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Relationship between the dietary inflammation index and hypertension in American children and adolescents: findings from the national health and nutrition examination survey 1999–2018

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Abstract

This study aimed to examine the relationship between the dietary inflammatory index (DII) and hypertension in children and adolescents using data from the National Health and Nutrition Examination Survey (NHANES) conducted between 1999 and 2018. The analysis included 18,460 participants aged 8 to 17 years, with 2,070 diagnosed with youth hypertension, defined as blood pressure above the 95th percentile for their age and gender. Dietary information was collected to calculate the DII, which was initially treated as a continuous variable and later categorized into tertiles. Multivariable weighted logistic regression and restricted cubic spline (RCS) analyses were conducted to explore the association between DII and youth hypertension. The results revealed a positive relationship between higher DII scores and increased likelihood of hypertension in youth, with both regression and RCS analyses showing a linear positive correlation after adjusting for potential confounders. The findings suggest that managing dietary inflammation may be an important strategy for preventing hypertension in children and adolescents.

Keywords DII, Hypertension, Adolescents, Cross-sectional study, NHANES

Introduction

Hypertension is one of the most common chronic diseases, globally, the prevalence of hypertension is over 30% [1]. In some developing countries and regions, the prevalence rate of hypertension may be even higher [2, 3]. In total, there are 27 countries worldwide where the prevalence of hypertension exceeds 45% [4]. Hypertension can cause damage to target organs such as the heart, kidneys, and retinas [5]. Hypertension is a significant risk factor for atherosclerosis, which can cause narrowing of the cardiovascular and cerebrovascular arteries, leading to coronary heart disease and stroke [6]. Additionally,

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kidney complications of hypertension are also leading causes of mortality in patients with hypertensive [7].

Youth hypertension refers to children or adolescents under 18 years of age whose systolic blood pressure (SBP) and/or diastolic blood pressure (DBP) is higher than the 95th percentile for children of the same age and gender [8]. Hypertension in children and adolescents is primarily primary hypertension [9]. In recent years, there has been a gradual increase in the prevalence of hypertension among children and adolescents, which is very concerning [10]. This trend may be closely related to lifestyle changes, poor dietary habits, lack of exercise, and environmental changes, etc [11, 12]. Additionally, the social and academic pressures can also contribute to the occurrence of hypertension among children and adolescents [13]. Moreover, obesity is another main factor leading to hypertension due to poor dietary habits [14]. Therefore, controlling the dietary quality is very important for prevention of youth hypertension.

The Dietary Inflammatory Index (DII) is a novel tool used to assess the impact of individual dietary habits on body integrate inflammation levels [15]. It is based on the potential effects of various dietary components and nutrients on inflammation [16]. By calculating the sum of inflammatory scores for all nutrients in an individual's diet, the overall DII is obtained, reflecting the impact of the diet on overall inflammation levels. A close association of DII with Hypertension was observed among adults in US and China, however, the association of DII with youth hypertension remains exclusive [17, 18]. Lowering the DII can help reduce inflammation level and decrease the risk of developing chronic diseases.

Considering the close association of dietary inflammatory potential with hypertension, we firstly enrolled children and adolescent participants from NHANES database to investigate the association between and youth hypertension in this large-scale multi-racial cross-sectional study.

