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10-year trajectory of Life's Essential 8 and incident hypertension: a community-based cohort study

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Abstract

Background The health effects of Life's Essential 8 (LE8) on chronic diseases have been disclosed, but its association with hypertension remains unknown. The current study aimed to explore the potential link between 10-year LE8 trajectory and the incidence of hypertension.

Methods LE8 was constructed from four behaviors and four metabolic factors, ranging from 0 to 100. Latent mixture models were used to identify trajectories of LE8 scores during 2006 to 2016. Incident hypertension was diagnosed based on self-reported clinical diagnoses and physical examinations from 2016 to 2020. Cox models were employed to assess the association of LE8 trajectories with hypertension. In addition to incorporating the mean hs-CRP levels from 2006 to 2016, age, sex, monthly income, educational level, and occupation at recruitment were adjusted for as confounding factors.

Results 7500 participants aged 40.28 ± 10.35 years were included in the study, of whom 2907 (38.76%) were women. Five LE8 trajectory patterns were identified. After around four-year follow-up, 667 hypertension events were observed. Compared to the Low-Stable trajectory, the hazard ratios and 95% confidence intervals for the Moderate-Increasing, Moderate-Decreasing, Moderate-Stable, and High-Stable trajectories were 0.51 (0.40, 0.65), 0.81 (0.64, 1.02), 0.45 (0.36, 0.58), 0.23 (0.16, 0.33), respectively. The risk of incident hypertension decreased as participants improved their LE8 status. The robustness of the primary results was confirmed through several sensitivity analyses.

Conclusions LE8 trajectories were associated with the incident hypertension. People who improved their LE8 scores over time experienced a decreased risk of hypertension, even if they started with lower LE8 scores initially.

Keywords Life's essential 8, Hypertension, Trajectory analysis

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Introduction

Hypertension accounted for 10.8 million deaths worldwide and 2.6 million deaths in China, according to the Global Burden of Disease Study 2019 [1]. Blood pressure (BP) is the most common contributing factor for cardiovascular diseases (CVD) [2, 3]. Hypertension is a leading risk factor for all-cause mortality both globally and in China [4]. Therefore, it is imperative to explore novel strategies to reduce the health burden and promote longevity.

The American Heart Association (AHA) initially proposed Life's Simple 7 (LS7), which includes diet, body mass index (BMI), physical activity (PA), smoking, BP, blood lipids (BL), and fasting blood glucose (FBG), as a tool to assess cardiovascular health (CVH) and to encourage its measurement, thereby advancing the promotion of CVH [5]. Recognizing the importance of sleep quality as a crucial behavior for CVH and the need for more precise CVH measurement, the AHA developed Life's Essential 8 (LE8), which incorporated sleep quality for a more comprehensive assessment of CVH. Each factor of LE8 ranges from 0 to 100 [6]. These distinctions allow the public to better understand and quantify their CVH levels using LE8 and suggest that LE8 may serve as a more reliable and precise indicator of CVH compared to LS7. Furthermore, the potential value of LE8 in evaluating hypertension risk among the normotensive population is barely explored.

Besides its association with CVD, LE8 had also been linked to various other diseases [7–11] and incident hypertension [12]. However, none of these studies described the 10-year trajectory of LE8 or explored the potential benefits of improving LE8 among normotensive individuals using repeated measurements. Therefore, the longitudinal association of LE8 with incident hypertension was evaluated using data from the biennially followed Kailuan cohort study.

Methods

Study population

The Kailuan study began in 2006–2007 in the Kailuan community in Tangshan, China. It was strategically designed to elucidate potential health determinants [13–15]. A total of 101,510 adults were recruited between June 2006 and October 2007. Each participant underwent thorough assessments, which primarily encompassed three sections: a standardized questionnaire survey, clinical examinations, and laboratory testing. These assessments were conducted biennially.

The present study estimated the effect of the 10-year trajectory of LE8 on incident hypertension. Initially, 48,521 participants were excluded: 44,655 due to existing hypertension and 3866 due to incomplete LE8 at baseline. Additionally, 45,489 participants with new-onset hypertension or those who were lost to follow-up during the trajectory construction from 2006 to 2016 were excluded, as the goal of this study was to observe hypertension cases from 2016 to 2020, and hypertension was the outcome event that should be excluded during trajectory construction according to previous studies [13]. Finally, 7500 participants who were free of hypertension after the trajectory construction period were included (Fig. 1).

