Preventive Medicine Reports 36 (2023) 102421

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Association between healthy eating index-2015 and abdominal aortic calcification: A population-based cross-sectional study

Lu Liu [a], Tiantian Xie [a], Zhongshun Hu [b,*], Jinsong Liu [a,*]

[a] Department of Pathology, Lu'an People's Hospital of Anhui Province, Lu'an Hospital of Anhui Medical University, Lu'an, Anhui 237005, China
[b] Department of Ultrasound, Lu'an People's Hospital of Anhui Province, Lu'an Hospital of Anhui Medical University, Lu'an, Anhui 237005, China

ARTICLE INFO

Keywords:
Abdominal aortic calcification
Cross-sectional study
Healthy eating index-2015
National Health and Nutrition Examination Survey
United States

ABSTRACT

Background: An association between the healthy eating index (HEI)-2015 and risk of abdominal aortic calcification (AAC) is unclear in the general population of the United States (U.S.). Therefore, we examined the relationship between HEI-2015 and AAC risk in our research.
Methods: A cross-sectional study of National Health and Nutrition Examination Surveys (NHANES) participants between 2013 and 2014 was conducted. For the analysis of the association between HEI-2015 and AAC, the restricted cubic spline (RCS) plot and multivariable logistic regression models were used. In addition, we also conducted subgroup analysis for the relationship between HEI-2015 and AAC.
Results: There was a total of 1162 individuals. As shown by the RCS plot, HEI-2015 was linked with AAC risk in a U-shaped pattern (P for nonlinearity < 0.05). Taking into account known confounding variables, compared with the lowest quartiles, the odds ratios with 95% confidence intervals for AAC across the quartiles were 0.637 (0.425,0.956), 0.763 (0.499, 1.167), and 0.842 (0.561, 1.265). Based on the results of subgroup analysis, the HEI-2015 and AAC risk were U-curve correlated among all age groups, sex, with or without hypertension or DM, and BMI of <30 kg/m^2. The greens and beans, and whole fruits are independent protective factor for AAC.
Conclusions: The U-shaped relationships exist between HEI-2015 and prevalence of AAC in the general U.S. population. Consequently, prevalence of AAC may be mitigated with reasonable and balanced diet.

1. Introduction

Vascular calcification refers to the pathological process of hydroxyapatite mineral deposition in the vascular system (Lee et al., 2020). Calcification of arteries appears to be specific to arteries, which can involve the carotid artery, cerebral arteries, coronary artery, thoracic aorta, and abdominal aorta (Wu et al., 2016). Among them, abdominal aortic calcification (AAC), an early manifestation of abdominal aortic wall atherosclerosis, driven by inflammation (Yang et al., 2023). Meanwhile, AAC also is a marker of subclinical atherosclerosis and a predictive factor of subsequent vascular-associated morbidity and mortality (Chow et al., 2008). In addition to significantly lowering bone mineral density, AAC increases the risk of cardiovascular complications (Chuang et al., 2017). Additionally, the mortality rate of cardiovascular events is higher in subjects with advanced abdominal aortic calcifications (AAC) (Knauer et al., 2023).

Healthy eating habits are associated with good health, whereas unhealthy eating habits can lead to chronic diseases (Noratto et al., 2018). The HEI-2015 is used to assess concordance of the diet with the dietary guidelines for Americans (DGA), with a higher score indicating better compliance and consists of 13 components (Krebs-Smith et al., 2018). The quality of American diets can be measured using this metric, which can be applied to any defined set of foods (McGill et al., 2016). In addition, different population subgroups and nutrition-related interventions also can be assessed using the HEI-2015 (Reedy et al., 2018). Several previous studies have explored the association between dietary element intake and AAC. Shang X et al. revealed that in older women, the intake of α-linolenic acid and total ω-3 fatty acids is an important predictor of the development of AAC, but not in older men (Shang et al., 2015). Bondonno NP and his team founded that severe AAC was not associated with the consumption of total and other individual fruit intake. In addition, in older women, apple but not total or other fruit intake is independently negatively associated with the risk of AAC (Bondonno et al., 2016). Chen W et al. revealed that noninstitutionalized individuals in the United States (U.S.), an increase in dietary zinc intake was independently associated with a lower risk of severe AAC (Chen

---

* Corresponding authors.
E-mail addresses: 707383198@qq.com (Z. Hu), 13655594763@163.com (J. Liu).

https://doi.org/10.1016/j.pmedr.2023.102421
Received 11 February 2023; Received in revised form 12 September 2023; Accepted 13 September 2023

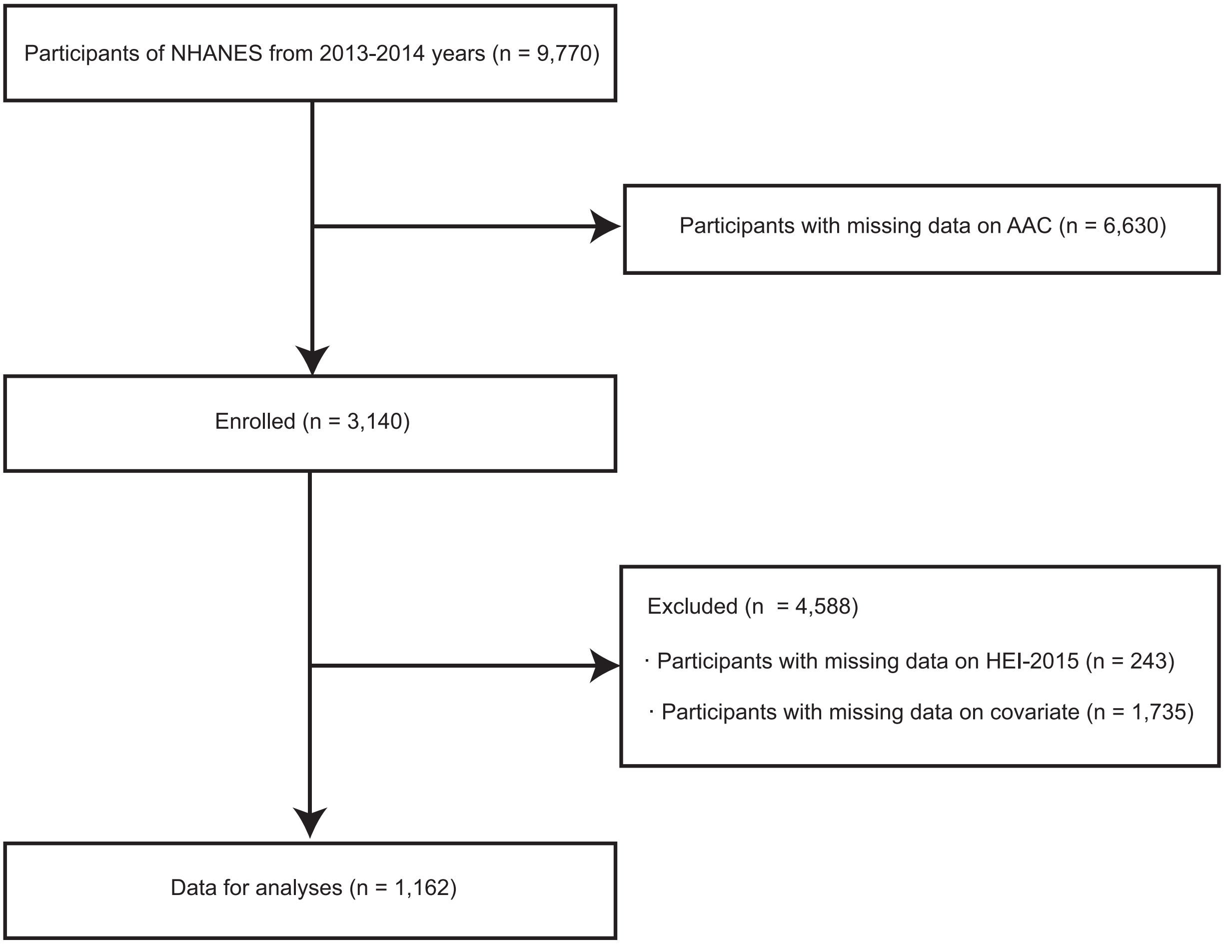

Fig. 1. Study flow chart for this study from NHANES 2013–2014. Abbreviations: NHANES, National Health and Nutrition Examination Surveys; AAC, abdominal aortic calcification; HEI-2015, healthy eating index.

