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Insights into associations between Life's essential 8 and lung function from NHANES data

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The Life's Essential 8 (LE8) is a novel indicator of cardiovascular health proposed by the American Heart Association. While numerous studies have demonstrated its guiding value in chronic diseases, research on its role in lung function remains limited. This study utilized data from the National Health and Nutrition Examination Surveys (NHANES 2007–2012), which included comprehensive measurements of lung function, diet, physical activity, nicotine exposure, sleep patterns, body mass index (BMI), blood glucose, blood pressure, blood lipids, and relevant covariates. We calculated lung function Z-score and LE8 scores, employing multiple linear regression, multivariable logistic regression, and restricted cubic spline models to evaluate their correlations. In this study of 10,400 participants (mean age 44 years; 48.75% male), participants were classified into threeforcedexpiratory volume in one second (FEV1) Z-score groups: Z1 (normal lung function, *n* = 9,600), Z2 (mild impairment, *n* = 618), and Z3 (moderate to severe impairment, *n* = 182). Significant differences in demographic characteristics and health parameters were observed among the groups. Notably, variations in the Healthy Eating Index 2015 (HEI-2015), physical activity, nicotine exposure, and sleep patterns were identified within the LE8 health behavior domain. Higher LE8 scores were found to be positively associated with lung function, even after adjusting for demographic and health factors. Further analysis revealed positive correlations between lung function and favorable dietary habits, higher physical activity levels, reduced nicotine exposure, and improved sleep quality. Conversely, BMI, blood lipids, blood glucose, and blood pressure exhibited variable effects. Subgroup and sensitivity analyses consistently supported findings, confirming a positive correlation between LE8 and lung function. Our study highlights significant associations between LE8 scores and lung function, demonstrating that higher LE8 scores, which reflect better cardiovascular health behaviors, are positively correlated with improved lung function.

Keywords Life's essential 8, LE8, Lung function, NHANES

Abbreviations

LE8	Life's Essential 8
COPD	obstructive pulmonary disease
ATS	American Thoracic Society
ERS	European Respiratory Society
CVH	cardiovascular health
FEV1	First second forced expiratory volume
ALT	Alanine Aminotransferase
AST	Aspartate Aminotransferase
PIR	poverty income ratio
PA	Physical activity
BP	Blood pressure
BMI	Body Mass Index
eGFR	estimated glomerular filtration rate

Respiratory system diseases remain a pressing global public health issue, with chronic respiratory ailments representing a substantial burden and ranking as the third leading cause of mortality worldwide, following

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cardiovascular diseases and malignancies[1]. Lung function testing is a cornerstone for diagnosing pulmonary diseases and functional impairments, widely applying in the evaluation of conditions such as chronic obstructive pulmonary disease (COPD) and asthma[2,3].

In 2021, the American Thoracic Society (ATS) and the European Respiratory Society (ERS) introduced the Z-score methodology to replace traditional indicators for assessing airflow limitation, including the percentage of forced expiratory volume in one second (FEV1%) and the ratio of FEV1 to forced vital capacity (FEV1/FVC)[4]. This scoring system stratifies the severity of lung function impairment using Z-scores (e.g., −2, −2.5, −3, and −4 for FEV1), facilitating a nuanced characterization of airflow limitation severity. It demonstrates favorable consistency with ATS/ERS severity classifications. Notably, the Z-score method mitigates biases related to age, gender, and height, thereby enhancing the objectivity and accuracy of the assessment[4,5].

The link between lung function and cardiovascular disease has long been of interest. A cohort study identified a decline in lung function as a significant risk factor for cardiovascular disease[6]. Epidemiological evidence further underscores that reduced lung function, particularly when persistently declining, correlates with diminished cardiac performance and elevated risks of all-cause and cardiovascular mortality[7–9].

The American Heart Association (AHA) recently proposed a groundbreaking cardiovascular health (CVH) framework, emphasizing a shift from solely treating diseases to actively promoting health across the lifespan. Central to this initiative is the concept of Life's Essential 8 (LE8), a comprehensive tool for evaluating CVH[10]. Research indicates that LE8 scores correlate inversely with chronic conditions, such as diabetes, non-alcoholic fatty liver disease, and all-cause mortality[11–13]. However, LE8 is not confined to cardiovascular health. It integrates both health behaviors and factors. For example, good lung function has been associated with increased consumption of vitamin-rich fruits and vegetables[14], while smoking has been linked to declines in FVC and FEV1. Conversely, increased physical activity levels correlate with improved FVC. These findings highlight the importance of prioritizing smoking cessation and regular physical activity to preserve lung function[15].

These studies represent only a fraction of the LE8 framework, which encompasses a broader range of factors contributing to both cardiovascular and pulmonary health. By integrating multiple components, LE8 offers a holistic approach to understanding the determinants of long-term health outcomes, making it a valuable tool for evaluating cardiovascular and pulmonary health in diverse populations. Despite substantial evidence linking health behaviors and factors to lung function, no prior research has specifically examined the relationship between LE8 components and lung function. To address this gap, we conducted a study using the National Health and Nutrition Examination Survey (NHANES) database to investigate the potential association between LE8 scores and lung function Z-score. Our findings provide novel insights that could inform prevention and treatment strategies for lung function diseases in clinical practice.

Materials and methods

Ethics Statement

The NHANES program was approved by the National Center for Health Statistics Ethics Review Board, and all participants provided informed consent. Data were anonymized before public release, ensuring confidentiality. As this study involved secondary analysis of publicly available data, no additional ethical approval or consent was required. Further details are available on the website (https://www.cdc.gov/nchs/nhanes/irba98.htm).

Study design and participants

This analysis utilized data from five NHANES cycles (2007–2016), encompassing 30,443 participants. After excluding individuals aged < 20 years (n = 12,729), those with missing lung function data (n = 4,327), those with incomplete LE8 score calculations (n = 2,290), and participants with a history of coronary heart disease, angina pectoris, myocardial infarction, or stroke (n = 697),the final cohort consisted of 10,400 participants. A detailed flowchart of the selection process is provided in Fig. 1.