Data collection

Medical workers conducted face-to-face interviews to gather demographic factors (such as sex, birthdate, level of education, monthly income, and occupation), health conditions (including self-reported clinical diagnoses of chronic diseases, and medication history), and lifestyle information (such as smoking habits, PA levels, duration of sleep, daily diet, and alcohol consumption) using a standardized questionnaire. Educational levels were determined according to the number of years of schooling, with categories including primary school or below (≤6 years), middle school (7–9 years), and high school or above (>9 years). Monthly income was self-reported and categorized as <800 CNY or ≥800 CNY. Occupation types were classified based on responses to questions about employment in mining and engagement in manual or mental labor. Participants were categorized as coal miners if they worked in the mine and mainly performed manual labor. Those working in the mine but engaged in mental labor were classified as other blue-collar workers. Participants not working in the mine but mainly involved in manual labor were also categorized as other blue-collar workers, while those primarily engaged in mental labor and not working in the mine were classified as white-collar workers. Participants were asked about clinically diagnosed conditions, including hypertension and other chronic diseases, with follow-up questions about medication usage if conditions were affirmed. Smoking habits were assessed by inquiring whether participants currently smoked or had quit smoking, along with detailed questions about smoking frequency. PA levels were assessed based on weekly frequency and duration of sessions lasting at least 20 min. Participants reported their average nightly sleep duration in hours. Dietary habits were evaluated through questions about flavor preferences, frequency of consuming fatty foods, and tea consumption. Alcohol consumption was categorized into three groups: current, past, and never, with detailed information gathered from participants who reported current or past drinking, including drinking patterns and withdrawal behaviors. Interviewers recorded participants' responses to each question.

The weight and height of each participant were measured by trained medical workers, and weight (kg)

