Consistency With the DASH Diet and Incidence of Heart Failure

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Background: The Dietary Approaches to Stop Hypertension (DASH) diet effectively reduces blood pressure. In observational studies, the association between diets consistent with DASH and risk of coronary heart disease and stroke has been examined with varying results. We hypothesized that diets consistent with the DASH diet would be associated with a lower incidence of heart failure (HF).

Methods: We conducted a prospective observational study in 36,019 participants in the Swedish Mammography Cohort who were aged 48 to 83 years and without baseline HF, diabetes mellitus, or myocardial infarction. Diet was measured using food-frequency questionnaires. We created a score to assess consistency with the DASH diet by ranking the intake of DASH diet components and 3 additional scores based on food and nutrient guidelines. Cox proportional hazards models were used to calculate rate ratios of HF-associated hospitalization or death, determined using the Swedish inpatient and cause-of-death registers between January 1, 1998, and December 31, 2004.

Results: During 7 years, 443 women developed HF. Women in the top quartile of the DASH diet score based on ranking DASH diet components had a 37% lower rate of HF after adjustment for age, physical activity, energy intake, education status, family history of myocardial infarction, cigarette smoking, postmenopausal hormone use, living alone, hypertension, high cholesterol concentration, body mass index (calculated as weight in kilograms divided by height in meters squared), and incident myocardial infarction. Rate ratios (95% confidence intervals) across quartiles were 1 [Reference], 0.85 (0.66-1.11), 0.69 (0.54-0.88), and 0.63 (0.48-0.81); \( P_{\text{trend}} < .001 \). A similar pattern was seen for the guideline-based scores.

Conclusion: In this population, diets consistent with the DASH diet are associated with lower rates of HF.

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Although dietary patterns and food choices have been associated with risk factors for heart failure (HF), little is known about whether diet may help prevent or delay HF. A recent American Heart Association scientific statement stresses the importance of preventing HF with medical treatment and lifestyle interventions that target HF risk factors including the Dietary Approaches to Stop Hypertension (DASH) diet. The DASH diet may contribute to prevention of HF in some cases because it effectively reduced blood pressure and low-density lipoprotein cholesterol levels in clinical trials. This diet features high intake of fruits, vegetables, low-fat dairy products, and whole grains, resulting in high potassium, magnesium, calcium, and fiber consumption, moderately high protein consumption, and low total and saturated fat consumption. The National Heart, Lung, and Blood Institute has made public recommendations on food and nutrient intake for the prevention and treatment of hypertension based on the DASH diet. However, trials of the diet have not been of sufficient duration to determine the overall effect on cardiovascular events.

In a recent observational study by Fung et al, women with the highest values of a score designed to measure consistency with DASH had a 24% lower risk of coronary heart disease and an 18% lower risk of stroke. Using a different DASH score, Folsom et al did not find statistically significant associations with cardiovascular events. However, women with diets most consistent with DASH had an 18% lower rate of death from coronary heart disease and a 14% lower rate of death from stroke, which is similar to the projected effect from the DASH trial.

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We hypothesized that diets consistent with the DASH diet would be associated with lower rates of HF. We constructed 4 scores to assess consistency with the DASH diet, 2 patterned on previously published scores, a score based on food intake recommendations, and a score based on nutrient intake recommendations. We examined the associations between the DASH...
diet scores and incident HF in a population of women who were middle aged or older.

METHODS

STUDY POPULATION

The present study included 36,019 women who participated in the Swedish Mammography Cohort. The recruitment process, characteristics, and study methods in this population-based cohort have been previously described. The Swedish Mammography Cohort includes women born between 1914 and 1948 living in Västmanland and Uppsala counties in central Sweden who completed questionnaires between September 1997 and January 1998 with items on demographic, behavioral, and anthropometric data and consumption of foods and beverages. Participants who did not provide or provided incorrect national identification numbers, who reported implausible energy intakes (>3 SDs from the natural logarithm-transformed mean), who had a previous diagnosis of cancer other than nonmelanoma skin cancer, or who did not complete more than half of the food and beverage items were excluded from our study. In addition, for these analyses, participants who at baseline had a history of HF, myocardial infarction (MI), or diabetes mellitus were excluded. Participants with baseline MI or diabetes were excluded because individuals who develop these diseases receive dietary counseling and may change both their diet and their reporting of diet. History of HF and MI were determined using linkage to the inpatient register, and history of diabetes was assessed using self-report and linkage to the inpatient register. The study was approved by the Regional Ethical Review Board at Karolinska Institute, Stockholm, Sweden. Completion and return of the self-administered questionnaire was assumed to imply consent.

