Adults allostatic load is less with greater dietary quality: National Health and Nutrition Examination Survey (NHANES) 2015–2018

doi: 10.6133/apjcn.202304/PP.0002
Published online: April 2023

Running title: Allostatic load is less with greater dietary quality PAEE

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ABSTRACT

Background and Objectives: Few studies have explored the relationship between overall diet quality and stress load. Therefore, we have evaluated the association between dietary quality and allostatic load (AL) in adults. **Methods and Study Design:** The data were derived from the 2015-2018 National Health and Nutrition Examination Survey (NHANES). Dietary intake information was obtained by 24-hour dietary recall. The Healthy Eating Index (HEI) 2015 version was estimated as an indicator of dietary quality. The AL was indicative of the accumulated chronic stress load. The weighted logistic regression model was used to explore the relationship between dietary quality and the risk of high AL in adults. **Results:** A total of 7557 eligible adults older than 18 years were enrolled in this study. After being fully adjusted, we found a significant association between HEI score and the risk of high AL (OR_{Q2} =0.73, 95% CI: 0.62,0.86; OR_{Q3} =0.66, 95% CI: 0.55,0.79; OR_{Q4} =0.56, 95% CI: 0.47,0.67) in logistic regression model. Increased intake of total fruits and whole fruits or decreased intake of sodium, refined grains, saturated fats and added sugars were associated with the risk of high AL ($OR_{\text{total fruits}}$ =0.93, 95%CI: 0.89,0.96; $OR_{\text{whole fruits}}$ =0.95, 95%CI: 0.91,0.98; $OR_{\text{whole grains}}$ =0.97, 95%CI: 0.94,0.997; $OR_{\text{fatty acid}}$ =0.97, 95%CI: 0.95,0.99; OR_{sodium} =0.95, 95%CI: 0.92,0.98; $OR_{\text{refined grains}}$ =0.97, 95%CI: 0.94,0.99; $OR_{\text{saturated fats}}$ =0.96, 95%CI: 0.93,0.98; $OR_{\text{added sugars}}$ =0.98, 95%CI: 0.96,0.99). **Conclusions:** We found that dietary quality was inversely associated with allostatic load. High dietary quality presumptively less cumulative stress.

Key Words: dietary guidelines, dietary quality, allostatic load, NHANES

INTRODUCTION

A national survey found that nearly 50 percent of people report feeling more stressed now than they did five years ago, and 43 percent report using food to cope with stress.[1] Stress can affect eating behavior, and diet can affect a person's physiological and behavior response to stress.[2,3] Stress is a common risk factor for 75% to 90% of disease,4 and the most common stress-related diseases are chronic diseases, metabolic diseases, psychiatric and neurodegenerative diseases, cancer, etc.[5-8] According to a former review, long-term exposure to stress can overwhelm the compensating response (‘toxic stress’) and shorten life span.[9]

Allostatic load (AL) is a comprehensive indicator of dysregulation across multiple physiological systems, defined as the cumulative dysregulation of long-term or poorly

regulated responses of biological systems to internal and external stressors with pervasive effects on both physical and mental health.[10,11] AL quantified by the allostatic load score (ALS) is one of the most commonly used methods to assess the physiological response to stress.[11,12] Higher AL represents greater cumulative chronic stress.

In recent years, some studies have begun to explore the relationship between different diets and AL. A previous review 2 found that perceived stress was associated with less healthy eating. A study of dietary habits and AL showed that the increased intake of meat, sweets, and chips were significantly associated with high AL, while the traditional Puerto Rican diet of rice, beans, and oil was not.[13] AL was negatively correlated with intake of green and yellow vegetables and meat and positively correlated with confectionery and sweets in an elderly Japanese population.[14] A fat-rich diet has been shown to exacerbate harmful autonomic nervous system and cardiovascular responses to stress,[15] while an increase in polyunsaturated fat reduces these stress-induced cardiovascular responses.[16] According to the revelant studies, a diet rich in vegetables, fresh fruits, whole grains, and legumes, as well as lean, low-fat protein sources such as the American Heart Association diet (AHA) recommended, and a diet rich in fruits and vegetables, reduces AL and improves metabolic syndrome.[14,17-19] High sodium intake was associated with high AL in both women and men.[14,17,19]

The Dietary Guidelines for Americans (DGA) provides evidence-based advice designed to help Americans reduce their risk of developing multiple chronic diseases through a review of evidence on healthy eating patterns rather than foods or nutrients.[20,21] The Healthy Eating Index (HEI) score is used to evaluate dietary treatment, and a higher HEI score indicates relatively more adherence to the DGA recommendations. HEI-2015, the latest version of HEI, is made up of 13 different components, including 9 sufficient dietary components and 4 moderate dietary components, with higher scores in sufficient dietary component representing higher intake.[22] Refined grains, sodium, added sugars, and saturated fats are ingredients that people must consume in moderation, so the scores are reversed (higher scores represent lower intake). At present, there are some studies on the relationship between single nutrients or diet and AL, but there are still few studies exploring the relationship between comprehensive dietary quality and AL. The purpose of this study was to investigate the association between dietary quality and AL.

