Published in final edited form as:

J Am Coll Cardiol. 2019 April 30; 73(16): 2036–2045. doi:10.1016/j.jacc.2019.01.067.

Dietary Patterns and Incident Heart Failure in U.S. Adults Without Known Coronary Disease

Kyla M Lara, MD, MS[1], **Emily B Levitan, ScD**[2], **Orlando M Gutierrez, MD, MMSc**[3], **James M Shikany, DrPH, PA-C**[4], **Monika M Safford, MD**[5], **Suzanne E Judd, PhD**[6], and **Robert S Rosenson, MD**[7]

[1]Icahn School of Medicine at Mount Sinai, New York, NY

[2]Department of Epidemiology, University of Alabama at Birmingham, AL

[3]Department of Medicine, University of Alabama at Birmingham, Birmingham, AL

[4]Division of Preventive Medicine, School of Medicine, University of Alabama at Birmingham, AL

[5]Division of General Internal Medicine, Department of Medicine, Weill Cornell Medicine, New York, NY

[6]Department of Biostatistics, University of Alabama at Birmingham, AL

[7]Mount Sinai Heart, Icahn School of Medicine at Mount Sinai, New York, NY

Abstract

Background: Dietary patterns and associations with incident heart failure (HF) are not well established in the United States.

Objectives: Determine associations of 5 dietary patterns with incident HF hospitalizations among US adults.

Methods: The REasons for Geographic and Racial Differences in Stroke (REGARDS) is a prospective cohort of black and white adults followed from 2003-2007 through 2014. Inclusion criteria included completion of a food frequency questionnaire (FFQ) and no baseline coronary heart disease or HF. Five dietary patterns (Convenience, Plant-based, Sweets, Southern, and Alcohol/Salads) were derived from principal component analysis. The primary endpoint was incident HF hospitalization.

Results: We included 16,068 participants (mean age of 64.0 years SD 9.1, 58.7% women, 33.6% black participants, 34.0% residents of the stroke belt). After a median of 8.7 years of follow up, 363 participants had incident HF hospitalizations. Compared to the lowest quartile, the highest

Corresponding Author: Kyla M. Lara, MD, Department of Cardiovascular Disease, Mayo Clinic, Rochester, MN, 200 First Street S.W., Rochester, MN 55905, Telephone: 507-284-3304, Fax: 507-266-3594, Lara.Kyla@mayo.edu, Twitter: @kyla_lara.

Twitter handle: In U.S. adults without baseline CAD or heart failure (HF), highly adhering to a plant-based diet was associated with a 41% lower risk of incident HF. @kyla_lara

quartile of adherence to the Plant-based dietary pattern was associated with a 41% lower risk of HF in multivariable-adjusted models (HR 0.59 [95% CI 0.41, 0.86], p=0.004). Highest adherence to the Southern dietary pattern was associated with a 72% higher risk of HF after adjusting for age, sex and race and for other potential confounders [education, income, region of residence, total energy intake, smoking, physical activity, and sodium intake; HR 1.72 (95% CI 1.20, 2.46), p=0.005]. However, the association was attenuated and no longer statistically significant after further adjusting for BMI in kg/m^2, WC, hypertension, dyslipidemia, DM, AF, and CKD. No statistically significant associations were observed with incident HFrEF or HFpEF hospitalizations and the dietary patterns. No associations were observed with the other 3 dietary patterns.

Conclusions: Adherence to a Plant-based dietary pattern was inversely associated with incident HF risk, while the Southern dietary pattern was positively associated with incident HF risk.

CONDENSED ABSTRACT:

Limited knowledge exists on the prevention of heart failure (HF) through diet composition in a diverse population without known coronary heart disease. The present study from the Reasons for Geographic and Racial Differences in Stroke (REGARDS) cohort evaluates the five dietary patterns of Convenience, Plant-based, Sweets, Southern, and Alcohol/Salads and their associations with incident HF hospitalization. The Plant-based dietary pattern was inversely associated with incident HF risk, after a median of 8.7 years, while the Southern dietary pattern was positively associated with incident HF risk.

Keywords

heart failure; incident heart failure; Plant-based diet; Southern diet; diet; prevention

Introduction

Heart failure (HF) is a progressive chronic disease that affected 5.7 million adults in the United States in 2012. By 2030, it is projected that the prevalence of HF will be ~3%, resulting in >8 million people with HF (1,2). The need for population-based preventive strategies is critical given the staggering economic implications that are anticipated to rise to $53.1 billion by 2030 (1). HF preventive strategies have emphasized smoking cessation, managing hypertension, and maintaining a “healthy diet and weight” to prevent ischemic heart disease. However, less attention has focused on dietary patterns and incident HF in patients without coronary heart disease (CHD). Prior studies on diet and HF have examined associations with specific food types such as fried foods, eggs, and high-fat dairy (3,4). Many studies have shown inverse associations with the Mediterranean diet and Dietary Approaches to Stop Hypertension (DASH) diet and incident HF (5); however, these studies were limited to participants from populations that lacked racial and ethnic diversity.

The REasons for Geographic and Racial Differences in Stroke (REGARDS) study aims to understand differences in stroke mortality between whites and blacks and geographic differences in stroke rates across the United States. Five major dietary patterns have been empirically identified within the REGARDS study population: Convenience, Plant-based, Sweets, Southern, and Alcohol and Salad (6). In prior studies, adherence to the Southern diet was associated with a higher incidence of CHD events and hypertension (7,8).

