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Associations between diet quality and NT-proBNP in U.S. adults, NHANES 1999-2004

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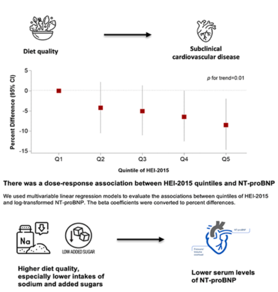
GRAPHICAL ABSTRACT



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ABSTRACT

Objective: N-terminal pro-brain-type natriuretic peptide (NT-proBNP) is a marker of cardiac wall stress and is a predictor of cardiovascular disease. Higher diet quality is associated with lower risk of cardiovascular disease. The association between diet quality and subclinical cardiovascular disease assessed by NT-proBNP is uncharacterized. We investigated the associations between diet quality, using Healthy Eating Index-2015 (HEI-2015), and NT-proBNP from the National Health and Nutrition Examination Survey (NHANES) 1999-2004.

Methods: We included 9,782 adults from NHANES 1999-2004 without self-reported cardiovascular disease. The HEI-2015 ranges from 0 to 100, with higher scores indicating better diet quality. The HEI-2015 was categorized into sex-specific quintiles. Regression models were used to quantify associations between the overall HEI-2015 score and its 13 components with log-transformed NT-proBNP. The beta coefficients were converted to percent differences.

Abbreviations: HEI-2015, Healthy Eating Index-2015; NT-proBNP, N-terminal pro B-type natriuretic peptide; BMI, Body mass index; NHANES, National Health and Nutrition Examination Survey.

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Results: Among 9,782 participants, mean age was 45 years, 48% were men, and 72% were non-Hispanic White adults. After adjusting for sociodemographic characteristics, lifestyle factors, and medical history, those in the highest vs. lowest HEI-2015 quintile had an 8.5% (95% CI: -14.6% to -2.0%) lower NT-proBNP level. There was a dose-response association between HEI-2015 and NT-proBNP (P value for trend = 0.01). Each 1-unit higher in sodium and added sugars score indicating lower intake was associated with lower NT-proBNP by 7.7% (95% CI: -12.8% to -2.2%) and 6.5% (95% CI: -12.0% to -0.7%), respectively.
Conclusion: Higher diet quality, especially lower intakes of sodium and added sugars, was associated with lower serum levels of NT-proBNP.

Introduction

Heart failure, a serious condition defined by reduced cardiac output, is a public health problem that affects an estimated 6.2 million adults and accounts for about 380,000 deaths each year in the United States [1]. Unhealthy lifestyle behaviors, including certain dietary exposures, increase the risk of heart failure. While established evidence indicates that low diet quality is associated with higher risk of coronary artery disease and stroke, there is limited information on the association between low diet quality and heart failure, as well as related subclinical states, especially among younger adults. Therefore, it is important to understand this association to prevent preclinical heart failure, especially in this population.

N-terminal pro-brain-type natriuretic peptide (NT-proBNP), an inactive and stable amino acid fragment secreted from the ventricular cardiac myocytes indicating left ventricular strain or ischemia [2], is a widely used diagnostic biomarker for heart failure [3,4]. NT-proBNP has also been shown to be a useful screening biomarker for asymptomatic left ventricular dysfunction [5]. Importantly, studies suggest that NT-proBNP elevations were predictive of incident heart failure, all-cause mortality, and cardiovascular mortality [6,7]. It is unknown whether diet quality is associated with subclinical heart failure, as assessed with NT-proBNP.

To address this knowledge gap, we examined associations between diet quality, assessed using the Healthy Eating Index-2015 (HEI-2015), and NT-proBNP in a nationally representative sample of US adults aged 20 and older from the National Health and Nutrition Examination Survey (NHANES), 1999-2004.

Methods

Study Design

NHANES is a nationally representative, cross-sectional study designed to monitor the health and nutritional status of the U.S. noninstitutionalized, civilian population [8]. The survey included an in-home interview on general health status, diet and lifestyle characteristics, as well as physical examinations at a mobile examination center. All participants provided written informed consent, and all NHANES protocols were approved by the National Center for Health Statistics ethics review board.

Study Population

Our study included participants aged 20 years and older in three NHANES cycles (1999-2000, 2001-2002, 2003-2004) who were not pregnant, with no history of self-reported cardiovascular disease (coronary heart disease, heart failure, angina, heart attack, stroke) and with no missing NT-proBNP or HEI-2015 data. The final analytic sample was 9,782 (eFigure1).

