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Association of health behaviors in life's essential 8 and hypertension in adolescents: a cross-sectional study from the NHANES database

Zhiyong Zhang[1], Xuejiao Wu[1], Yu Qu[2], Dapeng Zhang[1] and Weiming Li[1*]

Abstract

Background Hypertension is a common condition during adolescence with increasing prevalence globally, alongside the epidemic of unhealthy lifestyles and obesity. Health behaviors have been shown to be associated with hypertension risk in adults. Life's essential 8 (LE8), as a comprehensive indicator to evaluate cardiovascular health (CVH), includes 4 health factors and 4 health behaviors. This study aims to evaluate the association between health behaviors defined in LE8 and hypertension among adolescents.

Methods Data of this study were extracted from the National Health and Nutrition Examination Surveys (NHANES) 2007–2018. Health behaviors of LE8 including diet, physical activity and tobacco smoke exposure. The outcome was the odd of hypertension in adolescents. The weighted univariate and multivariate logistic regression was unitized to explore the relationship between CVH score and hypertension in adolescents. Subgroup analysis and sensitivity analysis were further conducted to explore the association across different populations.

Results Totally 3,941 adolescents aged 12–17 years were included, with the mean aged of 14.48 ± 0.04 years. Of whom, 203 (5.15%) had hypertension. After adjusted all covariates, high CVH score was associated with the lower odds of hypertension (OR = 0.32, 95%CI: 0.17–0.61), especially in boys (OR = 0.23, 95%CI: 0.11–0.51) and adolescents with overweight/obesity (OR = 0.24, 95%CI: 0.10–0.56). Sensitivity analysis reported that the association between CVH score and the odds of hypertension was also robust after excluding self-reported hypertension and medication taking (OR = 0.37, 95%CI: 0.18–0.74).

Conclusion A high CVH score, indicating a greater adherence of health behaviors, was associated with a reduced odds of hypertension, especially among boys and overweight/obesity adolescents. Large-scale prospective cohort studies are needed to further explore the association between health behaviors defined in LE8 and hypertension among adolescents.

Keywords Life's essential 8, Health behaviors, Hypertension, Adolescents, NHANES database

*Correspondence:
Weiming Li
wml13671116978@outlook.com

[1]Heart Center and Beijing Key Laboratory of Hypertension, Beijing Chaoyang Hospital, Capital Medical University, No. 8 Gongti South Road, Chaoyang District, Beijing 100020, China
[2]Geriatric Department, Linhe People's Hospital of Bayannur City, Bayannur, Inner Mongolia 015000, China

Background

Hypertension was a prevalent chronic disease worldwide featured by elevated arterial blood pressure (BP). It affected approximately 1.2 billion people and has become one of the most vital health problem [1]. Recently, with the epidemic of unhealthy lifestyles as well as overweight/obesity in adolescents, the trend of the early onset of hypertension was more obvious [2]. Hypertension in adolescents was associated with long-term negative health effects of hypertension and cardiovascular disease (CVD) in adulthood [3]. Even worse, adolescent hypertension may also lead to irreversible end-organ and vascular damage like hypertension in adults [4]. Control of hypertension in adolescence was becoming a major challenge in primary health care [3].

Previous study reported that daily lifestyle behaviors such as diet and physical activity are considered to be important modifiable factors for the prevention and control of hypertension [5]. Focusing on modifiable risk factors, the American Heart Association (AHA) proposed a cardiovascular health (CVH) quantification tool-life's essential 8 (LE8). LE8 contains 4 health behaviors (diet, physical activity, tobacco smoke exposure and sleep duration) and 4 health factors [body mass index (BMI), non-high-density-lipoprotein, blood glucose and BP] [6]. In the adult-based cohort studies, adherence to the health behaviors defined in LE8 was associated with the lower risk of hypertension and diabetes [7, 8]. However, the association of adherence to the health behaviors including diet, physical activity and exposure to tobacco smoke defined in LE8 and hypertension among adolescents remains unclear.

Herein, the purpose of this study was to evaluate the relationship between health behaviors defined in LE8 and hypertension among adolescents based on the data from the National Health and Nutrition Examination Surveys (NHANES). The association was further evaluated stratified by gender and body mass index (BMI) Z-score in different subpopulations.

Methods

Study design and population

Data of adolescents for present study were extracted from the NHANES 2007–2018. The NHANES was a large-scale, periodic survey program using a stratified, multistage, and probability-cluster design to collect a nationally representative sample of non-institutionalized US civilians. This survey was conducted at National Center for Health Statistics (NCHS), the Centers for Diseases Control and Prevention (CDC). The requirement of ethical approval for this was waived by the Institutional Review Board of Beijing Chaoyang Hospital, Capital Medical University, because the data was accessed from NHANES (a publicly available database). The need for written informed consent was waived by the Institutional Review Board of Beijing Chaoyang Hospital, Capital Medical University due to retrospective nature of the study. All methods were performed in accordance with the relevant guidelines and regulations.