In this study, we examined the association between these previously identified dietary patterns and incident HF hospitalizations in REGARDS participants without known CHD or HF at baseline. We additionally examined the associations of dietary patterns and hospitalizations for HF with reduced ejection fraction (HFrEF) and HF with preserved ejection fraction (HFpEF) separately. We hypothesized that greater adherence to the Southern and Convenience dietary patterns and lower adherence to a Plant-based dietary pattern would be associated with incident HF.

Methods

Study Population

Details of the study design and methods of the REGARDS cohort have been previously reported (9). Briefly, we included participants in the REGARDS study, a national prospective cohort study of 30,239 black and white adults aged 45 years and older, who were recruited from January 2003 to October 2007. The cohort was designed to study risk factors for stroke incidence and mortality and to address geographic and racial differences in stroke with particular attention to the stroke buckle (20% of participants who reside in the coastal plain regions of the Carolinas and Georgia) and the stroke belt (30% of participants who reside in the remainder of North Carolina, South Carolina, and Georgia as well as Alabama, Mississippi, Tennessee, Arkansas, and Louisiana).

Potential participants were initially contacted by mail, and interviewed by telephone for information on sociodemographic characteristics, risk factors for stroke, and psychosocial characteristics. Exclusion criteria included £45 years of age, race other than black or white, active treatment for cancer, medical conditions preventing long-term participation or cognitive impairment, residence in nursing homes or on a waiting list for a nursing home, and inability to communicate in English. During a subsequent in-home visit, a trained health professional obtained study consent and measurements of blood pressure, height, weight, and waist circumference (WC). A physical evaluation was performed for each participant and spot urine and fasting blood samples were also collected. The Block 98 food frequency questionnaire (FFQ) and a pre-paid envelope were provided to participants during the in-home visit for completion and returned after the visit.

Fifty-six REGARDS participants have missing baseline forms and are excluded from all analyses. Of the remaining 30,183 REGARDS we excluded 8,344 participants with suspected HF based on taking HF-related medications at baseline, those without HF follow-up or whom baseline HF was undetermined, and with baseline CHD. An additional 5,771 participants were excluded for incomplete and missing FFQs. The final sample size included 16,068 participants (Online Figure 1, Exclusion Flow Chart). HF-related medications included use of carvedilol, any loop diuretic, angiotensin converting enzyme inhibitors or angiotensin II receptor blockers plus beta blockers in the absence of hypertension, or digoxin in the absence of atrial fibrillation.

All participants provided written informed consent and signed medical record release forms allowing medical records to be retrieved for research purposes. The Institutional Review Board at the participating institutions approved the study.

Dietary Assessment Using Exploratory and Confirmatory Factor Analysis

The Block 98 FFQ contains 150 multiple-choice questions based on 107 food items. The FFQ has been validated in diverse populations and was developed by Block Dietary Data Systems (Berkeley, CA, USA) and distributed by Block FFQ (10,11). Of the participants, 72% provided usable FFQ data, while 17% did not return the FFQ, 3% returned a blank FFQ, 5% did not answer at least 85% of the questions, and 3% had biologically implausible energy intake (<3347 kJ/d or >20,920 kJ/d) (12).

Based on original FFQ data, 56 food groups were derived based on culinary use, nutrient similarities, and previous studies. Principle component analysis (PCA), an exploratory factor analysis (EFA), was then used to derive the factor loadings, followed by confirmatory factor analysis for validation of the PCA analysis (6). Five patterns were named based on factor loadings that contributed most highly to each pattern (Online Table 1, Intake of Food Groups by Quartile of Dietary Patterns & Online Table 2, Final Factor Loadings). We used an orthogonal rotation (varimax in Proc Factor) and used the scree plot to guide selection of factors. Additional details are provided in the dietary patterns derivation methods paper (6). Factor 1, or the "Convenience" dietary pattern, loaded most heavily on meat dishes, pasta, Mexican dishes, pizza, fried potatoes, Chinese dishes and fast food. Factor 2, or the "Plant-based" pattern, loaded most heavily on cruciferous vegetables and other vegetables, fruit, beans, and fish. Factor 3, or "Sweets/Fats" pattern, loaded most heavily on desserts, bread, sweet breakfast foods, chocolate, candy, solid fats and oils, and miscellaneous sugar. Factor 4, or the "Southern" pattern, was similar to the culinary pattern of the Southeastern US and was loaded most heavily on fried food, organ meats, processed meats, eggs, added fats, and sugar-sweetened beverages. Lastly, factor 5, or "Alcohol/Salads," loaded most heavily on wine, liquor, beer, leafy greens and salad dressing (6). Each participant received a score for each dietary pattern based on the factor loadings and was grouped into 1 of 4 quartiles of adherence to each pattern, with quartile 1 (Q1) being the lowest adherence and quartile 4 (Q4) having the highest adherence, to each dietary pattern.

Adjudication of HF Hospitalizations

Participant follow-up interviews were conducted every 6 months by telephone with a follow-up period extending through the earliest of December 31, 2014, death from a cause other than HF, withdrawal from the study, or loss to follow-up. During follow-up interviews, participants self-reported hospitalizations. Medical records for potentially heart-related hospitalizations were retrieved for adjudication. Adjudication of HF hospitalizations was based on signs and symptoms, laboratory studies including troponin-I, troponin-T, creatinine kinase-MB (CK-MB), and brain natriuretic peptide (BNP), electrocardiogram (ECG), and assessments of left ventricular (LV) function documented in the medical records (Online Table 3, Adjudication of HF Events). Signs and symptoms of HF included paroxysmal nocturnal dyspnea, orthopnea, abnormal jugular vein distension, pulmonary rales, cardiomegaly, central venous pressure >16 mm Hg, edema, nocturnal cough, exertional dyspnea, hepatomegaly, pleural effusion, heart rate >120/minute, and >4.5 kilogram weight loss in 5 days with diuresis. HFrEF was defined as EF <40% or qualitative report of reduced EF. HFpEF was defined as EF >50% or qualitative report of preserved EF. Adjudication of HF and other heart disease outcomes were performed independently by two clinician investigators with disagreements resolved by discussion. If agreement fell below 80%, adjudicators were retrained.