Assessment of Dietary Scores

We used the HEI-2015 as a measure of diet quality. The HEI assesses the degree of alignment to the *2015-2020 U.S. Dietary Guidelines for Americans* [9]. HEI-2015 was calculated using 24-hour dietary recalls linked to the MyPyramid Equivalent Databases and total nutrient intakes. We used the first day of 24-hour dietary recalls for all survey cycles, given that only one dietary recall was conducted in the 1999-2000 and 2001-2002 cycles. The total score for HEI-2015 ranges from 0 to 100, with a higher score indicating a healthier diet. HEI-2015 consists of 13 components, including nine adequacy components (total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids) and four moderation components (refined grains, sodium, added sugars, and saturated fats) [9]. For the nine adequacy components, higher intakes receive higher scores. For the four moderation components, lower intakes receive higher scores. HEI-2015 was categorized into sex-specific quintiles given that the HEI-2015 distribution differed between men and women.

Assessment of NT-proBNP

Laboratory testing for NT-proBNP was performed at the Clinical Chemistry Research Laboratory at the University of Maryland School of Medicine between 2018 and 2020. NT-proBNP was measured in serum on the Roche Cobas e601 autoanalyzer (Roche Diagnostics). The coefficient of variation was 3.1% at low levels of NT-proBNP (46 pg/mL) and 2.7% at high levels of NT-proBNP (32,805 pg/mL) [10]. Previous studies have demonstrated that NT-proBNP remains stable when measured in biospecimens that have undergone long-term storage and after multiple freeze-thaw cycles [11–14].

Assessment of Covariates

Sociodemographic characteristics included age, sex, race (non-Hispanic White, Non-Hispanic Black, Mexican American and other Hispanic, other race), ratio of household income to the federal poverty level (<1.3, 1.3–3.5, and >3.5), and education (<high school, high school or equivalent, >high school). Lifestyle behaviors included smoking status (never: <100 cigarettes in life; former: ≥100 cigarettes in life and not currently smoking; current: ≥100 cigarettes in life and currently smoking), and physical activity status (yes or no) was determined from self-reported 150 minutes per week of moderate/vigorous physical activity.

Body mass index (BMI) and blood pressure were measured at the mobile health clinic. BMI was calculated as weight (kg) divided by height squared (m^2) and classified into 3 groups (< 25 kg/m^2, 25 to <30 kg/m^2, or ≥30 kg/m^2). Blood pressure was measured by a physician certified in blood pressure measurement using the standardized protocol of the American Heart Association during a single mobile examination center visit [15,16]. The first blood pressure measurement was recorded after a 5-minute period of rest with two additional readings obtained 30 seconds apart using the same arm. A fourth reading was recorded in case one or more of the readings were unobtainable. Hypertension status (yes or no) was defined as average systolic blood pressure ≥130 mm Hg, average diastolic blood pressure ≥80 mm Hg, or use of anti-hypertensive medication. Diabetes status (yes or no) was determined from self-reported physician diagnosis of diabetes, use of diabetes medication, or hemoglobin A1c ≥ 6.5%. Chronic kidney disease (yes or no) was defined as estimated glomerular filtration rate (eGFR) <60 mL/min/1.73 m^2 or urine albumin-to-creatinine ratio >30 mg/g. Dyslipidemia (yes or no) was defined as total cholesterol ≥ 200 mg/dL, use of cholesterol-lowering medication, or self-reported physician diagnosis of hyperlipidemia. Missing covariates were imputed to the mode.

Statistical Analysis

All analyses were weighted and accounted for the complex survey design of NHANES. We compared the population characteristics by quintiles of HEI-2015 in the overall study population using chi-square tests for categorical variables and ANOVA for continuous variables. Means (standard error) were calculated for continuous variables, and frequency percentages were calculated for categorical variables.

We used weighted multivariable linear regression models to calculate β coefficients and corresponding 95% confidence intervals for the associations between quintiles of HEI-2015 score and natural log-transformed NT-proBNP. The β coefficients were converted to percent differences by exponentiating the β coefficient, subtracting one, and then multiplying by 100. Model 1 was adjusted for age, sex, race/ethnicity, and total energy intake. Model 2 additionally adjusted for education, family poverty ratio, BMI categories, smoking status, and physical activity. Model 3 was further adjusted for diabetes, hypertension, chronic kidney disease, and dyslipidemia. *P* values for trend across quintiles were calculated using the median value of HEI-2015 score within each quintile. We repeated the analyses for HEI-2015 with β coefficients estimated per 10-unit higher in HEI-2015 score.