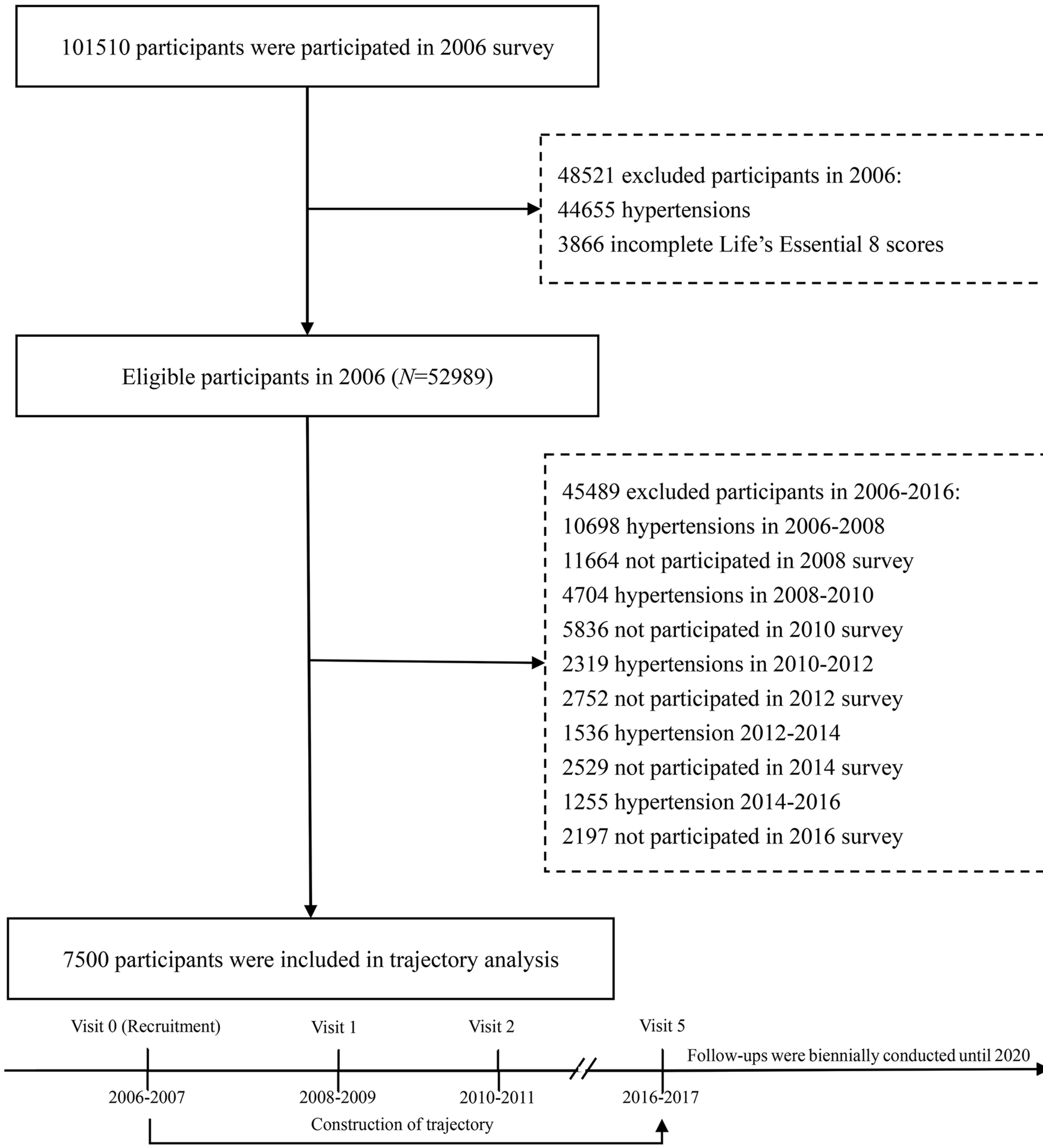

Fig. 1 Flow diagram for participants included in the study

divided by height squared (m^2) was used for BMI (kg/m^2) calculation. The procedures for the measurement of biochemical indicators were as follows: venous blood samples were extracted from the antecubital vein by a professional nurse following an overnight fast of about eight to twelve hours. All the samples were stored at -80 °C. Subsequently, an auto-analyzer machine (Hitachi 747; Hitachi, Tokyo, Japan) was utilized to measure biochemical indices, including FBG, total cholesterol (TC), HDL-C, and high-sensitivity C-reactive protein (hs-CRP) in these blood samples at the central laboratory of Kailuan Hospital [14, 16]. Non-HDL-C levels were calculated as TC subtracting HDL-C. BP metrics were assessed three times with a calibrated mercury sphygmomanometer while interviewees were seated after a 5-minute rest period. BP was re-assessed if the difference between adjacent two measurements was more than five mmHg. The mean of the three BP measurements was used for subsequent analysis [17, 18].

Assessment of life's essential 8

The LE8 primarily included four health-related indicators (BMI, FBG, BL, and BP) and four lifestyle factors (tobacco smoking, diet, sleep duration, and PA). Each component of LE8 was assessed biennially. Detailed definitions and scoring methodologies for the components of LE8 were outlined in Table S1 and elsewhere [19–21]. The LE8 score was counted by summing the scores of the each factor and then dividing the total score by eight. This resulted in a LE8 score ranging from 0 to 100. The LE8 trajectories in the current study depicted different change models of LE8 from 2006 to 2016 utilizing a latent mixture model.

Assessment of hypertension

In each follow-up survey, the interviewees were asked whether they had been clinically diagnosed with hypertension. If the answer was affirmative, further inquiries to obtain detailed information on antihypertensive medication intake. The procedure for BP measurement was explained in a previous section. Hypertension was determined based on one of the following criteria: self-reported clinical diagnosis, intake of antihypertensive drugs, or increased systolic/diastolic BP (≥140/90 mm Hg) [22].

Assessment of covariates

The potential confounders were selected based on previous studies [23, 24]. Demographic information, including age, sex, monthly income, educational status, and occupation, was included. Alcohol consumption was categorized as never, past, or current based on information acquired during the interview. Given the significant impact of inflammation on the cardiovascular system [25], the mean hs-CRP level during the period from 2006 to 2016 was also included as an important covariate. Apart from hs-CRP, the other covariates were collected in 2006 and incorporated into subsequent analyses according to a previous study [13].

Statistical analysis

Continuous variables were described using mean ± standard deviation and median with interquartile range (25–75%), while categorical variables were presented as numbers and percentages. The person-time was calculated from the 2016 survey until the onset of hypertension, death, loss to follow-up, or the endpoint (December 31, 2020), whichever came first.

A latent mixture model within the PROC TRAJ procedure was employed to classify the trajectory patterns of LE8 from 2006 to 2016, following established methodology [26, 27]. Various parameters and fit statistics were used to determine the optimal number of trajectories, including the proportion in each trajectory, Bayesian Information Criteria, average posterior probability in each trajectory, and visual inspection of the trajectories. The model with five trajectories provided the best fit (Table S2). Models with different functional forms (e.g., 3-cubic, 2-quadratic, and 1-linear) were compared and evaluated based on their significance levels, utilizing the highest polynomial term. Ultimately, we identified two pattern with quadratic order terms and three patterns with up to cubic order terms, which met the statistical conditions necessary for constructing trajectory patterns. The Low-Stable trajectory was set as the reference for subsequent analysis.

The cumulative incidence of hypertension by LE8 trajectories was described using the Kaplan-Meier method, followed by a Log-rank test. The association between these LE8 trajectory patterns and the risk of hypertension was evaluated using the Cox model to calculate hazard ratios (HR) and 95% confidence intervals (CI). Before constructing the model, the proportional hazards assumption was satisfied using Schoenfeld residual methods [28]. The crude model was adjusted for none, while Model 1 was adjusted for age (years), sex (women, men), education level (elementary school or below, middle school, high school and above), monthly income (<800, ≥800 CNY), occupation (coal miner, other blue-collar, white collar), alcohol consumption (never, abstainer, current), and mean hs-CRP concentration during 2006–2016. Additionally, LE8 scores in 2006, 2008, 2010, 2012, 2014, and 2016 were included as additional adjustments based on Model 1 to examine whether the association of LE8 trajectories with incident hypertension could be explained by a single LE8 measurement in the follow-up.