Covariates

Hypertension was defined as systolic blood pressure >140 mm Hg and/or diastolic blood pressure >90 mm Hg, or self-reported current medication use to control blood pressure. Dyslipidemia was defined as total cholesterol (TC) >240 mg/dL, low-density lipoprotein (LDL) cholesterol >160 mg/dL, high-density lipoprotein (HDL) cholesterol <40 mg/dL, or self-report of lipid-lowering medication. Diabetes mellitus (DM) was defined as having fasting blood glucose >126 mg/dL, non-fasting glucose >200 mg/dL, or reported diabetic medications including insulin. Atrial fibrillation (AF) was defined by ECG or self-reported diagnosis. Chronic kidney disease (CKD) was defined by an estimated glomerular filtration rate (eGFR) from the CKD-Epi equation < 60 mL/min/1.73m^2 (13).

Statistical Analysis

Incident rates of HF hospitalizations were expressed as number of cases per 10,000 person years of follow-up by quartile of the diet pattern adherence scores. Hazard ratios (HR) of incident HF by quartile of the diet scores were determined by using Cox proportional hazards regression. The median score in each quartile was included as a continuous variable to test for linear trends. We evaluated the proportional hazards assumption by including an interaction between the diet pattern variables and the natural logarithm of time; we did not find evidence the associations varied over the follow-up period.

We constructed models 1 through 3 sequentially; model 1 included age, sex, and race; model 2 was comprised of model 1 plus socioeconomic factors (education, household income), region, total energy intake, smoking, physical activity and sodium intake as a continuous variable; model 3 was comprised of model 2 plus body mass index (BMI) in kg/m^2, WC, hypertension, dyslipidemia, DM, AF, and eGFR. Given that the aforementioned comorbidities could be considered mediators or confounders, Model 2 accounts for co-morbidities as mediators, and model 3 accounts for co-morbidities as confounders.

The incidence of HF subtypes (HFrEF, HFpEF) was also examined using Lunn-McNeil competing risk models adjusted as described above (14). These models allow for calculation of HRs for the association of the diet patterns with each type of HF and a test for whether the associations differ by type of HF. Additional stratified analyses of other established risk factors for HF including history of hypertension or diabetes, race, eGFR, BMI, age, sex, physical activity, and smoking status were also performed. Tests of interaction were conducted by including cross-product terms between risk factors described above and dietary patterns. Multiple imputation using fully conditional specification was used to account for missing data for the covariates (Online Table 4, Number and Percent Missing

Data Before Imputation). Analyses were conducted within each of the 20 imputed datasets, and results were combined across datasets (SAS version 9.3. Cary, NC).

Results

Study Population

At baseline, REGARDS participants had a mean age of 64.0 years (SD 9.1) and were comprised of 58.7% women, 33.6% black participants, and 34.0% residents of the stroke belt. Baseline participant characteristics including BMI, WC, physical activity, educational status, household income, alcohol consumption, tobacco use, and medical history are provided for Q1 and Q4 of the Plant-Based and Southern Dietary Patterns in Table 1 (Characteristics of Participants at Baseline in Quartile 1 and Quartile 4 of the Plant-Based and Southern Dietary Patterns). Participants in Q4 of the plant-based pattern were comprised of more women and smoked less when compared to Q1 of the plant-based pattern. Participants in Q4 of the Southern pattern were comprised of more men and black race, smoked more, were less college graduates, and had more hypertension and diabetes when compared to Q1 of the Southern pattern. Baseline characteristics by all the dietary pattern quartiles are found in Online Table 5 (Baseline Characteristics of Participants).

Associations of Dietary Patterns with Incident Heart Failure Hospitalizations

There were 363 adjudicated new HF hospitalizations over 8.7 years of median follow up, with 7.1 years (2582 days) of follow up in the 25th percentile and 10.1 years (3697 days) of follow up in the 75th percentile. The HR of incident HF by quartile of consumption of each of the 5 dietary patterns are given in Table 2 (Hazard Ratio of Incident Total Heart Failure by Quartile of Consumption of the 5 Dietary Patterns). In fully adjusted analyses (model 3), we observed a 41% lower risk of new HF hospitalizations for participants most adherent (Q4) to the plant-based dietary pattern, compared to the least adherence (Q1). Highest adherence (Q4) to the Southern dietary pattern was associated with a 72% higher risk of HF hospitalization in models adjusted for age, sex and race (Model 1), and after further adjustment for other potential confounders (education, income, region of residence, total energy intake, smoking, physical activity and sodium intake, Model 2). The association of greater adherence to the Southern dietary pattern with higher incident HF risk was attenuated and no longer statistically significant after adjusting for potential mediating factors (Model 3). Several potential mediators contributed to the attenuation of the associations (Online Table 6, Hazard Ratio of Incident Total HF by Quartile of Consumption of the Southern Dietary Pattern). No statistically significant associations were found among the remaining dietary patterns after multivariable adjustment.