We conducted subgroup analyses defined by age group (20-39 years, 40-59 years, ≥60 years), sex, race/ethnicity (Non-Hispanic White, Non-Hispanic Black, Mexican American and other Hispanic, other race), BMI (<25 kg/m^2, 25 to <30 kg/m^2, or ≥30 kg/m^2), physically active (yes, no), diabetes status (yes, no), hypertension (yes, no), chronic kidney disease (yes, no), and dyslipidemia (yes, no). We also analyzed the association between the 13 individual components of HEI-2015 (per 1-unit higher) and log-transformed NT-proBNP to assess if any specific component was driving the association between diet quality and NT-proBNP. Statistical analyses were performed using the SAS statistical package (version 9.4; SAS Institute Inc) and Stata software (version 16.0, StataCorp LLC). All statistical tests were two-sided, and p <0.05 was considered statistically significant.

Results

Among 9,782 participants aged ≥20 years weighted to the US population in 1999-2004, the mean (standard error) age was 44.8 (0.2) years, approximately half of the population was men, and the majority of individuals were non-Hispanic White (71.6%), followed by Hispanic (13.5%), non-Hispanic Black (10.6%) and other race (4.3%) (Table 1). US adults with higher adherence to HEI-2015 were older, had higher income and education level, were less likely to be non-Hispanic black, obese, or current smokers, and were more likely to be physically active, have diabetes or hypertension, and have high cholesterol compared to individuals with lower adherence to HEI-2015 (Table 1).

Higher diet quality was associated with lower serum levels of NT-proBNP (Table 2). After adjusting for age, sex, race/ethnicity, and total energy intake, persons in the highest HEI-2015 quintile had lower levels of NT-proBNP by 13.4% (95% CI: -19.2% to -7.1%) compared to those in the lowest HEI-2015 quintile. The association was partially attenuated after additional adjustment for sociodemographic and lifestyle characteristics (Model 2 percent difference between quintile 5 and

Table 1
Characteristics among US adults ≥20 years according to quintile of HEI-2015, NHANES 1999–2004[a]

Characteristics	Sex-specific quintiles of HEI-2015[b]					
	Overall n=9782	Quintile 1 n=1755	Quintile 2 n=1884	Quintile 3 n=1953	Quintile 4 n=2024	Quintile 5 n=2166
HEI-2015 score	50.0±12.7	32.5±4.4	41.7±2.1	48.4±2.0	55.3±2.4	67.8±6.9
Age, years[c]	44.8 ± 0.2	39.4 ± 0.4	42.7 ± 0.4	44.5 ± 0.4	46.8 ± 0.4	50.6 ± 0.4
Male sex, %	48	48	48	48	48	48
Race/ethnicity, %						
Non-Hispanic White	72	72	71	70	72	74
Non-Hispanic Black	11	13	12	11	10	8
Mexican American and other Hispanic	14	12	13	15	14	14
Other race	4	4	4	5	4	5
Family poverty ratio[d]**, %**						
<1.3	26	32	26	26	25	19
1.3-3.5	34	35	37	36	33	31
>3.5	40	34	37	38	43	50
Education, %						
<High school	19	23	21	19	17	14
High school or equivalent	26	31	30	25	23	21
>High school	55	46	49	56	59	65
Body mass index, kg/m^2, %						
<25	36	35	35	34	36	40
25-<30	34	32	32	36	36	35
≥30	30	33	33	30	28	25
Smoking status, %						
Never smoker	51	47	47	51	53	57
Former smoker	24	18	22	23	27	30
Current smoker	25	35	31	26	21	13
Physically active, %	65	60	61	64	68	74
Diabetes, %	7	5	7	7	8	10
Hypertension, %	47	40	44	47	50	51
Chronic kidney disease, %	11	11	11	9	11	11
Dyslipidemia, %	57	52	54	55	58	63

Abbreviations: HEI-2015, Healthy Eating Index-2015; NHANES, National Health and Nutrition Examination Survey.
[a] All analyses were weighted.
[b] Quintiles of HEI-2015 were generated separately in men and women.
[c] Mean ± standard error.
[d] Represents the ratio of family income to the federal poverty threshold, adjusting for household size. A higher ratio indicates a higher level of income.