MATERIALS AND METHODS

Ethics approval

The NHANES protocal was approved by the National Center for Health Statistic (NCHS) Research Ethics Review Board.

Ethical approval number of the study are at list: Continuation of Protocol #2011-17 (NHANES 2015-2016); Protocol #2018-01 (Effective beginning October 26, 2017, NHANES 2017-2018); Continuation of Protocol #2011-17 (Effective through October 26, 2017, NHANES 2017-2018).

Data source and study sample

The National Health and Nutrition Examination Survey (NHANES) is a major program of the National Center for Health Statistics (NCHS). Data were collected over a two-year period cycle using a multi-stage probabilistic sampling design to select a stratified random sample representative of the non-institutional United States (U.S.) population. The survey aims to assess the health and nutritional status of children and adults in the United States.

Data from NHANES 2015-2016 and 2017-2018 cycles were selected for this study, which included a total of 19,225 participants. There were 7,377 adolescents(<18 years old), 882 with missing BMI data or BMI less than 18.5, and 2,657 with missing energy data or unreasonable energy intake[23] (less than 500Kcal/day or more than 3500Kcal/day for women, For men with less than 800Kcal/day or more than 4200Kcal/day), 752 individuals with deficient AL building variables(blood pressure, BMI, hba1c, total cholesterol, high-density lipoprotein cholesterol, high-sensitivity c-reactive protein, albumin, and creatinine clearance) were excluded. Therefore, 7557 eligible adults were enrolled in this study (Figure 1).

Allostatic load

In order to elevate the allostatic load, ten biological indicators (systolic blood pressure, diastolic blood pressure, body mass index (BMI), glycosylated hemoglobin, total cholesterol, high-density lipoprotein (HDL) cholesterol, total cholesterol /HDL cholesterol ratio, C-reactive protein, albumin and creatinine clearance) representing cardiovascular, metabolic and immune system as Rodriquez[24] were selected for construction.

AL was calculated as a physiological disorder index for each participant, which was quantified in three ways by assigning and adding the values of ten biomarkers, respectively. After choosing these biomarkers, values were assigned according to clinical cut-points of different biomarkers, and AL was divided into high AL and low AL.

AL was calculated by assigning 1 point to the high-risk category, 0.5 point to the medium-risk category, and 0 point to the low-risk category. In order to consider the effect of substance used on AL, we chose to add 0.5 point to the total score of participants who reported taking hypertension or diabetes or cholesterol medications but showed low risk in blood pressure, glycated hemoglobin, or cholesterol risk.[24,25]

The maximum possible AL1 score is 10. We defined high AL as a total AL score of 4 or more, because previous studies have shown that intergroup differences in morbidity and mortality are observed when the AL scores reach above 3 or 4.[25,26] The following clinically relevant cut-points were used: systolic blood pressure (>150mmHg, 120 to<150mmHg, and <120mmHg), diastolic blood pressure (>90mmHg, 80 to <90mmHg, and <80mmHg), HDL cholesterol (<40mg/dL, 40 to <60mg/dL, and >60mg/dL), albumin (<3.0μg/mL, 3.0 to <3.8μg/mL, and >3.8 μg/mL), body mass index (>30kg/m^3, 25 to <30 kg/m^3, and 18 to <25kg/m^3), total/HDL cholesterol ratio (>6, 5 to <6, and <5), high sensitivity C-reactive protein (>3 mg/L, 1 to <3 mg/L, and <1 mg/L), glycohemoglobin (>6.5%, 5.7% to <6.5%), total cholesterol (>240 mg/dL,200 to <240 mg/dL, and <200 mg/dL), creatinine clearance was distinguished by the 60th percentile. Direct creatinine clearance data were not available in the database, and the following formula[27] was used to calculate it.

Cr = ([(140-age)(wt kg)]/(72*Scr (mg/100ml)) *(15% less in females)

We use another way to build quantitative AL and explore the main component analysis as a sensitivity analysis, respectively. The score of AL is to standardize and add the individual Z-score of each ten biomarkers as a quantitative variable for further analysis and calculation. Principal component analysis was used to generate a new variable AL from 10 biomarkers, which could explain 70% of the variation of the original variable.

In NHANES 2015-2016 and 2017-2018 cycles, different instruments (DxC 660i, Cobas 6000) were used to measure high-sensitive C-reactive protein. According to the publication recommended by The Centers for Disease Control and Prevention of the United States, the following formula[28] was used to convert the measured data from 2015 to 2016.

Conversion from 2015-2016 to 2017-2018: (applicable to DxC 660i values ⩽23 mg/L) : Y (Cobas 6000) =0.8695 (95% CI: 0.8419, 0.8971) * X (DxC 660i) + 0.2954 (95% CI: 0.2786, 0.3121).