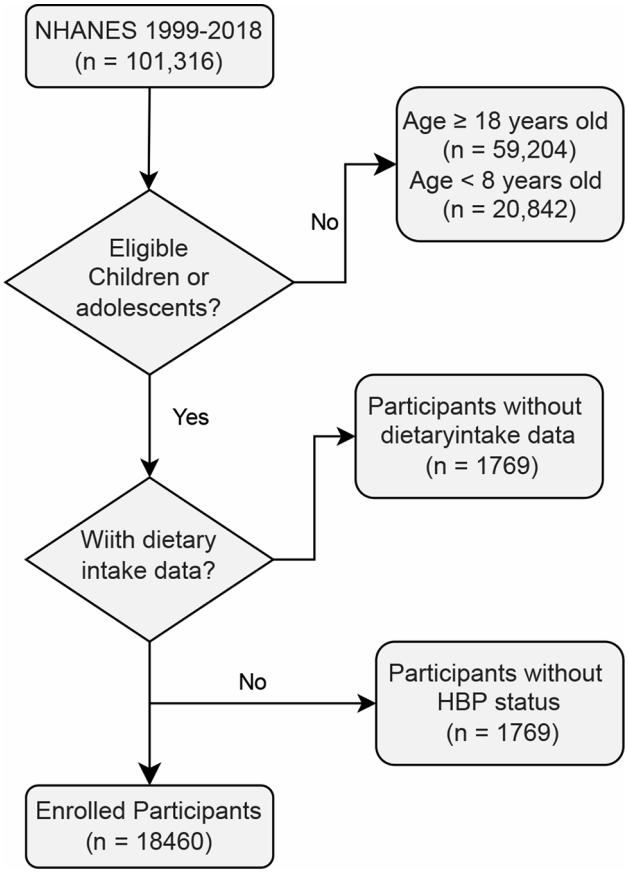

Fig. 1 Flowchart of children and adolescents enrollment

Methods

Study population

NHANES is a large-scale cross-sectional study conducted nationwide in the United States, aimed at assessing the health and dietary status of American residents [19]. Many studies have utilized its publicly available data (https://www.cdc.gov/nchs/nhanes/index.htm, accessed on 11 November 2022) to explore the risk factors for various diseases, providing significant assistance for clinical diagnosis and treatment. In this study, we obtained data from all 10 complete cycles of NHANES from 1999 to 2018. The protocol number for NCHS IRB/ERC is #2018-01. Clinical trial number: not applicable. By excluding participants over 18 years old and under 8 years old, we successfully screened children and adolescents. We excluded participants without dietary data and those without hypertension status, resulting in a total of 18,460 patients included. The representativeness of the NHANES study population was determined through a stratified sampling approach, where the study sample was designed to closely mirror the broader demographic characteristics of adolescents in the U.S., including age, gender, race/ethnicity, and geographic distribution, etc. We used data from the NHANES database, which is nationally representative and routinely adjusted to account for sampling weights and population characteristics. The total of 18,460 children and adolescents included in the study reflects the weighted representation of approximately 37 million children and adolescents in the U.S. See Fig. 1 for detailed participant recruitment flowchart.

Figure Legends.

DII calculation

Nutrition methodology working group of the NHANES conducted comprehensive dietary recall interviews for detailed dietary information. The first dietary review was conducted face-to-face in the mobile examination center (MEC) [20]. The second review was conducted via

telephone follow-up. For all participants, dietary recall was conducted with the assistance of a parent or guardian. This approach has been commonly used in large-scale surveys such as NHANES to ensure more accurate data collection across different age groups. In this study, we chose the average of two dietary interviews as the representation of an individual's daily dietary intake, and to calculate DII. Based on previously published literature and its methodologies by Shivappa et al., we calculated the DII [21]. All available food components in the NHANES database were included in the calculation of the DII, and each dietary component was assigned a specific DII score based on its impact on six major inflammatory biomarkers: IL-1β, IL-4, IL-6, IL-10, TNF-α, and CRP. Based on the intake of a specific food component, we can calculate the DII for each food component [21]. To assess the impact of all dietary intakes on inflammation for a participant within a day, the individual DII scores calculated for all food components are summed up to derive the overall DII. A positive score indicates pro-inflammatory potential, while a negative score represents anti-inflammatory potential. In this study, DII was initially studied as a continuous variable to examine its relationship with the occurrence of youth hypertension. Based on the values of DII, we then divided the entire study population into three groups (T1: -3.97-1.53; T2: 1.53–2.95; T3: 2.95–5.42). Further investigation was conducted to explore the relationship between DII and the occurrence of youth hypertension.

Outcome of youth hypertension

The experienced staff used standardized equipment to measure the blood pressure of each participant. We used the average of multiple measurements as the final blood pressure. According to current clinical guidelines, we defined participants whose blood pressure exceeded the 95th percentile for children and adolescents of the same age and gender as having youth hypertension, serving as the outcome measure for this study [22].

Covariates

NHANES team collected all demographic data used in this study through standardized questionnaires, including age, gender, and race. We obtained the above data directly from the NHANES official website. Body mass index (BMI), derived from dividing weight in kilograms (kg) by height in meters squared (m^2). The data for body height and body weight are measured by experienced staff using standardized equipment. According to WHO standards, when BMI falls between 18.5 kg/m^2 and 24.9 kg/m^2, we consider the individual to have a normal weight. When BMI falls between 25 kg/m^2 and 29.9 kg/m^2, we consider the individual to be overweight. When BMI is greater than 30 kg/m^2, we consider the individual to be obesity. To calculate the estimated glomerular filtration rate (eGFR), NHANES utilized a formula by the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) [23]. This formula integrates variables such as age, sex, race/ethnicity, and serum creatinine (SCr) to accommodate diverse population groups. Fasting blood glucose (FBG), glycated hemoglobin (HbA1c), triglyceride (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), hemoglobin (Hb), red blood cell (RBC) counts and hemoglobin were obtained after fasting for at least 8 h by standardized laboratory tests. Anyone with diabetes history was defined as patients with diagnosed diabetes, while those without diagnosed diabetes but with any of the following items was classified as having undiagnosed diabetes: (1) HbA1c level 6.5 or higher, (2) FPG level 7.0 mmol/L or higher, (3) 2-hour oral glucose tolerance test (OGTT) plasma glucose 11.1 mmol/L or higher [24].

