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DASH Eating Pattern Is Associated with Favorable Left Ventricular Function in the Multi-Ethnic Study of Atherosclerosis

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Abstract

Objective—Potential associations between consistency with the Dietary Approaches to Stop Hypertension (DASH) diet and preclinical stages of heart failure (HF) in a large multiethnic cohort have not been evaluated. This study sought to determine the cross-sectional relationship between the DASH eating pattern and left ventricular (LV) function in the Multi-Ethnic Study of Atherosclerosis (MESA).

Design—A total of 4506 men and women from four ethnic groups (40% white, 24% African American, 22% Hispanic American, and 14% Chinese American) aged 45–84 years and free of clinical cardiovascular disease (CVD) were studied. Diet was assessed using a validated food-frequency questionnaire. LV functional parameters including end-diastolic volume, stroke volume, and LV ejection fraction were measured by magnetic resonance imaging. Multivariate analyses were conducted to examine the association between LV function and DASH eating pattern (including high consumption of fruits, vegetables, whole grains, poultry, fish, nuts, and low-fat dairy products and low consumption of red meat, sweets, and sugar-sweetened beverages).

Results—A 1-unit increase in DASH eating pattern score was associated with a 0.26 ml increase in end-diastolic volume and increases of 0.10 ml/m^2 in stroke volume, adjusted for key confounders. A 1-unit increase in DASH eating pattern score was also associated with a 0.04% increase in ejection fraction, but the relationship was marginally significant ($p = 0.08$).

Conclusions—In this population, greater DASH diet consistency is associated with favorable LV function. DASH dietary patterns could be protective against HF.

Keywords

DASH diet; LV function; preclinical heart failure

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INTRODUCTION

Heart failure (HF) is a serious and progressive disorder that often begins with left ventricular (LV) systolic and diastolic dysfunction [1–3]. Subclinical LV dysfunction has been linked to higher rates of HF and is considered a precursor to the development of clinically overt HF [4,5]. Recent HF guidelines emphasize the prevention of HF by targeting its preclinical stages and treating known risk factors that may substantially reduce the risk for HF [6,7]. The effectiveness of dietary modifications in the prevention and treatment of various types of cardiovascular diseases is well recognized [8,9], and dietary patterns similar to the Dietary Approaches to Stop Hypertension (DASH) diet have shown an inverse association with HF [10–12].

The DASH diet emphasizes consumption of fruits, vegetables, whole grains, poultry, fish, nuts, and low-fat dairy products and minimizes consumption of red meat, sweets, and sugar-sweetened beverages. The DASH diet has attracted much attention due to its evidence-based beneficial effects on blood pressure [13–17]. High blood pressure is associated with functional changes in the heart and blood vessels, including impaired LV function [18–20]. Consequently, this suggests that a DASH-type diet could also be of benefit in reducing the risk of LV dysfunction. The potentially beneficial outcomes of consistency with a DASH-type diet on LV functions, including end-diastolic volume, stroke volume, and LV ejection fraction, in a large multiethnic cohort have not been evaluated.

We examined the cross-sectional association between the DASH eating pattern and LV function in the Multi-Ethnic Study of Atherosclerosis (MESA). We hypothesized that greater consistency with the DASH diet would be associated with better LV function, a risk factor considered to be involved in the preclinical stages of HF.

MATERIALS AND METHODS

Participants

The MESA is a population-based sample of 6814 men and women from four ethnic groups (38% white, 28% African American, 22% Hispanic, and 12% Chinese) aged 45–84 years without known clinical cardiovascular disease (CVD) prior to recruitment. A full description of MESA is available elsewhere [21]. Briefly, participants were recruited from 6 US communities: Baltimore City and Baltimore County, MD; Chicago, IL; Forsyth County, NC; Los Angeles County, CA; northern Manhattan and Bronx, NY; and St Paul, MN. The MESA protocols were approved by each field center's institutional review board. Informed consent was obtained from all participants. Exclusion criteria included a self-reported medical history of heart attack, angina, cardiovascular procedures, HF, cerebrovascular disease, active treatment for cancer, or pregnancy. For this cross-sectional analysis, we used baseline data from 2000–2002 and included participants with diet data using the food-frequency questionnaire (FFQ), complete cardiac magnetic resonance imaging (MRI) scans, measures of LV function, and laboratory data.