The association between the slope of LE8 during 2006–2016 and hypertension risk was examined. The magnitude of the annual change rate indicates the extent of the annual change, with a larger magnitude indicating a greater rate of change and a steeper trend for LE8. The positive or negative symbol associated with the slope indicates the overall direction of change: a positive slope denotes an increase, while a negative slope represents a decrease. The slope calculation methods were in accordance with a previous study [29]. A restricted cubic spline model with three (25th, 50th, 75th percentiles) knots was performed to evaluate the underlying relationship between LE8 slope and incident hypertension after adjusting for the impact of confounders and the 2006 LE8. This approach helps capture potential non-linear associations between the annual change rate of LE8 and hypertension risk.

$$Slope = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sum (x - \bar{x})}$$

Note:
x: Timepoint of Measurement
y: Life's Essential 8
Slope: Annual Change Rate

Several sensitivity analyses were conducted. First, the primary results were re-analyzed after excluding women, considering the distribution of sex and the particularity of occupation. Second, participants were divided into five groups according to the quintile of 2016 LE8, and numeric values were assigned to the LE8 groups to examine the trend in the adjusted model. Third, stratified and interaction analyses were performed for age (<45, ≥45) and sex (women, men). Fourth, to account for differences in gender and age among the five trajectory groups, the strata option was used for sex and age modeled as a time scale, allowing for better control of the impact of these factors. Fifth, BP was removed from LE8, and then the LE8 score was recalculated using the remaining seven factors to exclude the impact derived from BP. Sixth, to address the issue of multiple comparisons and potential inflation of type-I error rates, the Bonferroni correction was applied by adjusting alpha and the corresponding CIs. The alpha level was set as 0.05/4, as there were four hypothesis tests conducted. Seventh, the 'evalue hr' code in Stata was used to calculate E-values to consider the potential impact derived from unmeasured residual factors [30]. The comparison between the inclusion and exclusion groups was conducted because the non-participant population was significantly larger than the participant population. Individuals who self-reported clinically diagnosed hypertension were further excluded to address potential errors in self-reported hypertension.

All analyses were conducted using Stata/MP2 V17 (Stata Corp LLC, Texas, TX, United States) and SAS 9.4 (SAS Institute, Cary, NC), and a 2-sided *P* value<0.05 was deemed significant.

Results

A total of 7500 individuals were included in the analyses, all of whom met the inclusion criteria and were free of hypertension from 2006 to 2016. The mean (SD) age at baseline in 2016 was 40.28 (10.35) years, with 2,907 (38.76%) of the participants being women. Five LE8 trajectories from 2006 to 2016 were determined: Low-Stable (*n*=762), Moderate-Increasing (*n*=1275), Moderate-Decreasing (*n*=1172), Moderate-Stable (*n*=2690), and High-Stable (*n*=1601) (Fig. 2). Individuals in the High-Stable trajectory tended to be women, younger, engaged in other blue-collar occupations, abstainers from alcohol, and had higher educational statuses (Table 1).

The incidence of hypertension significantly varied across trajectories (*P* for log-rank test<0.001) (Figure S1). In the trajectory analysis, a total of 667 incident hypertension events were diagnosed during the period from 2016 to 2020. LE8 trajectories were significantly associated with new-onset hypertension (Table 2). Compared to the Low-Stable trajectory, the Moderate-Increasing (adjusted HR: 0.51; 95% CI, 0.40, 0.65), Moderate-Deceasing (adjusted HR: 0.81; 95% CI, 0.64, 1.02), Moderate-Stable (adjusted HR: 0.45; 95% CI, 0.36, 0.58), and High-Stable (adjusted HR: 0.23; 95% CI, 0.16, 0.33) trajectories were all related to a lower risk of hypertension. These results remained stable after additional adjustments for LE8 scores in 2006, 2008, 2010, 2012, 2014, and 2016 as continuous variables. Improvement in LE8 was

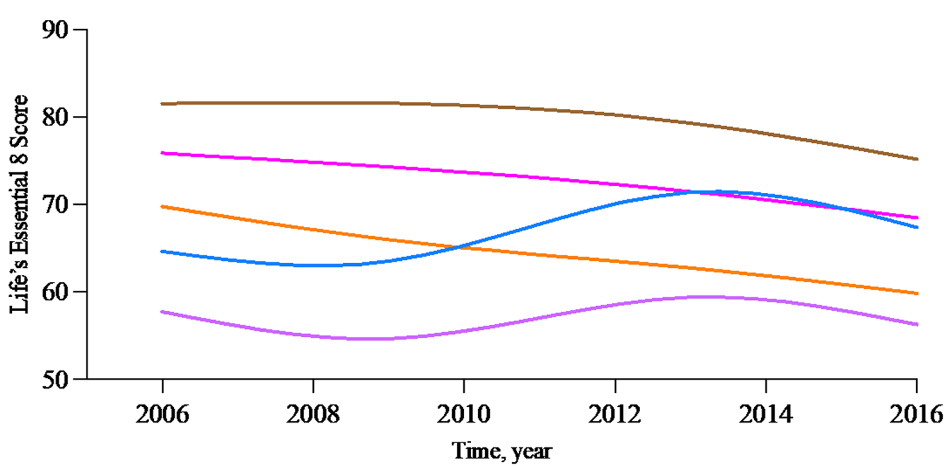

Fig. 2 Mean Life's Essential 8 score from 2006 to 2016 according to five Life's Essential 8 trajectories. High-Stable (brown line) means participants maintained a high LE8 score. Moderate-Stable (magenta line) means participants maintained a moderate LE8 score. Moderate-Decreasing (orange line) means participants started with a moderate LE8 score and then decreased. Moderate-Increasing (blue line) means participants started with a moderate LE8 score and then increased. Low-Stable (purple line) means participants maintained a low LE8 score