Spirometry

Lung function testing in NHANES is supported by the National Heart, Lung, and Blood Institute (NHLBI), the Centers for Disease Control and Prevention (CDC), the National Center for Health Statistics (NCHS), and the National Institute for Occupational Safety and Health (NIOSH), in accordance with the American Thoracic Society guidelines[16]. Exclusion criteria included individuals aged < 6 or > 79 years, those experiencing current chest pain or physical limitations, users of supplemental oxygen, individuals undergoing recent surgeries (eye, chest, or abdomen), and those with a history of heart attack, stroke, tuberculosis exposure, or recent hemoptysis. Additional exclusions included adults with a history of retinal detachment or collapsed lung, as well as children with painful ear infections.For this study, participants were categorized based on FEV1 z-scores into the following groups: normal lung function, mild impairment, and moderate to severe impairment. The z-score reflects the number of standard deviations a measurement deviates from the predicted mean value, accounting for gender, age, height, and ethnicity to provide a more precise assessment of lung function severity. A z-score greater than − 1.645 indicates normal lung function, −1.645 to −2.5 indicates mild impairment, −2.51 to −4indicates moderate impairment, and less than − 4 indicates severe impairment[4,17]. We used the prediction equations from the Global Lung Function Initiative (GLI-2012) and employed specialized software (www.lungfunction.org/files/InstallGLI2012_DataConversion.EXE) to calculate predicted FEV1 values and z-scores[18].

Measurement of Life's essential 8

The Life's Essential 8 comprises two facets: Health Behaviors and Health Factors. Health Behaviors encompass diet, physical activity, nicotine exposure, and sleep health. Meanwhile, Health Factors include Body Mass Index (BMI), Blood Lipids, Blood Glucose, and Blood Pressure[10]. The evaluation of dietary indicators involves the

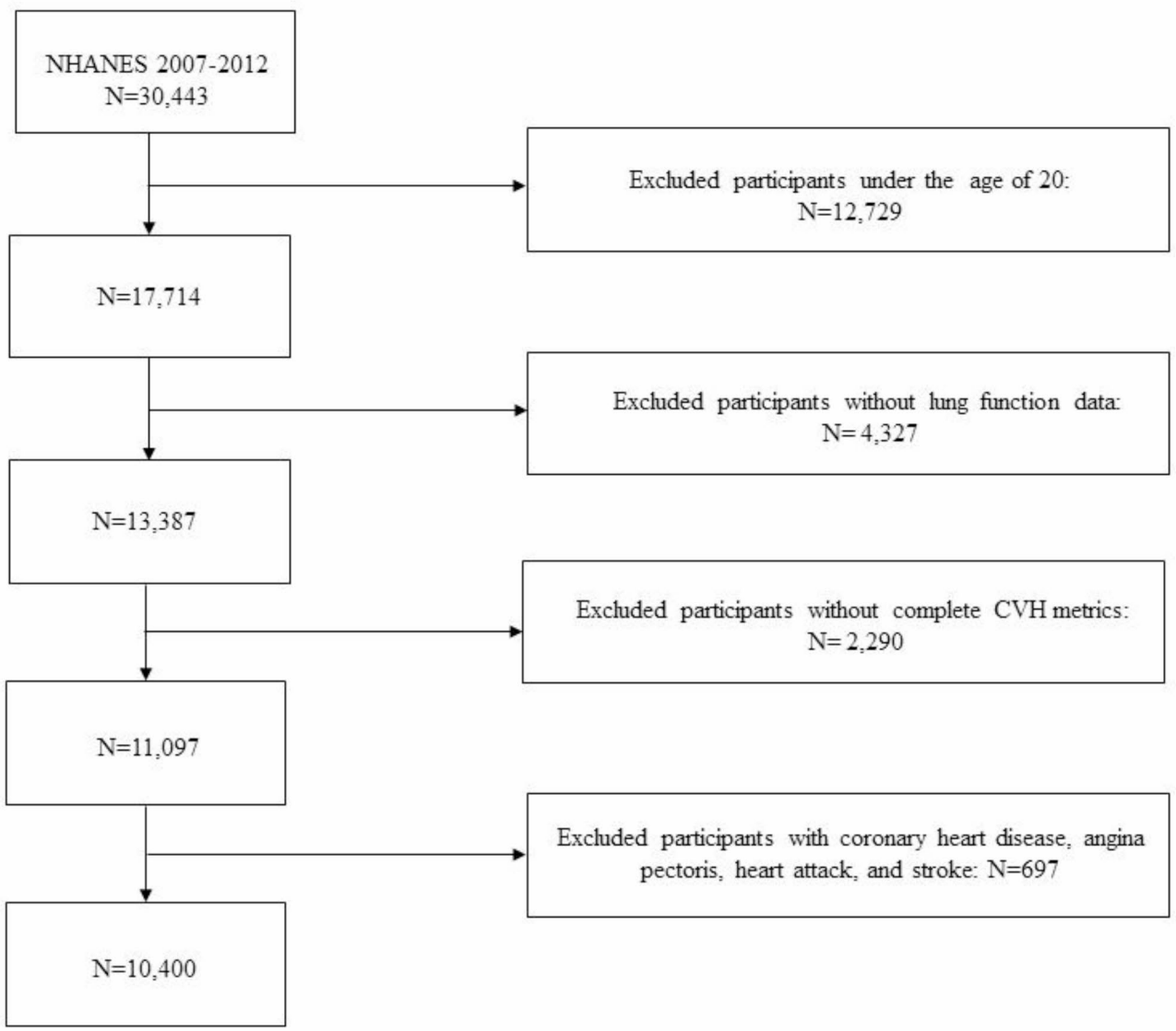

Fig. 1. Flowchart depicting the Screening Process for Selecting the Study Population.

utilization of the Healthy Eating Index (HEI-2015), which is based on two interviewer-administered 24-hour dietary recalls. This index, developed by the United States Department of Agriculture, aligns with the food pyramid and dietary guidelines, providing an efficient assessment of daily food intake composition and content relative to established dietary guidelines[19,20]. Physical activity, nicotine exposure, sleep duration, diabetes history, and medication history are collected via self-reported questionnaires. BMI and blood pressure are measured through physical examinations, while non-HDL cholesterol, plasma glucose, and hemoglobin A1c levels are obtained from blood samples[21]. Each of the eight indicators is scored on a scale of 0–100. Cardiovascular health scores are determined by averaging these eight indicator scores, ranging from 0 to 100. Participants with high CVH are considered to have LE8 scores of 80–100; moderate CVH, 50–79; and low CVH, 0–49[10]. The detailed methodology for calculating LE8 scores using the NHANES database can be found in the official LE8 guidelines[10].