Table 2
Associations between HEI-2015 and NT-proBNP among US adults ≥20 years, NHANES 1999–2004

	Percent Difference in NT-proBNP[a] (95% CI)		
	Model 1[c]	Model 2[d]	Model 3[e]
All			
HEI-2015 (continuous)[b]	-3.62 (-5.29 to -1.93)	-2.68 (-4.40 to -0.93)	-2.25 (-3.94 to -0.53)
Quintile of HEI-2015			
Quintile 1	0 (Reference)	0 (Reference)	0 (Reference)
Quintile 2	-4.92 (-11.24 to 1.84)	-4.21 (-10.48 to 2.50)	-4.38 (-10.53 to 2.19)
Quintile 3	-7.68 (-13.67 to -1.26)	-5.75 (-11.81 to 0.74)	-5.06 (-11.05 to 1.33)
Quintile 4	-9.50 (-15.50 to -3.07)	-7.15 (-13.25 to -0.62)	-6.47 (-12.55 to 0.03)
Quintile 5	-13.36 (-19.19 to -7.10)	-10.15 (-16.27 to -3.58)	-8.52 (-14.63 to -1.97)
P-value for trend	<0.001	0.002	0.01

Abbreviations: HEI-2015, Healthy Eating Index-2015; NT-proBNP, N-terminal pro B-type natriuretic peptide; NHANES, National Health and Nutrition Examination Survey.
[a] Percent difference in NT-proBNP was calculated per ten points higher in HEI-2015 for the continuous analysis and between each quintile and the reference category (quintile 1).
[b] We used multivariable linear regression models to evaluate the associations between HEI-2015 (continuous, per ten points higher in HEI-2015) and log-transformed NTproBNP.
[c] Model 1: adjusted for age, sex, race/ethnicity, and total energy intake
[d] Model 2: all variables in Model 1, plus education, family poverty ratio, body mass index categories, smoking status, and physical activity
[e] Model 3: all variables in Model 2, plus diabetes, hypertension, chronic kidney disease, and dyslipidemia

quintile 1: -10.2%, 95%CI: -16.3% to -3.6%). After further adjustment for diabetes, hypertension, chronic kidney disease and dyslipidemia, the association remained significant but was further attenuated (Model 3 percent difference between quintile 5 and quintile 1: -8.5%, 95% CI: -14.6% to -2.0%). There was a dose-response association between HEI-2015 quintiles and NT-proBNP (P value for trend = 0.01) (Table 2; Fig. 1).

The observed association between continuous HEI-2015 and NT-proBNP was consistent across age groups, sex, race/ethnicity, BMI, physical activity, diabetes, hypertension, chronic kidney disease and dyslipidemia, and there was no significant interaction (P value for interaction for all subgroups > 0.05) (Fig. 2).

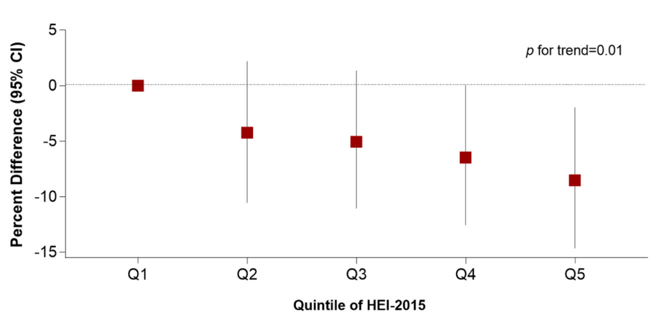


Fig. 1. Associations Between HEI-2015 and NT-proBNP among US Adults ≥ 20 years, NHANES 1999–2004. We used multivariable linear regression models to evaluate the associations between quintiles of HEI-2015 and log-transformed NT-proBNP. Multivariable-adjusted model was adjusted for age, sex, race/ethnicity, total energy intake, education, family poverty ratio, body mass index categories, smoking status, physical activity, diabetes, hypertension, chronic kidney disease, and dyslipidemia. Percent difference in NT-proBNP was calculated by comparing values of NT-proBNP for each quintile of HEI-2015 to quintile 1 (reference group),
Abbreviations: HEI-2015, Healthy Eating Index-2015; NT-proBNP, N-terminal pro B-type natriuretic peptide; NHANES, National Health and Nutrition Examination Survey.

Among the 13 components of HEI-2015, for each 1-unit higher score for sodium and added sugars (higher scores indicate lower intake), NT-proBNP was lower by 7.7% (95% CI: -12.8 % to -2.2%) and 6.5% (95% CI: -12.0% to -0.7%), respectively, after adjusting for sociodemographic characteristics, lifestyle factors, and health status (Table 3). In Model 1, adjusted for age, sex, race/ethnicity, and total energy intake, higher scores for whole fruits, total vegetables, total protein foods, seafood and plant proteins, and fatty acids were associated with lower serum levels of NT-proBNP, but not after additional adjustment for education, income, BMI, smoking, and physical activity in Model 2 (Table 3).