Table 1 Characteristics of 7500 participants according to the trajectories of Life's essential 8 from 2006 to 2016

Characteristic	Total	10-Years Trajectory of Life's Essential 8				
		Low-Stable	Moderate-Increasing	Moderate-Decreasing	Moderate-Stable	High-Stable
No., %	7500 (100)	762 (10.16)	1275 (17.00)	1172 (15.63)	2690 (35.87)	1601 (21.35)
Age (years)	40.28 ± 10.35	40. 71 ± 9.90	40.46 ± 9.61	41.97 ± 10.83	41.50 ± 10.55	36.63 ± 9.56
LE8 in 2006	72.54 ± 9.95	57.89 ± 8.17	64.63 ± 7.16	69.75 ± 6.93	76.23 ± 6.15	81.62 ± 5.44
hs-CRP, IQR	1.24 (0.72, 2.15)	1.64 (1.01, 2.71)	1.22 (0.72, 2.12)	1.62 (0.95, 2.67)	1.20 (0.70, 2.09)	0.93 (0.56, 1.55)
Gender, %						
Women	2907 (38.76)	35 (4.59)	77 (6.04)	314 (26.79)	1279 (47.55)	1202 (75.08)
Men	4593 (61.24)	727 (95.41)	1198 (93.96)	858 (73.21)	1411 (52.45)	399 (24.92)
Income per month (CNY), %						
< 800	6129 (81.76)	621 (81.60)	1015 (79.67)	994 (84.96)	2234 (83.05)	1265 (79.01)
≥ 800	1367 (18.24)	140 (18.40)	259 (20.33)	176 (15.04)	456 (16.95)	336 (20.99)
Education level, %						
Elementary school or below	183 (2.44)	31 (4.07)	37 (2.90)	32 (2.73)	68 (2.53)	15 (0.94)
Middle school	4413 (58.86)	470 (61.76)	781 (61.30)	768 (65.53)	1631 (60.63)	763 (47.66)
High school or above	2903 (38.70)	260 (34.17)	456 (35.79)	372 (31.74)	991 (36.84)	823 (51.41)
Occupation, %						
Coalminers	1898 (25.31)	355 (46.59)	597 (46.82)	337 (28.75)	486 (18.07)	123 (7.69)
Other blue collars	4699 (87.98)	354 (46.46)	576 (45.18)	730 (62.29)	1853 (68.88)	1186 (74.17)
White collars	901 (12.02)	53(6.96)	102 (8.00)	105 (8.96)	351 (13.05)	290 (18.14)
Alcohol consumption, %						
Never	4629 (61.74)	242 (31.80)	451 (35.37)	703 (59.98)	1938 (72.10)	1295 (80.89)
Past	131 (1.75)	22 (2.89)	44 (3.45)	21 (1.79)	33 (1.23)	11 (0.69)
Current	2737 (36.51)	497 (65.31)	780 (61.18)	448 (38.23)	717 (26.67)	295 (18.43)

Abbreviations: LE8, Life's Essential 8; hs-CRP, high-sensitivity C-reactive protein; IQR, interquartile range

Values were means ± SD or n (percentages) or median (25th, 75th percentiles)

Table 2 Association between Incidence of Hypertension and trajectories of LE8 from 2006 to 2016

Hypertension	LE8 Trajectories, HR (95% CI)				
	Low-Stable	Moderate-Increasing	Moderate-Decreasing	Moderate-Stable	High-Stable
No. of cases/Total	132/762	116/1275	164/1172	202/2690	53/1601
Incidence rate per 1000 person-years	87.93	45.09	68.57	36.76	16.42
Crude model	1.0 (reference)	0.50 (0.39, 0.64)	0.73 (0.58, 0.92)	0.38 (0.31, 0.47)	0.17 (0.12, 0.23)
Age- and sex-adjusted model	1.0 (reference)	0.50 (0.39, 0.65)	0.79 (0.62, 0.99)	0.44 (0.35, 0.55)	0.22 (0.16, 0.31)
Multiple model 1[a]	1.0 (reference)	0.51 (0.40, 0.65)	0.81 (0.64, 1.02)	0.45 (0.36, 0.58)	0.23 (0.16, 0.33)
Multiple model 2[b]	1.0 (reference)	0.49 (0.38, 0.64)	0.76 (0.58, 0.99)	0.42 (0.31, 0.56)	0.20 (0.13, 0.31)
Multiple model 3[c]	1.0 (reference)	0.53 (0.40, 0.69)	0.85 (0.64, 1.13)	0.49 (0.35, 0.69)	0.25 (0.16, 0.40)
Multiple model 4[d]	1.0 (reference)	0.57 (0.44, 0.75)	0.90 (0.70, 1.17)	0.56 (0.41, 0.76)	0.31 (0.20, 0.48)
Multiple model 5[e]	1.0 (reference)	0.50 (0.37, 0.67)	0.80 (0.63, 1.02)	0.44 (0.33, 0.59)	0.22 (0.14, 0.34)
Multiple model 6[f]	1.0 (reference)	0.56 (0.42, 0.76)	0.82 (0.65, 1.04)	0.50 (0.38, 0.66)	0.27 (0.18, 0.41)
Multiple model 7[g]	1.0 (reference)	0.68 (0.51, 0.90)	0.90 (0.70, 1.15)	0.64 (0.48, 0.85)	0.39 (0.25, 0.59)