In present study, 5,982 adolescents aged 12–17 years in NHANES 2007–2018 were initial extracted. Then, 1,209 adolescents missing physical activity information, 544 missing tobacco smoke exposure information, 134 missing the complete dietary approach to stop hypertension (DASH) calculation information, 106 missing BP measurement data, 27 missing height data, 20 missing information of sedentary time and 1 missing BMI data were excluded. Finally, 3,941 eligible adolescents were included for further analysis. The screening process was shown in Fig. 1.

BP measurements and definition of hypertension in adolescents

Adolescents were defined as hypertensive if they (1) aged (16–17 years) or their parent/guardian (aged 12–15 years) respond that they were diagnosed as hypertension by clinician and then irrespective their BP value; (2) or taking antihypertensive medication irrespective their BP value; (3) or categorized as having hypertension/elevated according to the 2017 guideline from the American Academy of Pediatrics (AAP) [9]. This guideline recommended that participants with a systolic BP (SBP)≥130 mmHg and/or diastolic BP (DBP)≥80 mmHg were defined as having hypertension. For criteria 3, BP was measured in NHANES as follows: after participants sat quietly for 5 min and after determining the participants' maximum inflation level (MIL), three times of BP value was measured. If the BP measurement was interrupted or incomplete, a forth BP value was measured. SBP and DBP were taken in the mobile examination center (MEC), and the means value was calculated. The BP measurers were certified for BP test via a training program from Shared Care Research and Education Consulting.

Health behaviors defined in LE8

The CVH status of adolescents was represented by the total score of each health behaviors. In present study, we focused on three health behaviors of LE8 including diet, physical activity and tobacco smoke exposure to evaluate the association between health behaviors and hypertension in adolescents to fit the NHANES database. The detailed algorithms for calculating LE8 score for each item using NHANES data have been reported previously [10]. The definitions and levels of each items have been described in Supplementary Table S1 [10, 11]. Each of the three CVH metrics was scored ranging from 0 to 100 points. The overall CVH score was calculated as the unweighted average of the three metrics. Adolescents