et al., 2020). Blekkenhorst LC et al. also found that increasing cruciferous vegetable consumption may prevent vascular calcification (Blekkenhorst et al., 2021). In addition, Román-García P and his team suggested that calcification of the arteries is induced by a high phosphorus diet in rat model (Román-García et al., 2010). Therefore, lifestyle interventions to improve diet are crucial to preventing calcification and achieving long-term health benefits.

Accumulating research evidence suggests that that high scores on the HEI (which corresponds to a healthy eating pattern) are inversely related with a reduced risk of chronic disease (Al-Ibrahim and Jackson, 2019). In a study by Li XY, patients with a higher healthy eating index had a lower prevalence of periodontitis (Li et al., 2022). In light of the detrimental effects of AAC, especially severe AAC, it is highly advantageous to recognize risk factors for AAC and devise measures to avoid or control the bad consequences as soon as possible. Epidemiological research has not been able to determine the association between the HEI-2015 and the risk for AAC in the general U.S. population. And, an improved understanding of the relationships between dietary pattern and health outcomes will help identify appropriate tools to reduce the risk of developing AAC. Therefore, we investigated the association between HEI-2015 and the prevalence of AAC by analysing data from the Nutrition and Health Examination Survey (NHANES) 2013–2014.

2. Material and methods

2.1. Study population

A multistage stratified random sampling method is used in NHANES to collect information about the health and nutrition of the general population (https://www.cdc.gov/nchs/nhanes/). The NHANES data from 2013 to 2014 were used and analyzed in our study. A total of 9,770 adult participants enrolled in the NHANES from 2013 to 2014. We excluded participants with missing AAC data (n = 6630) and HEI-2015 data (n = 243). In addition, participants with missing covariate data were also removed (n = 1735). Finally, a total of 1162 individuals were included in this research (Fig. 1). We computed that the number of participants in this research may be representative of the total population of 48,891,875 in the United States. Informed consent was obtained from every participant in the NHANES study, which was authorized by the National Center for Health Statistics study ethical review board (Zipf et al., 2013).

2.2. HEI-2015 calculation

In the NHANES dietary data, trained interviewers conducted in-person 24-hour dietary recalls using the US Department of Agriculture's (USDA's) Automated Multiple-Pass Method (Blanton et al., 2006; Moshfegh et al., 2008). For each food, nutrient values have been assigned based on the USDA Food and Nutrient Database for Dietary Studies (Fan et al., 2021). The components of food, with the exception of fatty acids, are scored on a density basis (per 1000 kcal or as a percentage of energy). An unsaturated/saturated fatty acid ratio is used to express fatty acids.

The method used to calculate HEI-2015 were included and referenced from the National Cancer Institute website (https://www.cancer.gov/about-cancer). There are 13 dietary components in the HEI-2015.

Table 1
Characteristics of the study population based on HEI-2015 quartiles from NHANES 2013–2014 (n = 1,162).

HEI-2015	Total (n = 1162)	Q1 (n = 291)	Q2 (n = 290)	Q3 (n = 290)	Q4 (n = 291)	*P*-value
Age, years	58.10±0.53	56.14±0.78	56.62±0.80	59.38±0.88	60.21±0.90	0.001
Sex, n (%)						0.034
Male	575 (49.5%)	145 (12.5%)	150 (12.9%)	153 (13.2%)	127 (10.9%)	
Female	587 (50.5%)	146 (12.6%)	140 (48.3%)	137 (11.8%)	164 (14.1%)	
Race/ethnicity, n (%)						0.111
Mexican American	148 (12.7%)	41 (3.5%)	43 (3.7%)	36 (3.1%)	28 (2.4%)	
Other Hispanic	101 (8.7%)	21 (1.8%)	26 (2.2%)	28 (2.4%)	26 (2.2%)	
Non-Hispanic Black	210 (18.1%)	62 (5.3%)	54 (4.6%)	45 (3.9%)	49 (4.2%)	
Non-Hispanic White	562 (48.4%)	149 (12.8%)	144 (12.4%)	136 (11.7%)	133 (11.4%)	
Other race	141 (12.1%)	18 (1.5%)	23 (2.0%)	45 (3.9%)	55 (4.7%)	
Family PIR	3.19±0.15	2.67±0.26	3.03±0.14	3.42±0.15	3.61±0.12	< 0.001
Education level, n (%)						0.011
High school	245 (21.1%)	90 (7.7%)	68 (5.9%)	52 (4.5%)	35 (3.0%)	
College	241 (20.7%)	70 (6.0%)	63 (5.4%)	65 (5.6%)	43 (3.7%)	
Graduate	676 (58.2%)	131 (11.3%)	159 (13.7%)	173 (14.9%)	213 (18.3%)	
Marital status, n (%)						0.206
Having a partner	766 (65.9%)	179 (15.4%)	194 (16.7%)	194 (16.7%)	199 (17.1%)	
No partner	301 (25.9%)	88 (7.6%)	66 (5.7%)	77 (6.6%)	70 (6.0%)	
Unmarried	95 (8.2%)	24 (2.1%)	30 (2.6%)	19 (1.6%)	22 (1.9%)	
Hypertension, n (%)						0.190
No	531 (45.7%)	121 (10.4%)	137 (11.8%)	137 (11.8%)	136 (11.7%)	
Yes	631 (54.3%)	170 (14.6%)	153 (13.2%)	153 (13.2%)	155 (13.3%)	
DM, n (%)						0.067
No	873 (75.1%)	223 (19.2%)	209 (18.0%)	215 (18.5%)	226 (19.4%)	
Yes	289 (24.9%)	68 (5.9%)	81 (7.0%)	75 (6.5%)	65 (5.6%)	
Smoker, n (%)						< 0.001
No	610 (52.5%)	124 (10.7%)	145 (12.5%)	156 (13.4%)	185 (15.9%)	
Former	341 (29.3%)	77 (6.6%)	85 (7.3%)	99 (8.5%)	80 (6.9%)	
Now	211 (18.2%)	90 (7.7%)	60 (5.2%)	35 (3.0%)	26 (2.2%)	
Alcohol user, n (%)						0.004
Never	156 (13.4%)	30 (2.6%)	39 (3.4%)	44 (3.8%)	43 (3.7%)	
Former	252 (21.7%)	80 (6.9%)	60 (5.2%)	64 (5.5%)	48 (4.1%)	
Mild	448 (38.6%)	95 (8.2%)	100 (8.6%)	103 (8.9%)	150 (12.9%)	
Moderate	151 (13.0%)	38 (3.3%)	47 (4.0%)	37 (3.2%)	29 (2.5%)	
Heavy	155 (13.3%)	48 (4.1%)	44 (3.8%)	42 (3.6%)	21 (1.8%)	
CHD, n (%)						0.266
No	1104 (95.0%)	278 (23.9%)	278 (23.9%)	278 (23.9%)	270 (23.2%)	
Yes	58 (5.0%)	13 (1.1%)	12 (1.1%)	12 (1.0%)	21 (1.8%)	
CHF, n (%)						0.448
No	1121 (96.5%)	283 (24.4%)	279 (24.0%)	281 (24.2%)	278 (23.9%)	
Yes	41 (3.5%)	8 (0.7%)	11 (0.9%)	9 (0.8%)	13 (1.1%)	
Angina, n (%)						0.251
No	1126 (96.9%)	281 (24.2%)	282 (24.3%)	284 (24.4%)	279 (24.0%)	
Yes	36 (3.1%)	10 (0.9%)	8 (0.7%)	6 (0.5%)	12 (1.0%)	
Heart attack, n (%)						0.795
No	1100 (94.7%)	275 (23.7%)	271 (23.3%)	274 (23.6%)	280 (24.1%)	
Yes	62 (5.3%)	16 (1.4%)	19 (1.6%)	16 (1.4%)	11(0.9%)	
Stroke, n (%)						0.034
No	1106 (95.2%)	269 (23.1%)	277 (23.8%)	276 (23.8%)	284 (24.4%)	
Yes	56 (4.8%)	22 (1.9%)	13 (1.1%)	14 (1.2%)	7 (0.6%)	
BMI, kg/m^2	28.49±0.33	28.82±0.58	29.28±0.41	28.28±0.43	27.55±0.45	0.409
SBP, mmHg	124.77±0.97	124.47±1.37	126.41±1.56	123.59±1.59	124.65±1.26	0.256