Associations of Diet Patterns with Incident HF Stratified by HF Subgroups

There were 133 cases of HFpEF and 157 cases of HFrEF hospitalizations. There were 73 cases of HF with intermediate ejection fraction or without documented ejection fraction. In Model 2 for the Southern dietary pattern, there was a 97% increased risk that was significant for HFrEF. In fully adjusted analyses that included potential mediating variables (Model 3), there were no statistically significant associations of the dietary patterns with incident HFrEF or HFpEF hospitalizations (Table 3, Hazard Ratio of Incident Heart Failure by

Ejection Fraction and Quartile of Consumption of the 5 Dietary Patterns). There were no significant differences in the associations of the diet patterns with HF by EF.

Associations of Diet Patterns with Incident HF Stratified by Established Risk Factors

Although inverse associations were observed in men and participants with an eGFR >60 mL/min/1.73m^2, BMI <30 kg/m^2, no history of diabetes, and past smoking history in Q4 of the plant-based dietary pattern, the p values for interactions between these subgroups were not significant (Online Table 7, Hazard Ratio of Incident HF by Sex and Quartile of Consumption of the 5 Dietary Patterns; Online Table 8, Hazard Ratio of Incident HF by eGFR and Quartile of Consumption of the 5 Dietary Patterns; Online Table 9, Hazard Ratio of Incident HF by BMI and Quartile of Consumption of the 5 Dietary Patterns; Online Table 10, Hazard Ratio of Incident HF by History of Diabetes and Quartile of Consumption of the 5 Dietary Patterns; Online Table 11, Hazard Ratio of Incident HF by Smoking Status and Quartile of Consumption of the 5 Dietary Patterns). A statistically significant interaction in the Southern dietary pattern was observed and showed a stronger positive association with HF in participants <65 years of age (Online Table 12, Hazard Ratio of Incident HF by Age and Quartile of Consumption of the 5 Dietary Patterns). There were no meaningful interactions by race, hypertension, or physical activity given the non-significant p values for interaction (Online Table 13, Hazard Ratio of Incident HF by Race and Quartile of Consumption of the 5 Dietary Patterns; Online Table 14, Hazard Ratio of Incident HF by Quartile of Consumption of the 5 Dietary Patterns Among Those With and Without Hypertension at Baseline; Online Table 15, Hazard Ratio of Incident HF by Physical Activity and Quartile of Consumption of the 5 Dietary Patterns).

Discussion

Our study shows that higher adherence to a plant-based diet is associated with a 41% lower risk of incident HF hospitalization (Central Illustration). These results derived from a large, diverse, and contemporary U.S. population both extend and complement previous findings of randomized controlled trials and observational studies of plant-based diet patterns. Additionally, adherence to the Southern dietary pattern was associated with a 72% higher risk of incident heart failure; however, this association was attenuated after adjusting for potential mediating factors (BMI, WC, hypertension, dyslipidemia, DM, AF, ACR and eGFR). No significant associations were observed in the other patterns.

Similar to our plant-based dietary pattern, the cardioprotective effect of the Mediterranean style dietary pattern (MedDiet) similarly emphasizes a diet high in fruits, vegetables, beans, nuts, seeds, and minimal consumption of red meat, poultry and eggs (5). The Lyon Heart Study found significant beneficial cardioprotective effects after a first myocardial infarction when compared to the Western-type diet, with secondary endpoints finding fewer HF events in the MedDiet group (15). In contrast, the population we studied had no established CHD that limited the influence of CHD and its implications on ischemic HF. In the PREDIMED study, incident HF was not different in the MedDiet groups (MedDiet + virgin olive oil, MedDiet + nuts, and low-fat diet control group), however a lower risk of HF was associated with reductions in BNP and LDL cholesterol (16,17). Our results are also consistent with earlier studies of Swedish women in whom a diet of at least five daily servings of fruits/vegetables resulted in an inverse association with incident HF (18), Swedish cohorts finding a risk reduction in HF with the MedDiet and DASH diet (19–21), and a comprehensive review of dietary studies highlighting the DASH and MedDiet and their inverse associations with risk of HF (5). Considering that CHD represents the most common cause of HF, a meta-analysis including 124,706 participants from 7 cohort studies (Europe, Japan, and California) showed that a vegetarian diet was associated with a 29% risk reduction in mortality from ischemic heart disease (22).

This population was diverse with regard to sex, inclusion of African Americans, health behaviors, education level achieved, geographic region, income, and medical comorbidities. More than half of the cohort was represented by women and the high prevalence of low socioeconomic status within the group offers much insight into the dietary habits of many Americans living in the US. Among a population with HF risk factors, high adherence to the plant-based diet was associated with a lower risk of incident HF. Decreased risk and management of diabetes with a plant-based diet through improvement of insulin sensitivity and decreasing insulin resistance have been well studied (23–28). Although no specific research has been done on AF and plant-based dietary patterns, the Long-Term Effect of Goal-Directed Weight Management in an Atrial Fibrillation Cohort: A Long-Term Follow-Up Study (LEGACY), showed that long-term weight loss with low-fat, low-glycemic index, plant-based diets (29–31), was associated with a significant decrease in AF burden (32). Plant-based proteins may also have beneficial effects on blood pressure, proteinuria, and GFR, which may slow down the development and progression of CKD (33).

The effect of diet on hypertension has been well-studied, with evidence that plant-based, low-sodium diets like DASH are associated with lower systolic and diastolic blood pressure (20,34). These diets are recommended for preventing hypertension and managing blood pressure to prevent the deleterious consequences such as HF (20).