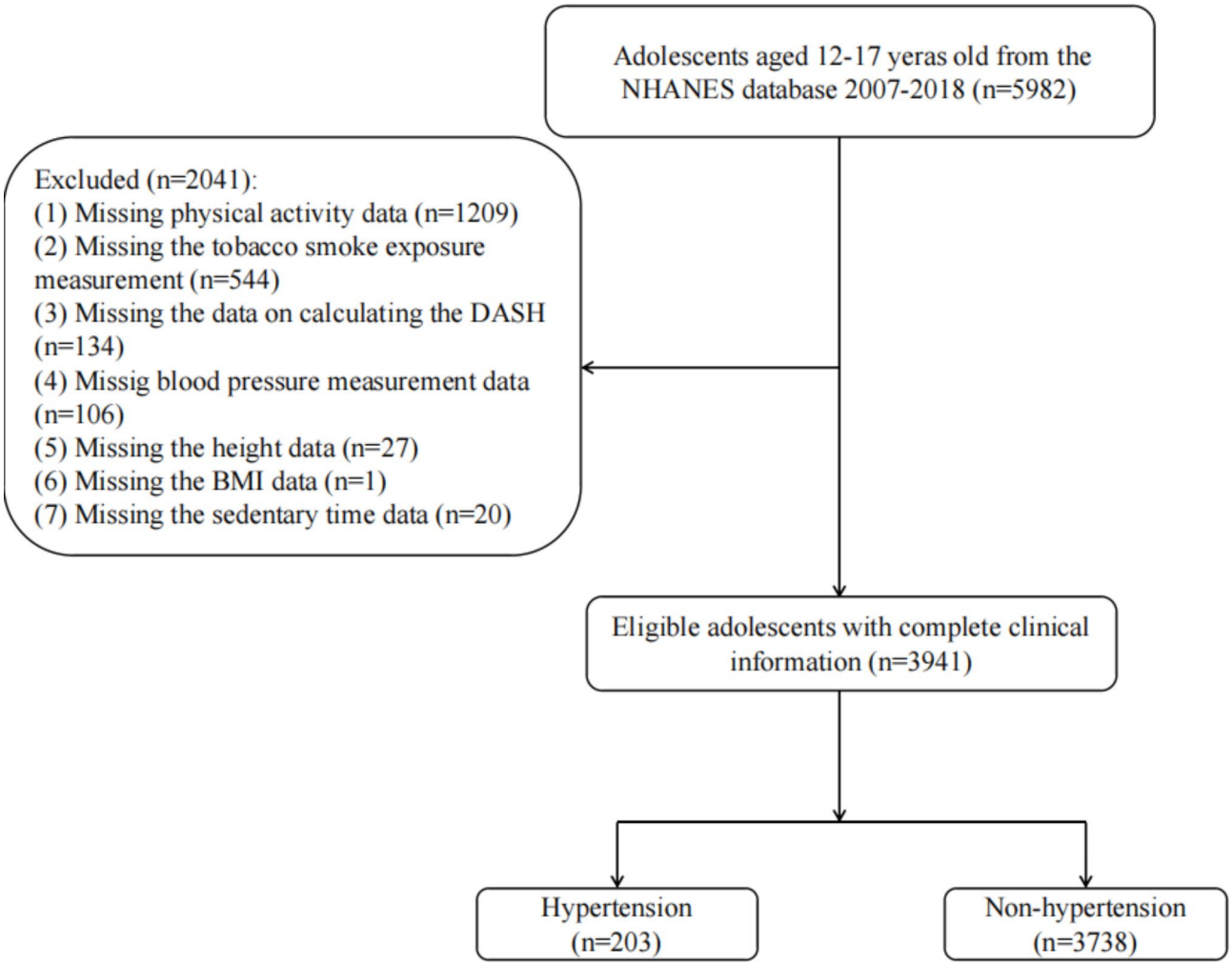

Fig. 1 Subject screening flowchart

with a health behaviors score of 80–100 were considered to be at good CVH status; 50–79 were moderate CVH status; and 0–49 were poor CVH status [10].

Dietary intake information was obtained from 24 h interview. The interview was conducted at Mobile Test Center through face-to-face communication. Adolescents were asked to recall all the types and amount of food and drink as well as the supplements consumed in the 24 h prior the interview. The United States Department of Agriculture's (USDA) Food and Nutrient Database for Dietary Studies and NHANES Dietary Supplement Database were used to calculate daily intakes of energy, nutrients, and other food components [12].

Physical activity was measured by the ActiGraph GT1M accelerometer (ActiGraph, LLC, Penscola, FL). Adolescents was asked to wear accelerometers while they were awake for 7 days, with exception of water activities such as bathing ad swimming. Physical activity volume was calculated as mean accelerometer counts per minute, and physical activity intensity was calculated using established thresholds [13].

Tobacco smoke exposure was evaluated by serum cotinine level which measured via the isotope-dilution liquid chromatography-tandem mass spectrometry method. According to the analysis in the NAHNES 1999–2004, the optimal serum cotinine cut point to distinguish adolescents between smoke and non-smoke as 2.99 ng/mL [14].

Potential covariates

The potential covariates included in present study were demographic information, physical examination and laboratory values. Age, gender and race were self-reported demographic information. The birth weight below 2,500 g was defined as a low birth weight. In 2007–2026, the sedentary time was assessed as the total time of a participant spent lying or sitting at school, at work, or at home during the day. In 2017–2018, the sedentary time was divided as <5 h and ≥ 5 h according to screen time.

The trained research assistants measured child height and weight without shoes and in light clothing using a Seca scale and a stadiometer. From these measurements, child BMI, and age- and sex-specific BMI Z-score and percentile categories were calculated, basing the CDC guidelines. Percentile categories were defined as normal (≥5th to <85th percentile), overweight (≥85th to <95th percentile), obesity (≥95th percentile), and severe obesity (≥120% of the 95th percentile) [15]. Insulin resistance status was expressed by HOMA-IR and HOMA-IR = fasting blood glucose (mmol/L) × fasting insulin (μU/mL). Based on the National Cholesterol Education Program guidelines, abnormal serum total cholesterol ≥ 200 mg/dL, high-density lipoprotein cholesterol ≤ 35 mg/dL, low-density lipoprotein cholesterol ≥ 130 mg/dL, triglyceride ≥ 150 mg/dL, glucose ≥ 100 mg/dL and HOMA-IR ≥ 4.39 [16].

Statistical analysis

All statistical analyzes were performed using R v 4.20 (R Foundation for Statistical Computing, Vienna, Austria) and SAS v. 9.4 (SAS Institute, Cary, North Carolina) software. The finally sample size was weighted with SDMVSTRA, SDMVPSU and WTMEC2YR. SDMVSTRA means the CI being applied to assess the reliability of an estimate. SDMVPSU was the masked variance unit pseudo-substrate. WTMEC2YR was the MEC exam weight used for weighting.

Continuous data were expressed as mean and standard error (S.E.), and the weighted t-test was used for comparison between groups. Categorical variables were described as the number and percentage [n (%)], and comparisons between groups used the weighted chi-squared test. The weighted univariate logistics regression was unitized to screen the covariates that associated with the risk of hypertension (Supplementary Table S2). Then, weighted multivariate logistics regression was used to explore the relationship between health behaviors represented by CVH score and the risk of hypertension in adolescents, with odd ratios (ORs) and 95% confidence intervals (CIs). Model 1 was the crude model without adjusted for covariates. Model 2 adjusted for age, gender, low birth weight, BMI Z-score and HDL-C abnormal. Subgroup analysis was conducted to explore the association based on the gender and BMI Z-score. Sensitivity analysis was further used to evaluate these association excluding the self-reported hypertension and taking hypertension medication. Two-sided *P*-value < 0.05 was considered statistically significant.

Results

Description of study population

Totally, 3,941 eligible adolescents were included, with the mean age of 14.48 ± 0.04 years. Of whom, 203 (5.15%) had hypertension. Characteristics of included participants were shown in Table 1. The proportion of adolescents with higher CVH in hypertension group was lower than in the non-hypertension group (13.27% vs. 27.82%). Difference was found in age, gender, the level of PIR, low birth weight and BMI Z-score and HDL-C abnormal between two groups (all $P < 0.05$).