Statistical methods

In this study, all analyses were weighted based on the complex sampling method employed by NHANES. We conducted the study in accordance with the data analysis guidelines provided by NHANES. In this study, continuous variables are presented as means and 95% confidence intervals, while categorical variables are presented as percentages and 95% confidence intervals. We employed t-tests and chi-square tests to conduct detailed comparisons of baseline demographic and clinical dat. Weighted multivariate logistic regression analysis was adopted to explore the association of DII with youth hypertension. Moreover, the correlation of DII with youth hypertension was investigated and visualized by restricted cubic spline (RCS) curve. Additionally, we conducted detailed subgroup analyses by stratifying children and adolescents based on different ages, genders, races, and BMI. We performed all statistical analyses using R software version 4.1.6 (http://www.R-project.org, The R Foundation, Vienna, Austria), with statistical significance set at a two-tailed P-value < 0.05.

Results

Demographical and clinical characteristics of the study population

In this study, we ultimately included a total of 18,460 children and adolescents aged between 8 and 17 years old, representing 37 million children and adolescents across US. Among all participants, 2,070 children and adolescents were diagnosed with hypertension. Children and adolescents aged 8 to 12 years old accounted for approximately 52.5% of the entire study cohort, while those aged 12 to 17 years old comprised about 47.5%. Across the entire cohort, the proportion of male

and female participants was approximately 50% each. By comparing the baseline clinical and demographic data tables of children and adolescents with and without youth hypertension across the entire study cohort, we found that those with youth hypertension tended to be older and had a higher proportion of males. The mean systolic blood pressure for children and adolescents with hypertension was 118.51 mmHg, and the mean diastolic blood pressure was 65.45 mmHg. In contrast, the mean systolic blood pressure for children and adolescents without hypertension was 104.06 mmHg, and the mean diastolic blood pressure was 57.25 mmHg. Among children and adolescents with hypertension, the proportion of overweight and obese individuals is significantly higher compared to those without hypertension. Additionally, we found that among children and adolescents with youth hypertension, fasting blood glucose (FBG), glycosylated hemoglobin (HbA1c), and the incidence rates of diabetes (DM) were significantly elevated compared to those without youth hypertension. In terms of blood lipid profile, we found that levels of triglycerides (TG), total cholesterol (TC), and low-density lipoprotein cholesterol (LDL-C) in children and adolescents with youth hypertension are higher compared to those without youth hypertension. Conversely, the levels of high-density lipoprotein cholesterol (HDL-C) in children and adolescents with hypertension are lower compared to those without hypertension. Additionally, the levels of red blood cells (RBC) in children and adolescents with youth hypertension are significantly higher compared to those without youth hypertension (Table 1). Detailed comparisons of baseline demographical and clinical characteristics can be found in Table S1. Additionally, we conducted a detailed comparison of the DII and the intake of DII components between children and adolescents with hypertension and those without hypertension. We found that the levels of DII were significantly higher among children and adolescents with hypertension. However, among the

Table 1 Baseline demographical and clinical characteristic

Variables	Overall (*n* = 18460)	Non-Youth HBP (*n* = 16390)	Youth HBP (*n* = 2070)	*P* value
Age, %				< 0.001***
8–12 years	52.53 [50.03, 55.03]	53.44 [52.35, 54.53]	44.79 [41.88, 47.71]	
12–17 years	47.47 [45.22, 49.72]	46.56 [45.47, 47.65]	55.21 [52.29, 58.12]	
Gender, %				0.06
Female	49.25 [46.90, 51.61]	49.58 [48.50, 50.67]	46.45 [43.36, 49.53]	
Male	50.75 [48.34, 53.16]	50.42 [49.33, 51.50]	53.55 [50.47, 56.64]	
Ethnicity, %				0.01*
Non-Hispanic White	57.82 [53.26, 62.37]	58.15 [55.64, 60.67]	54.94 [50.75, 59.14]	
Non-Hispanic Black	14.17 [12.94, 15.41]	13.77 [12.34, 15.21]	17.58 [14.99, 20.16]	
Mexican American	13.41 [11.89, 14.93]	13.36 [11.74, 14.99]	13.80 [11.46, 16.14]	
Other Hispanic	6.78 [5.72, 7.85]	6.88 [5.77, 7.98]	6.00 [4.36, 7.63]	
Other	7.82 [6.95, 8.68]	7.83 [6.99, 8.68]	7.69 [6.03, 9.35]	
SBP, mmHg	105.59 [105.29, 105.88]	104.06 [103.81, 104.32]	118.51 [117.87, 119.16]	< 0.001***
DBP, mmHg	58.12 [57.68, 58.55]	57.25 [56.85, 57.66]	65.45 [64.38, 66.51]	< 0.001***
BMI, %				< 0.001***
Normal weight	77.97 [74.27, 81.68]	79.58 [78.61, 80.55]	65.09 [62.00, 68.19]	
Over weight	8.55 [7.92, 9.19]	7.53 [6.93, 8.13]	17.36 [15.16, 19.56]	
Obesity	13.37 [12.53, 14.20]	12.89 [12.18, 13.61]	17.55 [15.24, 19.85]	
eGFR,	136.33 [135.66, 137.00]	136.21 [135.52, 136.90]	137.54 [136.06, 139.01]	0.08
FBG, mmol/L	5.26 [5.21, 5.30]	5.25 [5.20, 5.30]	5.35 [5.27, 5.42]	0.04*
HbA1c, %	5.20 [5.19, 5.22]	5.20 [5.18, 5.21]	5.25 [5.20, 5.30]	0.03*
DM, %	0.74 [0.53, 0.94]	0.65 [0.47, 0.84]	1.45 [0.67, 2.24]	0.004**
TG, mmol/L	0.94 [0.91, 0.96]	0.92 [0.90, 0.94]	1.13 [1.01, 1.26]	0.001**
TC, mmol/L	4.12 [4.10, 4.13]	4.10 [4.08, 4.12]	4.25 [4.20, 4.30]	< 0.001***
HDL-C, mmol/L	1.35 [1.34, 1.36]	1.36 [1.35, 1.37]	1.31 [1.28, 1.33]	< 0.001***
LDL-C, mmol/L	2.30 [2.27, 2.33]	2.28 [2.25, 2.31]	2.48 [2.40, 2.56]	< 0.001***
RBC, $\times 10^9$/L	4.75 [4.73, 4.76]	4.74 [4.72, 4.75]	4.82 [4.79, 4.84]	< 0.001***
Hemoglobin, g/L	13.82 [13.77, 13.87]	13.82 [13.77, 13.87]	13.82 [13.74, 13.90]	0.99