Abbreviations: HR, hazard ratio; CI, confidence interval; LE8, Life's Essential 8; hs-CRP, high-sensitivity C-reactive protein

[a] Model 1 adjusted for age (years), sex (women, men), educational level (elementary school or below, middle school, high school and above), income per month (< 800, ≥ 800 CNY), occupation (coal miner, other blue-collar, white collar), alcohol consumption (never, abstainer, current), and mean serum concentration of hs-CRP during 2006–2016

[b] Model 2 adjusted for multiple model 1 + LE8 at 2006

[c] Model 3 adjusted for multiple model 1 + LE8 at 2008

[d] Model 4 adjusted for multiple model 1 + LE8 at 2010

[e] Model 5 adjusted for multiple model 1 + LE8 at 2012

[f] Model 6 adjusted for multiple model 1 + LE8 at 2014

[g] Model 7 adjusted for multiple model 1 + LE8 at 2016

related to a decreased incident hypertension risk, and the faster the growth, the more the risk falls (Fig. 3).

After excluding female participants, the adjusted HR comparing the High-Stable trajectory with the Low-Stable one was 0.28 (95% CI, 0.17, 0.46) (Table S3). Consistently, a higher LE8 level was related to a lower risk of incident hypertension (P-trend < 0.001) (Table S4). Moreover, the results from stratified analysis further supported the primary findings, and no effect-modifying factors were found in the association between LE8 trajectories and incident hypertension (P-interaction > 0.05 for all) (Table S5). The results remained virtually unchanged when age was modeled as a time scale and sex was used as the strata option (Table S6). LE7, removing BP from LE8, was strongly associated with the risk of incident hypertension, and the results were consistent with the primary findings (Table S7). Slight changes were observed after Bonferroni correction (Table S8). The E-value tested the sensitivity to unmeasured confounding, and the primary findings remained stable, suggesting that they may not be invalidated with the current evidence (Table S9). Excluded participants were older, had relatively lower LE8 levels, higher systemic inflammation, were predominantly men, and had lower educational attainment compared to those included (Table S10). The results remained consistent with the primary findings after accounting for potential errors in self-reported hypertension (Table S11).

Discussion

Five distinct trajectories were identified, which revealed varying associations with the risk of hypertension. Individuals who consistently maintained the highest LE8 level over the 10-year period experienced a remarkable 78% reduction in the risk of developing incident hypertension compared to those who consistently remained at the lowest LE8 level. The findings suggested that improvement in LE8 status was beneficial for hypertension prevention, regardless of baseline LE8 status, and indicate that the faster the improvement, the better.

The present study included 7500 participants who were free of hypertension from 2006 to 2010, representing a subset of the original Kailuan cohort. This selection was made due to the high incidence of hypertension and the restrictive inclusion criteria necessary for the current research objectives. The included participants were not fully representative, as they were generally healthier than those excluded. Specifically, they were younger, had a favorable sex distribution, and possessed higher levels of education. These factors naturally positioned them at an advantageous status for hypertension prevention, making them less likely to develop hypertension. Although the