Covariates assessment

The study incorporated potential confounding variables, including age, gender and race (Non-Hispanic Black, Non-Hispanic White, Mexican American, and Other). Household poverty was assessed by calculating the ratio of monthly family income to poverty levels as defined by the Department of Health and Human Services guidelines. Income categories included low income (≤ 1.30), low-middle income (1.31–1.85), middle income (1.86–3.50), and high income (> 3.50)[22]. Serum samples from participants were sent to the laboratory for testing, including albumin, Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST), creatinine, and vitamin D indicators. Creatinine clearance rates, assessing kidney function, were computed using the CKD-EPI Creatinine Eq. (2021)[23]. Additionally, participant questionnaires were used to ascertain histories of alcohol intake, emphysema, waist circumference, menopause, chronic bronchitis and asthma.

Statistical analyses

The data were analyzed in accordance with NHANES guidelines and recommended survey weights. In our analysis, the continuous variable FEV1 Z-score was categorized into three groups based on standard deviations, with subsequent statistical descriptions. Initial normality testing using the Kolmogorov-Smirnov test indicated non-normal distributions. Non-normally distributed metric data were represented using median and quartiles, and inter-group comparisons were conducted using the Kruskal-Wallis H test. Categorical data were presented as composition ratios, with inter-group comparisons also assessed using the Kruskal-Wallis H test. Count data were expressed as composition ratios, and inter-group comparisons were performed using the chi-square test. Following this, LE8 scores were stratified into three groups (Low CVH, Medium CVH, and High CVH), alongside the division of its eight components into three groups. FEV1 Z-score was considered the dependent variable. Weighted linear regression analysis was conducted to calculate β coefficients, estimating the correlation strength between the variables, and the results were illustrated through forest plots. In multivariate linear regression models, an extended model approach was applied for covariate adjustments. Three models were provided: Model 1, unadjusted variables; Model 2, adjusted for gender, age, race, and household poverty ratio; and Model 3, with additional adjustments for albumin, ALT, AST, eGFR, vitamin D, alcohol, asthma, emphysema, chronic bronchitis, and waist circumference. It is important to note that menopause was not included as a covariate in these analyses, as its data are only available for female participants. Including menopause would effectively exclude all male participants, reducing the sample size by nearly half. Therefore, we chose not to incorporate menopause as a covariate except in the sensitivity analysis, where it is treated as a supplementary analysis. Finally, restricted cubic spline regression explored potential nonlinear relationships between LE8 scores and FEV1 Z-score, with nonlinearity testing conducted using likelihood ratio tests. Subgroup analyses were performed by grouping variables such as gender and age. Sensitivity analysis was conducted by excluding three underlying diseases (asthma, emphysema, chronic bronchitis) from the analysis. All statistical analyses were conducted using SPSS 21.0 and R 4.0.0 software. Two-tailed statistical tests were performed, with $P < 0.05$ indicating statistical significance.

Results

Baseline characteristics

This study comprised 10,400 participants, with an average age of 44 years, and males accounting for 48.75% of the cohort. Detailed demographic characteristics are provided in Table 1. Participants were categorized into three groups based on FEV1 Z-scores: Z1 representing normal lung function ($n = 9,600$), Z2 indicating mild lung function impairment ($n = 618$), and Z3 representing moderate to severe lung function impairment ($n = 182$). Differences between groups in age, race, poverty ratio, serum albumin, kidney function, vitamin D levels, chronic respiratory diseases, menopausal status and waist were all statistically significant ($P < 0.001$). In the LE8 health behavior domain, significant differences were found among the groups in HEI-2015 diet, physical activity, nicotine exposure, and sleep ($P < 0.001$). Notable characteristics of the Z3 cohort included a median age of **55** years, higher male prevalence (56.59%), older age distribution, increased proportion of Non-Hispanic Black individuals (46.70%), and a higher incidence of low-income participants (48.35%). The Z3 subgroup exhibited the lowest median scores in LE8 (53.50), health behaviors (47.50), and health factors (58.12). Additionally, the Z2/Z3 lung function impairment groups displayed lower median scores in diet (25.00), physical activity (0.00), and nicotine exposure (75.00) compared to the normal group; the Z3 group manifested the poorest sleep patterns (70.00). In the LE8 health factors domain, apart from no statistical difference in blood lipid levels among the groups ($P = 0.533$), significant differences were observed in BMI, blood glucose, and blood pressure scores ($P < 0.001$). The Z2/Z3 lung function impairment groups had lower blood glucose scores (60.00) compared to the normal group, and the Z3 group exhibited poorer blood pressure scores (52.50).

Association of LE8 score with lung function

As presented in Table 2, a linear regression model was employed to analyze the association between low, moderate, and high LE8 scores and lung function. Model 1 remained unadjusted, while Model 2 was adjusted for gender, age, race, and family poverty rate. Model 3 encompassed all covariates from Model 2 along with additional factors (albumin, ALT, AST, eGFR, vitamin D, alcohol, asthma, emphysema, chronic bronchitis and waist). In Model 1, devoid of covariate adjustments, the high LE8 score group exhibited a notable increase of 0.748 in FEV1 Z-score (95% CI 0.650–0.847, $P < 0.001$) compared to the low LE8 score group; similarly, the moderate group showed an increase of 0.498 in FEV1 Z-score (95% CI 0.413–0.583, $P < 0.001$). Upon adjusting for demographic factors (gender, age, race, family poverty ratio), the high score group displayed an adjusted increase of 0.552 in FEV1 Z-score (95% CI 0.454–0.650, $P < 0.001$) relative to the low score group, while the moderate group manifested an adjusted increase of 0.401 in FEV1 Z-score (95% CI 0.313–0.489, $P < 0.001$). In Model 3, after accounting for all covariates, the high score group demonstrated an adjusted increase of 0.413 in FEV1 Z-score compared to the low score group (95% CI **0.270–0.557**, $P < 0.001$), whereas the moderate group exhibited an adjusted increase of 0.312 in FEV1 Z-score (95% CI 0.196–0.428, $P < 0.001$). The restricted cubic spline analysis reveals a significant non-linear relationship between LE8 total scores and lung function (P nonlinear < 0.001, Fig. 2A). Before the turning point at an LE8 score of 64.02, lung function increases significantly with higher LE8 scores. However, beyond this threshold, the improvement trend slows, indicating a plateau effect. In contrast, no non-linear relationship was observed between health behavior scores and lung function (P nonlinear = 0.883, Fig. 2B). Additionally, a significant non-linear association was found between health factor scores and lung function (P nonlinear < 0.001, Fig. 2C), with a turning point at 71.09. Before this point, improvements in health factors are strongly associated with enhanced lung function, while beyond it, the positive effects diminish but remain significant.