(*continued on next page*)

Table 1 (*continued*)

HEI-2015	Total (n = 1162)	Q1 (n = 291)	Q2 (n = 290)	Q3 (n = 290)	Q4 (n = 291)	*P*-value
DBP, mmHg	69.72±0.49	70.20±0.48	71.26±0.65	68.60±0.98	68.83±0.77	0.083
FBG, mg/mL	107.76±1.13	108.30±1.97	112.80±2.97	106.99±2.05	102.84±1.22	0.411
HbA1c, %	5.76±0.04	5.79±0.09	5.86±0.09	5.73±0.07	5.66±0.05	0.192
Fast insulin, pmol/L	72.47±4.37	71.81±7.05	87.06±13.00	71.55±4.83	59.06±3.38	0.092
eGFR, ml/min/1.73 m^2	84.72±0.78	87.13±1.31	86.38±1.17	83.89±1.44	81.50±1.24	0.003
Alk, u/L	65.28±0.90	69.04±1.92	63.63±1.00	66.73±3.16	61.69±1.46	0.098
Total Bilirubin, mg/dL	0.69±0.01	0.65±0.03	0.69±0.02	0.70±0.02	0.70±0.02	0.236
Hb, g/dL	14.30±0.06	14.36±0.07	14.35±0.10	14.32±0.10	14.16±0.10	0.284
BUN, mg/dL	14.04±0.26	13.01±0.54	13.99±0.32	14.32±0.42	14.83±0.23	0.003
UA, mg/dL	5.47±0.06	5.40±0.16	5.49±0.07	5.55±0.07	5.41±0.08	0.539
Scr, mg/dL	0.92±0.02	0.92±0.02	0.91±0.01	0.91±0.02	0.94±0.04	0.877
TC, mg/dL	195.98±1.32	192.71±3.06	198.15±3.73	195.94±1.90	197.04±2.53	0.573
TG, mg/dL	123.83±3.31	124.43±4.45	138.04±7.38	120.84±5.40	111.79±5.02	0.055
HDL-C, mg/dL	55.60±0.74	53.63±1.48	52.85±1.17	56.48±1.95	59.46±1.07	0.005
Calcium, mg/dL	9.41±0.01	9.37±0.03	9.44±0.02	9.39±0.02	9.45±0.02	0.136
Phosphorus, mg/dL	3.73±0.02	3.63±0.03	3.71±0.03	3.76±0.03	3.80±0.05	0.005

Abbreviations: Q1:16.0–42.6; Q2:42.7–52.7; Q3: 52.8–63.1; and Q4: 63.2–95.8; HEI, healthy eating index; AAC, abdominal aortic calcification; DM, diabetes mellitus; BMI, body mass index; Hb, hemoglobin; FBG, fast glucose; fast insulin, HbA1c, glycohemoglobin; Alk, alkaline phosphatase; BUN, blood urea nitrogen; Scr, serum creatinine; UA, uric acid; eGFR, estimated glomerular filtration rate; TC, total cholesterol; TG, triglyceride; HDL-C, high density lipoprotein-cholesterol. The continuous variable *P*-value comes from the weighted student *t*-test; The categorical variable *P*-value is derived from the weighted chi-squared test.

There are nine components that evaluate adequacy of intake, including total fruit, all fruit, all vegetables, greens and legumes, whole grains, dairy products, all protein foods, seafood and vegetable proteins, and fatty acids. Four components evaluate moderation of dietary intake – refined grains, sodium, added sugars and saturated fats. Each element can be rated up to 5 points or a maximum of 10 points. The total score is 100, with higher scores indicating closer to the recommended range or number (Reedy et al., 2018). A higher score indicates better quality for the adequacy components. Lower intakes result in higher scores in the moderation components.

2.3. Covariates

In the study, the following covariates were considered: age, sex, race/ethnicity, family poverty income ratio (PIR), education level, marital status, the complication of hypertension, and diabetes mellitus (DM), smoker, drinker, the complication of coronary heart disease (CHD), congestive heart failure (CHF), angina pectoris, heart attack, and stroke, body mass index (BMI), hemoglobin (Hb), fast glucose (FBG), fast insulin, glycohemoglobin (HbA1c), alkaline phosphatase (Alk), total bilirubin, uric acid (UA), blood urea nitrogen (BUN), serum creatinine (Scr), estimated glomerular filtration rate (eGFR), serum phosphorus, serum calcium (Ca), total cholesterol (TC), triglyceride (TG), and high density lipoprotein-cholesterol (HDL-C). You can find more information about the variables in this study here www.cdc.gov/nchs/nhanes/.

2.4. AAC measurement

In order to obtain and quantify abdominal aortic calcification, the dual-energy X-ray absorptiometry (DXA, Densitometer Discovery A, Hologic, Marlborough, MA, USA) was conducted on the lumbar spine (vertebrae L1-L4) and the Kauppila score system was employed (Kauppila et al., 1997; Schousboe et al., 2007). At the NHANES mobile examination center, trained and certified radiology technologists performed DXA scans. Higher AAC scores indicated a more serious abdominal aortic calcification condition. In this study, the Kauppila scores range between 0 and 24, with >6 indicating significant calcification and has been defined as SAAC (Chen et al., 2020; Górriz et al., 2015; Qin et al., 2021). A detailed description of AAC measurements is available in https://wwwn.cdc.gov/Nchs/Nhanes/2013-2014/DXXAAC_H.htm.