Dietary quality

We used the HEI score designed and recommended by the United States Department of Agriculture (USDA) to describe the characteristics of overall dietary quality. HEI-2015

contains 13 ingredients, including 9 sufficient ingredients (total vegetables, greens and beans, total fruits, whole fruits, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids) and 4 moderate ingredients (sodium, refined grains, saturated fats, and added sugars).[29,30] The fatty acids was calculated as (total monounsaturated fatty acids + total polyunsaturated fatty acids)/total saturated fatty acids. Dietary quality was categorized based on quartiles (Q1: <=25th percentile, Q2: >25th to 50th percentile, Q3: >50th to 75th percentile, Q4: >75th percentile), Q1 was the referent category.

We estimated the intake of 13 food components using the NHANES personal dietary review data and the Food Patterns Equivalents Database (FPED) dietary data. Each food is classified according to the USDA Codex Alimentarius. The final score of HEI-2015 was calculated using SAS codes recommended by the United States National Cancer Institute (NIH). SAS 9.4 software is used to calculate the score of dietary quality. For HEI-2015, a higher score represents more healthy dietary quality.

Covariates

Trained NHANES investigators obtained demographic information from participants living in the sample area. The data included age (actual value), sex (men, women), race/ethnicity (Mexican American, Other Hispanic, non-Hispanic White, non-Hispanic Black, and Other Race),education of household referent (less than high school, high School, more than high school), ratio of family income to poverty(low: <1.3, medium: 1.3-3.5, high: >3.5), marital status (married/living with partner, widowed/divorced/separated/never married), energy intake (actual value), smoke smoking (never smoker: lifetime intake of no more than 100 cigarettes, former smoker: lifetime intake of more than 100 cigarettes but current serum cotinine does not reach the threshold, current smoker: lifetime intake of more than 100 cigarettes and current serum cotinine reach the threshold), work activity (vigorous activity, moderate activity, and low activity), recreational activity (vigorous activity, moderate activity, and low activity).The threshold for smokers were non-Hispanic whites >4.85 ng/mL, non-Hispanic black >5.92 ng/mL, Mexican American >0.84 ng/mL, and others >3.08 ng/mL.[31]

Statistical analysis

The analysis was performed using Stata 12.0 (Stata Corporation, College Station, TX, USA) and weighted to obtain representative estimates. Student’s t-tests or chi-square tests were adopted to compare the differences between the high AL group and the low AL group. All

statistical analyses were adjusted based on survey design and weighted variables to take into account the complex sample design and to ensure nationally representative estimates. Since we combined the two cycles of the NHANES data, the new sample weight (the original 2-year sample weight divided by 2) was constructed according to the NHANES analysis guidelines.

Multivariate logistic regression model was used to evaluate the association between HEI score (Q1-Q4) and AL. In sensitive analysis, we use multivariate linear regression to assess the correlation between HEI score and AL. The crude model include only diet quality and did not adjust for covariates, model 1 was adjusted for age and sex, and model 2 was further adjusted for race/ethnicity, education, poverty ratio, energy intake, smoke, work activity, recreational activity and marital status. We performed a stratified analysis to determine whether the association between HEI score and AL score varied by age, sex, education and poverty ratio. Components of HEI-15 were analyzed to prove whether there was any association between each components and AL. In order to make our results more representative, we conducted a sensitivity analysis. Sensitivity analysis was modeled by standardizing the construction of continuity with AL scores and principal component analysis, respectively. We considered *p* value <0.05 to be statistically significant (two-sided).

Data availability statement

The data are available at https://www.cdc.gov/nchs/nhanes/index.htm (access date: 5 August 2022).

RESULTS

Table 1 shows baseline characteristics of participants in terms of allostatic load. A total of 7,557 eligble members were included in the study, in which the proportion of high AL was 47.4% in males and 52.6% in females. The high AL rates of 18-39, 40-59 and over 60 years old were 12.4%, 35.2% and 52.4%, respectively. Participants in the high AL group were more likely to occur in 40-59 years old, older than 60 years old, more than high school and Non-Hispanic White participants.

Table 2 shows the results of the relationship between HEI score and AL. Weighted logistic regression was used to explore the associated between HEI score and high AL. Compared with the lowest quartile group (Q1), there was statistically significant association between Q4 group and high AL (OR =0.80, 95% CI: 0.67,0.90). After adjusting for age and sex, Q2, Q3 and Q4 were all statistically related to high AL. After further adjustment for poverty ratio,

education level, race, energy intake, smoke, work activity, recreational activity and marital status, HEI score was inversely associated with high AL (OR_{Q2} =0.73, 95% CI: 0.62,0.86; OR_{Q3} =0.66, 95% CI: 0.55,0.79; OR_{Q4} =0.56, 95% CI: 0.47,0.67).