Discussion

In this nationally representative sample of US adults, higher diet quality, and specifically lower dietary intake of sodium and added sugar, was associated with lower serum levels of NT-proBNP. There was a dose-response association between HEI-2015 and NT-proBNP even after accounting for sociodemographic characteristics, lifestyle factors, and health status. Our findings were similar in subgroups defined by age, sex, race/ethnicity, BMI, physical activity, diabetes, hypertension, chronic kidney disease, and dyslipidemia. Our study is the first-of-its-kind to evaluate the association between diet quality and NT-proBNP in a nationally representative sample of US adults.

Our results are consistent with studies on diet quality and subclinical cardiovascular disease using cardiac imaging. In the Northern Manhattan Study, higher adherence to a Mediterranean diet was associated with lower left ventricular mass [17]. Similarly, higher adherence to the Mediterranean diet was favorably associated with left ventricular function in the Multi-Ethnic Study of Atherosclerosis study [18]. Several observational studies have shown that higher adherence to the Dietary Approaches to Stop Hypertension (DASH) diet was favorably associated with left ventricular function [19] and a lower risk of heart failure [20–22].

Previous research has demonstrated that higher diet quality, defined using adherence to various healthy dietary patterns, is associated with lower risk of incident cardiovascular disease. In the Atherosclerosis Risk in Communities study of middle-aged adults [23], higher diet quality, characterized by the HEI-2015, Alternative Healthy Eating Index–2010 (AHEI-2010), DASH diet, and alternate Mediterranean diet, was associated with a lower risk of incident cardiovascular disease, which was a composite outcome of coronary heart disease, stroke, and heart failure, among US adults. In adult men enrolled in the Health Professionals Follow-up Study [24], AHEI-2010 was associated with lower risk of heart failure with reduced ejection fraction but not overall heart failure and heart failure with preserved ejection fraction indicated by medical records. In the Multiethnic Cohort [25], consuming a high-quality diet, characterized by the HEI-2015, AHEI-2010, DASH, and alternate Mediterranean diet, was associated with lower risk of all-cause mortality and cardiovascular mortality. These other measures of diet quality, AHEI-2010, DASH, and alternate Mediterranean diet, are similar to HEI-2015 in that they assign higher scores for higher intake of fruits, vegetables, whole grains, legumes, and nuts, [26] all of which have been associated with lower risk of cardiovascular disease.

Clinical trials have demonstrated that consuming a Mediterranean diet or DASH diet results in lower blood levels of NT-proBNP. In the Prevención con Dieta Mediterránea (PREDIMED) trial, [27] which enrolled individuals at a high-risk of cardiovascular disease, those following a traditional Mediterranean diet had lower NT-proBNP levels compared to those assigned to a low-fat diet. In the DASH trial [28], individuals who were randomly assigned to the DASH diet intervention for 8 weeks had lower levels of NT-proBNP than those who followed a control diet, similar to a typical American diet. In the DASH-Sodium trial [29], which enrolled participants with hypertension, reducing sodium reduced NT-proBNP by 19% independent of the overall diet (DASH vs.