Association between health behaviors in LE8 and hypertension in adolescents

We employed two logistic regression models to explore the association between health behaviors and hypertension in adolescents, as presented in Table 2. After adjustment for age, gender, low birth weight, BMI Z-score and HDL-C abnormal in model 2, we observed that high CVH score was associated with the lower odds of adolescents with hypertension (OR = 0.32, 95%CI: 0.17–0.61). The finding also indicated that with each 10 score increase in CVH, the odds of hypertension diminished by 2% (OR = 0.98, 95%CI: 0.97–0.99).

Association between health behaviors in LE8 and hypertension in adolescents based on different gender and BMI Z-score

Further association between health behaviors and hypertension in adolescents was explored based on different gender and BMI Z-score. As shown in Fig. 2, after adjustment for age, gender, low birth weight, BMI Z-score and HDL-C abnormal in model 2, high CVH was associated with the lower odds of adolescents with overweight or obesity, especially in boys (OR = 0.23, 95%CI: 0.11–0.51) and adolescents with overweight/obesity (OR = 0.24, 95%CI: 0.10–0.56). We also observed that in girls (OR = 0.98, 95%CI: 0.97–0.99) and underweight or normal adolescents (OR = 0.99, 95%CI: 0.98–0.99), each 10 scores increase in CVH was associated with the lower odds of hypertension.

Sensitivity analysis of association between health behavior in LE8 and hypertension in adolescents

After excluding self-reported hypertension and medication use, the association between health behaviors and hypertension in adolescents was further explored. Table 3 reports that after adjustment for age, gender, low birth weight, BMI Z-score and HDL-C abnormal, the association between health behaviors and hypertension in adolescents was unchanged. High CVH score was related to lower odds of hypertension in adolescents (OR = 0.37, 95%CI: 0.18–0.74) and with each 10 score increase in CVH, the odds of hypertension decreased by 2% (OR = 0.98, 95%CI: 0.97–0.99). Taken together, given the two definitions of hypertension among adolescents in present study, the results were robust that higher health

Table 1 Characteristics of study adolescents

Variables	Total ($n=3961$)	Non-hypertension ($n=3738$)	Hypertension ($n=203$)	*P*
Age, years, Mean (S.E)	14.48 (0.04)	14.45 (0.04)	15.05 (0.14)	< 0.001
Gender, n (%)				0.005
Female	1931 (49.94)	1863 (50.57)	68 (37.81)	
Male	2010 (50.06)	1875 (49.43)	135 (62.19)	
Race, n (%)				0.166
Mexican American	903 (13.43)	859 (13.44)	44 (13.23)	
Non-Hispanic Black	956 (13.63)	891 (13.35)	65 (19.14)	
Non-Hispanic White	1125 (57.88)	1069 (57.94)	56 (56.66)	
Other Hispanic	473 (7.08)	454 (7.12)	19 (6.27)	
Other Race-Including Multi-Racial	484 (7.98)	465 (8.15)	19 (4.70)	
PIR, n (%)				0.016
≤1.85	1980 (37.46)	1874 (37.16)	106 (43.16)	
>1.85	1645 (56.58)	1568 (57.11)	77 (46.45)	
Unknown	316 (5.96)	296 (5.73)	20 (10.39)	
Low birth weight, n (%)				< 0.001
No	2236 (57.82)	2159 (58.93)	77 (36.43)	
Yes	330 (7.62)	315 (7.58)	15 (8.41)	
Unknown	1375 (34.56)	1264 (33.49)	111 (55.16)	
BMI Z-score, n(%)				< 0.001
Underweight	81 (2.13)	80 (2.21)	1 (0.65)	
Healthy weight	2241 (59.07)	2169 (60.49)	72 (31.70)	
Overweight	713 (17.76)	676 (17.65)	37 (19.77)	
Obesity	906 (21.04)	813 (19.65)	93 (47.88)	
Sedentary time, mins, n (%)				0.809
<300	346 (8.12)	330 (8.15)	16 (7.61)	
≥300	3595 (91.88)	3408 (91.85)	187 (92.39)	
TC abnormal, n (%)				0.311
No	3308 (83.73)	3147 (83.93)	161 (80.02)	
Yes	234 (6.15)	218 (6.17)	16 (5.80)	
Unknown	399 (10.12)	373 (9.90)	26 (14.18)	
HDL-C abnormal, n (%)				0.016
No	3308 (83.70)	3153 (84.18)	155 (74.49)	
Yes	399 (10.12)	373 (9.90)	26 (14.18)	
Unknown	2297 (58.74)	2175 (58.61)	122 (61.27)	
LDL-C abnormal, n (%)				0.756
No	1558 (39.13)	1482 (39.24)	76 (37.08)	
Yes	86 (2.13)	81 (2.15)	5 (1.65)	
Unknown	86 (2.13)	81 (2.15)	5 (1.65)	
TAG abnormal, n (%)				0.426
No	3054 (76.40)	2907 (76.61)	147 (72.43)	
Yes	473 (13.25)	443 (13.25)	30 (13.39)	
Unknown	414 (10.35)	388 (10.15)	26 (14.18)	
Fasting glucose abnormal, n (%)				0.426
No	1309 (33.33)	1251 (33.56)	58 (28.86)	
Yes	380 (8.90)	354 (8.79)	26 (11.00)	
Unknown	2252 (57.77)	2133 (57.64)	119 (60.14)	
HOMA-IR abnormal, n (%)				0.253
No	1244 (32.83)	1193 (33.13)	51 (26.99)	
Yes	388 (8.15)	359 (7.97)	29 (11.59)	
Unknown	2309 (59.03)	2186 (58.90)	123 (61.42)	
Energy, kcal, Mean (S.E)	2083.59 (22.16)	2081.95 (22.82)	2115.33 (75.47)	0.670
Health behaviors CVH, n (%)				< 0.001
Low CVH	793 (19.11)	735 (18.36)	58 (33.53)	