Table 3 shows the correlation between 13 different components in HEI-2015 and AL, respectively. Based on weighted logistic regression in model 2, we found that high intake of total fruits, whole fruits, whole grains and fatty acid was inversely associated with high AL ($OR_{total\ fruits}$ =0.93, 95%CI: 0.89, 0.96; $OR_{whole\ fruits}$ =0.95, 95%CI: 0.91,0.98; $OR_{whole\ grains}$ =0.97, 95%CI: 0.94,0.997; $OR_{fatty\ acid}$ =0.97, 95%CI: 0.95,0.99), respectively. A lower intake of sodium, refined grains, saturated fats and added sugars in diet was inversely associated with high AL (OR_{sodium} =0.95, 95%CI: 0.92,0.98; $OR_{refined\ grains}$ =0.97, 95%CI: 0.94,0.99; $OR_{saturated\ fats}$ =0.96, 95%CI: 0.93,0.98; $OR_{added\ sugars}$ =0.98, 95%CI: 0.96,0.99). As the results shows, no statistical significance was observed between the increase of total vegetables, greens and beans, total protein foods, dairy and seafood and plant proteins and AL (p>0.05).

Supplementary table 1 and Supplementary table 2 show the association between HEI score and AL in different ages and sex, respectively. Through multiple logistic regression, we found that the association between Q4 and high AL was statistically significant in the crude model and model 1 of different age groups compared with the control group, and the association still existed in the fully adjusted model ($OR_{18\text{-}39\ years}$ =0.59, 95%CI: 0.38,0.91; $OR_{40\text{-}59\ years}$ =0.52, 95%CI: 0.37,0.73; $OR_{>=60\ years}$ =0.53, 95%CI: 0.36,0.80). When exploring the association between HEI score and AL in different sex, logistic regression results in all adjusted model show that compared with Q1, Q4 group was associated with high AL (OR_{men} =0.53, 95%CI: 0.40,0.70; OR_{women} =0.60, 95%CI: 0.46,0.79).

Supplementary table 3 shows the results of sensitivity analysis, the association between HEI-2015 and AL obtained by standardizing the values of ten biomarkers. Weighted multiple linear regression results show that, after adjusting for age, sex, race/ethnicity, education, poverty ratio, energy intake, smoke, work activity, recreational activity and marital status, the association between Q2, Q3 and Q4 and AL were statistically significant compared with the control group (β_{Q2} =-0.54, 95%CI: -0.90,-0.19; β_{Q3} =-0.46, 95% CI: -0.83,-0.09; β_{Q4} =-0.11, 95% CI:-1.44,-0.79). We further generated continuous AL from ten different biological markers by principal component analysis, and explored the association between HEI-2015 and AL through multiple linear regression model. The results remain the same compared with before (β_{Q2} =-0.09, 95%CI: -0.15,-0.03; β_{Q3} =-0.08, 95% CI: -0.14,-0.02; β_{Q4} =-0.20, 95% CI:-0.25,-0.14).

DISCUSSION

Our results suggested that in adults, high dietary quality is inversely associated with high AL. We found that increased intake of total fruits, whole fruits, whole grains and fatty acid were inversely associated with the risk of high AL. The decreased intake of sodium, refined grains, saturated fats and added sugars were associated with the odds of high AL. In different age and sex groups, high dietary quality was correlated with high AL. We used continuous AL and principal component analysis models as the sensitive analysis to explore their correlation, and the results were still stable consistent.

Several studies have explored the relationship between dietary quality and AL-related indicators. Previous studies[32,33] have shown that higher diet quality is associated with a lower risk of disease and death. A systematic review[34] of 34 observational studies explored the association between dietary quality and obesity and found an inverse association between HEI and obesity. General obesity is usually determined by BMI. Previous studies[35-37] have also reported an inverse association between dietary quality and various biomarkers (systolic blood pressure, diastolic blood pressure, cholesterol, glycosylated hemoglobin). A review[38] also reviewed the association between dietary patterns and inflammatory markers and found that adherence to a healthy diet score was associated with lower inflammatory status.

We found the increased intake of total fruits, whole fruits, whole grains and fatty acid and the decreased intake of sodium, refined grains, saturated fats and added sugars were inversely associated with high AL. According to Global Burden of Disease (GBD) Study 2017, lower intake of whole grains and whole fruites and higher intake of sodium are the main risk factors for mortality and disability-adjusted life-years (DALYs) in many countries worldwide,[39] which is consistent with what we found in the association between HEI components and AL.