2.5. Statistical analysis

The R version 3.6.4 (R Foundation for Statistical Computing, Vienna, Austria), and Stata version 13.0 (Stata Corporation, College Station, TX, USA) were performed for all analyses. The weighted NHANES sample was used to calculate all estimates. We also removed the individuals with missing covariates in this study. *P*-value < 0.05 was regarded as statistically significant. The HEI-2015 were divided into quartiles (Q1:16.0–42.6; Q2:42.7–52.7; Q3: 52.8–63.1; and Q4: 63.2–95.8), and the lowest quartile (Q1) served as the reference group (Q1). Continuous variables are expressed as the means (standard deviations, SDs) and categorical variables are presented as numbers (%). To calculate differences between groups, we used weighted linear regression models (continuous variables) and weighted chi-square tests (categorical variables). An analysis of multivariate logistic regression was used to investigate the relationship between HEI and the risk of AAC. First, model 1 was adjusted for age and sex. Second, model 2 was adjusted for model 1 variables plus race/ethnicity, education level, marital status, family PIR, smoke status, drink status, the history of hypertension, and DM. Finally, model 3 was adjusted for model 2 variables plus BMI, Hb, FBG, fast insulin, HbA1c, Alk, total bilirubin, BUN, UA, Scr, eGFR, serum phosphorus, Ca, TC, TG, and HDL-C.

3. Results

3.1. Baseline characteristics

The baseline characteristics of the research participants was shown in Table 1. This group had a prevalence of 47.5% of AAC. We classified the participants according to their HEI quartiles (Q1:16.0–42.6; Q2:42.7–52.7; Q3: 52.8–63.1; and Q4: 63.2–95.8). There is a significant difference in age, sex, family PIR, education level, smoker, drinker, the history of stroke, BMI, eGFR, BUN, HDL-C, and phosphorus among Q1, Q2, Q3, and Q4 group. Compared with Q1, Q3, and Q4 group, participants in Q2 group occupied a higher proportion of DM, had the highest levels of BMI, SBP, DBP, FBG, HbA1c, Fast insulin, and had the lowest levels of HDL-C. Individuals in Q3 group occupied a lowest proportion of angina and had the lowest levels of UA. In addition, the Q4 group were older, occupied a highest proportion of CHD, CHF, as well as angina, and a lowest proportion of heart attack and stroke, had the highest levels of family PIR, BUN, Scr, HDL-C, Ca, phosphorus, and had the lowest levels of eGFR, Alk, Hb, and TG.

Table 2
Association of HEI-2015 with prevalence of AAC in individuals from NHANES 2013–2014.

HEI-2015	Model 1	Model 2	Model 3
	OR (95 %CI)	OR (95 %CI)	OR (95 %CI)
Q1	Ref.	Ref.	Ref.
Q2	0.596 (0.408, 0.870) **	0.618 (0.418, 0.912) *	0.637 (0.425,0.956) *
Q3	0.690 (0.476, 1.000)	0.777 (0.520, 1.161)	0.763 (0.499, 1.167)
Q4	0.781 (0.542, 1.126)	0.822 (0.558, 1.211)	0.842 (0.561, 1.265)
P for trend	0.154	0.459	0.447

Abbreviations: Q1:16.0–42.6; Q2:42.7–52.7; Q3: 52.8–63.1; and Q4: 63.2–95.8; HEI, healthy eating index; AAC, abdominal aortic calcification; $*P < 0.05$; $**P < 0.01$; OR, odd ratio; CI, confidence interval; Model 1: age and gender. Model 2: model 1 variables plus race/ethnicity, education level, marital status, family poverty income ratio, hypertension, diabetes mellitus, smoke status, and drink status. Model 3 was adjusted for model 2 variables plus body mass index, hemoglobin, fast glucose, fast insulin, glycohemoglobin, alkaline phosphatase, total bilirubin, uric acid, blood urea nitrogen, serum creatinine, estimated glomerular filtration rate, serum phosphorus, serum calcium, total cholesterol, triglyceride, and high-density lipoprotein-cholesterol;

3.2. Association between HEI-2015 and AAC

In the restricted cubic spline plot, we can see HEI-2015 is associated with a U-shaped association with the prevalence of AAC (*P* for nonlinearity < 0.05, Fig. 1A). As HEI-2015 increased, the risk of AAC decreased significantly. When the HEI-2015 reached 55.9, the risk of AAC was the lowest, and then the curve showed an upward trend. Table 2 shows the findings of multivariate logistic regression analysis for the link between HEI-2015 and the prevalence of AAC. After adjusting for interfering factors, compared with the lowest quartiles (Q1), the odds ratios (ORs) with 95% confidence intervals (CIs) for AAC across the quartiles were 0.637 (0.425,0.956), 0.763 (0.499, 1.167), and 0.842 (0.561, 1.265).

3.3. Subgroup analyses

The subgroup analysis was conducted, stratified by age, sex, hypertension, DM, and BMI, to determine the link between HEI-2015 and the risk of AAC (Table 3). The stratified analysis revealed the U-shaped associations of HEI-2015 with AAC were found among participants in all age groups, either men or women, with or without hypertension or DM, and with BMI of < 30 kg/m^2 (Fig. 2B – F). However, there was a negative linear correlation between HEI-2015 and AAC in participants with BMI of >30 kg/m^2 (Fig. 2F). In different age and BMI populations, the association between HEI-2015 and the risk of SAAC was significantly different (*P* for interaction < 0.05).

3.4. Association between HEI-2015 components and AAC

Based on the multivariate regression analysis of the HEI-2015 components, in fully adjusted model III, we found that greens and beans, and total fruits were all significantly associated with AAC ($P < 0.05$, Table 4). The OR value of greens and beans, and total fruits were 0.941, and 0.929, respectively. These two HEI-2015 components were protective factor for AAC.

4. Discussion

The HEI-2015 measures quality of diet overall, was created based on the 2015 Dietary Guidelines for Americans (Nunn et al., 2009). Previous studies have shown that alternate healthy eating index can be used to measure diet quality (Reedy et al., 2008). In addition, most cardiovascular disease-related events could be prevented or substantially delayed with improved diet and lifestyle (Radavelli-Bagatini et al., 2020). Therefore, the aim of the study was to explore the association between HEI-2015 and the risk of AAC and find which component of food intake is critical for the prevention of AAC. According to RCS plot, we revealed that there a U-curve relationship between HEI-2015 and prevalence of AAC. A turning point for HEI-2015 was observed and prevalence of AAC was lowest when the HEI-2015 was 55.9. In addition, the stratified analysis revealed the U-shaped associations of HEI-2015 with prevalence of AAC were found among participants in all age groups, either men or women, with or without hypertension or DM, and with BMI of <30 kg/m^2. Finally, we found that two HEI-2015 components (greens and beans, and total fruits) were protective factor for AAC.

Dietary intake regulates inflammation, which contributes to chronic

Table 3
Stratification by age, sex, hypertension, DM, and BMI in the associations of HEI-2015 with prevalence of AAC in individuals from NHANES 2013–2014.