Dietary Assessment

Usual dietary intake was assessed using a 120-item FFQ [22]. The FFQ was developed in the validated Block format and was based on the FFQ used in the Insulin Resistance Atherosclerosis Study. It has been validated in non-Hispanic white, African American, and Hispanic individuals [23] and later modified for use in the MESA by including Chinese foods and culinary practices [24]. Participants recorded serving size (small, medium, or large) and frequency of consumption of specific beverage and food items. Nine frequency options were given, ranging from “rare or never” to a maximum of “2 × times per day” for foods and a maximum of “6 × times per day” for beverages. Servings per day for each item were calculated as the product of the reported frequency and serving size (small weighted by 0.5, medium by 1.0, and large by 1.50).

DASH Eating Pattern Score

Consistency with the DASH diet was assessed using an established *a priori* index that has been associated with the risk of cardiovascular events in previous epidemiological studies [12,25]. The score comprises individual quintile ranks for 8 food groups: (1) fruits, (2) vegetables, (3) whole grains, (4) nuts and legumes, (5) low-fat dairy products, (6) red meat and processed meats, (7) sweetened beverages, and (8) sodium [12,25]. For favorable food groups (fruits, vegetables, whole grains, nuts and legumes, and low-fat dairy products), the highest quintile is assigned 5 points, and the lowest quintile is assigned 1 point. For unfavorable food groups (red and processed meats, sweetened beverages, and sodium), reverse quintile scoring is applied. Quintile ranks are then summed to obtain a DASH eating-pattern component score (theoretical range, 8–40). Higher scores indicate greater consistency with the DASH diet.

Left Ventricular Function Assessments

Cardiac MRI was performed using 1.5-Tesla magnets at each center. The MESA MRI protocol has been described in detail elsewhere [26]. Briefly, imaging was performed with a 4-element, phased-array surface coil placed anteriorly and posteriorly, electrocardiogram gating, and brachial artery blood pressure monitoring. Cine MRI of the heart with temporal resolution ≤50 milliseconds was used to determine LV functional parameters, with imaging data analyzed using commercially available software (MASS, version 4.2; Medis, Leiden, The Netherlands) by MESA-trained readers at a single reading center. End-systolic volume and end-diastolic volume were measured. Stroke volume was defined as end-diastolic volume minus end-systolic volume. Stroke volume was indexed according to body surface area (BSA). BSA (m^2) was calculated as 0.20247 × height $(m)^{0.725}$ × weight $(kg)^{0.425}$ [26]. LV ejection fraction was defined as (stroke volume / end-diastolic volume) × 100. The interreader intraclass correlation coefficients were 0.98 for end-diastolic volume, 0.94 for stroke volume, and 0.81 for ejection fraction [26].

Covariates

Standardized questionnaires and calibrated devices were used to obtain personal characteristics, including gender, age, education level, race/ethnicity, body mass index (BMI; calculated as weight in kilograms divided by height in meters squared), cigarette smoking (none, former, and current), total daily energy intake, alcohol intake (grams of ethanol per day), moderate/vigorous physical activity (moderate/vigorous metabolic equivalent tasks per minute per week), medical conditions, and current prescription medication usage. Resting seated blood pressure was measured three times using a Dinamap automated oscillometric sphygmomanometer (model Pro 100; Critikon, Tampa, FL); the last two measurements were averaged for analysis. Fasting blood glucose and lipids were analyzed at a central laboratory. Individuals were considered to have diabetes if they replied yes to the question "Has a doctor ever told you that you had diabetes?" and/or the medication inventory included hypoglycemic drugs or if fasting blood glucose was ≥7.0 mmol/l (126 mg/dl).

Statistical Analysis

Descriptive statistics were used to describe the study sample. Baseline characteristics were reported as mean ± SD unless otherwise stated. We examined participant characteristics and LV indices by quintiles of the DASH eating pattern score. A χ^2 statistic was used to examine differences in categorical variables. Tests for linear trend were conducted by entering the median value in each quintile of the DASH score and modeling them as a continuous predictor. Partial correlations adjusted for gender, age, educational level, and race/ethnicity were used to determine relationships between individual DASH food group components and LV functional parameters.

A series of multiple regression models were used to estimate the independent relationship between the DASH eating pattern as the primary predictor and each of the LV functional parameters as the outcomes. Model 1 was adjusted for demographic variables (gender, age, and educational level); CVD risk factors (BMI, cigarette smoking, high-density lipoprotein [HDL] cholesterol, low-density lipoprotein [LDL] cholesterol, diabetes mellitus, and systolic blood pressure); clinical variables (use of diabetes medications and use of blood pressure-lowering medications); and lifestyle factors (alcohol intake and physical activity). Model 2 included all factors from Model 1 and added energy intake to reduce measurement error in the assessment of dietary factors included in the DASH eating pattern score. Model 3 included all components of Model 2 and additionally adjusted for race/ethnicity to test whether it explained the associations of LV function with the DASH eating pattern. Model 1 also initially included interaction terms between the DASH eating pattern with gender, age, and educational level. We found no statistically significant interactions, and therefore, no interaction terms were included in the analysis. In sensitivity analyses, we examined the robustness of results by excluding participants with baseline diabetes mellitus. These individuals may receive nutrition counseling and may influence diet reporting and confound the observed dietary effects. Results in those with diabetes were not different when compared with those in the total sample. Hence, we report results for the total sample. Statistical analysis was performed using SAS 9.1 (SAS Institute, Inc, Cary, NC).