A proposed mechanism that may contribute to a lower risk of HF in those with high adherence to a plant-based dietary pattern include the abundance of antioxidants and anti-inflammatory effects associated with this dietary pattern (29,35). Reactive oxygen species (ROS) promote myocyte hypertrophy, aortic stiffness, apoptosis, and interstitial fibrosis, all which can possibly contribute to the development of HF (36,37). Plant antioxidants reduce the amount of ROS via proposed pathways of redox balance, cell signaling, and cell function (38). ROS also potentially decrease myocardial contractility (39,40) that may improve with plant-based diets (41). Systemic inflammatory biomarkers are associated with a higher incidence of HF (42), and plant-based diets have been associated with decreased serum concentrations of CRP, interleukin-6, and soluble intercellular adhesion molecule-1 (43–45).

Of the five dietary patterns, the Southern dietary pattern was associated with an increased risk of HF, including the HFrEF subgroup after adjusting for major confounders. Because this association was attenuated after adjusting for potential mediators, it is plausible that the Southern dietary pattern may increase the risk of HF through a variety of factors associated with obesity, visceral adiposity, hypertension, dyslipidemia, and CKD.

The main strength of this study is the large sample size from a diverse demographic and socioeconomic background in the US. Other strengths included adjudicated HF hospitalizations and assessment of HFrEF and HFpEF. However, the present study has a number of limitations. Misclassification from inaccuracies of reporting dietary intake in the FFQ likely occurred. Diet was only assessed at the beginning of the study and dietary changes may have occurred at any time after the initial assessment. The potential for residual confounding, inability to detect HF diagnosed in the outpatient setting, and a study population that did not include individuals with race/ethnicity other than non-Hispanic black or white may have altered and/or limited the generalizability of the results.

Conclusions

This study contributes new evidence that adherence to a plant-based diet was inversely associated with developing HF in a diverse population of American adults. The association was evident even in adults with baseline hypertension, a known risk factor for HF. These findings support a population-based dietary strategy for lowering the risk of incident HF.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Funding and Acknowledgments:

This research project is supported by a cooperative agreement U01 NS041588 from the National Institute of Neurological Disorders and Stroke, National Institutes of Health, Department of Health and Human Service. Additional support was provided by R01 HL80477 from the National Heart Lung and Blood Institute. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute of Neurological Disorders and Stroke or the National Institutes of Health. Representatives of the funding agency have been involved in the review of the manuscript but not directly involved in the collection, management, analysis or interpretation of the data. The authors thank the other investigators, the staff, and the participants of the REGARDS study for their valuable contributions. A full list of participating REGARDS investigators and institutions can be found at http://www.regardsstudy.org.

Disclosures: Emily B. Levitan, Research funding from Amgen, Amgen advisory board, scientific consulting for a research project sponsored by Novartis; Kyla M. Lara, Orlando M. Gutierrez, James M. Shikany, Monika, M. Safford, Suzanne E Judd, Robert Rosenson, None.

Abbreviations:

HF	heart failure
CHD	coronary heart disease
HFrEF	heart failure with reduced ejection fraction
HFpEF	heart failure with preserved ejection fraction
WC	waist circumference
FFQ	food frequency questionnaire
PCA	principal component analysis
BNP	brain natriuretic peptide

ECG	electrocardiogram
LV function	left ventricular function
TC	total cholesterol (TC)
LDL	low-density lipoprotein
HDL	high-density lipoprotein
DM	diabetes mellitus
AF	atrial fibrillation
CKD	chronic kidney disease
eGFR	estimated glomerular filtration rate
BMI	body mass index

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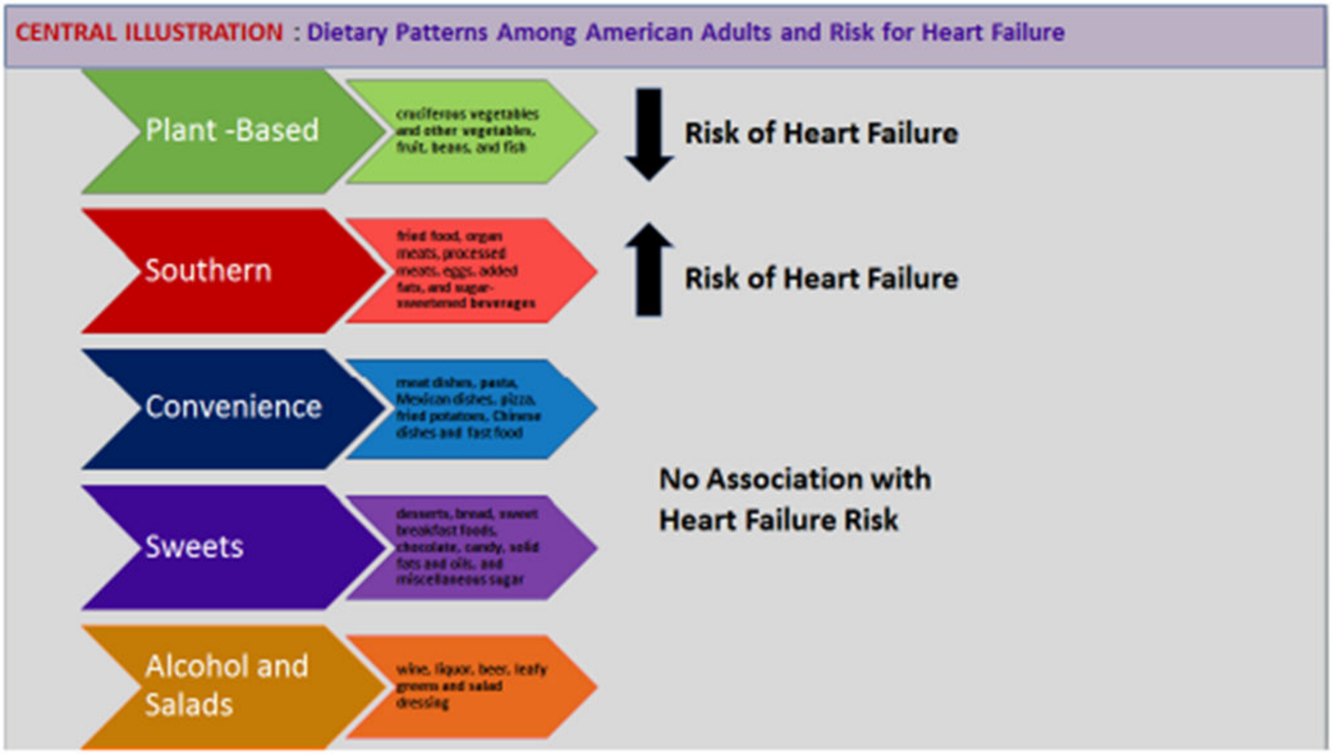
PERSPECTIVES