HEI-2015	Q1	Q2	Q3	Q4	*P* for trend	*P* for interaction
	OR (95 % CI)	OR (95 %CI)	OR (95 %CI)	OR (95 %CI)		
Age						0.027
< 60	Ref.	0.547 (0.295, 1.016)	0.910 (0.473, 1.750)	1.141 (0.629, 2.071)	0.875	
≥ 60	Ref.	0.702 (0.387, 1.273)	0.766 (0.387, 1.287)	0.856 (0.468, 1.566)	0.073	
Sex						0.426
Male	Ref.	0.606 (0.336, 1.091)	0.709 (0.394, 1.276)	0.713 (0.378, 1.346)	0.400	
Female	Ref.	0.620 (0.336, 1.145)	0.837 (0.453, 1.547)	0.973 (0.523, 1.813)	0.884	
Hypertension						0.343
No	Ref.	0.586 (0.302, 1.137)	0.733 (0.357, 1.504)	0.930 (0.483, 1.791)	0.701	
Yes	Ref.	0.713 (0.410, 1.240)	0.801 (0.456, 1.083)	0.849 (0.490, 1.471)	0.592	
DM						0.353
No	Ref.	0.587 (0.358, 0.963)	0.888 (0.544, 1.450)	0.916 (0.511, 1.523)	0.912	
Yes	Ref.	0.561 (0.240, 1.311)	0.402 (0.152, 1.064)	0.546 (0.222, 1.342)	0.089	
BMI						0.002
< 30	Ref.	0.700 (0.418, 1.174)	0.892 (0.533, 1.494)	1.107 (0.657, 1.863)	0.492	
≥ 30	Ref.	0.826 (0.388, 1.760)	0.448 (0.215, 0.935) *	0.247 (0.099, 0.616) **	0.020	

Abbreviations: Q1:16.0–42.6; Q2:42.7–52.7; Q3: 52.8–63.1; and Q4: 63.2–95.8; HEI, healthy eating index; AAC, abdominal aortic calcification; OR, odd ratio; CI, confidence interval; Analysis was adjusted for age, gender, race/ethnicity, education level, marital status, family poverty income ratio, hypertension, diabetes mellitus, smoker, alcohol user, body mass index, hemoglobin, fast glucose, fast insulin, glycohemoglobin, alkaline phosphatase, total bilirubin, uric acid, blood urea nitrogen, serum creatinine, estimated glomerular filtration rate, serum phosphorus, serum calcium, total cholesterol, triglyceride, and high-density lipoprotein-cholesterol;

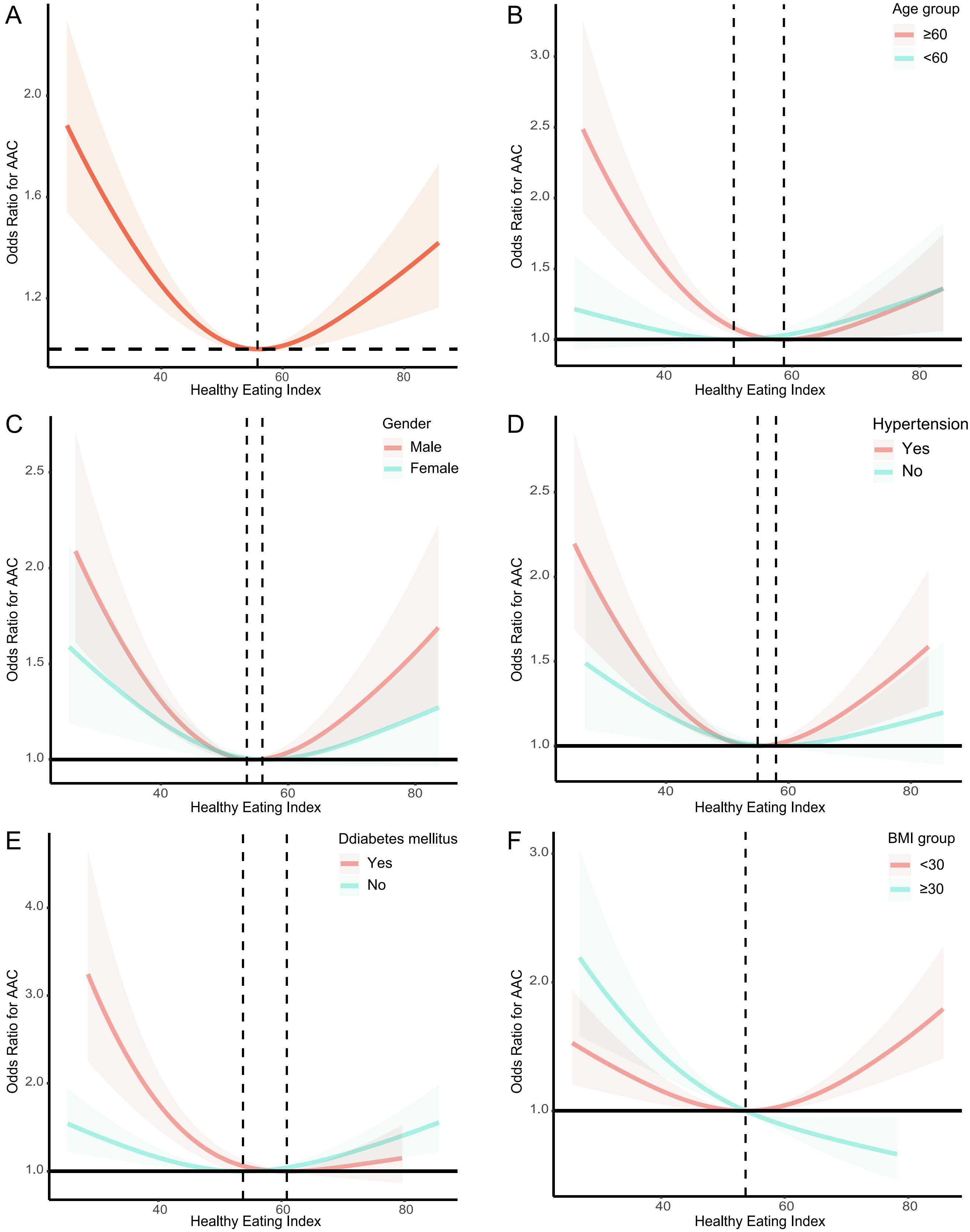

Fig. 2. Restricted cubic spline curve for the association of HEI-2015 with prevalence of AAC in individuals from NHANES 2013–2014. (a) The association between HEI-2015 and AAC; (b) The association between HEI-2015 and AAC stratified by age; (c) The association between HEI-2015 and AAC stratified by sex; (d) The association between HEI-2015 and AAC stratified by hypertension; (e) The association between HEI-2015 and AAC stratified by DM; (f) The association between HEI-2015 and AAC stratified by BMI.Abbreviations: HEI-2015, healthy eating index; AAC, abdominal aortic calcification; DM, diabetes mellitus; BMI, body mass index.

Table 4
Association of HEI-2015 components with prevalence of AAC in individuals from NHANES 2013–2014.