RESULTS

Of the 6814 MESA participants, 5004 (73%) agreed to undergo MRI and had technically adequate cardiac MRI data. We also excluded 253 individuals on the basis of extreme total energy intakes (<600 or >6000 kcal/d) to reduce measurement error in the DASH eating pattern score. This sample of 4751 was further reduced to the 4507 participants who completed the FFQ and had complete laboratory data. Compared with those who were excluded, those included were about 2 years younger, had lower systolic blood pressure (4.3 mm Hg lower), and were less likely to have treated hypertension (7.0% less) or diabetes (3.0% less). There were a total of 2394 women and 2172 men in the present cross-sectional analysis. They had a mean age of 61.6 years; 40% were white, 14% were Chinese American, 24% were African American, and 22% were Hispanic American.

Participant characteristics and LV function by quintiles of the DASH eating pattern score are presented in Table 1. The observed range of the DASH eating pattern score was 11 to 39. There were significant differences in gender, age, education, race/ethnicity, smoking status, alcohol intake, and use of blood pressure-lowering medications across quintiles of the DASH eating pattern score. Participants in the higher quintiles of the DASH eating pattern score generally had lower BMIs, lower energy intakes, and higher HDL concentrations. Significant linear trends were observed in mean end-diastolic volume, stroke volume, and ejection fraction across quintiles of the DASH eating pattern score. We examined partial correlations (adjusted for gender, age, educational level, and race/ethnicity) between individual DASH components and LV parameters (Table 2). Although many of the individual DASH components showed some associations with LV indices, the correlations were entirely of small magnitude.

Table 3 presents the association between DASH eating pattern and LV function. Consistency with DASH diet was significantly associated with end-diastolic volume and stroke volume, adjusted for gender, age, educational level, BMI, cigarette smoking, HDL cholesterol, LDL cholesterol, diabetes mellitus, systolic blood pressure, use of diabetes medications, use of blood pressure-lowering medications, alcohol intake, and physical activity (Model 1). A 1-unit increase in the DASH eating pattern score was associated with a 0.31 ml increase in end-diastolic volume and increases of 0.12 ml/m^2 in stroke volume. Further adjusting for energy intake (Model 2) and race/ethnicity (Model 3) did not alter these relationships. In the full model adjusted for race/ethnicity, a 1-unit increase in the DASH eating pattern score was associated with a 0.04% increase in ejection fraction, but the relationship was marginally significant ($p = 0.08$).

DISCUSSION

The MESA study is the first epidemiologic study that has used cardiac MRI in a large ethnically diverse cohort to study the relationship between DASH eating pattern and LV function. Greater consistency with DASH diet was associated with favorable end-diastolic volume, stroke volume, and ejection fraction, adjusting for potential confounders. Results are consistent with previous studies that have yielded positive or at least encouraging data supporting DASH diet consistency and lower rates of HF and other cardiovascular events [12,13,27]. These results suggest that DASH-type diets represent a potentially effective strategy to reduce the incidence of HF.

We find that end-diastolic volume, stroke volume, and ejection fraction all are in a beneficial direction with respect to HF. LV function, particularly decreased end-diastolic volume, has been described as an independent risk factor for the future development of HF and cardiac death [28–30]. The relationship between ejection fraction and incident HF has not been studied extensively, specifically in individuals without prevalent cardiovascular disease at enrollment. Our study participants had no known cardiovascular disease at baseline, and ejection fraction in this asymptomatic group has not been predictive of HF [31]. Despite the high relative risk of LV dysfunction, the actual risk of this for HF depends on multiple parameters, especially long-standing hypertension, and other factors such as age, gender, clinical coronary heart disease, and heart rate [30,32]. Furthermore, the general applicability of our results regarding the association of LV function with HF may be limited because we focus on early subclinical changes in LV function linked to the DASH diet. Nonetheless, the HF practice guidelines have emphasized the efficacy of therapy to prevent or delay the progression of preclinical LV dysfunction to HF [6].