Continuous variables showed as the mean [95% CI], category variables showed as the proportion [95% CI]

Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; eGFR, estimated glomerular filtration rate; FBG, fasting blood glucose; HbA1c, glycated hemoglobin; DM, diabetes; TG, triglycerides; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; RBC, red blood cells; CI, confidence interval

* *P* value < 0.05, ** *P* value < 0.01, *** *P* value < 0.001

individual components of the DII, only the intake of fiber and vitamin A showed statistically differences (Table 2).

Associations between DII and prevalence of youth hypertension

To explore the relationship between DII and the prevalence of youth hypertension in children and adolescents, we employed a multivariable logistic regression analysis. In the unadjusted model, both DII as a continuous variable and as a categorical variable were significantly positively associated with the prevalence of hypertension in children and adolescents (OR: 1.05; 95% CI: 1.00-1.09). This correlation was statistically significant. In Model 1, we adjusted for age, gender, and race. Similar to the unadjusted model, in Model 1, DII remained significantly positively associated with the occurrence of hypertension in children and adolescents, whether as a continuous variable (OR: 1.05; 95%CI: 1.01–1.10) or a categorical variable. Importantly, in the fully adjusted model, we adjusted for age, gender, race, family income, energy intake, BMI, eGFR, and DM. We found a more significant correlation between DII and the prevalence of hypertension in children and adolescents. For every increase of 1 in DII, there was an approximately 11% (95% CI: 1-21%) increase in the occurrence of hypertension in children and adolescents. In children and adolescents in T2, the prevalence of hypertension was 1.58 times (95% CI: 1.20–2.09) that of T1, and in children and adolescents in T3, the prevalence of hypertension was 1.71 times (95% CI: 1.25–2.34) that of T1 (Table 3). Additionally, we employed RCS analysis to analyze and visualize the relationship between DII and the incidence of youth hypertension. We found that after adjusting for age, sex, race, family income, energy intake, BMI, eGFR, and diabetes, there was a linear positive correlation between DII and the incidence of hypertension in children and adolescents (Fig. 2).

Subgroup analysis on the associations of DII with prevalence of youth hypertension

Furthermore, to explore the relationship between DII and the occurrence of youth hypertension among children and adolescents across different demographic characteristics, we conducted detailed subgroup analyses, as shown in Table 4. We found significant