Variables	Total ($n=10400$)	*Z1 ($n=9600$)	*Z2 ($n=618$)	*Z3 ($n=182$)	H/χ^2	*P*
Age, M (Q_1, Q_3)	44.00 (31.00, 58.00)	43.00 (30.00,58.00)	51.00 (35.00,63.00)	55.00 (44.00,64.00)	99.60	< 0.001
Gender, n (%)					14.83	< 0.001
Male	5070 (48.75)	4628 (48.21)	339 (54.85)	103 (56.59)		
Female	5330 (51.25)	4972 (51.79)	279 (45.15)	79 (43.41)		
PIR, n (%)					25.63	< 0.001
low income (≤ 1.30)	3789 (36.43)	3456 (36.00)	245 (39.64)	88 (48.35)		
low middle income (1.31–1.85)	1247 (11.99)	1138 (11.85)	88 (14.24)	21 (11.54)		
middle income (1.86–3.50)	2214 (21.29)	2036 (21.21)	139 (22.49)	39 (21.43)		
high income (> 3.5)	3150 (30.29)	2970 (30.94)	146 (23.62)	34 (18.68)		
Race, n (%)					553.95	< 0.001
Mexican American	1710 (16.44)	1683 (17.53)	21 (3.40)	6 (3.30)		
Other Hispanic	1128 (10.85)	1090 (11.35)	27 (4.37)	11 (6.04)		
Non-Hispanic White	4602 (44.25)	4345 (45.26)	188 (30.42)	69 (37.91)		
Non-Hispanic Black	2127 (20.45)	1718 (17.90)	324 (52.43)	85 (46.70)		
Other Race	833 (8.01)	764 (7.96)	58 (9.39)	11 (6.04)		
LE8 score, M (Q_1, Q_3)	64.00 (53.00, 74.00)	65.00 (54.00,75.00)	56.00 (46.00,66.00)	53.50 (43.00,61.00)	271.77	< 0.001
HEI-2015 Diet score, M (Q_1, Q_3)	50.00 (25.00, 50.00)	50.00 (25.00,50.00)	25.00 (25.00,50.00)	25.00 (25.00,50.00)	16.97	< 0.001
PA score, M (Q_1, Q_3)	40.00 (0.00, 100.00)	40.00 (0.00,100.00)	0.00 (0.00,100.00)	0.00 (0.00,60.00)	74.16	< 0.001
Nicotine exposure core, M (Q_1, Q_3)	100.00 (0.00, 100.00)	100.00 (0.00,100.00)	75.00 (0.00,100.00)	75.00 (0.00,100.00)	72.45	< 0.001
Sleep score, M (Q_1, Q_3)	100.00 (70.00, 100.00)	100.00 (70.00,100.00)	90.00 (47.50,100.00)	70.00 (40.00,100.00)	49.65	< 0.001
BMI score, M (Q_1, Q_3)	70.00 (30.00, 100.00)	70.00 (30.00,100.00)	70.00 (30.00,100.00)	70.00 (18.75,100.00)	37.29	< 0.001
Blood lipids score, M (Q_1, Q_3)	60.00 (40.00, 100.00)	60.00 (40.00,100.00)	60.00 (40.00,100.00)	60.00 (40.00,100.00)	1.26	0.533
Glucose score, M (Q_1, Q_3)	100.00 (60.00, 100.00)	100.00 (60.00,100.00)	60.00 (60.00,100.00)	60.00 (60.00,100.00)	215.56	< 0.001
BP score, M (Q_1, Q_3)	80.00 (50.00, 100.00)	80.00 (50.00,100.00)	55.00 (30.00,100.00)	52.50 (25.00,80.00)	126.06	< 0.001
Health Behaviors, M (Q_1, Q_3)	56.25 (47.50, 74.06)	57.50 (47.50,75.00)	50.00 (35.00,62.50)	47.50 (31.25,56.25)	164.56	< 0.001
Health Factors, M (Q_1, Q_3)	71.25 (55.00, 85.00)	71.25 (56.25,85.00)	61.25 (46.25,77.50)	58.12 (44.06,72.50)	141.76	< 0.001
Alcohol, n (%)					3.93	0.140
Yes	7134 (74.69)	6596 (74.93)	417 (72.40)	121 (69.94)		
No	2418 (25.31)	2207 (25.07)	159 (27.60)	52 (30.06)		
Vitamin D (nmol/L), M (Q_1, Q_3)	61.00 (44.30, 78.50)	61.60 (45.10,79.00)	52.00 (35.95,71.85)	53.30 (34.00,68.10)	84.52	< 0.001
Albumin, M (Q_1, Q_3)	43.00 (41.00, 45.00)	43.00 (41.00,45.00)	42.00 (40.00,44.00)	41.00 (39.00,43.00)	84.64	< 0.001
ALT (U/L), M (Q_1, Q_3)	21.00 (16.00, 29.00)	21.00 (16.00,29.00)	21.00 (16.00,28.00)	21.00 (16.00,29.00)	1.94	0.380
AST (U/L), M (Q_1, Q_3)	23.00 (20.00, 28.00)	23.00 (20.00,28.00)	23.00 (20.00,27.50)	23.00 (20.00,27.00)	0.28	0.867
eGFR (mL/min/1.73m^2), M (Q_1, Q_3)	7.08 (5.84, 128.17)	7.17 (5.85,128.97)	6.56 (5.64,115.31)	6.45 (5.59,121.19)	40.62	< 0.001
Asthma, n (%)					126.53	< 0.001
Yes	1432 (13.78)	1231 (12.83)	132 (21.39)	69 (37.91)		
No	8959 (86.22)	8361 (87.17)	485 (78.61)	113 (62.09)		
Emphysema, n (%)					210.22	< 0.001
Yes	95 (0.96)	56 (0.62)	21 (3.54)	18 (10.17)		
No	9773 (99.04)	9042 (99.38)	572 (96.46)	159 (89.83)		
Chronic Bronchitis, n (%)					131.46	< 0.001
Yes	423 (4.29)	347 (3.82)	39 (6.58)	37 (20.90)		
No	9436 (95.71)	8742 (96.18)	554 (93.42)	140 (79.10)		
Menopause, n (%)					22.31	< 0.001
Yes	1794 (43.27)	1633 (42.33)	123 (53.71)	38 (64.41)		
No	2352 (56.73)	2225 (57.67)	106 (46.29)	21 (35.59)		
Waist (cm), M (Q_1, Q_3)	96.60 (86.40, 107.50)	96.30 (86.10,107.00)	100.35 (90.30,114.25)	104.20 (93.57,115.67)	49.04	< 0.001

Table 1. Baseline characteristics of the Study Population. PIR, poverty income ratio; PA, Physical activity; BP, Blood pressure; BMI, Body Mass Index; eGFR, estimated glomerular filtration rate. *Classification based on FEV1 Z-score is as follows: Greater than − 1.645 indicates normal lung function (Z1); between − 1.65 and − 2.5 indicates mild impairment (Z2); between − 2.51 and − 4 indicates moderate impairment, and less than − 4.1 indicates severe impairment, with moderate and severe impairments combined as Z3.