HEI-2015 components (Range of Points)	Model 1 OR (95 %CI)	Model 2 OR (95 %CI)	Model 3 OR (95 %CI)
Adequacy Components			
Total vegetables (0–5)	0.957 (0.884, 1.035)	0.978 (0.900, 1.063)	0.968 (0.887, 1.056)
Greens and beans (0–5)	0.927 (0.873, 0.984) *	0.938 (0.881, 0.999) *	0.941 (0.881, 0.994) *
Total fruit (0–5)	0.932 (0.874, 0.994) *	0.958 (0.895, 1.026)	0.944 (0.878, 1.014)
Whole fruits (0–5)	0.910 (0.857, 0.966) **	0.913 (0.853, 0.976) **	0.929 (0.872, 0.990) *
Whole grains (0–10)	1.014 (0.979, 1.051)	1.022 (0.984, 1.061)	1.026 (0.987, 1.068)
Dairy (0–10)	0.973 (0.936, 1.011)	0.975 (0.937, 1.015)	0.971 (0.931, 1.062)
Total protein foods (0–5)	0.973 (0.873, 1.085)	0.978 (0.874, 1.095)	0.964 (0.857, 1.083)
Seafood and plant proteins (0–5)	0.948 (0.894, 1.004)	0.951 (0.895, 1.011)	0.951 (0.892, 1.013)
Fatty acids (0–10)	0.957 (0.884, 1.035)	0.978 (0.900, 1.063)	0.968 (0.887, 1.056)
Moderation Components			
Sodium (0–10)	0.988 (0.952, 1.026)	0.987 (0.949, 1.026)	0.988 (0.948, 1.029)
Refined grains (0–10)	1.014 (0.978, 1.051)	1.020 (0.982, 1.060)	1.015 (0.976, 1.056)
Saturated fats (0–10)	0.996 (0.959, 1.034)	0.999 (0.961, 1.038)	1.003 (0.963, 1.045)
Added sugars (0–10)	1.005 (0.964, 1.047)	1.004 (0.961, 1.049)	1.010 (0.965, 1.057)

Abbreviations: HEI, healthy eating index; AAC, abdominal aortic calcification; *$P < 0.05$; **$P < 0.01$; OR, odd ratio; CI, confidence interval; Model 1: age and gender. Model 2: model 1 variables plus race/ethnicity, education level, marital status, family poverty income ratio, hypertension, diabetes mellitus, smoke status, and drink status. Model 3 was adjusted for model 2 variables plus body mass index, hemoglobin, fast glucose, fast insulin, glycohemoglobin, alkaline phosphatase, total bilirubin, uric acid, blood urea nitrogen, serum creatinine, estimated glomerular filtration rate, serum phosphorus, serum calcium, total cholesterol, triglyceride, and high-density lipoprotein-cholesterol.

conditions such as type 2 diabetes, metabolic syndrome, and cardiovascular disease (CVD). (Calle and Andersen, 2019; Phillips et al., 2018). According to a cross-sectional study of 667 participants in the Malmo Diet and Cancer study, higher diet quality, which indicates greater compliance with Swedish nutrition recommendations, is associated with lower levels of inflammation (Dias et al., 2015). Moreover, Dias JA et al. also found that based on data from the Cork and Kerry Diabetes and Heart Disease Study, a higher HEI-2015 was inversely associated with inflammatory biomarkers in middle-to-older-aged adults (Millar et al., 2021). Therefore, higher HEI-2015, meaning more intake of adequacy components, may affect vascular calcification by altering inflammation levels. Stefan N and his team shown that when added sugars are consumed, fat cells release pro-inflammatory cytokines that trigger inflammation (Stefan et al., 2021). In the study, we also found that whole grains, refined grains, saturated fats, and added sugars was positively associated with the risk of AAC. Therefore, discovery of U-shaped relationship between HEI-2015 and prevalence of AAC provided some relevant implications for future prospective research.

The relationship between dietary intake and vascular calcification has received attention from investigators and has been explored in previous studies, although there is no consistent conclusion. In terms of a dietary planning, Nicoll R indicated that avoiding sugar and the trans fats and preservatives and adopting a diet rich in oily fish and vegetables can be effective in preventing calcification (Nicoll et al., 2015). In addition, Anderson JJ found that in older adults, excess calcium intake may increase the risk of arterial calcification and cardiovascular diseases (Anderson and Klemmer, 2013). Gripeteg L also emphasized that the combination of healthy food intake and higher cardiopulmonary fitness may counteract the development of coronary artery calcification (Gripeteg et al., 2018). In addition, the intake of vitamin K in the diet is thought to reduce vascular calcification, which is thought to reduce the risk of CVD (Vissers et al., 2013). High intake of fruit and vegetable play an important role in establishing a healthy diet early in life. Miedema MD also revealed that following 20 years of follow-up, young adults with higher intakes of fruit and vegetables were less likely to develop coronary artery calcium (Miedema et al., 2015). Fruit and vegetables improved the risk indicators of CVD better than oral NaHCO3 treated CKD patients, making it a potentially better treatment option for CVD risk reduction (Goraya et al., 2019). Bondonno NP found that there is a negative association between apple intake and AAC in older women, but not with total or other fruit intake (Bondonno et al., 2016). In addition, Sandoval-Ramírez BA and his colleagues revealed that consuming between 100 and 150 g/day of whole apples can be effective in preventing cardiovascular disease (Sandoval-Ramírez et al., 2020). Mudryj AN also pointed out that adding pulses to your diet is a healthy way to meet dietary recommendations and has been linked to a reduced risk of several chronic diseases (Mudryj et al., 2014). Additionally, Miller V and his team found that a lower rate of non-cardiovascular and total mortality was associated with higher consumption of fruit, vegetables, and legumes (Miller et al., 2017). Higher HEI scores also mean lower intakes of moderation components, such as sodium, saturated fat, added sugars, and refined grains, in addition to higher scores on adequacy components. Jahns et al. found that people who had a higher dietary energy intake had a lower intake of fruits, vegetables, whole grains, and lean meat at weekends, which corresponds to a lower HEI score (Jahns et al., 2017). Previous studies have found that nutritional intakes, such as vitamin B6, carotenoids, and dietary fiber, are negatively associated with inflammatory biomarkers (Bird, 2018; Iddir et al., 2022). Additionally, Zhu et al. suggested that adults with higher diet quality scores had higher eating frequency (Zhu and Hollis, 2016). HEI was negatively correlated with some biomarkers of low-grade chronic inflammation, but not oxidative stress. Therefore, better healthy eating patterns can promote health-related effects via reducing chronic low-grade inflammation (Millar et al., 2021). Vahid et al. revealed that significant inverse relationships were observed between HEI and inflammatory mediators, including IL-1β and hs-CRP. However, they could not observe the same trend for all the inflammatory biomarkers (Vahid et al., 2022). In addition, this may be related to the U-shaped curve caused by these people with related primary cardiovascular disease following doctors' recommendations for healthy eating. After they have the underlying cardiovascular disease, they begin to pay attention to dietary factors and follow the doctor's recommendations for a healthy diet.

NHANES database provides nationally representative estimates based on standardized protocols for data collection. Consequently, the current findings can be generalized widely. However, it is important to note that our study has several limitations. Firstly, the study only included the general population of the United States from of NHANES 2013–2014. Secondly, self-reported confounders, including the complication of CHD, CHF, angina pectoris, heart attack, and stroke, may be biased due to self-reporting questionnaire. Thirdly, dietary intake data was also self- reported, but that the 24-hour recall has been shown to adequately assess population intake (Moshfegh et al., 2008). Finally, as a cross-sectional study, conclusions were limited to associations rather than causality.

5. Conclusion

In conclusion, the relationship between HEI-2015 and the risk of AAC presented a U-shaped curve in the American population. A turning point for HEI-2015 was observed and the prevalence of AAC was lowest when the HEI-2015 was 55.9. In addition, this U-shaped correlation was found among all age groups, sex, with or without hypertension or DM, and BMI of <30 kg/m^2. However, HEI-2015 and AAC showed a linear inverse correlation in participants with BMI ≥ 30 kg/m^2. Results of this study suggest that consuming greens and beans, and fruit may be associated with a lower risk for AAC.

