it is reasonable to assume that maintaining an ideal cumulative CVH to prevent cognitive decline could begin with adopting a healthy lifestyle, like exercising regularly, quitting smoking, and getting sufficient sleep.

The first strength of the current study was that we calculated the cumulative modified LE8 score over 8 years, which reflects the long-term maintenance of CVH, therefore providing insights into the relationship between long-term VRFs and cognitive change. Second,

consistent results were obtained from two independent longitudinal cohorts, which largely enhanced the robustness of the current findings.

This study also has several limitations. First, the observational design of this study precludes the confirmation of a causal relationship. Second, although we have controlled for a wide range of potential confounders, residual confounding cannot be ruled out. Third, it is worth noting that the risk profiles of LE8 components vary across different geographical regions and ethnic groups. A large proportion (89.1%) of participants included in the present study were of White ethnicity, which hampers the generalizability of the present findings to other populations. Fourth, according to the study design, dietary information was not collected during the primary follow-up of either cohort. Fifth, both the HRS and the ELSA collected information about PA, sleep, and smoking based on self-reported data, which may cause recall bias. Sixth, as the average age of participants in both cohorts was over 60 years at the commencement of cumulative LE8 exposure assessment, it remains unclear whether improving the cumulative LE8 score in midlife or earlier could delay cognitive decline. This needs to be explored in future research. Finally, this study focused on the cumulative burden of LE8 over time. An important and complementary future direction would be to examine trajectories or changes of LE8 scores.

5. Conclusions

In this longitudinal study of 1345 participants from the HRS and 2865 participants from the ELSA, we observed that a higher cumulative modified LE8 score over 8 years was significantly associated with a slower rate of decline in global cognition, executive function, memory, and orientation during 8 to 11 years of follow-up. This finding highlights the importance of maintaining long-term ideal CVH in late adulthood, regardless of the initial levels, to prevent cognitive decline and dementia.

Data availability

All data supporting the findings of this study are available on the official websites of the HRS (<https://hrs.isr.umich.edu/>) and the ELSA (<https://www.elsa-project.ac.uk/>).

Declaration of the use of generative AI and AI-assisted technologies in scientific writing and in figures, images, and artwork

We have not used AI in the writing process or in the creation of figures.

Acknowledgments

We appreciate all the participants from the HRS and the ELSA for their participation. We also appreciate the efforts made by the original data creators, depositors, copyright holders, the funders of the data collections, and their contributions to data access from the HRS and the ELSA.

CRediT authorship contribution statement

Yiwen Dai: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yuling Liu:** Writing – review & editing. **Yang Pan:** Writing – review & editing. **Menghan Zhu:** Writing – review & editing. **Xuyang Diao:** Writing – review & editing. **Xinqing Yang:** Writing – review & editing. **Jingya Ma:** Writing – review & editing. **Darui Gao:** Writing – review & editing. **Yanyu Zhang:** Writing – review & editing. **Mengmeng Ji:** Writing – review & editing. **Yichi Zhang:** Writing – review & editing. **Wuxiang Xie:** Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization. **Fanfan Zheng:** Writing – review & editing, Supervision,

Project administration, Methodology, 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.

Source of funding

This study was supported by grants from the National Natural Science Foundation of China (82373665), the Non-profit Central Research Institute Fund of Chinese Academy of Medical Sciences (2021-RC330-001), and the 2022 China Medical Board-open competition research grant (22-466).

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.tjpad.2026.100548](https://doi.org/10.1016/j.tjpad.2026.100548).

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