The potentially beneficial association between the DASH diet and LV parameters (and HF) may be the result of some of its food components such as fruits and vegetables, nuts and legumes, and low intake of sodium. For example, the gradual reduction in CVD risks (1.0, 0.78, 0.72, 0.68, and 0.68) for increasing quintiles of total fruit and vegetable intake suggested a possible dose-response effect [33]; there is a reduced risk (range, 0.43 to 0.82) of coronary heart disease for individuals who consumed nuts more than 5 times/week compared with no consumption [34,35]; and a low sodium-DASH diet was associated with lowering of systolic and diastolic blood pressures [13,18]. Hence, individual food components of the DASH diet can substantially prevent and control high blood pressure and associated CVD. However, numerous studies now suggest the examination of composite dietary patterns such as the DASH diet in order to capture food dimensions that may be missed by single nutrients but also to overcome potential interactions and intercorrelations among single nutrients and foods [17,36,37]. Additionally, in a partial correlation analysis adjusting for gender, age, education, and race/ethnicity, we found small-magnitude correlations between individual components of the DASH diet and LV function. Our finding shows little support for the association between individual components of the DASH diet and LV function in this cohort without clinical cardiovascular disease.

The analysis is one of the first large-scale investigations of the potentially beneficial outcomes of consistency with a DASH-type diet on LV function in a multiethnic cohort, increasing the external validity of the findings. LV function was precisely determined by MRI. Measures for multiple potential confounders were assessed with standardized questionnaires and calibrated devices and adjusted for in the analyses. Dietary data were assessed with a widely used instrument that has been validated in minority populations. We examined a composite dietary pattern, the DASH diet, that has been found to be effective in reducing clinic-measured blood pressure [13,16], lowering plasma levels of total cholesterol and LDL cholesterol [38], and cardiovascular biomarkers of risk such as pulse wave velocity and baroreflex sensivitity [39].

Findings are limited by the cross-sectional design and therefore cannot address the temporal relation between dietary intake and LV function. Future prospective studies are needed to confirm these results. The effects of DASH eating pattern on LV function may constitute an acceptable basis for estimating potential impact of future HF events. However, previous studies suggest that intermediate variables may not suffice to confidently project hard end points. For example, the Lyon Diet Heart Study revealed that plasma lipids, as intermediate variables, could not explain the absolute risk of CVD conferred by the Mediterranean diet [40]. Other studies documented the absolute risk of coronary heart disease that varied substantially at the same level of plasma cholesterol, possibly due to differences in dietary habits [41,42]. Our study of LV function may be useful in understanding the mechanistic pathways of DASH diet benefits, but future studies are needed to evaluate the impact of DASH diet on LV function and subsequent hard clinical end points including HF. Finally, as in any observational study, concern remains about residual confounding, despite our controlling for CVD risk factors and lifestyle factors.

CONCLUSION

In summary, this study finds associations of end-diastolic volume, stroke volume, and ejection fraction with greater consistency with the DASH diet, emphasizing fruits, vegetables, whole grains, poultry, fish, nuts, and low-fat dairy products while reducing consumption of red meat, sweets, and sugar-sweetened beverages. Our cross-sectional study provides an opportunity to examine preclinical stages of HF as mechanistic pathways of DASH diet benefits. Ultimately, future prospective studies are needed to determine the association between DASH dietary exposures and heart failure.

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Abbreviations

CVD	cardiovascular disease
DASH	Dietary Approaches to Stop Hypertension
FFQ	food-frequency questionnaire
HF	heart failure
LV	left ventricular
MESA	Multi-Ethnic Study of Atherosclerosis
MET	metabolic equivalent tasks
MRI	magnetic resonance imaging
Q	quintile
SD	standard deviation

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Table 1

Participant Characteristics and LV Function by Quintiles of the DASH Eating Pattern Score