The activation of hypothalamic-pituitary-adrenal axis (HPA) may be one of the mechanisms of dietary quality leading to the increased risk of AL. HPA plays a key role in the pathophysiology of AL.[40,41] Cortisol, an end-product of HPA axis secretion, is positively correlated with the amount of chronic stress experienced and has been linked to stress-related disorders.[42-44] Duong et al[45] found that people who ate high levels of saturated fat, fast food, candy showed higher cortisol levels. There is some evidence that increased sodium or salt load increases urinary cortisol, and sodium restriction seems to decrease urinary cortisol.[46,47] A previous review48 suggested that increased HPA axis activity, a chronic low-grade

inflammatory state maintained by increased pro-inflammatory cytokines, and metabolic abnormalities can lead to an unhealthy diet-related increase in AL.

Although dietary components have been shown to be associated with biological indicators commonly used to construct AL in many studies, there have been relatively few studies complete report overall dietary quality and AL. Most of the previous studies paid attention to single foods, nutrients or a specific dietary pattern. A previous study[24] that examined the association between dietary quality and AL showed that unhealthy dietary quality increased the risk of AL in various ethnic groups. A prospective study[18] from Puerto Rico showed that a healthy diet may prevent the further development of metabolic syndrome (METS) and high AL in adults. What we found was consistent with these research. Some studies[19,49] have found no statistical association between dietary quality and AL.

Our study has several advantages. Firstly, the fact that NHANES is a large, nationally representative sample indicates the results are likely to have a high degree of external validity. Secondly, we adopted multivariate regression models in which as more as related factors of high AL were adjusted to minimize the confounding by covariates. Thirdly, we calculated HEI-2015 score by FPED dietary data approach with 24-hour dietary reviews from NHANES, rather than relying solely on self-reported measures of dietary intake.

This study does have some limitations. Firstly, this study was a cross-sectional study, and the observed association should not be interpreted as a causal relationship directly, requiring further prospective studies. Secondly, only 24-hour dietary reviews may not accurately reflect the daily diet of participants, and memory errors of participants may have a certain impact on our results. Thirdly, although we adjusted for some potential confounders, we could not control for unmeasured elements and unknown factors.

Conclusion

Our findings suggest that dietary quality was inversely associated with allostatic load, high dietary quality was associated with lower odds of high AL. In addition, we found that the increased intake of total fruits, whole fruit, whole grains and fatty acid and the decreased intake of sodium, refined grain, saturated fats and added sugars were inversely associated with the risk of high AL. High dietary quality was also negatively associated with the odds of

AL in adults that in different ages or sex. Larger prospective studies are needed to confirm our findings.

ACKNOWLEDGEMENTS

We acknowledge the staff at USDA and the National Center for Health Statistics at the CDC, who design, collect, administer the NHANES data and release the data available for public use.

CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare no competing financial interest. Junteng Pang is/was employed by Beijing improve quality Technology Co., LTD.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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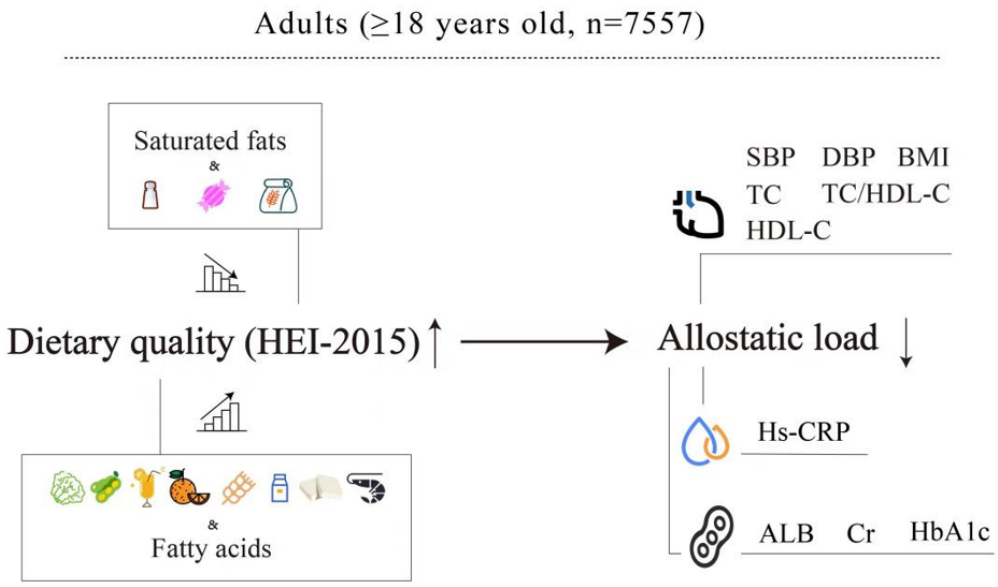