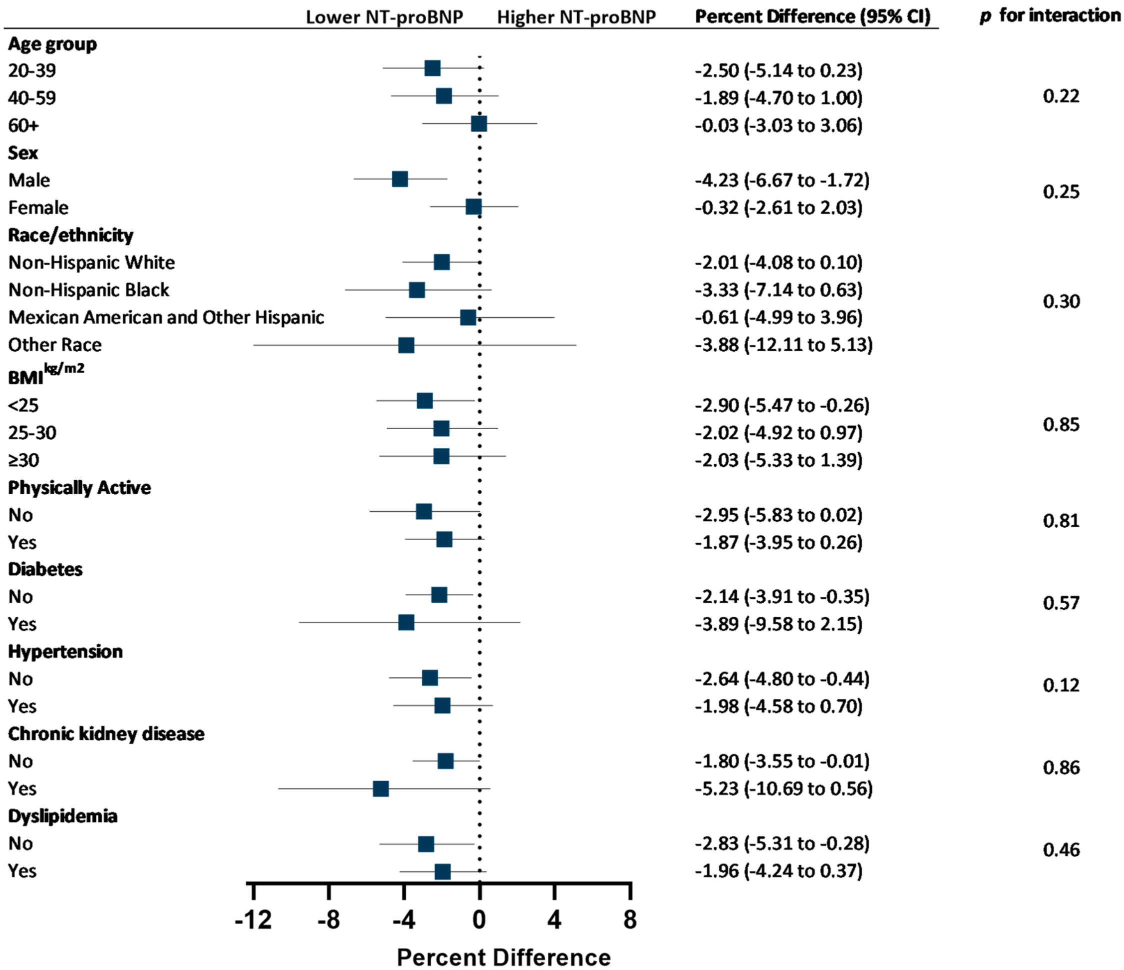


Fig. 2. Subgroup Analysis for the Association between HEI-2015 score and NT-proBNP among US Adults ≥20 years, NHANES 1999–2004.
We used multivariable linear regression models to evaluate the associations between HEI-2015 (continuous): per ten points higher in HEI-2015 and log-transformed NTproBNP.
Multivariable-adjusted model was adjusted for age, sex, race/ethnicity, and total energy intake, education, family poverty ratio, body mass index categories, smoking status, and physical activity, diabetes, hypertension, chronic kidney disease, and dyslipidemia.
Abbreviations: HEI-2015, Healthy Eating Index-2015; NT-proBNP, N-terminal pro B-type natriuretic peptide; NHANES, National Health and Nutrition Examination Survey.

control), suggesting that lower intake of sodium may improve cardiac function in adults with elevated levels of blood pressure. Further, in the DASH-Sodium trial, combining the DASH diet with sodium reduction reduced NT-proBNP by 23%. Our findings on the association of HEI-2015 with NT-proBNP combined with evidence from these previous clinical trials provides support for the benefit of an overall healthy diet on subclinical cardiovascular disease.

Our study demonstrated that higher intakes of sodium and added sugars were inversely associated with NT-proBNP. Previous studies [30–32] have shown that the consumption of added sugar and sodium was associated with higher risk of cardiovascular mortality and heart failure. The Study of Dietary Intervention under 100 mmol in Heart Failure (SODIUM-HF) trial [32] showed that dietary sodium reduction (to a target of <1500 mg/day) led to lower BNP levels and an improved quality of life for patients with heart failure. These results emphasize the importance of considering dietary factors as part of a holistic approach to managing heart failure. The American Heart Association's scientific statement (*2021 Dietary Guidance to Improve Cardiovascular Health)* [*33*] emphasizes the importance of dietary patterns to promote cardiometabolic health including reducing the intake of added sugars and adhering to a low sodium diet. The American College of Cardiology/American Heart Association/Heart Failure Society of America [34] guidelines recommended sodium restriction to prevent and manage heart failure, which is also a recommendation endorsed by World Health Organization guidelines on sodium intake for adults and children [35]. Our findings support sodium restriction as an important strategy for reducing risk of heart failure specifically and cardiovascular morbidity more broadly in the general population.