DIET ASSESSMENT AND DASH DIET SCORES

Self-administered food-frequency items in questionnaires asked participants to report usual frequency of consumption of 96 foods and beverages during the previous year. For foods and beverages such as cheese and bread and milk and coffee, which are commonly consumed in Sweden, participants reported their consumption in servings per day or per week. For other foods, there were 8 predefined responses ranging from never to 3 times per day or more. Portion sizes for most foods were not specified. In validation studies using weighed diet records, habitual portion sizes were found to vary by age. The total consumption of foods and beverages was calculated by multiplying the frequency of consumption by age-specific portion sizes. To make the food intake data comparable to US dietary recommendations, we standardized portion sizes to those used in the United States. Nutrient values were calculated using food composition data from the Swedish National Food Administration.

The first score (DASH diet component score) was based on one proposed by Fung et al that ranked participants on intake of fruits, vegetables, nuts and legumes, low-fat dairy products, whole grains, sodium, sweetened beverages, and red and processed meats. Participants in the highest quintile of fruits, vegetables, nuts and legumes, low-fat dairy products, and whole grains received a score of 5, and those in the lowest quintile received a score of 1. Participants in the highest quintile of sodium, sweetened beverages, and red and processed meats received a score of 1, and those in the lowest quintile received a score of 5. The scores for each component were summed to yield the overall score.

The second score (food and nutrient recommendations) was constructed based on one proposed by Folsom et al with a combination of food and nutrient guidelines: fruits, vegetables, nuts and legumes, dairy products, total grains, whole grains, sodium, sweets, meats, total fat, and saturated fat. Participants could receive 0, ½, or 1 point for each component.

The third score (food recommendations) was based on the guidelines for fruits; vegetables; nuts, seeds, and legumes; low-fat dairy products; total grains; whole grains; sweets and added sugars; lean meats, poultry, and fish; fats and oils, and alcoholic beverages. The guidelines state that the most grain servings should be whole grain; we defined the whole-grain target as half the recommended total number of grain servings. For total grain; dairy; lean meats; and nuts, seed, and legumes, the maximum score received was for consumption near the guidelines, with partial points for consuming more or less depending on the percentage of deviation. For vegetables, fruits, and whole grains, participants received 1 point for eating at least as many servings as recommended, and partial points for less consumption. For sweets and for fats and oils, participants received full points for consumption of no more than the recommended levels, and partial points for more consumption. Participants received full points for alcohol consumption of 2 drinks per day or fewer, and no points for more than 2 drinks per day.

The final score (nutrient recommendations) was based on the guidelines for nutrients: total fat, saturated fat, protein, carbohydrate, cholesterol, sodium, potassium, calcium, magnesium, and fiber. Participants received a maximum of 1 point for consumption of total fat, saturated fat, protein, and carbohydrate near energy-level specific guidelines. Participants received 1 point for cholesterol and sodium consumption less than or equal to the guideline, and fewer points for exceeding the guideline depending on the percentage exceeded. Participants received 1 point for potassium, calcium, magnesium, and fiber consumption meeting or exceeding the energy-level specific guidelines, and partial points for less consumption.