	Model 1		Model 2		Model 3	
	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
LE8 score						
Low(0–49)	Reference	/	Reference	/	Reference	/
Moderate(50–79)	0.498(0.413, 0.583)	< 0.001	0.401(0.313, 0.489)	< 0.001	0.312 (0.196, 0.428)	< 0.001
High(80–100)	0.748(0.650, 0.847)	< 0.001	0.552(0.454, 0.650)	< 0.001	0.413 (0.27, 0.557)	< 0.001

Table 2. Linear regression between LE8 and lung function FEV1 Z-score. Model 1: unadjusted; Model 2: adjusted for gender, age, race, and poverty income ratio; Model 3: additional adjustments for albumin, ALT, AST, eGFR, vitamin D, alcohol, asthma, emphysema, chronic bronchitis and waist; 95%CI, Confidence Interval.

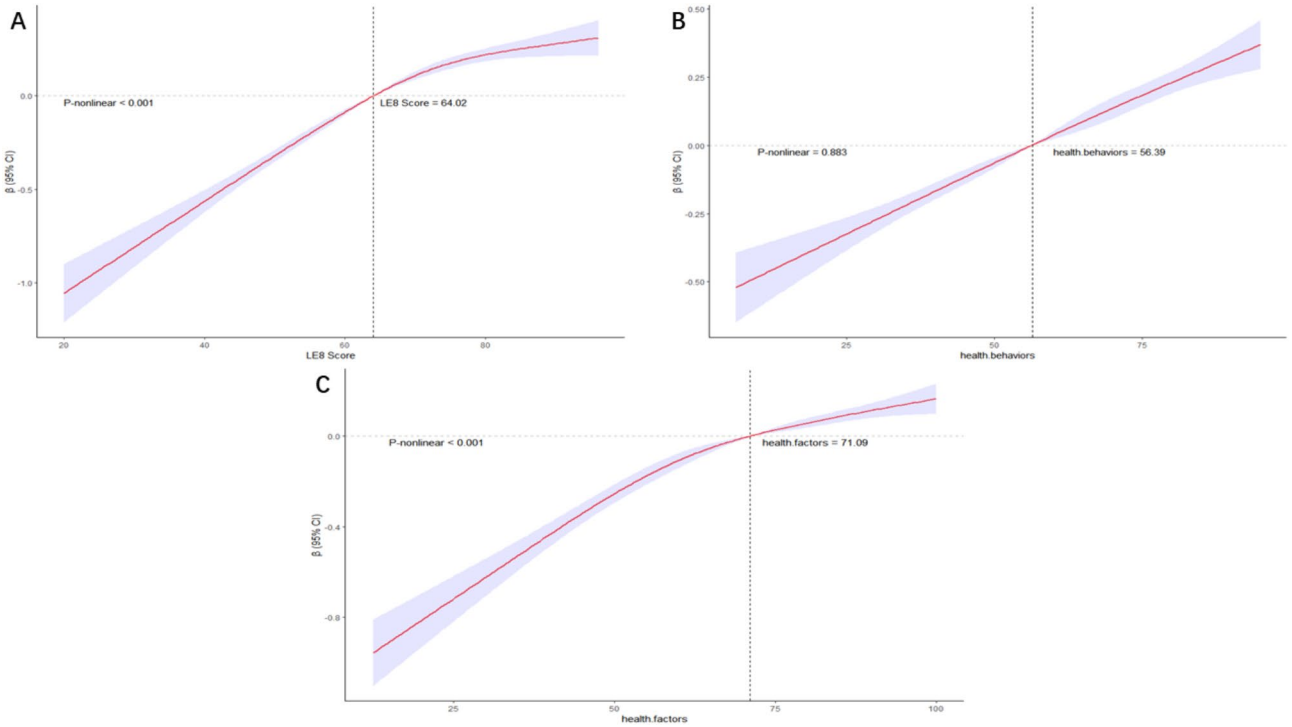

Fig. 2. Nonlinear associations between LE8 (A), Health behaviors (B), Health Factors (C), and lung function.

Correlation analysis of LE8 subcomponents with lung function

In this study, linear regression analyses were performed to examine the association between the eight components of the LE8 score (HEI-2015 diet, physical activity, nicotine exposure, sleep, blood pressure, blood lipids, blood glucose, and BMI scores) and lung function (FEV1 Z-scores) under different adjustment models (Table 3). Among the LE8 components, higher HEI-2015 diet scores were significantly associated with improved lung function. In Model 3, the high diet score group demonstrated an increase of 0.225 (95% CI 0.046–0.404, $P = 0.017$) in FEV1 Z-scores compared to the low score group, highlighting the beneficial impact of dietary quality on pulmonary health. Physical activity scores also showed a significant positive association with lung function. In Model 3, the high PA score group exhibited a β coefficient of 0.131 (95% CI 0.035–0.227, $P = 0.012$), while the moderate PA group did not demonstrate statistical significance, suggesting that higher levels of physical activity contribute more substantially to lung function enhancement. Nicotine exposure scores, where higher values indicate reduced exposure risk, were strongly correlated with better lung function. The high nicotine exposure score group presented a significant increase of 0.380 (95% CI 0.281–0.480, $P < 0.001$) in FEV1 Z-scores in Model 3, indicating the protective role of minimized nicotine exposure against pulmonary impairment. Sleep quality also emerged as a significant factor. Participants with high sleep scores exhibited an increase of 0.165 (95% CI 0.062–0.267, $P = 0.004$) in FEV1 Z-scores compared to the low sleep score group, emphasizing the positive contribution of better sleep quality to lung health.