Graphical abstract

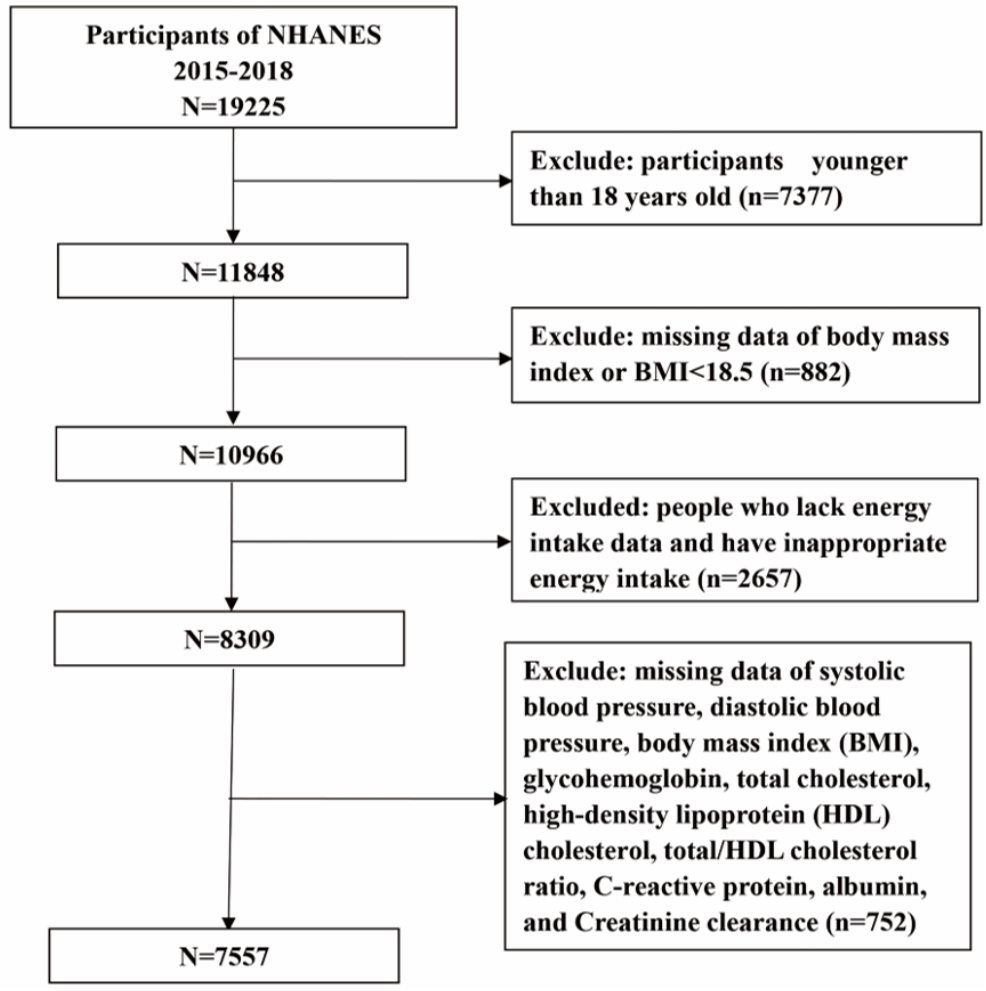

Figure 1. Flow chart of the screening process for the selection of eligible participants

Table 1. Characteristics of participants by different AL level NHANES 2015–2018 (N=7557)

	Low AL	High AL	*p* value
Number of participants (%)	4109(54.4)	3448(45.6)	
Age (%)†			<0.001
18-39 years	2089(50.8)	427(12.4)	
40-59 years	1177(28.6)	1213(35.2)	
≥60 years	843(20.5)	1808(52.4)	
Gender (%)†			<0.001
Men	1831(44.6)	1748(50.7)	
Women	2278(55.4)	1700(49.3)	
Race/ethnicity (%)†			<0.001
Mexican American	628(15.3)	531(15.4)	
Other Hispanic	437(10.6)	393(11.4)	
Non-Hispanic White	1497(36.4)	1245(35.1)	
Non-Hispanic Black	848(20.6)	805(23.3)	
Other race	699(17.0)	474(13.7)	
Education of household referent (%)†			<0.001
More than high school	608(16.0)	717(20.9)	
Less than high school	823(21.7)	857(25.0)	
High school	2365(62.3)	1858(54.1)	
Ratio of family income to poverty (PIR) (%)†			0.137
Low (PIR<1.3)	1263(30.7)	1076(31.2)	
Medium (PIR1.3-3.5)	1285(31.3)	1135(32.9)	
High (PIR>3.5)	1561(38.0)	1237(35.9)	
Marital status (%)†			0.156
Married/Living with partner	2275(59.9)	2114(61.6)	
Widowed/Divorced/Separated/Never married	1520(40.1)	1319(38.4)	
Work activities(%)†			0.001
Vigorous activity	982(23.9)	772(22.4)	
Moderate activity	991(24.1)	736(21.3)	
Low activity	2136(52.0)	1940(56.3)	
Recreational activities(%)†			<0.001
Vigorous activity	1427(34.7)	525(15.2)	
Moderate activity	925(22.5)	882(25.6)	
Low activity	1757(42.8)	2041(59.2)	
Smoking(%)†			<0.001
No smoker	2648(64.5)	1822(52.9)	
Former smoker	635(15.5)	919(26.7)	
Current smoker	824(20.1)	704(20.4)	
HEI score (mean±SE)‡	53.59±0.21	53.28±0.25	0.352

AL: xxxxx; PIR: XXXXXX; HEI: XXXX\

†p-value was tested by chi-square test

‡p-value was tested by student's t-test.