Table 1 (continued)

Variables	Total ($n=3961$)	Non-hypertension ($n=3738$)	Hypertension ($n=203$)	*P*
Moderate CVH	2122 (53.79)	2016 (53.82)	106 (53.20)	
High CVH	1026 (27.10)	987 (27.82)	39 (13.27)	
Per 10 points increase, Mean (S.E)	66.37 (0.42)	66.83 (0.43)	57.38 (2.06)	< 0.001
DASH score, n (%)				< 0.001
High CVH	1040 (26.91)	994 (27.26)	46 (20.10)	
Low CVH	1918 (49.88)	1794 (49.02)	124 (66.51)	
Moderate CVH	983 (23.21)	950 (23.72)	33 (13.39)	
DASH 10 increase, Mean (S.E)	40.82 (0.85)	41.33 (0.89)	31.00 (2.86)	0.001
Physical activity score, n (%)				
High CVH	2337 (63.25)	2209 (63.37)	128 (60.85)	
Low CVH	1378 (30.35)	1310 (29.99)	68 (37.22)	
Moderate CVH	226 (6.40)	219 (6.64)	7 (1.94)	
Physical activity score 10 increase, Mean (S.E)	72.29 (0.77)	72.54 (0.81)	67.38 (4.14)	0.236
Tobacco smoke exposure score, n (%)				< 0.001
High CVH	3414 (85.18)	3260 (85.96)	154 (70.09)	
Low CVH	243 (7.13)	216 (6.58)	27 (17.80)	
Moderate CVH	284 (7.69)	262 (7.46)	22 (12.11)	
Tobacco smoke exposure score 10 increase, Mean (S.E)	86.98 (0.58)	87.61 (0.55)	74.83 (3.40)	< 0.001

t: t-test; χ^2: chi-square test; S.E.: standard error; PIR: poverty-to-income ratio; BMI: body mass index; TC: total cholesterol; HDL-C: high-density lipoprotein cholesterol; TAG: triglyceride; HOMA-IR: homeostasis model assessment of insulin resistance; CVH: cardiovascular health; DASH: dietary approach to stop hypertension

Table 2 Association between health behaviors in LE8 and hypertension in adolescents

Variables	Model 1		Model 2	
	OR (95%CI)	*P*	OR (95%CI)	*P*
Health behaviors score				
Low CVH	Ref		Ref	
Moderate CVH	0.54 (0.35–0.84)	0.006	0.60 (0.39–0.92)	0.021
High CVH	0.26 (0.14–0.48)	< 0.001	0.32 (0.17–0.61)	< 0.001
Per 10 points increase	0.98 (0.97–0.99)	< 0.001	0.98 (0.97–0.99)	< 0.001
DASH score, n (%)				
Low CVH	Ref		Ref	
Moderate CVH	0.42 (0.24–0.73)	0.003	0.47 (0.26–0.85)	0.012
High CVH	0.54 (0.35–0.84)	0.006	0.63 (0.40–0.98)	0.039
DASH 10 increase, Mean (S.E)	0.99 (0.98–0.99)	0.003	0.99 (0.98–0.99)	0.016
Physical activity score, n (%)				
Low CVH	Ref		Ref	
Moderate CVH	0.24 (0.10–0.58)	0.002	0.30 (0.12–0.75)	0.010
High CVH	0.77 (0.50–1.21)	0.255	0.75 (0.47–1.18)	0.212
Physical activity score 10 increase, Mean (S.E)	1.00 (0.99-1.00)	0.215	1.00 (0.99-1.00)	0.165
Tobacco smoke exposure score, n (%)				
Low CVH	Ref		Ref	
Moderate CVH	0.60 (0.25–1.44)	0.248	0.59 (0.26–1.37)	0.218
High CVH	0.30 (0.18–0.52)	< 0.001	0.37 (0.22–0.63)	< 0.001
Tobacco smoke exposure score 10 increase, Mean (S.E)	0.99 (0.98–0.99)	< 0.001	0.99 (0.98–0.99)	< 0.001