Table 2 Intake of DII Components among Non-youth HBP Group and Youth HBP Group

Variables	Overall (*n* = 8460)	Non-Youth HBP (*n* = 6390)	Youth HBP (*n* = 2070)	*P* value
DII	2.06 [2.02, 2.10]	2.05 [2.01, 2.09]	2.16 [2.06, 2.27]	0.03*
Energy intake, kcal	2057.10 [2038.70, 2075.51]	2057.58 [2038.32, 2076.84]	2052.99 [2002.43, 2103.55]	0.86
Carbohydrate intake, g	272.55 [269.86, 275.24]	272.68 [269.78, 275.57]	271.48 [265.52, 277.44]	0.72
Protein intake, g	73.60 [72.85, 74.35]	73.70 [72.94, 74.46]	72.74 [70.25, 75.22]	0.45
Cholesterol intake, mg	235.80 [232.57, 239.04]	236.74 [233.35, 240.13]	227.76 [217.75, 237.78]	0.1
Total fat intake, g	77.09 [76.29, 77.89]	77.07 [76.24, 77.90]	77.27 [74.82, 79.72]	0.88
Total saturated fat intake, g	26.91 [26.59, 27.22]	26.93 [26.61, 27.25]	26.75 [25.81, 27.69]	0.72
MUFA intake, g	27.62 [27.32, 27.93]	27.57 [27.26, 27.88]	28.06 [27.12, 29.00]	0.32
PUFA intake, g	15.97 [15.77, 16.18]	15.98 [15.78, 16.19]	15.90 [15.31, 16.48]	0.78
Fiber intake, g	13.88 [13.67, 14.08]	13.92 [13.71, 14.14]	13.47 [13.05, 13.88]	0.04*
Vitamin A intake, mcg	598.78 [586.71, 610.85]	601.57 [589.15, 614.00]	574.83 [548.10, 601.56]	0.05*
Thiamin intake, mg	1.64 [1.62, 1.66]	1.65 [1.62, 1.67]	1.63 [1.58, 1.68]	0.49
Riboflavin intake, mg	2.09 [2.06, 2.12]	2.09 [2.06, 2.12]	2.07 [1.99, 2.14]	0.52
Niacin, mg	22.75 [22.46, 23.05]	22.79 [22.48, 23.09]	22.46 [21.67, 23.25]	0.43
Vitamin B6 intake, mg	1.80 [1.77, 1.83]	1.81 [1.78, 1.84]	1.76 [1.69, 1.83]	0.2
Vitamin B12 intake, mcg	5.07 [4.97, 5.16]	5.08 [4.99, 5.18]	4.91 [4.66, 5.16]	0.18
Vitamin C intake, mg	76.67 [74.87, 78.47]	76.69 [74.82, 78.55]	76.49 [72.66, 80.32]	0.92
Vitamin D intake, mcg	5.30 [5.15, 5.45]	5.32 [5.16, 5.48]	5.14 [4.84, 5.44]	0.29
α-tocopherol intake, mg	61.84 [56.97, 66.72]	61.09 [56.07, 66.11]	68.32 [50.22, 86.43]	0.45
β-carotene intake, mcg	1203.11 [1149.60, 1256.63]	1214.26 [1158.23, 1270.28]	1104.18 [978.46, 1229.89]	0.1
Folate intake, mcg	390.47 [384.21, 396.74]	391.35 [384.67, 398.04]	382.91 [369.35, 396.47]	0.26
Iron intake, mg	15.16 [14.96, 15.36]	15.16 [14.96, 15.37]	15.15 [14.61, 15.69]	0.95
Zinc intake, mg	11.12 [10.98, 11.26]	11.14 [11.00, 11.28]	10.95 [10.51, 11.38]	0.4
Magnesium intake, mg	239.29 [236.37, 242.22]	239.91 [236.88, 242.95]	233.97 [226.38, 241.57]	0.14
Selenium intake, mcg	100.04 [98.91, 101.17]	100.29 [99.11, 101.46]	97.88 [94.49, 101.28]	0.18
Caffeine intake, mg	37.75 [35.90, 39.60]	38.08 [36.18, 39.98]	34.90 [31.28, 38.51]	0.08

Data showed as the mean and 95% confidence interval

Abbreviations: DII, dietary inflammatory index; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids

* *P* value < 0.05

Table 3 Weighted Multivariate Logistic Regression on Association of DII with Youth Hypertension from NHANES 1999–2018

DII	Non-adjusted model		Model I		Model II	
	OR [95% CI]	*P*value	OR [95% CI]	*P*value	OR [95% CI]	*P*value
Continuous DII	1.05 [1.00, 1.09]	0.04*	1.05 [1.01, 1.10]	0.03*	1.11 [1.01, 1.21]	0.02*
T1	Reference	-	Reference	-	Reference	-
T2	1.2 [1.01, 1.43]	0.04*	1.2 [1.01, 1.43]	0.04*	1.58 [1.20, 2.09]	0.001**
T3	1.2 [1.02, 1.42]	0.03*	1.23 [1.04, 1.45]	0.02*	1.71 [1.25, 2.34]	< 0.001***

Data are presented as OR (95% CI). Model I adjusted for age, sex, and race/ethnicity. Model II adjusted for age, sex, and race/ethnicity, family income, Total energy intake, BMI, eGFR, DM. Abbreviations: NHANES, National health and nutritional examination survey; DII, dietary inflammation index; OR, odds ratio; CI, confidence interval; BMI, body mass index; eGFR, estimated glomerular filtration rate; DM, diabetes. * *P* value < 0.05, ** *P* value < 0.01, *** *P* value < 0.001