Blood glucose and pressure scores were positively associated with lung function in the fully adjusted model. The high blood glucose score group demonstrated an increase of 0.365 (95% CI 0.242–0.488, $P < 0.001$), while the high blood pressure score group showed a β coefficient of 0.159 (95% CI 0.055–0.263, $P = 0.006$). These findings underline the importance of managing metabolic and cardiovascular risk factors for maintaining lung

	Model 1		Model 2		Model 3	
	β (95% CI)	*P*	*β* (95% CI)	*P*	*β* (95% CI)	*P*
HEI-2015 Diet score						
Low(0–49)	Reference	/	Reference	/	Reference	/
Moderate(50–79)	0.143 (0.078, 0.208)	< 0.001	0.166 (0.103, 0.229)	< 0.001	0.122 (0.047, 0.198)	0.004
High(80–100)	0.228 (0.098, 0.359)	0.001	0.288 (0.160, 0.415)	< 0.001	0.225 (0.046, 0.404)	0.017
PA score						
Low(0–49)	Reference	/	Reference	/	Reference	/
Moderate(50–79)	0.127(−0.002, 0.256)	0.053	0.071(−0.057, 0.199)	0.271	0.066 (−0.047, 0.179)	0.231
High(80–100)	0.276(0.209, 0.343)	< 0.001	0.199(0.130, 0.268)	< 0.001	0.131 (0.035, 0.227)	0.012
Nicotine exposure score						
Low(0–49)	Reference	/	Reference	/	Reference	/
Moderate(50–79)	0.134(0.022, 0.246)	0.020	0.199(0.087, 0.311)	0.001	0.267 (0.131, 0.403)	0.001
High(80–100)	0.292(0.209, 0.374)	< 0.001	0.307(0.235, 0.379)	< 0.001	0.380 (0.281, 0.480)	< 0.001
Sleep score						
Low(0–49)	Reference	/	Reference	/	Reference	/
Moderate(50–79)	0.206(0.099, 0.314)	< 0.001	0.131(0.030, 0.232)	0.012	0.123 (0.028, 0.219)	0.016
High(80–100)	0.322(0.231, 0.412)	< 0.001	0.184(0.101, 0.267)	< 0.001	0.165 (0.062, 0.267)	0.004
BMI score						
Low(0–49)	Reference	/	Reference	/	Reference	/
Moderate(50–79)	0.265(0.193, 0.337)	< 0.001	0.210(0.139, 0.282)	< 0.001	−0.190 (−0.283, −0.098)	0.001
High(80–100)	0.173(0.097, 0.249)	< 0.001	0.091(0.018, 0.164)	0.015	−0.491 (−0.632, −0.349)	< 0.001
Blood glucose score						
Low(0–49)	Reference	/	Reference	/	Reference	/
Moderate(50–79)	0.247(0.114, 0.381)	0.001	0.215(0.089, 0.340)	0.001	0.150 (−0.004, 0.305)	0.055
High(80–100)	0.646(0.519, 0.772)	< 0.001	0.463(0.334, 0.592)	< 0.001	0.365 (0.242, 0.488)	< 0.001
Blood lipids score						
Low(0–49)	Reference	/	Reference	/	Reference	/
Moderate(50–79)	0.131(0.058, 0.204)	0.001	0.092(0.018, 0.167)	0.016	0.058 (−0.064, 0.18)	0.321
High(80–100)	0.134(0.053, 0.216)	0.002	0.118(0.038–0.198)	0.005	0.050 (−0.070, 0.170)	0.385
BP score						
Low(0–49)	Reference	/	Reference	/	Reference	/
Moderate(50–79)	0.276(0.191–0.362)	< 0.001	0.154(0.059–0.248)	0.002	0.109 (−0.001, 0.219)	0.051
High(80–100)	0.365(0.282–0.448)	< 0.001	0.173(0.080–0.266)	0.001	0.159 (0.055, 0.263)	0.006

Table 3. Linear regression between LE8 subcomponents and lung function FEV1 Z-scores. Model 1: unadjusted; Model 2: adjusted for gender, age, race, and poverty income ratio; Model 3: additional adjustments for albumin, ALT, AST, eGFR, vitamin D, alcohol, asthma, emphysema, chronic bronchitis and waist; 95%CI, Confidence Interval. PA, Physical activity; BP, Blood pressure; BMI, Body Mass Index.

function. In contrast, BMI scores, which reflect lower obesity risk with higher values, exhibited a complex and seemingly adverse association with lung function. In Model 3, both the moderate (β = −0.190, 95% CI −0.283 to −0.098, $P = 0.001$) and high (β = −0.491, 95% CI −0.632 to −0.349, $P < 0.001$) BMI score groups were negatively associated with FEV1 Z-score. This suggests that even with lower obesity risk, as indicated by higher BMI scores, there may still be a detrimental effect on lung function. It is worth noting that the inclusion of waist circumference data in the model could introduce collinearity, potentially influencing these results. Waist circumference, as an indicator of central obesity, may overlap with BMI in capturing adiposity-related health risks, warranting careful interpretation of these findings. Further analyses are needed to disentangle the independent effects of BMI and waist circumference on lung function. Blood lipids, however, showed no significant associations in the fully adjusted model. Although moderate and high scores were associated with slight positive trends in the unadjusted models, these associations were not maintained after covariate adjustments, highlighting a potentially limited role of blood lipids in lung function within this population.

Subgroup and sensitivity analysis

The subgroup analysis demonstrated a consistent positive association between LE8 scores and lung function across most subgroups (Fig. 3). No significant interactions were found for sex ($P = 0.913$), race ($P = 0.842$), and poverty ratio ($P = 0.929$), indicating that these factors did not significantly influence the relationship between LE8 and lung function. However, a significant interaction with age was observed ($P = 0.011$), with a stronger association in the 60–79 age group (β = 0.016, 95% CI 0.010–0.022) compared to the 40–59 age group (β = 0.013, 95% CI 0.010–0.017). Sensitivity analyses further confirmed the robustness of these findings (Table 4). After