OR: odd ratios; CI: confidence interval; Ref: reference

LE8: life's essential 8; CVH: cardiovascular health

Model 1: crude model

Model 2: adjusted age, gender, low birth weight, BMI Z-score and HDL-C abnormal

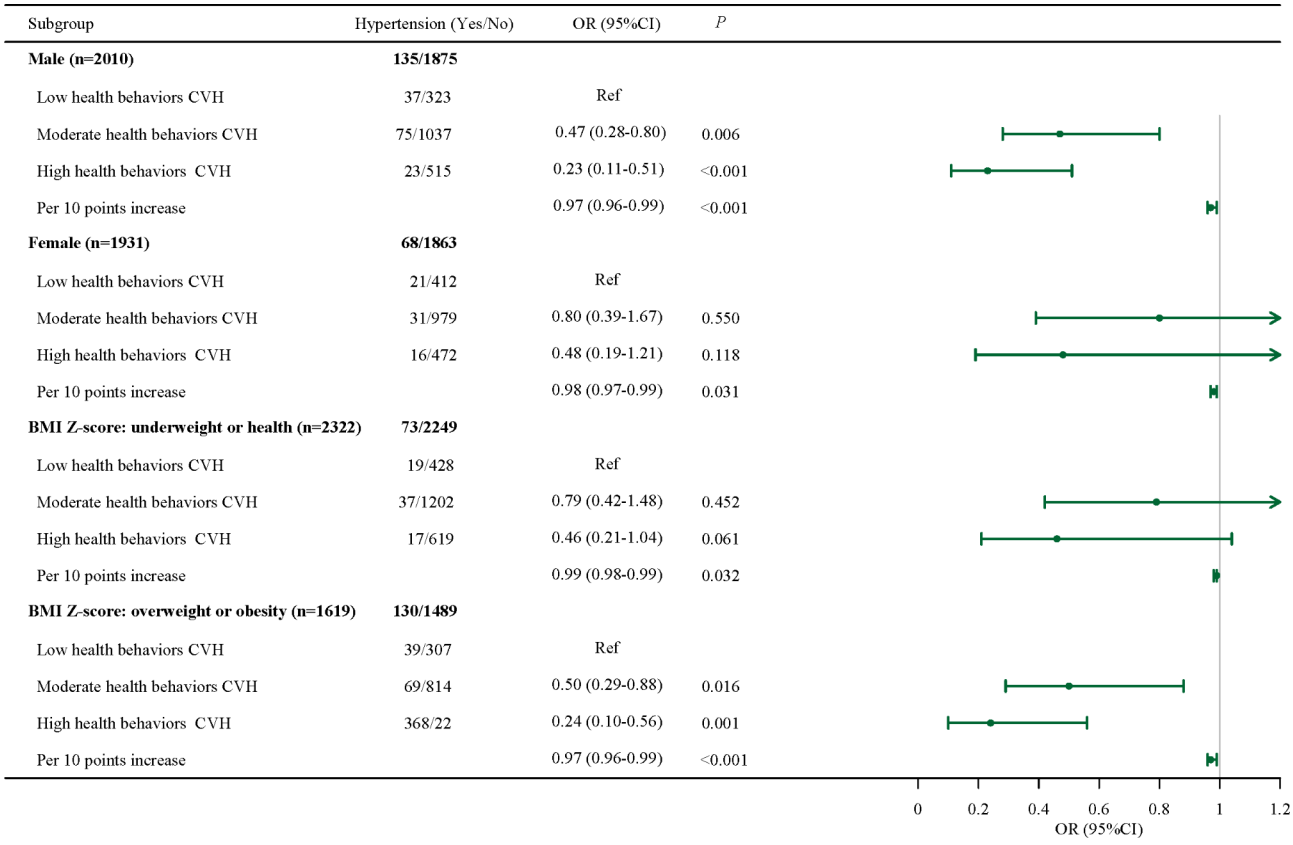

Fig. 2 Association between health behaviors in LE8 and hypertension in adolescents based on different gender and BMI Z-score

CVH score was associated with lower odds of hypertension among adolescents.

Discussion

In the present study, we investigated the association between health behaviors in LE8 and hypertension among adolescents. Our findings showed that high CVH score, representing greater adherence the health behaviors defined in LE8, was associated with the lower odds of hypertension in adolescents, especially in boys and overweight/obesity adolescents. Moreover, the association remained robust after excluding adolescents with self-reported hypertension and medication uses.

Hypertension was an ongoing clinical and public health challenge that has been proved to be related to health behaviors such as anti-inflammatory diet intake, reduced tobacco smoke exposure and adequate physical activity. However, there is no standardized or recognized behaviors intervention strategies as yet. Although initially considered a disease of adults, hypertension is increasing in adolescents. To our knowledge, previous studies on the association between health behaviors and hypertension have focused on adults' cohorts with inconsistent conclusions. A study from *Brazilian Longitudinal Study of Aging* based on general population suggested that health behaviors were associated with the lower risk of hypertension and the prevalence of hypertension control was 50.7%. Moreover, the effect of health behaviors on hypertension control showed a significant gender difference [17]. Similarly, a symposium presentation interested on the relationship between health behaviors and hypertension among females stated that addressing the barriers to adherence to health behaviors may have a substantial impact on reducing hypertension related cerebral vasospasm and improving heart diseases survival among female [18]. A study from Jordanian population aimed to evaluate the decisional balance of individuals in smoking, weight control, and physical exercise behaviors among hypertensive patients. In conclusion, that study showed that Jordanian hypertensive patients with higher physical exercise decisional balance and higher weight decisional balance had lower smoking decisional behaviors. Designing multidimensional interventions might be effective for modifying different types of health behaviors and decrease the burden of hypertension [19]. COOK WK et al. [20] reported that among White, Black, Hispanic, and Asian American adults, four unhealthy behaviors included alcohol misuse, smoking, poor diet, and physical inactivity were associated with the hypertension, although the results differed by the participants' race.