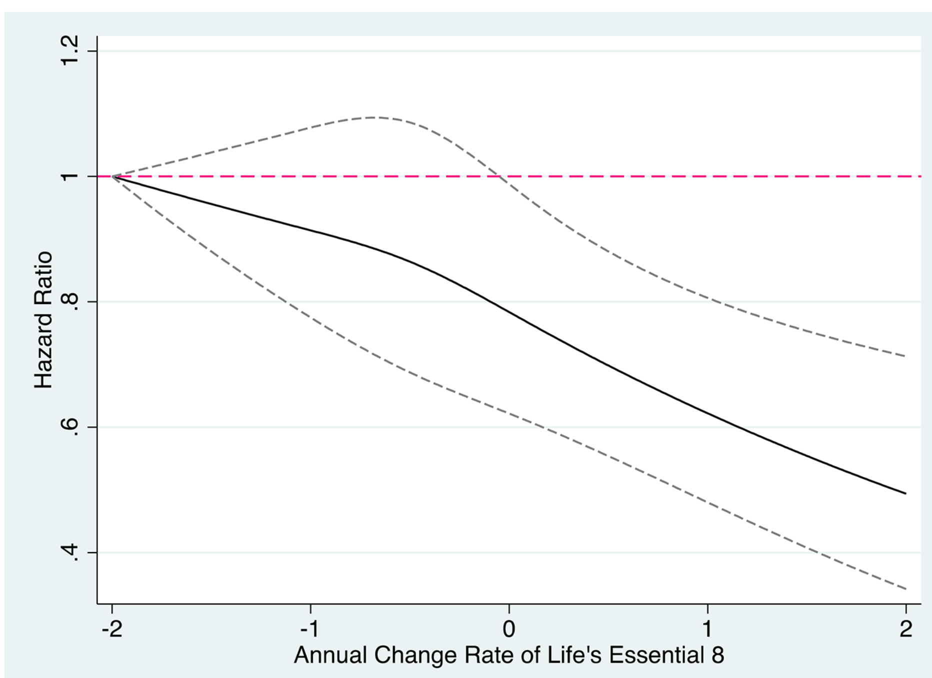

Fig. 3 Association between annual change rate of Life's Essential 8 and incident hypertension. The y-axis is hazard ratio with the area within dotted line representing 95% CIs. Data were fitted by a restricted cubic spline Cox proportional hazards regression model adjusted for age (years), sex (women, men), educational level (elementary school or below, middle school, high school and above), income per month (< 800, ≥ 800 CNY), occupation (coal miner, other blue-collar, white collar), alcohol consumption (never, abstainer, current), mean serum concentration of hs-CRP during 2006–2016, and 2006 Life's Essential 8 measurement

current study may have underestimated the actual association between LE8 trajectories and incident hypertension, a significant association between LE8 trajectories and incident hypertension persisted even after adjusting for each LE8 measurement from 2006 to 2010. Research unveiled the health effects of LE8 on various adverse health conditions [13–16]. However, prior studies primarily focused on individual health behaviors within LE8 and their associations with incident hypertension [31]. Another study involving 52,990 participants demonstrated that a higher LE8 score is linked to a reduced risk of hypertension [12]. Yet, the health effects of the 10-year trajectory of LE8 and its improvement on hypertension remained unexplored. Recently, a study indicated that a higher LE8 was linked to a reduced risk of hypertension. [32]. Another study delved into the association of four health behaviors within LE8 with the incidence of hypertension, revealing that each health behavior was independently associated with incident hypertension, and improvement in any of these behaviors was related to a reduced risk of developing hypertension [31]. The Jackson Heart Study also revealed that unhealthy lifestyles, characterized by less PA, smoking, and an absence of an ideal diet, were linked to a heightened risk of hypertension [33]. Additionally, sleep duration, as a new factor added to LE8, has been reported to be related to the risk of hypertension, indicating that poor sleep quality is associated with new-onset hypertension [34]. However, these studies failed to comprehensively investigate the association of complete LE8 with hypertension and discuss the long-term pattern of LE8 and its association with hypertension.

The current findings contributed to the body of evidence suggesting an inverse association between LE8 and the risk of hypertension. Importantly, despite the relatively low LE8 status at baseline, the improvement in LE8 significantly attenuated the risk of hypertension significantly (HR: 0.61, 95% CI: 0.48, 0.78 for Moderate-Increasing trajectory; HR: 0.79, 95% CI: 0.62, 0.99 for Moderate-Decreasing trajectory). These results underscored a critical concern, emphasizing the effectiveness of enhancing healthy behaviors and metabolic status within the context of LE8 as a preventive measure against the development of hypertension. The findings from a previous large-scale study revealed that arterial stiffness status partially mediated the association between LE8 and stroke, suggesting that the stiffness of blood vessels may serve as a potential mechanism [35]. These results underscored the importance of robust public health efforts aimed at improving CVH, which may counterbalance arterial stiffness. In essence, despite an overall decreasing trend in LE8 over time, individuals still have the potential to enhance their LE8 status. Regardless of whether they had lower LE8 levels at the beginning or not, they can benefit from improving their LE8 status. This highlighted the significance of ongoing efforts to promote healthy behaviors and metabolic health, as they may contribute to maintaining or improving CVH and potentially mitigate the risk of hypertension.

In contemporary times, individuals with ideal LE8 scores were relatively scarce [36–38]. However, the benefits of achieving a high LE8 extended beyond CVH, impacting a wide range of organs and systems [13–16]. The rate of improvement in LE8 over time emerges as a critical factor in reducing the risk of hypertension, with lower hypertension risk observed in individuals experiencing faster LE8 increases. These findings underscored the importance of continuous improvement in LE8 for reducing hypertension risk and enhancing CVH. LE8 may serve as an effective and feasible tool for evaluating the future risk of hypertension and identifying populations at high risk. This, in turn, could guide individuals towards addressing their health deficiencies, potentially preventing hypertension and its associated complications. Moreover, the utilization of LE8 could inform health managers in crafting timely and real-time health policies for residents, enhancing public health outcomes. Given the costs associated with LE8 measurement, alternative strategies such as implementing cost-effective campaigns such as health education and health knowledge contests could encourage the public to optimize their CVH status. Overall, striving to attain higher LE8 scores could prove to be a valuable strategy, offering a substantial reduction in hypertension risk and improving overall CVH in the population.