Possible mechanisms by which a healthy diet could reduce serum NT-proBNP could be through a decrease in oxidative stress and inflammation. The HEI-2015 has been previously associated with lower inflammatory biomarkers (i.e., C-reactive protein, interleukin-6, and white blood cells) [36]. Excessive salt intake induces inflammation, produces reactive oxygen species [37], activates transcription of mineralocorticoid receptor-dependent genes [38], which can raise circulating BNP levels. Excess sodium intake can also activate the renin-angiotensin-aldosterone system, leading to increased fluid retention and volume expansion, which can place a strain on the heart and blood vessels and thus elevate NT-proBNP [39]. The adverse effects of added sugar may be related to hyperinsulinemia which can induce myocardial dysfunction by stimulating smooth muscle cell proliferation [40], increasing lipogenesis [41], or inducing dyslipidemia [42], inflammation, oxidative stress, and platelet adhesiveness [43].

The strengths of our study include a large, nationally representative sample of US adults, rigorous measurement of NT-proBNP, and adjustment of a wide range of potential confounding factors. Several

Table 3
Associations between HEI-2015 components and NT-proBNP among US adults ≥20 years, NHANES 1999–2004.

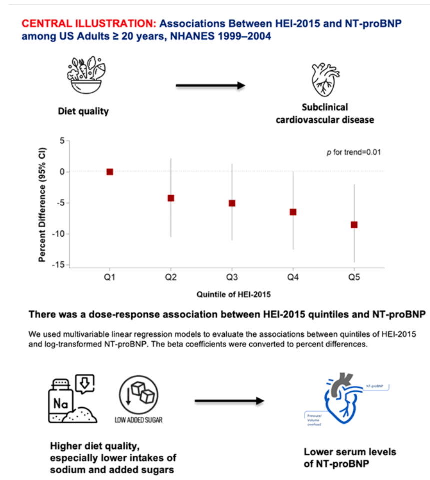
HEI-2015 Components[b]	Percent Difference in NT-proBNP[a] (95% CI) Model 1[c]	Model 2[d]	Model 3[e]
Adequacy components			
Total fruits	-3.03 (-8.10 to 2.32)	0.23 (-5.08 to 5.84)	0.79 (-4.46 to 6.33)
Whole fruits	-7.14 (-11.68 to -2.37)	-3.91 (-8.68 to 1.11)	-1.99 (-6.75 to 3.01)
Total vegetables	-8.97 (-14.93 to -2.59)	-5.44 (-11.59 to 1.14)	-4.64 (-10.77 to 1.90)
Greens and beans	-4.69 (-9.50 to 0.37)	-2.05 (-6.96 to 3.12)	-1.81 (-6.68 to 3.31)
Whole grains	-2.99 (-10.23 to 4.83)	0.80 (-6.69 to 8.89)	1.64 (-5.72 to 9.57)
Dairy	2.14 (-4.11 to 8.80)	4.17 (-2.17 to 10.92)	4.63 (-1.63 to 11.28)
Total protein foods	-8.97 (-16.03 to -1.30)	-6.20 (-13.43 to 1.64)	-3.74 (-11.07 to 4.20)
Seafood and plant proteins	-6.54 (-11.03 to -1.82)	-4.53 (-9.09 to 0.26)	-3.96 (-8.45 to 0.74)
Fatty acids	-6.35 (-12.05 to -0.29)	-5.16 (-10.85 to 0.89)	-5.28 (-10.88 to 0.66)
Moderation components			
Sodium	-4.22 (-9.76 to 1.66)	-7.44 (-12.74 to -1.83)	-7.65 (-12.82 to -2.18)
Refined grains	-2.29 (-7.92 to 3.69)	-3.37 (-8.88 to 2.47)	-2.29 (-7.74 to 3.48)
Added sugars	-10.73 (-16.05 to -5.06)	-7.61 (-13.09 to -1.78)	-6.53 (-12.00 to -0.72)
Saturated fats	0.91 (-5.44 to 7.70)	0.31 (-5.96 to 6.99)	-0.90 (-7.02 to 5.63)

Abbreviations: HEI-2015, Healthy Eating Index-2015; NT-proBNP, N-terminal pro B-type natriuretic peptide.
[a] We used multivariable linear regression models to evaluate the associations between HEI-2015 component score. Percent difference in NT-proBNP was calculated per one point higher in each HEI-2015 component score.
[b] Whole grains, dairy, fatty acids and all moderation components ranged from 0-10. All other components ranged from 0-5.
[c] Model 1: adjusted for age, sex, race/ethnicity, and total energy intake
[d] Model 2: all variables in Model 1, plus education, family poverty ratio, body mass index categories, smoking status, and physical activity
[e] Model 3: all variables in Model 2, plus diabetes, hypertension, chronic kidney disease, and dyslipidemia

limitations of our study should be acknowledged. First, self-reported dietary intake via a 24-hour dietary recall is prone to measurement error and misclassification and may not be representative of usual intake. Second, our study was cross-sectional. HEI-2015 and NT-proBNP were assessed at the same time point, precluding us from establishing temporality. Finally, although we adjusted for a comprehensive set of covariates in our multivariable models, given the observational study design, we cannot rule out residual confounding.