Table 2. Weighted odds ratios (ORs) with 95 percent confidence intervals (CIs) for HEI-2015 and allostatic load

	Allostatic load†					
	Crude model‡		Model 1§		Model 2¶	
	OR(95% CI)	*p* value	OR(95% CI)	*p* value	OR(95% CI)	*p* value
HEI score††						
Q1	Ref.		Ref.		Ref.	
Q2	0.92(0.78,1.08)	0.298	0.72(0.62,0.84)	<0.001	0.73(0.62,0.86)	0.001
Q3	0.86(0.72,1.04)	0.107	0.61(0.50,0.74)	<0.001	0.66(0.55,0.79)	<0.001
Q4	0.80(0.67,0.95)	0.012	0.49(0.42,0.58)	<0.001	0.56(0.47,0.67)	<0.001

†Calculated using logistic regression.

‡Crude model include only diet quality and did not adjust for covariates

§Model 1 adjusted for age and sex

¶Model 2 adjusted for age, sex, race/ethnicity, education, poverty ratio, energy intake, smoke, work activity, recreational activity and marital status

††Q1: ≤43.24, Q2: >43.24 to 52.78, Q3: >52.78 to 62.91, Q4: >62.9

Table 3. Weighted odds ratios (ORs) with 95 percent confidence intervals (CIs) for diet components and allostatic load

	Allostatic load[†]					
	Crude model[‡]		Model 1[§]		Model 2[¶]	
	OR(95% CI)	*p* value	OR(95% CI)	*p* value	OR(95% CI)	*p* value
Total vegetables	1.01(0.97,1.06)	0.611	0.95(0.90,0.997)	0.039	0.97(0.92,1.03)	0.331
Greens and beans	0.97(0.95,1.00)	0.058	0.97(0.94,1.01)	0.145	0.99(0.96,1.03)	0.707
Total fruits	0.99(0.96,1.02)	0.373	0.92(0.88,0.95)	<0.001	0.93(0.89,0.96)	<0.001
Whole fruits	1.00(0.97,1.04)	0.887	0.93(0.89,0.96)	<0.001	0.95(0.91,0.98)	0.005
Whole grains	0.99(0.97,1.02)	0.549	0.96(0.93,0.98)	0.003	0.97(0.94,0.997)	0.029
Dairy	0.97(0.95,0.99)	0.008	0.98(0.96,1.01)	0.131	1.00(0.98,1.03)	0.773
Total protein foods	1.12(1.05,1.19)	0.001	1.07(0.99,1.16)	0.072	1.08(0.99,1.17)	0.066
Seafood and plant proteins	1.00(0.98,1.03)	0.830	0.97(0.94,0.9995)	0.047	0.99(0.96,1.02)	0.649
Fatty acid	0.98(0.96,1.00)	0.083	0.97(0.95,0.99)	0.010	0.97(0.95,0.99)	0.003
Sodium[††]	0.98(0.96,1.00)	0.102	0.95(0.93,0.98)	0.002	0.95(0.92,0.98)	0.001
Refined grains[††]	1.00(0.98,1.02)	0.747	0.96(0.93,0.98)	0.001	0.97(0.94,0.99)	0.012
Saturated fats[††]	0.96(0.94,0.98)	0.001	0.97(0.94,0.99)	0.013	0.96(0.93,0.98)	0.003
Added sugars[††]	0.98(0.96,0.99)	0.013	0.96(0.94,0.98)	<0.001	0.98(0.96,0.99)	0.009

[†]Calculated using logistic regression.
[‡]Crude model include only diet quality and did not adjust for covariates.
[§]Model 1 adjusted for age and sex.
[¶]Model 2 adjusted for age, sex, race/ethnicity, education, poverty ratio, energy intake, smoke, work activity, recreational activity and marital status.
[††]Moderate ingredients, a lower intake means a higher score.