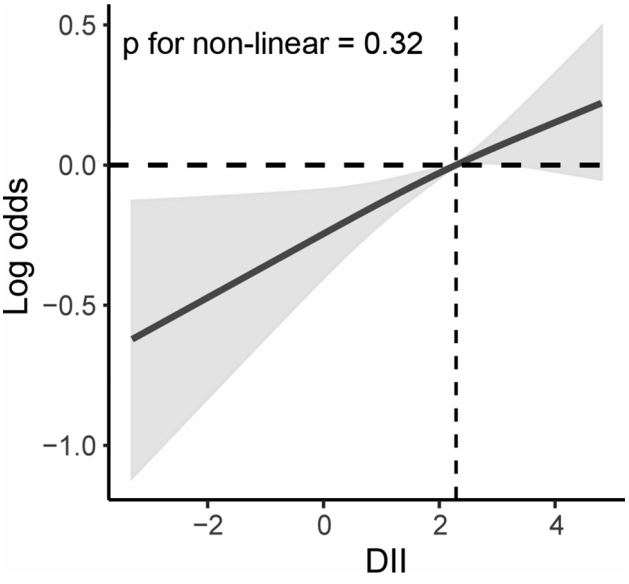

Fig. 2 RCS analysis of the association between DII and risk of youth hypertension among all enrolled children and adolescents. RCS was adjusted for age, sex, and race/ethnicity, family income, total energy intake, BMI, eGFR, DM. DII, dietary inflammation index; RCS, restricted cubic spline; BMI, body mass index; OR, odds ratio

positive correlations between DII and hypertension in children and adolescents of different ages and genders after adjusting for covariates including age, sex, race, family income, energy intake, BMI, eGFR, and diabetes. It is worth noting that we found a significant positive correlation between DII and the occurrence of hypertension in both white and other racial groups of children and adolescents. However, this correlation was not significant among black individuals, which may be related to reduced statistical power due to a smaller sample size. Furthermore, in the subgroup analysis based on BMI, we found a significant positive correlation between DII and hypertension occurrence among children and adolescents with normal weight. However, this correlation was not significant among overweight and obese children and adolescents (Table 4).

Discussion

This study is a large-scale cross-sectional study that, for the first time, investigates the relationship between DII and youth hypertension among adolescents and children in the US. We obtained data from the NHANES, comprising 18,046 multi-racial children and adolescents, representing of approximately 37 million American adolescents and children. After adjusting for age, gender, race, household income, energy intake, BMI, EGFR, and DM, we observed a linear positive correlation between DII and the incidence of hypertension.

Hypertension has an alarmingly high prevalence worldwide and ranks as the leading cause of global mortality [25]. Globally, the prevalence of hypertension exceeds 30%. Poorly controlled hypertension can lead to cardiovascular and cerebrovascular diseases. Kidney damage is also a common complication of hypertension [26]. In recent years, an increasing number of studies indicate a rising trend in the prevalence of hypertension among children and adolescents, posing significant threats to their health by causing organ damage [27, 28]. Due to the incomplete development of children and adolescents, the diagnostic criteria for hypertension in this population differ significantly from those used for adults [29]. However, hypertension in children and adolescents is primarily primary hypertension. It often accompanies a high incidence of hypertension after adolescence. Currently, diagnostic criteria set by clinical practice guidelines define hypertension in children and adolescents as when their systolic and/or diastolic blood pressure exceeds the 95th percentile for children and adolescents of the same age and gender [30]. An increasing number of studies have begun to focus on the research field of youth hypertension. Brathwaite et al. found a close correlation between low birth weight and the occurrence of high blood pressure in adolescents and children. Furthermore, children born with low birth weight are more prone to renal dysfunction [31]. Additionally, environmental studies suggest that heavy metal pollution may be one of the causes of youth hypertension in children and adolescents. Li et al. found a close correlation between thallium in urine and the occurrence of youth hypertension in children and adolescents [32]. In this study, the blood pressure of all included children and adolescents was obtained by

Table 4 Subgroup Analysis on Association of DII with Youth Hypertension Stratified by Age, Sex, Race, and BMI