Table 3 Sensitivity analysis of association between health behavior in LE8 and hypertension in adolescents

Variables	Model 1		Model 2	
	OR (95%CI)	*P*	OR (95%CI)	*P*
Health behaviors score				
Low CVH	Ref		Ref	
Moderate CVH	0.61 (0.39–0.94)	0.026	0.64 (0.40–1.01)	0.053
High CVH	0.31 (0.16–0.61)	< 0.001	0.37 (0.18–0.74)	0.006
Per 10 points increase	0.98 (0.97–0.99)	< 0.001	0.98 (0.97–0.99)	0.002
DASH score, n (%)				
Low CVH	Ref		Ref	
Moderate CVH	0.37 (0.20–0.70)	0.003	0.30 (0.10–0.86)	0.025
High CVH	0.56 (0.36–0.87)	0.011	0.92 (0.57–1.50)	0.744
DASH 10 increase, Mean (S.E)	0.99 (0.98–0.99)	0.005	1.00 (0.99–1.01)	0.716
Physical activity score, n (%)				
Low CVH	Ref		Ref	
Moderate CVH	0.24 (0.09–0.67)	0.007	0.30 (0.10–0.86)	0.025
High CVH	0.97 (0.61–1.53)	0.891	0.92 (0.57–1.50)	0.744
Physical activity score 10 increase, Mean (S.E)	1.00 (0.99–1.01)	0.894	1.00 (0.99–1.01)	0.716
Tobacco smoke exposure score, n (%)				
Low CVH	Ref		Ref	
Moderate CVH	0.84 (0.31–2.23)	0.717	0.82 (0.31–2.14)	0.676
High CVH	0.40 (0.22–0.74)	0.004	0.44 (0.24–0.81)	0.009
Tobacco smoke exposure score 10 increase, Mean (S.E)	0.99 (0.98–0.99)	< 0.001	0.99 (0.98–0.99)	< 0.001

OR: odd ratios; CI: confidence interval; Ref: reference

LE8: life's essential 8; CVH: cardiovascular health

Model 1: crude model

Model 2: adjusted for age, gender, low birth weight, BMI Z-score and HDL-C abnormal

However, a study included two large cohorts from Coronary Artery Risk Development in Young Adults and Jackson Heart Study suggested that no relationship was found between health behaviors score and nocturnal hypertension or non-dipping SBP [21].

Our study found that health behaviors defined in LE8 was associated with the hypertension among adolescents. However, few studies have focused the association between health behaviors and hypertension among adolescents. Several studies have focused the association between health diet, physical activity and tobacco smoke exposure with adolescent health. A study based on the nationally representative sample showed that the fast food consumption was a predictor of weight gain from adolescence to adulthood. It was lined with both the risk of obesity in youth and the later risk of developing diseases such as hypertension and CVD in adulthood [22]. Another cross-sectional study of Swedish adolescents reported that dietary diversity and health eating index were related to health dietary habits [23]. However, adolescents in the U.S. do not meet dietary recommendations and adolescent diet quality was becoming a public concern problem. In recent study, the overall Healthy Eating Index (HEI)-2015 score for adolescents 12–18 yeas was 52.0. Although this score has increased significantly over time, the current score was still very low [24]. The HEI-2015 scoring for fatty acids was based on a ratio of polyunsaturated and monounsaturated fatty acid relative to saturated fatty acid intake and the low HEI-2015 score suggested that adolescents were not meeting recommendations for fatty acids [25]. In generally population, high diet quality assessed by the HEI-2015 was inversely associated with risk of hypertension and other diseases [26]. Moreover, the overall unhealthy diet quality of adolescents was driven by the inadequate consumption of components considered more healthful, such as fresh fruits, vegetables, and whole grains [27]. Interventions aimed at improving diet quality in adolescents are important to maintain their health now and into adulthood.