In summary, our study provides new evidence that higher diet quality, especially lower dietary intake of sodium and added sugars, was associated with lower serum levels of NT-proBNP in a nationally representative study of US adults without cardiovascular disease. Improving overall diet quality may be a useful strategy for the primary prevention of heart failure.

Central illustration



Author Contributions

Study concept and design: P. Yang, E. Selvin, C.M. Rebholz
Acquisition: E. Selvin
Analysis: P. Yang
Interpretation of data: all authors
Drafting of the manuscript: P. Yang
Critical revision of the manuscript for important intellectual content: all authors
Statistical analysis: P. Yang
Administrative, technical, or material support: E. Selvin; R.H. Christenson
Study supervision: E. Selvin, C.M. Rebholz

Declaration of Competing Interest

R.H. Christenson reports a relationship with The Journal of Applied Laboratory Medicine that includes: employment. R.H. Christenson reports a relationship with American Association for Clinical Chemistry that includes: employment. E. Selvin reports a relationship with Diabetes Care that includes: employment. E. Selvin reports a relationship with Diabetologia that includes: employment. E. Selvin reports a relationship with American Heart Association that includes: employment. C. M. Rebholz reports a relationship with Diabetes Care that includes: employment. C.M. Rebholz reports a relationship with American Heart Association that includes: employment. R.H. Christenson reports a relationship with Quidel Medical that includes: consulting or advisory. R.H. Christenson reports a relationship with Roche Diagnostics that includes: consulting or advisory. R.H. Christenson reports a relationship with Siemens Healthineers that includes: consulting or advisory. R.H. Christenson reports a relationship with Beckman Coulter that includes: consulting or advisory. R.H. Christenson reports a relationship with Sphingotech that includes: consulting or advisory. R.H. Christenson reports a relationship with Pixcell Medical that includes: consulting or advisory. E. Selvin reports a relationship with Wolters Kluwer that includes: speaking and lecture fees. R.H. Christenson reports a relationship with Siemens Healthineers that includes: speaking and lecture fees. R.H. Christenson reports a relationship with Roche Diagnostics that includes: speaking and lecture fees. R.H. Christenson reports a relationship with Beckman Coulter that includes: speaking and lecture fees. R.H. Christenson reports a relationship with Sphingotech GHB that includes: speaking and lecture fees. R.H. Christenson reports a relationship with Quidel Medical that includes: speaking and lecture fees. E. Selvin reports a relationship with Foundation for the National Institutes of Health that includes: funding grants. J.B. Echouffo-Tcheugui reports a relationship with National Institutes of Health that includes: funding grants. E. Selvin reports a relationship with National Institutes of Health that includes: funding grants. C.M. Rebholz reports a relationship with National Heart Lung and Blood Institute that includes: funding grants. E. Selvin reports a relationship with American Diabetes Association that includes: employment. E. Selvin reports a relationship with Roche Diagnostics Corporation that includes: non-financial support.

Employment or Leadership

R.H. Christenson, The Journal of Applied Laboratory Medicine, AACC. E. Selvin, Diabetes Care; Diabetologia; American Diabetes Association; American Heart Association. C.M. Rebholz, Diabetes Care, American Heart Association.

Consultant or Advisory Role

R.H. Christenson, Quidel Medical, Roche Diagnostics, Siemens Healthineers, Beckman Coulter, Sphingotech, Pixcell Medical.

Stock Ownership

None declared.

Honoraria

E. Selvin receives payments from Wolters Kluwer for chapters and laboratory monographs in UpToDate on measurements of glycemic control and screening tests for type 2 diabetes. R.H. Christenson has received payments from Siemens Healthineers, Roche Diagnostics, Beckman Coulter, Sphingotech GHB, and Quidel Medical.

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Role of sponsor

The funding organizations played no role in the design of study, choice of enrolled patients, review and interpretation of data, preparation of manuscript, or final approval of manuscript.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajpc.2023.100528.

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