DII	Non-adjusted model		Model I		Model II	
	OR [95% CI]	*P*value	OR [95% CI]	*P*value	OR [95% CI]	*P*value
8–12 years						
Continuous DII	1.02 [0.95, 1.09]	0.59	1.02 [0.96, 1.09]	0.48	1.17 [0.88, 1.55]	0.28
T1	Reference	-	Reference	-	Reference	-
T2	1.04 [0.83, 1.30]	0.74	1.05 [0.84, 1.31]	0.66	1.58 [0.79, 3.15]	0.19
T3	1.04 [0.81, 1.32]	0.76	1.06 [0.83, 1.35]	0.64	2.52 [1.10, 5.77]	0.03*
13–17 years						
Continuous DII	1.07 [1.01, 1.14]	0.03*	1.08 [1.01, 1.15]	0.02*	1.09 [1.00, 1.18]	0.04*
T1	Reference	-	Reference	-	Reference	-
T2	1.38 [1.10, 1.75]	0.01*	1.41 [1.11, 1.79]	0.005**	1.55 [1.16, 2.05]	0.003**
T3	1.40 [1.11, 1.78]	0.01*	1.45 [1.13, 1.85]	0.003*	1.52 [1.11, 2.10]	0.01*
Female						
Continuous DII	1.07 [1.12, 1.13]	0.01*	1.08 [1.02, 1.14]	0.01*	1.10 [1.00, 1.22]	0.03*
T1	Reference	-	Reference	-	Reference	-
T2	1.23 [1.02, 1.69]	0.03*	1.32 [1.02, 1.69]	0.03*	1.40 [0.93, 2.10]	0.11
T3	1.30 [1.03, 1.64]	0.03*	1.33 [1.05, 1.68]	0.02*	1.56 [1.01, 2.42]	0.04*
Male						
Continuous DII	1.04 [0.98, 1.11]	0.15	1.03 [0.97, 1.10]	0.30	1.12 [1.00, 1.26]	0.05*
T1	Reference	-	Reference	-	Reference	-
T2	1.16 [0.93, 1.45]	0.18	1.13 [0.90, 1.41]	0.30	1.73 [1.21, 2.48]	0.003**
T3	1.20 [0.96, 1.49]	0.10	1.16 [0.93, 1.45]	0.19	1.82 [1.21, 2.74]	0.004**
White						
Continuous DII	1.04(0.98,1.11)	0.19	1.04(0.98,1.11)	0.23	1.09(0.95,1.25)	0.20
T1	Reference	-	Reference	-	Reference	-
T2	1.24 [0.94, 1.63]	0.12	1.21 [0.92, 1.60]	0.16	1.58 [1.03, 2.43]	0.04*
T3	1.17 [0.92, 1.50]	0.20	1.17 [0.92, 1.50]	0.21	1.65 [1.02, 2.69]	0.04*
Black						
Continuous DII	1.05 [0.99, 1.11]	0.11	1.05 [0.99, 1.11]	0.10	1.07 [0.97, 1.19]	0.18
T1	Reference	-	Reference	-	Reference	-
T2	1.23 [0.98, 1.54]	0.07	1.23 [0.98, 1.54]	0.07	1.34 [0.92, 1.96]	0.12
T3	1.20 [0.97, 1.48]	0.09	1.21 [0.98, 1.49]	0.08	1.39 [0.94, 2.04]	0.10
Others						
Continuous DII	1.05 [0.98, 1.11]	0.17	1.06 [0.99, 1.13]	0.10	1.15 [1.04, 1.28]	0.01*
T1	Reference	-	Reference	-	Reference	-
T2	1.10 [0.86, 1.40]	0.45	1.11 [0.87, 1.42]	0.41	1.71 [1.16, 2.50]	0.01*
T3	1.23 [0.97, 1.58]	0.09	1.30 [1.01, 1.67]	0.05*	1.94 [1.29, 2.93]	0.002**
Normal Weight						
Continuous DII	1.03 [0.98, 1.09]	0.26	1.03 [0.97, 1.09]	0.38	1.12 [0.99, 1.25]	0.06
T1	Reference	-	Reference	-	Reference	-
T2	1.24 [0.99, 1.54]	0.06	1.24(0.99,1.54)	0.06	1.64(1.16, 2.33)	0.01*
T3	1.16 [0.94, 1.44]	0.18	1.16(0.94,1.44)	0.18	1.87(1.25, 2.78)	0.002**
Over Weight						
Continuous DII	1.02 [0.93, 1.11]	0.72	1.03 [0.94, 1.14]	0.50	1.06 [0.89, 1.26]	0.52
T1	Reference	-	Reference	-	Reference	-
T2	0.94 [0.65, 1.35]	0.73	0.94 [0.64, 1.37]	0.75	0.92 [0.50, 1.70]	0.79
T3	0.99 [0.71, 1.38]	0.93	1.07 [0.75, 1.53]	0.70	1.22 [0.69, 2.17]	0.48
Obesity						
Continuous DII	1.07 [0.97, 1.18]	0.17	1.09 [0.99, 1.21]	0.08	1.13 [0.98, 1.31]	0.09
T1	Reference	-	Reference	-	Reference	-
T2	1.31 [0.83, 2.06]	0.24	1.38 [0.87, 2.20]	0.17	2.23 [1.15, 4.32]	0.02*
T3	1.34 [0.88, 2.02]	0.17	1.45 [0.94, 2.23]	0.09	1.90 [0.96, 3.76]	0.06

Data are presented as OR (95% CI). Model I adjusted for age, sex, and race/ethnicity. Model II adjusted for age, sex, and race/ethnicity, family income, Total energy intake, BMI, eGFR, DM. Abbreviations: NHANES, National health and nutritional examination survey; DII, dietary inflammation index; OR, odds ratio; CI, confidence interval; BMI, body mass index; eGFR, estimated glomerular filtration rate; DM, diabetes. * P value < 0.05, ** P value < 0.01, *** P value < 0.001

experienced staff using standardized instruments and measurement techniques [33]. We determined the average systolic and diastolic blood pressure for each individual based on multiple measurement results. Additionally, according to clinical practice guidelines, we diagnosed youth hypertension for each included participant. However, our study focuses on DII as a modifiable risk factor, it is crucial to recognize that genetic factors, along with environmental influences such as family history and lifestyle, are important contributors to the development of hypertension in children and adolescents.