CRediT authorship contribution statement

Lu Liu: Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization. **Tiantian Xie:** Conceptualization, Validation, Writing – review & editing. **Zhongshun Hu:** Formal analysis, Investigation, Data curation, Writing – review & editing, Visualization. **Jinsong Liu:** Conceptualization, Methodology, Software, Investigation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

In recognition of the valuable contribution of the NHANES study staff and participants, the authors would like to thank them.

References

Al-Ibrahim, A.A., Jackson, R.T., 2019. Healthy eating index versus alternate healthy index in relation to diabetes status and health markers in U.S. adults: NHANES 2007–2010. Nutrition Journal 18 (1).

Anderson, J.J., Klemmer, P.J., 2013. Risk of high dietary calcium for arterial calcification in older adults. Nutrients 5, 3964–3974.

Bird, R.P., 2018. The Emerging Role of Vitamin B6 in Inflammation and Carcinogenesis. Advances in food and nutrition research 83, 151–194.

Blanton, C.A., Moshfegh, A.J., Baer, D.J., Kretsch, M.J., 2006. The USDA Automated Multiple-Pass Method accurately estimates group total energy and nutrient intake. The Journal of nutrition 136 (10), 2594–2599.

Blekkenhorst, L.C., Sim, M., Radavelli-Bagatini, S., Bondonno, N.P., Bondonno, C.P., Devine, A., Schousboe, J.T., Lim, W.H., Kiel, D.P., Woodman, R.J., Hodgson, J.M., Prince, R.L., Lewis, J.R., 2021. Cruciferous vegetable intake is inversely associated with extensive abdominal aortic calcification in elderly women: a cross-sectional study. The British journal of nutrition 125 (3), 337–345.

Bondonno, N., Lewis, J., Prince, R., Lim, W., Wong, G., Schousboe, J., Woodman, R., Kiel, D., Bondonno, C., Ward, N., Croft, K., Hodgson, J., 2016. Fruit Intake and Abdominal Aortic Calcification in Elderly Women: A Prospective Cohort Study. Nutrients 8 (3), 159.

Calle, M.C., Andersen, C.J., 2019. Assessment of Dietary Patterns Represents a Potential, Yet Variable, Measure of Inflammatory Status: A Review and Update. Disease Markers 2019, 1–13.

Chen, W., Eisenberg, R., Mowrey, W.B., Wylie-Rosett, J., Abramowitz, M.K., Bushinsky, D.A., Melamed, M.L., 2020. Association between dietary zinc intake and abdominal aortic calcification in US adults. Nephrology, Dialysis, Transplantation 35, 1171–2118.

Chow, J.T., Khosla, S., Melton, L.J., Atkinson, E.J., Camp, J.J., Kearns, A.E., 2008. Abdominal aortic calcification, BMD, and bone microstructure: a population-based study. Journal of bone and mineral research : the official journal of the American Society for Bone and Mineral Research 23 (10), 1601–1612.

Chuang, T.-L., Li, Y.-D., Hsiao, F.-T., Chuang, M.-H., Wang, Y.-F., 2017. FRAX® Fracture Risks Are Associated with Coronary Artery Calcification Score. Disease Markers 2017, 1–6.

Dias, J.A., Wirfält, E., Drake, I., Gullberg, B.o., Hedblad, B.o., Persson, M., Engström, G., Nilsson, J., Schiopu, A., Fredrikson, G.N., Björkbacka, H., 2015. A high quality diet is associated with reduced systemic inflammation in middle-aged individuals. Atherosclerosis 238 (1), 38–44.

Fan, Y., Zhang, Y., Li, J., Liu, Y., Chang, H., Jiang, Y., Tuo, X., Zhou, L., Yu, Y., 2021. Association between healthy eating index-2015 and various cognitive domains in US adults aged 60 years or older: the National Health and Nutrition Examination Survey (NHANES) 2011–2014. BMC Public Health 21, 1862.

Goraya, N., Munoz-Maldonado, Y., Simoni, J., Wesson, D., 2019. Fruit and Vegetable Treatment of Chronic Kidney Disease-Related Metabolic Acidosis Reduces Cardiovascular Risk Better than Sodium Bicarbonate. American journal of nephrology 49 (6), 438–448.

Górriz, J.L., Molina, P., Cerverón, M.J., Vila, R., Bover, J., Nieto, J., Barril, G., Martínez-Castelao, A., Fernández, E., Escudero, V., Piñera, C., Adragao, T., Navarro-Gonzalez, J.F., Molinero, L.M., Castro-Alonso, C., Pallardó, L.M., Jamal, S.A., 2015. Vascular calcification in patients with nondialysis CKD over 3 years. Clinical Journal of the American Society of Nephrology 10 (4), 654–666.

Gripeteg, L., Arvidsson, D., Johannesson, E., Larsson, C., Sjöberg, A., Angerås, O., Fagman, E., Brandberg, J., Ekblom, Ö., Bergström, G., Börjesson, M., 2018. Concomitant Associations of Healthy Food Intake and Cardiorespiratory Fitness With Coronary Artery Calcium. The American Journal of Cardiology 122 (4), 560–564.

Iddir, M., Vahid, F., Merten, D., Larondelle, Y., Bohn, T., 2022. Influence of Proteins on the Absorption of Lipophilic Vitamins, Carotenoids and Curcumin - A Review. Molecular nutrition & food research 66, e2200076.

Jahns, L., Conrad, Z., Johnson, L.K., Scheett, A.J., Stote, K.S., Raatz, S.K., 2017. Diet Quality Is Lower and Energy Intake Is Higher on Weekends Compared with Weekdays in Midlife Women: A 1-Year Cohort Study. Journal of the Academy of Nutrition and Dietetics 117 (7), 1080–1086.e1.

Kauppila, L.I., Polak, J.F., Cupples, L.A., Hannan, M.T., Kiel, D.P., Wilson, P.W.F., 1997. New indices to classify location, severity and progression of calcific lesions in the abdominal aorta: a 25-year follow-up study. Atherosclerosis 132 (2), 245–250.

Knauer, K., Chaudry, O., Uder, M., Kohl, M., Kemmler, W., Bickelhaupt, S., Engelke, K., 2023. Effects of High-Intensity Resistance Training on Visceral Adipose Tissue and Abdominal Aortic Calcifications in Older Men with Osteosarcopenia - Results from the FrOST Study. Clinical interventions in aging 18, 71–80.

Krebs-Smith, S.M., Pannucci, T.E., Subar, A.F., Kirkpatrick, S.I., Lerman, J.L., Tooze, J.A., Wilson, M.M., Reedy, J., 2018. Update of the Healthy Eating Index: HEI-2015. Journal of the Academy of Nutrition and Dietetics 118 (9), 1591–1602.

Lee, S.J., Lee, I.-K., Jeon, J.-H., 2020. Vascular Calcification-New Insights Into Its Mechanism. International Journal of Molecular Sciences 21 (8), 2685.

Li, X.Y., Wen, M.Z., Xu, Y.H., Shen, Y.C., Yang, X.T., 2022. The association of healthy eating index with periodontitis in NHANES 2013–2014. Frontiers in nutrition 9, 968073.

McGill, C.R., Birkett, A., Fulgonii III, V.L., 2016. Healthy Eating Index-2010 and food groups consumed by US adults who meet or exceed fiber intake recommendations NHANES 2001–2010. Food & nutrition research 60 (1), 29977.