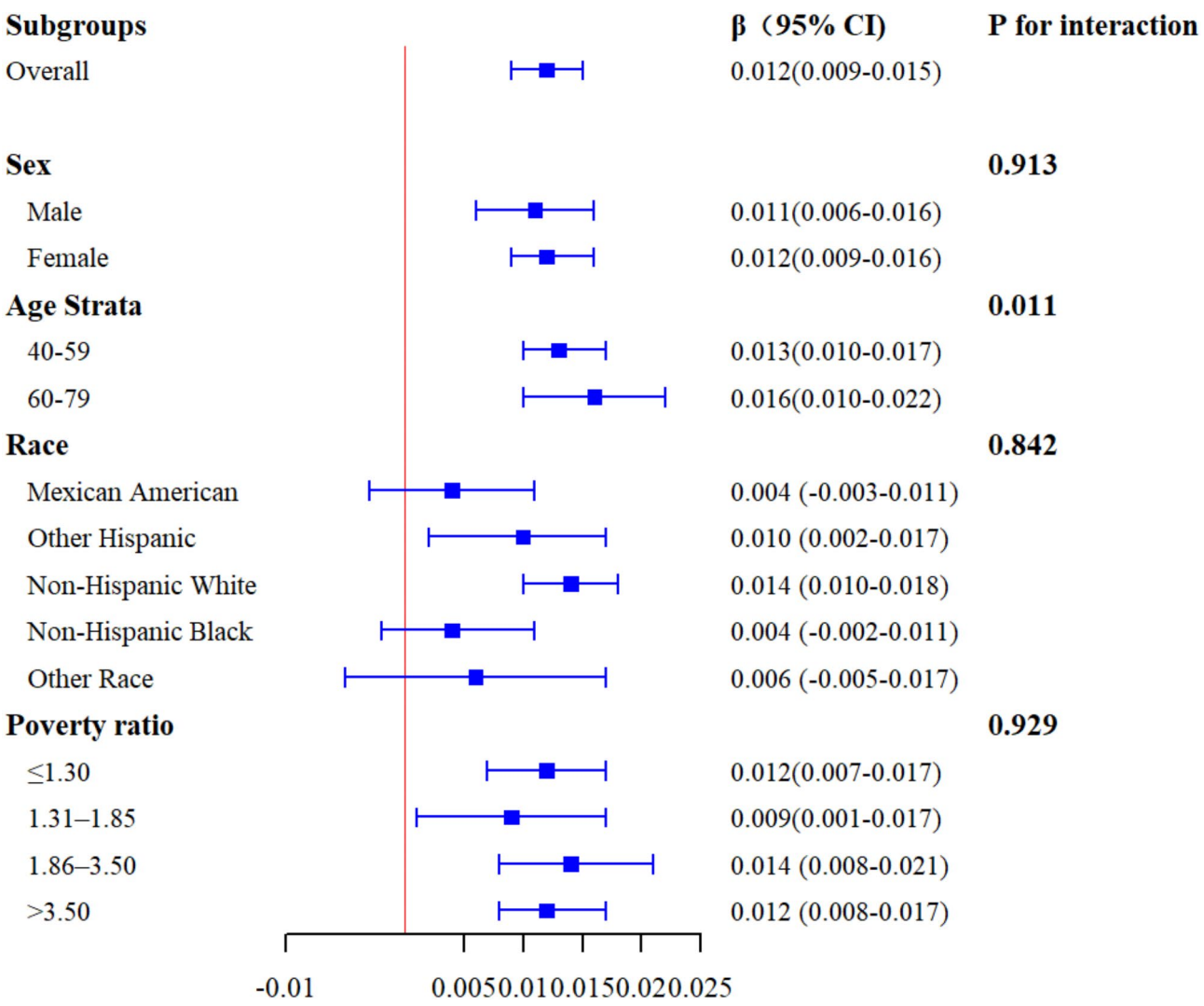

Fig. 3. Subgroup analysis of LE8 and lung function.

Subgroup	β (95% CI)	*P*
LE8	Excluding participants with history of Chronic lung disease*	
Low(0–49)	Reference	/
Moderate(50–79)	0.394(0.301–0.487)	< 0.001
High(80–100)	0.521(0.418–0.624)	< 0.001
LE8	Adjusted for menopause in the female population	
Low(0–49)	Reference	/
Moderate(50–79)	0.389(0.239,0.539)	< 0.001
High(80–100)	0.494(0.340,0.647)	< 0.001

Table 4. Sensitivity analysis for the associations between LE8 and lung function. LE8, Life's Essential 8; *Chronic lung diseases include asthma, emphysema and chronic bronchitis and adjusted for all covariates.

excluding participants with asthma, emphysema, and chronic bronchitis, the positive correlation between LE8 and lung function remained significant. In a fully adjusted model, the high LE8 group (β = 0.521, 95% CI 0.418–0.624, $P < 0.001$) and moderate LE8 group (β = 0.394, 95% CI 0.301–0.487, $P < 0.001$) showed significantly better lung function compared to the low LE8 group. After adjusting for menopause, these values remained

significant, at 0.494 (95% CI 0.340–0.647, $P<0.001$) and 0.389 (95% CI 0.239–0.539, $P<0.001$), respectively, further confirming the robustness of the positive association between LE8 scores and lung function.

Discussion

Life's Essential 8 (LE8) represents a novel paradigm in cardiovascular health (CVH) conceptualization, as proposed by the American Heart Association. This framework seeks to catalyze a fundamental shift from focusing solely on disease treatment to embracing a proactive approach that promotes and sustains health across individual lifespans and diverse population groups. This innovative approach emphasizes the creation of a distinctive and practical definition for fostering cardiovascular health[10]. Existing research indicates that adhering to the CVH model based on LE8 scoring can effectively reduce the incidence of chronic diseases[11–13].

To investigate the relationship between LE8 scores and lung function, we employed LE8 assessments to evaluate CVH levels alongside a novel standard for lung function assessment, the FEV1 Z-score. Our findings revealed a robust positive correlation between higher LE8 scores and improved lung function. Specifically, within the domain of healthy behaviors encompassed by LE8, higherscores indicating better dietary quality, increased physical activity, enhanced sleep quality, and reduced nicotine exposure (with higher scores denoting lower exposure) were significantly associated with better lung function. Moreover, health factor scores related to blood glucose, blood pressure and blood lipids also demonstrated a notable positive correlation with lung function. These associations remained statistically significant, even after accounting for potential confounding factors, such as lung diseases (e.g., emphysema, asthma, and chronic bronchitis), in subgroup and sensitivity analyses. Furthermore, these relationships persisted in the female population after adjusting for menopause. These findings suggest that adherence to the high LE8 score CVH model may confer protective or ameliorative effects on lung function.