Competency in Systems-Based Practice:

A plant-based diet reduced the risk for incident heart failure in U.S. adults. Educating the public on the potential hazards of a Southern diet and potential benefits of a plant-based diet may have important implications for ameliorating adverse national trends in the prevalence of heart failure.

Translational Outlook:

Additional studies are needed to expose the pathophysiological mechanisms underlying the relationship between a plant-based diet and reduction in incident heart failure.



Central Illustration. Dietary Patterns Among American Adults and Risk for Heart Failure.
These findings of the associations of dietary patterns and incident heart failure over 8.7 years of follow-up are based on this study's analysis.

Table 1.

Characteristics of Participants at Baseline in Quartile 1 and Quartile 4 of the Plant-Based and Southern Dietary Patterns

	Plant-Based		Southern	
Characteristic	**Quartile 1 (Lowest consumption) % or Mean +/−SD**	**Quartile 4 (Highest consumption) % or Mean +/− SD**	**Quartile 1 (Lowest consumption) % or Mean +/−SD**	**Quartile 4 (Highest consumption) % or Mean +/−SD**
Age-yr	61.8 (8.8)	64.9 (9.0)	64 (9.1)	63.1 (8.8)
Female sex- no. (%)	1957 (48.7%)	2657 (66.1%)	2654 (66.1%)	1874 (46.7%)
Race or Ethnic Group				
White	2903 (72.3%)	2523 (62.8%)	3657 (91%)	1596 (39.7%)
Black	1114 (27.7%)	1494 (37.2%)	360 (9%)	2421 (60.3%)
BMI	29 (6)	28.6 (6)	27.3 (5.2)	30.3 (6.5)
Waist Circumference	95.5 (14.9)	92.7 (14.8)	89.7 (14.2)	98.9 (15.2)
Physical Activity (per week)				
None	1530 (38.1%)	979 (24.4%)	1088 (27.1%)	1336 (33.2%)
1 to 3 times	1451 (36.1%)	1538 (38.3%)	1577 (39.2%)	1443 (35.9%)
4 or more times	1036 (25.8%)	1500 (37.3%)	1352 (33.7%)	1239 (30.8%)
Current Smoker	940 (23.4%)	299 (7.4%)	340 (8.5%)	850 (21.2%)
Alcohol Use				
Never	953 (23.7%)	1265 (31.5%)	939 (23.4%)	1194 (29.7%)
Past	626 (15.6%)	604 (15%)	471 (11.7%)	776 (19.3%)
Current	2438 (60.7%)	2148 (53.5%)	2607 (64.9%)	2047 (51%)
Education				
Less than high school	370 (9.2%)	277 (6.9%)	139 (3.5%)	606 (15.1%)
High school graduate	1170 (29.1%)	821 (20.4%)	764 (19%)	1225 (30.5%)
Some college	1141 (28.4%)	1075 (26.8%)	1001 (24.9%)	1152 (28.7%)
College graduate and above	1336 (33.3%)	1843 (45.9%)	2113 (52.6%)	1033 (25.7%)
Region				
Resident of Nonbelt	1760 (43.8%)	1825 (45.4%)	2073 (51.6%)	1475 (36.7%)
Resident of Stroke belt	1385 (34.5%)	1339 (33.3%)	1181 (29.4%)	1565 (39%)
Resident of Stroke buckle	872 (21.7%)	853 (21.2%)	763 (19%)	977 (24.3%)
Income				
<$20k	25 (0.6%)	16 (0.4%)	9 (0.2%)	45 (1.1%)
$20k-$34k	1023 (25.5%)	995 (24.8%)	805 (20%)	1237 (30.8%)
$35k-$74k	1502 (37.4%)	1461 (36.4%)	1467 (36.5%)	1435 (35.7%)
$75k and above	1061 (26.4%)	1026 (25.5%)	1215 (30.2%)	865 (21.5%)
Refused	406 (10.1%)	519 (12.9%)	521 (13%)	435 (10.8%)
Medical History				
Diabetes/Fasting glucose[a]	521 (13%)	647 (16.1%)	324 (8.1%)	889 (22.1%)