Roles of dietary habits and hypertension have always been a hot research topic. It is possible that controlling diet to reduce the occurrence of hypertension could be an effective and feasible approach. Dietary approaches to stop hypertension (DASH) diet have been confirmed not only to reduce the incidence of hypertension but also to decrease the incidence of other cardiovascular and cerebrovascular diseases [34, 35]. The high-sugar, high-fat Western dietary pattern is closely associated with the occurrence of hypertension. Studies have shown a significant positive correlation between the intake of fatty acids in the diet and the incidence of hypertension in children and adolescents [36]. Dietary habits can promote inflammation within the body. High-sugar, high-fat, and high-salt diets are often associated with increased levels of inflammation, while diets rich in fruits, vegetables, whole grains, and healthy fats are believed to have anti-inflammatory effects [37]. Some nutrients found in certain foods, such as antioxidants and polyunsaturated fatty acids, may help reduce inflammation. Additionally, fiber is also believed to help maintain gut health, thereby reducing inflammation levels within the body [38]. Dietary patterns also have a significant impact on the composition and function of the gut microbiota, which is closely related to the immune system [39]. Numerous studies have shown that the DII can contribute to the onset and progression of various diseases. Huang et al. found that elevated DII closely associated with the risk of stroke, and insulin resistance did not mediate the association between DII and stroke [20]. Therefore, diet may influence inflammation levels within the body by affecting the gut microbiota. Long-term, chronic inflammation may play an important role in the occurrence and development of hypertension. Inflammatory responses can cause dysfunction of endothelial cells, leading to vasoconstriction and elevated blood pressure [40]. Therefore, reducing overall inflammation levels through diet may be an important approach in treating hypertension. Researchers have investigated the correlation between dietary inflammatory index and the incidence of hypertension in adults, indicating a close association between dietary inflammatory index and hypertension in adults [18]. The study and our research both utilized NHANES data and employed a cross-sectional study design, making them highly similar. However, whether the dietary inflammatory index is positively correlated with the occurrence of hypertension in adolescents and children is currently unclear.

This study has some advantages that need to be acknowledged. Firstly, all participants in our study were directly obtained from the NHANES database. Therefore, this greatly enhances the representativeness of our sample and increases the representativeness of our conclusions. Secondly, all analytical methods in this study were conducted according to NHANES data analysis guidelines. Thus, all analyses were conducted using weighted approaches. As the database adopts a sampling method, our conclusions can be generalized to children and adolescents nationwide in the United States. Thirdly, while studies related to DII and other diseases have been reported, this is the first exploration of the relationship between DII and youth hypertension, thus showing a certain level of innovation. At the same time, we also acknowledge certain limitations of this study. Firstly, it is a cross-sectional study, thus unable to establish direct causal relationships. Further exploration through more prospective clinical studies is needed to elucidate the relationship between DII and hypertension. Secondly, all dietary components in this study were self-reported by the patients, which may introduce self-reporting bias. Thirdly, despite our efforts to adjust for confounding factors clinically and those associated with young hypertension, there might still be some unaccounted confounders, potentially leading to biases.

Conclusion

In this study, we enrolled a diverse population of children and adolescents across the United States, totaling 18,460 individuals, and found a significant positive correlation between DII and the incidence of youth hypertension. This suggests that adopting reasonable and healthy dietary habits may play a significant role in preventing and treating hypertension in adolescents.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12872-025-04515-z.

Supplementary Material 1

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Author contributions
Lanfei Du: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft.Jinxia Hao: Data curation, Investigation, Writing – review & editing.Kai Yu: Methodology, Data curation, Writing – review & editing.Peihong Su: Conceptualization, Formal analysis, Writing – review & editing.Jie Pu: Investigation, Data curation, Writing – review & editing.Zhiguo

Tang: Conceptualization, Methodology, Writing – review & editing.Fuqiang Liu: Conceptualization, Writing – review & editing.Jie Zhou: Supervision, Project administration, Writing – review & editing.

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Data availability
Publicly available datasets were analyzed in this study. All the raw data used in this study are derived from the public NHANES data portal (https://www.cdc.gov/nchs/nhanes/index.htm).

Declarations

Ethics approval and consent to participate
The NHANES protocol adheres to the Policy for the Protection of Human Research Subjects set forth by the U.S. Department of Health and Human Services. The protocol numbers for NCHS IRB/ERC are: NHANES 2017–2018: Protocol #2018-01 (Effective beginning October 26, 2017), Continuation of Protocol #2011-17 (Effective through October 26, 2017); NHANES 2015–2016: Continuation of Protocol #2011-17; NHANES 2013–2014: Continuation of Protocol #2011-17; NHANES 2011–2012: Protocol #2011-17; NHANES 2009–2010: Continuation of Protocol #2005-06; NHANES 2007–2008: Continuation of Protocol #2005-06; NHANES 2005–2006: Protocol #2005-06; NHANES 1999–2004: Protocol #98 – 12.

Consent for publication
Not Applicable.

Informed consent
was obtained from all subjects involved in the NHANES.

Clinical trial number
Not applicable.

Competing interests
The authors declare no competing interests.

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