Dietary habits, as one of the most routine aspects of life, are increasingly recognized for their gradual but profound impact on the occurrence, progression, and outcomes of chronic diseases[24]. Numerous studies have identified a healthy diet as a modifiable risk factor for reducing airway obstruction[25,26]. For instance, the Mediterranean diet appears to have beneficial effects on patients with airway diseases[27,28], and nutrients like carotenoids, vitamins A/C/D/E, curcumin, choline and omega-3 fatty acids have been shown to prevent or mitigate the development of conditions like asthma and COPD caused by environmental pollution[29–32].

In the realm of physical activity (PA) and lung function, extensive longitudinal studies have demonstrated a clear association between increased PA levels and slower rates of lung function decline, as well as reduced mortality rates. A decades-long cohort study revealed that men engaging in high levels of physical activity experienced a slower decline in lung function by 9.8 milliliters per year compared to their less active counterparts. Moreover, sustained high PA levels or an increase to high levels were associated with lower mortality **rates**[33]. Large observational studies have found that replacing sedentary behavior with physical activity or consistently increasing physical activity can significantly improve lung function in older adults, including those with obstructive pulmonary diseases and those without respiratory disorders[34,35]. Physical activity may confer its beneficial effects on lung function through mechanismssuch as reducing systemic inflammation and strengthening antioxidant defenses to mitigate oxidative stress, which contributes to age-related declines in lung function[36,37]. Additionally, we found that higher sleep scores, indicating better sleep quality, are associated with improved pulmonary function. Sleep disorders are prevalent in COPD patients and significantly affect both symptoms and overall health[38]. Compared to individuals with adequate sleep, those with shorter sleep durations are at higher risk of developing asthma, central obesity, and impaired lung function, with more pronounced inflammatory responses[39]. Changes in pulmonary function during sleep may be attributed to reduced CO2 chemoreception and diminished neural drive to breathe. The decrease in respiratory drive exacerbates the impact of CO2 fluctuations on breathing instability, leading to upper airway obstruction. Furthermore, oscillations in respiratory motor output can cause pharyngeal obstruction, particularly in individuals with collapsible airways, while reduced neural drive further impairs airflow and pharyngeal muscle activity, intensifying airway obstruction[40]. In animal studies, sleep deprivation resulted in significant oxidative DNA damage in pulmonary epithelial cells[41]. Nicotine exposure, a well-established hazard to lung health, has been shown to impair lung function more significantly in females than males under equivalent exposure levels[42,43]. Animal studies suggest that nicotine exposure alters gene expression in pulmonary cells, decreases cell proliferation, increases pulmonary endothelial permeability, and elevates inflammatory markers in lung tissues[44].

On health factors aspect, BMI as a general indicator of health, integrates various body components, such as waist circumference, visceral fat, and muscle mass. However, it fails to reflect the specific proportions and distribution of these components. While BMI provides an overall measure of obesity, it does not accurately describe the composition of body components or their individual impacts on health. This limitation introduces a degree of uncertainty when using BMI to evaluate health factors related to lung function. In the context of LE8 health factors, the relationship between BMI and lung function remains ambiguous. BMI does not account for the complex interplay of body components, such as adipose tissue and muscle mass, nor does it possess the sensitivity to determine the optimal body composition for health[45]. Research highlights a correlation between waist circumference—a marker of adipose tissue—and lung function[46]. Similarly, patients with sarcopenia exhibit a significant decline in the predicted FEV1 value[47]. However, the close association between BMI and waist circumference may lead to collinearity issues, complicating their use in analyses.

The relationship between blood glucose levels and lung function, particularly in diabetic patients, demonstrates a negative correlation, with elevated blood glucose levels, as well as the duration and severity of diabetes, associated with declining lung function[48,49]. Similarly, investigations into the relationship between blood pressure and lung function, utilizing data from diverse populations across multiple countries, reveal a negative correlation between blood pressure and lung function[50–52]. Additionally, a study examining the relationship between blood lipids and lung function (FEV1) found that higher levels of high-density lipoprotein

cholesterol and its associated apolipoprotein A-I correlate with increased FEV1, while elevated levels of low-density lipoprotein cholesterol and its apolipoprotein B correlate with decreased FEV1[53].

In summary, our study underscores the positive relationship between adherence to Life's Essential 8 and improved lung function. These findings support a holistic approach to cardiovascular and respiratory health and encourage the promotion of LE8 principles for better population health outcomes. Further research is needed to explore these associations and develop targeted interventions to optimize lung function.

Limitations

Despite the strengths of our study, several limitations should be considered. First, the cross-sectional design of the NHANES data limits our ability to infer causal relationships between LE8 scores and lung function. While we have established significant associations, future longitudinal studies are needed to confirm the directionality of these relationships. Second, although we included a broad range of covariates, some potentially important factors, such as air pollution exposure, were not available in the NHANES dataset. This could have influenced our findings, particularly regarding respiratory health. Despite these limitations, our study provides valuable insights into the associations between LE8 and lung function.

Conclusion

Our study demonstrates a significant positive correlation between Life's Essential 8 (LE8) and the FEV1 Z-score, highlighting that the components of LE8—including diet, physical activity, nicotine exposure, sleep quality, blood glucose, blood lipids, and blood pressure—collectively influence lung function. As a practical and valuable indicator for improving cardiovascular health, LE8 can be incorporated into clinical practice to enhance lung function, offering meaningful support to healthcare professionals in their efforts to improve patients' respiratory health.

Data availability

All data are sourced from the publicly available NHANES database. Please visit the website (https://www.cdc.gov/nchs/nhanes/index.htm) for access.

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Author contributions
TL wrote the main manuscript. HYM and ZKC conceived the article, while ZYX and HYM collected data. TL, SSH, HYM, and JCL conducted statistical analysis of the data, and TL and JLC created the figures. All authors finally reviewed the manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Consent for publication
The participant has consented to the submission of this article to the journal.

Ethics declarations
The National Health and Nutrition Examination Surveys (NHANES) program received approval from the

National Center for Health Statistics Research (NCHS) Ethics Review Board, and all survey participants consented by signing a consent form. The NCHS permits researchers to utilize the data they provide for research purposes. Prior to public release, the NCHS anonymizes NHANES data, ensuring anonymity throughout analysis. Hence, no additional ethical approval or informed consent was necessary for our secondary data analysis in this study. Further information regarding the NCHS Research Ethics Review Board Approval is available on the NHANES website (https://www.cdc.gov/nchs/nhanes/irba98.htm).

Additional information

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