As in adults, the main risk factors for adolescent with primary hypertension were excess adiposity and suboptimal lifestyles and physical activity was commonly recommended as an important factor of lifestyle modification [28]. A study reported that low physical activity level and long screen time were associated with higher odds of hypertension among children and adolescents [28]. A meta-analysis reported that many children and adolescents can successfully lower BP through nonpharmacologic lifestyles included physical activity changes [29]. The exact molecular basis of the beneficial effects of physical activity on BP was not fully understood, as the regulation of BP was complex and multifactorial. First, the main mechanism by which physical activity can affect BP was the regulation of endothelial function. Endothelial

regulates vascular health and resistance. Nitric oxide (NO) was a key mediator of endothelial function and clinical and preclinical studies have confirmed that exercise can improve No-dependent endothelial vasodilation [30]. Second, hypertension was featured by microvascular rarefaction caused by impaired angiogenesis, and sustained physical exercise has been shown to induce vascular adaptation and increase flow reserve [31]. However, data showed that 80% of children and adolescents in 105 countries do not meet the recommended physical activity level, that is, at least 60 min of moderate to vigorous physical activity daily [32]. Our finding showed that greater adherence to regular physical activity as one of the health behaviors defined in LE8 may has a positive effect on maintain BP among adolescents.

The association between tobacco smoke exposure as a risk factor and the incidence of developing hypertension has been evaluated in previous epidemiological studies and have shown that tobacco smoke exposure is linked with the high incidence of hypertension among adults [33, 34]. Liu et al. [35] showed that tobacco smoke exposure was associated with the DBP of U.S. adolescents. Another study also found the relationship between hair nicotine and higher BP in urban young children [36]. A study among the German preschool population showed an association between exposure to parental smoking and adolescents BP [37]. Tobacco smoke exposure as an element was defined in health behaviors in LE8 and smoking can product harmful substances such as NO, which may cause organ hypoxia and damage the endothelial cells of the arterial wall. Moreover, the nicotine in tobacco stimulated the heart and adrenaline to release large amounts of catecholamines, which cause blood vessels to constrict and raise BP [38]. Reducing tobacco smoke exposure, preferably in completely smoke-free environment, has potential benefits in the prevention and treatment of hypertension in adolescents.

Herein, we provided reference for the prevention and treatment of hypertension among adolescents on the relationship between health behaviors defined in the LE8 and the odds of hypertension. Hypertension among adolescents with increasing prevalence globally, alongside the epidemic of obesity and unhealthy lifestyle. As a comprehensive indicator of CVH, better compliance with the health behaviors defined in LE8 is of positive significance for the CVH and the lower risk of hypertension in adolescents. Eating more fruits and vegetables, replacing saturated fats and trans fats with unsaturated fats, reducing carbohydrate and red meat intake, more than 60 min of moderate-to-vigorous intensity physical activity daily primarily to strengthen muscle and bone, and living in a smoke-free environment have a positive impact on children's health. The behavior habits of adolescents are largely affected by the environment in which they are grown. Bad tendencies from parents and neglect of exposure problems may have adverse consequences on the development of healthy behavior habits of adolescents. The combination of these approaches with family and school-based multicomponent interventions and skill-building health education programs warrants further investigation. However, several limitations of this study should be considered. First, the cross-sectional study design of this study could not establish a causal relationship between health behaviors defined in LE8 and hypertension among adolescents. Second, the American Heart Association added the factor of sleep health factor to Life's Simple 7 and proposed the LE8 in 2020. Due to the database limitations, sleep information of adolescents was not recorded in the NHANES database, so the relationship between sleep health and the risk of hypertension in adolescents needs to be proved by further studies. Third, the NAHNES survey only represents the U.S. population, and considering the specificity of race, the applicability of LE8 in other populations need to be confirmed by more large-scale prospective cohort studies in the future.

Conclusion

Our analysis of the NHANES 2007–2018 data suggested that high CVH score of health behaviors defined in LE8 was related to the lower odds of hypertension among adolescents. This relationship suggested that health diet, appropriate physical activity and non-tobacco smoke exposure may have a beneficial effect for maintain a stable BP in adolescents, especially among boys and adolescents with overweight/obesity. Further longitudinal studies are essential to validate these findings and explore the underlying mechanisms.

Abbreviations

CVD	cardiovascular disease
AHA	American Heart Association
CVH	cardiovascular health
LE8	life's essential 8
BMI	body mass index
NHANES	National Health and Nutrition Examination Surveys
NCHS	National Center for Health Statistics
CDC	Centers for Diseases Control and Prevention
BP	Blood pressure
SBP	systolic BP
DBP	diastolic BP
USDA	United States Department of Agriculture's
S.E.	standard error
ORs	odd ratios
CIs	confidence intervals

Supplementary Information

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Supplementary Material 1

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Not applicable.

Author contributions
Weiming Li designed the study, Zhiyong Zhang wrote the manuscript, Xuejiao Wu, Yu Qu and Dapeng Zhang collected, analyzed and interpreted the data, Weiming Li critically reviewed the manuscript, all authors read and approved the manuscript.

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Data availability
The datasets generated and/or analyzed during the current study are available in the NHANES database, https://wwwn.cdc.gov/nchs/nhanes/.

Declarations

Ethics approval and consent to participate
The requirement of ethical approval for this was waived by the Institutional Review Board of Beijing Chaoyang Hospital, Capital Medical University, because the data was accessed from NHANES (a publicly available database). The need for written informed consent was waived by the Institutional Review Board of Beijing Chaoyang Hospital, Capital Medical University due to retrospective nature of the study. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication
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Competing interests
The authors declare no competing interests.

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