	Plant-Based		Southern	
Characteristic	**Quartile 1 (Lowest consumption) % or Mean +/−SD**	**Quartile 4 (Highest consumption) % or Mean +/− SD**	**Quartile 1 (Lowest consumption) % or Mean +/−SD**	**Quartile 4 (Highest consumption) % or Mean +/−SD**
Hypertension	2021 (50.3%)	2112 (52.6%)	1636 (40.7%)	2499 (62.2%)
Systolic, mm Hg	126.3 (15.9)	125.9 (15.9)	122.7 (15.2)	129.5 (16.4)
Diastolic, mm Hg	77 (9.5)	76.1 (9.3)	74.8 (8.7)	78.3 (9.8)
Atrial fibrillation	223 (5.6%)	245 (6.1%)	248 (6.2%)	222 (5.5%)
Dyslipidemia	2307 (57.4%)	2097 (52.2%)	2064 (51.4%)	2299 (57.2%)
LDL cholesterol	118.6 (35.2)	116.3 (34.7)	115.9 (33.1)	117.7 (36)
HDL cholesterol	51.4 (16.1)	54.9 (16.3)	55.6 (16.5)	51 (16)
Cholesterol	197.8 (39.1)	195.6 (38.8)	196.9 (37.1)	194.9 (39.9)
Triglycerides	138.7 (82.2)	121.4 (70.3)	126.5 (69.2)	131.2 (81.4)
eGFR Strata				
eGFR> 90 mL/min 1.73 m^2	2063 (51.4%)	1934 (48.2%)	1819 (45.3%)	2099 (52.3%)
eGFR 60–89 mL/min 1.73 m^2	1572 (39.1%)	1733 (43.1%)	1845 (45.9%)	1514 (37.7%)
eGFR 45-59 mL/min 1.73 m^2	190 (4.7%)	187 (4.6%)	172 (4.3%)	205 (5.1%)
eGFR 30-44 mL/min 1.73 m^2	45 (1.1%)	31 (0.8%)	41 (1%)	55 (1.4%)
eGFR 15-29 mL/min 1.73 m^2	11 (0.3%)	6 (0.1%)	4 (0.1%)	13 (0.3%)
eGFR <15 mL/min 1.73 m^2 or on dialysis	8 (0.2%)	4 (0.1%)	1 (0%)	15 (0.4%)
Albuminuria Categories				
ACR <30 μg/mg	3454 (86%)	3434 (85.5%)	3563 (88.7%)	3290 (81.9%)
ACR 30-300 μg/mg	346 (8.6%)	370 (9.2%)	272 (6.8%)	477 (11.9%)
ACR >300 μg/mg	59 (1.5%)	46 (1.1%)	23 (0.6%)	77 (1.9%)

[a] Fasting glucose, ≥126 mg/dL

Table 2.

Hazard Ratio of Incident Total HF by Quartile of Consumption of the 5 Dietary Patterns

	Total HF					
Dietary Pattern	**Model**	**Q1, HR (95% CI)**	**Q2, HR (95% CI)**	**Q3, HR (95% CI)**	**Q4, HR (95% CI)**	**p for linear trend**
Plant Based		N=95	N=105	N=99	N=64	
	1	1 (reference)	0.91 (0.69, 1.20)	0.82 (0.62, 1.09)	0.53 (0.38, 0.73)	<0.001
	2	1 (reference)	1.00 (0.75, 1.32)	0.95 (0.71, 1.28)	0.60 (0.42, 0.86)	0.005
	3	1 (reference)	0.98 (0.73, 1.32)	0.89 (0.65, 1.21)	0.59 (0.41, 0.86)	0.004
Convenience		N=103	N=77	N=100	N=83	
	1	1 (reference)	0.85 (0.63, 1.14)	1.15 (0.86, 1.52)	1.11 (0.82, 1.50)	0.24
	2	1 (reference)	0.88 (0.65, 1.19)	1.24 (0.92, 1.66)	1.14 (0.80, 1.63)	0.26
	3	1 (reference)	0.94 (0.69, 1.30)	1.39 (1.02, 1.90)	1.21 (0.83, 1.77)	0.17
Alcohol and Salads		N=119	N=76	N=96	N=72	
	1	1 (reference)	0.69 (0.52, 0.93)	0.89 (0.68, 1.17)	0.72 (0.53, 0.97)	0.10
	2	1 (reference)	0.74 (0.55, 0.99)	0.98 (0.74, 1.30)	0.85 (0.62, 1.17)	0.61
	3	1 (reference)	0.74 (0.54, 1.00)	0.92 (0.68, 1.24)	0.83 (0.59, 1.16)	0.45
Sweets		N=93	N=86	N=94	N=90	
	1	1 (reference)	0.86 (0.64, 1.16)	0.94 (0.71, 1.26)	0.96 (0.72, 1.29)	0.99
	2	1 (reference)	0.83 (0.62, 1.12)	0.83 (0.61, 1.14)	0.73 (0.51, 1.05)	0.11
	3	1 (reference)	0.78 (0.57, 1.06)	0.86 (0.62, 1.19)	0.76 (0.51, 1.11)	0.24
Southern		N=60	N=87	N=93	N=123	
	1	1 (reference)	1.46 (1.05, 2.03)	1.56 (1.11, 2.17)	2.35 (1.68, 3.29)	<0.001
	2	1 (reference)	1.35 (0.96, 1.88)	1.27 (0.91, 1.79)	1.72 (1.20, 2.46)	0.005
	3	1 (reference)	1.24 (0.88, 1.76)	1.02 (0.71, 1.45)	1.32 (0.90, 1.93)	0.24

Model 1 adjusts for age, sex, and race

Model 2 adjusts for factors in model 1 plus education, household income, and region, total energy intake, smoking, physical activity and sodium intake

Model 3 adjusts for factors in model 2 plus BMI, waist circumference, hypertension, dyslipidemia, diabetes, atrial fibrillation, eGFR, ACR

Table 3.