Supplementary Table 1. Weighted odds ratios (ORs) with 95 percent confidence intervals (CIs) for HEI score and allostatic load, stratified by age

	Allostatic load[†]					
	Crude model[‡]		Model 1[§]		Model 2[¶]	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
18-39 years						
Q1[††]	Ref.		Ref.		Ref.	
Q2	1.10(0.81,1.48)	0.539	1.12(0.81,1.55)	0.480	1.08(0.77,1.51)	0.662
Q3	0.84(0.59,1.20)	0.334	0.87(0.61,1.25)	0.435	0.91(0.62,1.33)	0.604
Q4	0.51(0.36,0.71)	<0.001	0.56(0.40,0.80)	0.002	0.59(0.38,0.91)	0.018
40-59 years						
Q1	Ref.		Ref.		Ref.	
Q2	0.61(0.44,0.84)	0.004	0.61(0.44,0.85)	0.005	0.60(0.43,0.84)	0.004
Q3	0.57(0.42,0.79)	0.001	0.58(0.42,0.79)	0.001	0.59(0.43,0.81)	0.002
Q4	0.45(0.32,0.64)	<0.001	0.46(0.33,0.65)	<0.001	0.52(0.37,0.73)	<0.001
≥60 years						
Q1	Ref.		Ref.		Ref.	
Q2	0.59(0.37,0.95)	0.030	0.59(0.37,0.93)	0.024	0.62(0.40,0.97)	0.036
Q3	0.50(0.32,0.77)	0.003	0.49(0.32,0.74)	0.002	0.55(0.37,0.82)	0.004
Q4	0.48(0.31,0.73)	0.001	0.47(0.31,0.72)	0.001	0.53(0.36,0.80)	0.004

[†]Calculated using logistic regression.
[‡]Crude model include only diet quality and did not adjust for covariates.
[§]Model 1 adjusted for sex.
[¶]Model 2 adjusted for sex, race/ethnicity, education, poverty ratio, energy intake, smoke, work activity, recreational activity and marital status.
[††]Q1: ≤43.24, Q2: >43.24 to 52.78, Q3: >52.78 to 62.91, Q4: >62.91.

Supplementary Table 2. Weighted odds ratios (ORs) with 95 percent confidence intervals (CIs) for HEI score and allostatic load, stratified by sex

	Allostatic load[†]					
	Crude model[‡]		Model 1[§]		Model 2[¶]	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Men						
Q1[††]	Ref.		Ref.		Ref.	
Q2	0.90(0.74,1.10)	0.289	0.76(0.62,0.93)	0.009	0.75(0.60,0.93)	0.009
Q3	0.81(0.63,1.03)	0.088	0.64(0.49,0.85)	0.002	0.65(0.49,0.86)	0.004
Q4	0.82(0.65,1.03)	0.084	0.51(0.39,0.66)	<0.001	0.53(0.40,0.70)	<0.001
Women						
Q1	Ref.		Ref.		Ref.	
Q2	0.97(0.75,1.25)	0.786	0.68(0.55,0.85)	0.001	0.72(0.58,0.88)	0.003
Q3	0.94(0.73,1.22)	0.644	0.57(0.45,0.72)	<0.001	0.67(0.54,0.83)	0.001
Q4	0.83(0.65,1.05)	0.115	0.48(0.37,0.61)	<0.001	0.60(0.46,0.79)	0.001

[†]Calculated using logistic regression.
[‡]Crude model include only diet quality and did not adjust for covariates.
[§]Model 1 adjusted for age.
[¶]Model 2 adjusted for age, race/ethnicity, education, poverty ratio, energy intake, smoke, work activity, recreational activity and marital status.
[††]Q1: ≤43.24, Q2: >43.24 to 52.78, Q3: >52.78 to 62.91, Q4: >62.91.

Supplementary Table 3. Weighted partial regression coefficient (β) with 95 percent confidence intervals (CIs) for HEI-2015 and allostatic load

	Allostatic load[†]							
	Crude model[‡]		Model 1[§]		Model 2[¶]			
	β(95% CI)	*p* value	β(95% CI)	*p* value	β(95% CI)	*p* value	β(95% CI)[††]	*p* value
HEI score								
Q1[‡‡]	Ref.		Ref.		Ref.		Ref.	
Q2	-0.43 (-0.78,-0.08)	0.017	-0.55 (-0.91,-0.20)	0.003	-0.54 (-0.90,-0.19)	0.004	-0.09 (-0.15,-0.03)	0.002
Q3	-0.45 (-0.81,-0.09)	0.015	-0.62 (-0.98,-0.25)	0.002	-0.46 (-0.83,-0.09)	0.016	-0.08 (-0.14,-0.02)	0.010
Q4	-1.14 (-1.46,-0.82)	<0.001	-1.38 (-1.72,-1.03)	<0.001	-0.11 (-1.44,-0.79)	<0.001	-0.20 (-0.25,-0.14)	<0.001

[†]Calculated using linear regression.
[‡]Crude model include only diet quality and did not adjust for covariates.
[§]Model 1 adjusted for age and sex.
[¶]Model 2 adjusted for age, sex, race/ethnicity, education, poverty ratio, energy intake, smoke, work activity, recreational activity and marital status.
[††]Generate a new variable AL from 10 biomarkers by principal component analysis, which could explain 70% of the variation of the original variable.
[‡‡]Q1: ⩽43.24, Q2: >43.24 to 52.78, Q3: >52.78 to 62.91, Q4: >62.