Miedema, M.D., Petrone, A., Shikany, J.M., Greenland, P., Lewis, C.E., Pletcher, M.J., Gaziano, J.M., Djousse, L., 2015. Association of Fruit and Vegetable Consumption During Early Adulthood With the Prevalence of Coronary Artery Calcium After 20 Years of Follow-Up: The Coronary Artery Risk Development in Young Adults (CARDIA) Study. Circulation 132 (21), 1990–1998.

Millar, S.R., Navarro, P., Harrington, J.M., Perry, I.J., Phillips, C.M., 2021. Dietary Quality Determined by the Healthy Eating Index-2015 and Biomarkers of Chronic Low-Grade Inflammation: A Cross-Sectional Analysis in Middle-to-Older Aged Adults. Nutrients 13 (1), 222.

Miller, V., Mente, A., Dehghan, M., Rangarajan, S., Zhang, X., Swaminathan, S., Dagenais, G., Gupta, R., Mohan, V., et al., 2017. Fruit, vegetable, and legume intake, and cardiovascular disease and deaths in 18 countries (PURE): a prospective cohort study. Lancet 390, 2037–2049.

Moshfegh, A.J., Rhodes, D.G., Baer, D.J., Murayi, T., Clemens, J.C., Rumpler, W.V., Paul, D.R., Sebastian, R.S., Kuczynski, K.J., Ingwersen, L.A., Staples, R.C., Cleveland, L.E., 2008. The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. The American journal of clinical nutrition 88 (2), 324–332.

Mudryj, A.N., Yu, N., Aukema, H.M., 2014. Nutritional and health benefits of pulses. Applied Physiology, Nutrition, and Metabolism 39 (11), 1197–1204.

Nicoll, R., Howard, J.M., Henein, M.Y., 2015. A review of the effect of diet on cardiovascular calcification. International Journal of Molecular Sciences 16, 8861–8883.

Noratto, G.D., Lage, N.N., Chew, B.P., Mertens-Talcott, S.U., Talcott, S.T., Pedrosa, M.L., 2018. Non-anthocyanin phenolics in cherry (Prunus avium L.) modulate IL-6, liver lipids and expression of PPARδ and LXRs in obese diabetic (db/db) mice. Food chemistry 266, 405–414.

Nunn, M.E., Braunstein, N.S., Kaye, E.A.K., Dietrich, T., Garcia, R.I., Henshaw, M.M., 2009. Healthy eating index is a predictor of early childhood caries. Journal of dental research 88 (4), 361–366.

Phillips, C., Shivappa, N., Hébert, J., Perry, I., 2018. Dietary Inflammatory Index and Biomarkers of Lipoprotein Metabolism, Inflammation and Glucose Homeostasis in Adults. Nutrients 10 (8), 1033.

Qin, Z., Chang, K., Liao, R., Jiang, L., Yang, Q., Su, B., 2021. Greater Dietary Inflammatory Potential Is Associated With Higher Likelihood of Abdominal Aortic Calcification. Front Cardiovasc Med 8, 720834.

Radavelli-Bagatini, S., Bondonno, C.P., Sim, M., Blekkenhorst, L.C., Anokye, R., Connolly, E., Bondonno, N.P., Schousboe, J.T., Woodman, R.J., Zhu, K., Szulc, P., Jackson, B., Dimmock, J., Schlaich, M.P., Cox, K.L., Kiel, D.P., Lim, W.H., Stanley, M., Devine, A., Thompson, P.L., Gianoudis, J., De Ross, B., Daly, R.M., Lewis, J.R., Hodgson, J.M., 2020. Modification of diet, exercise and lifestyle (MODEL) study: a randomised controlled trial protocol. BMJ Open 10 (11), e036366.

Reedy, J., Mitrou, P.N., Krebs-Smith, S.M., Wirfält, E., Flood, A., Kipnis, V., Leitzmann, M., Mouw, T., Hollenbeck, A., Schatzkin, A., Subar, A.F., 2008. Index-based dietary patterns and risk of colorectal cancer: the NIH-AARP Diet and Health Study. American Journal of Epidemiology 168 (1), 38–48.

Reedy, J., Lerman, J.L., Krebs-Smith, S.M., Kirkpatrick, S.I., Pannucci, T.E., Wilson, M. M., Subar, A.F., Kahle, L.L., Tooze, J.A., 2018. Evaluation of the Healthy Eating Index-2015. Journal of the Academy of Nutrition and Dietetics 118 (9), 1622–1633.

Román-García, P., Carrillo-López, N., Fernández-Martín, J.L., Naves-Díaz, M., Ruiz-Torres, M.P., Cannata-Andía, J.B., 2010. High phosphorus diet induces vascular calcification, a related decrease in bone mass and changes in the aortic gene expression. Bone 46 (1), 121–128.

Sandoval-Ramírez, B.A., Catalán, Ú., Calderón-Pérez, L., Companys, J., Pla-Pagà, L., Ludwig, I.A., Romero, M.P., Solà, R., 2020. The effects and associations of whole-apple intake on diverse cardiovascular risk factors. A narrative review. Critical reviews in food science and nutrition 60 (22), 3862–3875.

Schousboe, J.T., Wilson, K.E., Hangartner, T.N., Shea, B., 2007. Detection of aortic calcification during vertebral fracture assessment (VFA) compared to digital radiography. PLoS One1 2 (8), e715.

Shang, X., Sanders, K.M., Scott, D., Khan, B., Hodge, A., Khan, N., English, D.R., Giles, G. G., Ebeling, P.R., 2015. Dietary α-Linolenic Acid and Total ω-3 Fatty Acids Are Inversely Associated with Abdominal Aortic Calcification in Older Women, but Not in Older Men. The Journal of nutrition 145 (8), 1778–1786.

Stefan, N., Birkenfeld, A.L., Schulze, M.B., 2021. Global pandemics interconnected - obesity, impaired metabolic health and COVID-19. Nature reviews. Endocrinology 17 (3), 135–149.

Vahid, F., Jalili, M., Rahmani, W., Nasiri, Z., Bohn, T., 2022. A Higher Healthy Eating Index Is Associated with Decreased Markers of Inflammation and Lower Odds for Being Overweight/Obese Based on a Case-Control Study. Nutrients 14 (23), 5127.

Vissers, L.E., Dalmeijer, G.W., Boer, J.M., Monique Verschuren, W.M., van der Schouw, Y.T., Beulens, J.W., 2013. Intake of dietary phylloquinone and menaquinones and risk of stroke. Journal of the American Heart Association 2, e000455.

Wu, X.H., Chen, X.Y., Wang, L.J., Wong, K.S., 2016. Intracranial Artery Calcification and Its Clinical Significance. Journal of clinical neurology (Seoul, Korea) 12, 253–261.

Yang, X., Zhou, H., Zhang, H., Zhang, P., Zheng, Z., Xu, D., Zeng, Q., 2023. Association between urinary biomarkers of polycyclic aromatic hydrocarbons and severe abdominal aortic calcification in adults: data from the National Health and Examination Nutrition Survey. BMC Cardiovascular Disorders 23, 104.

Zhu, Y., Hollis, J.H., 2016. Associations between eating frequency and energy intake, energy density, diet quality and body weight status in adults from the USA. The British journal of nutrition 115 (12), 2138–2144.

Zipf, G., Chiappa, M., Porter, K.S., Ostchega, Y., Lewis, B.G., Dostal, J., 2013. National health and nutrition examination survey: plan and operations, 1999-2010. Vital and health statistics. Ser. 1, Programs and collection procedures:1-37.