Hazard Ratio of Incident HF by Ejection Fraction and Quartile of Consumption of the 5 Dietary Patterns

		HFrEF					*HFpEF*					
Dietary Pattern	**Model**	**Q1, HR (95% CI)**	**Q2, HR (95% CI)**	**Q3, HR (95% CI)**	**Q4, HR (95% CI)**	**p for linear trend**	**Q1, HR (95% CI)**	**Q2, HR (95% CI)**	**Q3, HR (95% CI)**	**Q4, HR (95% CI)**	**p for linear trend**	**p value for difference in associations with HFrEF and HFpEF**
Plant Based		N=35	N=53	N=47	N=22		N=36	N=33	N=33	N=31		
	1	1 (reference)	1.30 (0.85, 2.00)	1.13 (0.73, 1.77)	0.54 (0.31, 0.93)	0.01	1 (reference)	0.73 (0.46, 1.18)	0.69 (0.42, 1.11)	0.62 (0.38, 1.02)	0.08	0.49
	2	1 (reference)	1.49 (0.96, 2.30)	1.36 (0.85, 2.15)	0.66 (0.37, 1.19)	0.11	1 (reference)	0.78 (0.48, 1.27)	0.79 (0.48, 1.29)	0.74 (0.42, 1.28)	0.34	0.49
	3	1 (reference)	1.56 (0.99, 2.46)	1.40 (0.87, 2.27)	0.65 (0.35, 1.21)	0.13	1 (reference)	0.71 (0.43, 1.19)	0.68 (0.40, 1.15)	0.68 (0.38, 1.20)	0.23	0.42
Convenience		N=43	N=30	N=48	N=36		N=40	N=34	N=31	N=28		
	1	1 (reference)	0.76 (0.47, 1.21)	1.19 (0.78, 1.81)	1.02 (0.64, 1.62)	0.58	1 (reference)	0.98 (0.62, 1.55)	0.98 (0.61, 1.58)	1.04 (0.63, 1.72)	0.87	0.30
	2	1 (reference)	0.82 (0.51, 1.31)	1.31 (0.84, 2.02)	1.09 (0.63, 1.86)	0.49	1 (reference)	1.00 (0.63, 1.59)	1.04 (0.63, 1.71)	1.05 (0.58, 1.92)	0.84	0.30
	3	1 (reference)	0.81 (0.49, 1.33)	1.39 (0.88, 2.20)	1.11 (0.63, 1.95)	0.44	1 (reference)	1.14 (0.69, 1.89)	1.30 (0.76, 2.21)	1.33 (0.71, 2.52)	0.35	0.50
Alcohol and Salads		N=45	N=35	N=47	N=30		N=54	N=26	N=27	N=26		
	1	1 (reference)	0.81 (0.52, 1.27)	1.05 (0.69, 1.59)	0.70 (0.43, 1.12)	0.24	1 (reference)	0.53 (0.33, 0.84)	0.59 (0.36, 0.94)	0.62 (0.38, 1.01)	0.07	0.12
	2	1 (reference)	0.85 (0.54, 1.32)	1.11 (0.73, 1.70)	0.79 (0.48, 1.30)	0.54	1 (reference)	0.57 (0.35, 0.92)	0.66 (0.41, 1.07)	0.76 (0.46, 1.27)	0.32	0.12
	3	1 (reference)	0.84 (0.53, 1.34)	1.09 (0.70, 1.70)	0.83 (0.49, 1.38)	0.65	1 (reference)	0.51 (0.31, 0.85)	0.57 (0.34, 0.95)	0.65 (0.38, 1.12)	0.12	0.08
Sweets		N=39	N=36	N=36	N=46		N=38	N=30	N=37	N=28		
	1	1 (reference)	0.82 (0.52, 1.30)	0.79 (0.50, 1.25)	1.07 (0.69, 1.64)	0.60	1 (reference)	0.78 (0.48, 1.26)	1.00 (0.63, 1.58)	0.81 (0.49, 1.32)	0.57	0.26
	2	1 (reference)	0.77 (0.49, 1.22)	0.65 (0.40, 1.06)	0.73 (0.43, 1.23)	0.28	1 (reference)	0.80 (0.49, 1.30)	1.02 (0.61, 1.70)	0.79 (0.43, 1.47)	0.59	0.26
	3	1 (reference)	0.64 (0.39, 1.03)	0.67 (0.41, 1.09)	0.69 (0.40, 1.20)	0.29	1 (reference)	0.81 (0.48, 1.36)	1.02 (0.59, 1.77)	0.99 (0.51, 1.91)	0.88	0.50
Southern		N=23	N=38	N=43	N=53		N=28	N=32	N=31	N=42		
	1	1 (reference)	1.70 (1.01, 2.85)	1.95 (1.16, 3.27)	2.84 (1.69, 4.79)	<0.001	1 (reference)	1.12 (0.67, 1.87)	1.07 (0.63, 1.82)	1.61 (0.95, 2.74)	0.07	0.27
	2	1 (reference)	1.56 (0.92, 2.62)	1.56 (0.92, 2.63)	1.97 (1.13, 3.43)	0.02	1 (reference)	1.04 (0.62, 1.75)	0.94 (0.54, 1.62)	1.38 (0.77, 2.45)	0.31	0.27
	3	1 (reference)	1.46 (0.85, 2.50)	1.26 (0.73, 2.18)	1.60 (0.90, 2.87)	0.17	1 (reference)	0.97 (0.56, 1.68)	0.74 (0.42, 1.32)	0.94 (0.51, 1.73)	0.76	0.29

Model 1 adjusts for age, sex, and race

Model 2 adjusts for factors in model 1 plus education, household income, and region, total energy intake, smoking, physical activity and sodium intake

Model 3 adjusts for factors in model 2 plus BMI, waist circumference, hypertension, dyslipidemia, diabetes, atrial fibrillation, eGFR, ACR