Some studies derived from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative survey of individuals aged 45 and older in China, reported that approximately 25% of participants developed hypertension from 2011 to 2018 [39–41]. Although this rate was higher than the 8.89% incidence observed in the current study, it was difficult to draw a definitive conclusion. Because the lower incidence in this study may be attributed to the fact that participants were free of hypertension for the previous ten years, which could introduce a healthy population effect and attenuate the association between LE8 and incident hypertension. However, the significantly inverse association between LE8 and the risk of hypertension in this study remained, which further emphasized the health benefits of enhancing LE8.

Research conducted within the Atherosclerosis Risk in Communities study revealed a significant association between improvement in LS7 from midlife to late life and enhanced systolic and diastolic function, along with improvements in cardiovascular structure and function [42, 43]. Moreover, a Chinese cohort study involving more than 40,000 individuals demonstrated a potential role of LE8 in mitigating atherosclerosis progression [35]. Additionally, a study reported a noteworthy association between a higher cardiovascular score and decreased concentrations of pro-atherosclerotic and cardiac stress factors, as well as neurohormonal biomarkers, while simultaneously exhibiting higher levels of cardioprotective biomarkers [44]. Overall, these studies provided valuable insights into the biological pathways through which improvements in LE8 and CVH may influence cardiovascular structure, function, and disease progression, further highlighting the importance of optimizing CVH to reduce the risk of hypertension and improve overall cardiovascular outcomes.

Strengths and limitations

LE8 data were collected repeatedly from 2006 to 2016, ensuring consistency and minimizing random error. Moreover, this study was the first to discuss the impact of 10-year trajectories of LE8 and incident hypertension. However, several limitations should be acknowledged. First, the Kailuan cohort was predominantly composed of men, primarily representing people from the Kailuan community, potentially limiting the generalizability of current findings. Second, while efforts were made to account for potential confounders, some variables remain unmeasured. This limitation was mitigated by calculating an E-value to assess their potential impact and verify the stability of current findings. Third, the 10-year duration of LE8 trajectories examined in the current study may not entirely reflect an individual's CVH throughout their lifespan. Fourth, the current results relied heavily on questionnaires, which could introduce biases and reduce reliability. To address this issue, future studies should consider quantifying LE8 components where feasible. For example, biomarkers such as urinary cotinine could be utilized to quantify smoking status, thereby enhancing the accuracy of LE8 assessments. Fifth, the complex interplay of factors such as alcohol consumption with obesity, diabetes, and smoking suggests careful consideration. Despite removing BP from LE8 calculation and conducting sensitivity analysis to examine the stability of the current findings, caution was advised in interpreting the observed associations. Finally, while the reliability of current findings through various analyses was verified, such as E-value calculation, using age as time scale and sex as strata option, and Bonferroni correction, further studies are needed to comprehensively quantify these factors and their associations with hypertension.

Conclusions

The findings of this study underscored a significant link between the 10-year trajectories of LE8 and the risk of incident hypertension. Maintaining a high level of LE8 or improving LE8 status was linked to a decreased risk of hypertension. Notably, individuals with initially low LE8 levels could also experience a reduced risk of hypertension by enhancing their LE8 status, potentially even reversing their risk of hypertension. These results highlighted the importance of encouraging efforts aimed at optimizing and maintaining high CVH status among the public. Furthermore, they suggested that the LE8 could serve as a powerful tool for evaluating the risk of hypertension. By enhancing LE8 status, individuals and healthcare providers alike may effectively mitigate the risk of hypertension and promote CVH.

Abbreviations

AHA	American Heart Association
BMI	Body mass index
BP	Blood pressure
BL	Blood lipids
CVH	Cardiovascular health
CI	Confidence interval
CHARLS	China Health and Retirement Longitudinal Study
FBG	Fasting blood glucose
HR	Hazard ratio
HDL-C	High-density lipoprotein cholesterol
hs-CRP	high-sensitivity C-reactive protein
LS7	Life's Simple 7
LE8	Life's Essential 8
PA	Physical activity
SD	Standard deviation
TC	Total cholesterol

Supplementary Information

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Supplementary Material 1

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Author contributions

J.Z. and J.J.: Conceptualization, Software, Formal analysis, Writing - original draft, Writing - review & editing. L.G., Y.L., S.W., X.P., S.C., X.Q., and S.D.: Writing - review & editing., R.H., and W.Z.: Conceptualization, Review & editing, Supervision, Resources. J.Z. and J.J.: contributed equally as co-first authors. R.H. and W.Z.: contributed equally as co-corresponding authors. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study adhered to the guidelines of the Helsinki Declaration and received approval from the Ethics Committee of Kailuan General Hospital (Approval Number: 2006-05). All participants volunteered to join the study and provided signed informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare that there were no competing interests.

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