	DASH Eating Pattern Score					
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	***p* value**
Range	11–21	22–24	25–26	27–29	30–39	
Categorical variables[a] (%)						
Female	38.9	43.0	53.5	56.3	67.9	<0.001
White	33.9	34.3	42.6	43.9	50.4	<0.001
Chinese American	9.9	18.7	14.6	13.9	10.6	
African American	32.7	23.0	22.0	21.5	18.4	
Hispanic American	23.4	24.0	20.7	20.7	20.6	
College graduate or more	29.5	37.2	41.2	42.1	46.3	<0.001
Current smokers	22.8	13.7	11.4	8.3	3.8	<0.001
Diabetes mellitus	10.3	13.7	11.0	11.0	10.7	0.140
Use of diabetes drugs	7.9	10.2	8.5	8.4	8.4	0.509
Use of blood pressure drugs	32.1	34.3	33.4	37.0	39.2	<0.05
Continuous variables[b]						
Age (y)	58.4 ± 9.5[c]	60.5 ± 9.8	61.3 ± 10.2	63.2 ± 10.2	64.8 ± 9.9	<0.001
BMI	28.5 ± 5.3	27.7 ± 4.9	27.6 ± 4.6	27.5 ± 4.8	26.8 ± 4.5	<0.001
Alcohol intake (ethanol, g/d)	6.9 ± 16.8	5.6 ± 14.3	5.1 ± 10.3	4.9 ± 10.5	4.1 ± 9.3	<0.001
Total daily energy intake (kcal)	1712.0 ± 759.0	1547.0 ± 769.0	1569.7 ± 800.3	1498.9 ± 741.3	1453.9 ± 678.5	<0.001
Physical activity (MET min/wk)	6384.6 ± 7172.1	5568.7 ± 5469.9	5411.6 ± 5172.3	5689.5 ± 5944.9	5851.6 ± 5590.4	<0.01
LDL cholesterol (mg/dl)	119.2 ± 31.1	116.0 ± 30.2	117.2 ± 31.4	116.6 ± 32.3	115.2 ± 30.0	0.275
HDL cholesterol (mg/dl)	49.0 ± 14.2	49.1 ± 13.7	51.3 ± 15.3	51.9 ± 15.0	54.9 ± 15.6	<0.001
Systolic blood pressure (mmHg)	124.4 ± 20.3	124.9 ± 21.3	124.8 ± 20.9	125.1 ± 20.5	127.3 ± 22.4	<0.05
End-diastolic volume (ml)	131.2 ± 31.8	129.3 ± 33.4	126.4 ± 30.6	125.3 ± 30.7	119.8 ± 28.7	<0.001
Stroke volume/BSA (ml/m^2)	88.3 ± 20.4	87.3 ± 20.7	86.2 ± 18.9	86.6 ± 19.8	83.8 ± 18.7	<0.001
LV ejection fraction (%)	67.9 ± 7.3	68.3 ± 8.1	69.0 ± 7.3	69.7 ± 7.2	70.5 ± 6.8	<0.001

[a] χ^2 test.

[b] Test for trend across quintiles of the DASH eating pattern score.

[c]Mean ± SD (all such values).

Table 2

Partial Correlation Coefficients between Individual Components of the DASH Diet and LV Function in the Multi-Ethnic Study of Atherosclerosis: 2000–2002 (n = 4507)[1]

	LV Function Parameters		
DASH Components	**End-Diastolic Volume**	**Stroke Volume**	**LV Ejection Fraction**
Fruits	0.03[4]	0.05[3]	0.02
Vegetables	−0.03	−0.01	0.03[4]
Whole grains	0.08[2]	0.07[2]	−0.02
Nuts/legumes	−0.02	−0.01	0.02
Low-fat dairy	0.05[4]	0.05[2]	0.01
Meats	0.03[4]	0.02	−0.02
Sweetened beverages	0.03	0.01	−0.04[4]
Sodium	0.04[2]	0.04[3]	−0.04[4]

[1]Partial correlation coefficients were adjusted for gender, age, educational level, and race/ethnicity.

[2]$p < .001$.

[3]$p < .01$.

[4]$p < .05$.

Table 3

Associations of DASH Eating Pattern Score with LV Function in 4507 Participants in the Multi-Ethnic Study of Atherosclerosis

	End-Diastolic Volume		Stroke Volume		LV Ejection Fraction	
	β (SE)	***p* Value**	**β (SE)**	***p* Value**	**β (SE)**	***p* Value**
Crude	−0.77 (0.09)	<0.001	0.06 (0.02)	<0.05	0.20 (0.02)	<0.001
Model 1*	0.31 (0.08)	<0.001	0.12 (0.03)	<0.001	0.03 (0.02)	0.15
Model 2†	0.31 (0.08)	<0.001	0.12 (0.03)	<0.001	0.03 (0.02)	0.15
Model 3‡	0.26 (0.08)	<0.01	0.10 (0.03)	<0.001	0.04 (0.02)	0.08

SE = standard error.

* Adjusted for gender, age, educational level, BMI, cigarette smoking, HDL cholesterol, LDL cholesterol, diabetes mellitus, systolic blood pressure, use of diabetes medications, use of blood pressure-lowering medications, alcohol intake, and physical activity.

† Adjusted for Model 1 plus energy intake.

‡ Adjusted for Model 2 plus race/ethnicity.