HF FOLLOW-UP

Participants were followed up from January 1, 1998, to December 31, 2004, using linkage to the Swedish inpatient and cause-of-death registers. The inpatient register captures more than 99% of inpatient care. Hospitalization for or death from HF was identified by codes 428 (International Classification of Diseases, Ninth Revision) or I50 or I11.0 (International Classification of Diseases, Tenth Revision). A previous study found that 95% of individuals with these codes as primary diagnosis in the inpatient register had HF on medical record review using European Society of Cardiology criteria. We included only hospitalizations or deaths with HF listed as the primary diagnosis and only the first HF event recorded in the registers for each individual. Incident MI during follow-up was also assessed using the inpatient register.

STATISTICAL ANALYSIS

Because some participants had missing data on body mass index (calculated as weight in kilograms divided by height in meters squared) (1.6%) and physical activity (22.1%), we used Markov chain Monte Carlo multiple imputation to simulate 5 complete data sets. All statistical analyses described except for the penalized spline were performed in each of the data sets separately. The results were averaged, and 95% confidence intervals (CIs) and P values were calculated accounting for the uncertainty of the imputed estimates. Results from the complete case analyses were similar, although done with wider CIs; only the multiple imputation analyses are presented.
Table 1. DASH Diet Scores, Nutrient Intake, and Food Intake

<table>
<thead>
<tr>
<th>Variable</th>
<th>DASH Diet Component Score</th>
<th>Food and Nutrients</th>
<th>Food</th>
<th>Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlations with other scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DASH diet component score</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food and nutrient recommendations</td>
<td>0.60</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food recommendations</td>
<td>0.57</td>
<td>0.44</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Nutrient recommendations</td>
<td>0.61</td>
<td>0.68</td>
<td>0.46</td>
<td>1</td>
</tr>
</tbody>
</table>

Mean nutrient intake in Q1 and Q4^a (2-sided) was considered statistically significant.

Abbreviations: DASH, Dietary Approaches to Stop Hypertension Study; Q, quartile.
^aNutrients (except alcohol) were adjusted for energy intake using the residuals method.

**RESULTS**

The DASH diet scores were moderately correlated with each other (9 = 0.44-0.68) (Table 1). Women in the top quartile of the DASH component score ate, on average, 3.0 servings of fruit, 3.5 servings of vegetables, 3.1 servings of whole grains, 1.6 servings of low-fat dairy products, 0.1 servings of sweetened beverages, and 0.8 servings of red or processed meat per day. In comparison, women in the bottom quartile of the score ate, on average, 1.4 servings of fruit, 1.8 servings of vegetables, 3.3 servings of whole grains, 0.6 servings of low-fat dairy products, 0.4 servings of sweetened beverages, and 1.3 servings of red or processed meat per day. For all of the DASH scores, higher scores seemed to be associated with food and nutrient intake patterns that were closer to the DASH diet than were lower scores.

During 7 years of follow-up, 443 of 36,019 women developed HF (415 hospitalizations and 28 deaths with HF as the primary diagnosis), corresponding to a rate of 18.1 per 10,000 women per year. Participants who developed HF tended to be older and to have a higher body mass index, and were more likely to be current smokers and to have a history of hypertension and high cholesterol concentration (Table 2).

After controlling for potential confounders, the score based on ranking participant intake of DASH diet com-
We used 4 different approaches to create diet scores to assess consistency with the DASH diet. We found a 37% lower rate of HF in the 25% of women whose diets were closest to the DASH diet as assessed by ranking intake of key components of the diet; a similar pattern was observed with the other scores.

Although the association between the DASH diet and HF is unknown, several observational studies have examined other cardiovascular outcomes. Fung et al found statistically significant associations between a DASH diet score and incidence of coronary heart disease and stroke. Folson et al found that a different DASH diet score was not statistically significantly associated with incident hypertension or death from coronary heart disease, stroke, or cardiovascular disease, although there was a trend toward decreased risk. In a cross-sectional analysis, in individuals in the top quartile of a DASH diet score that measured intake of fruits, vegetables, and dairy, systolic blood pressure was 1.5 mm Hg lower and diastolic blood pressure was 1.4 mm Hg lower. After a mean of 5.4 years of follow-up, blood pressure in those in the top quartile of the DASH score had increased less than in those with lower DASH scores. The PREMIER trial of multiple lifestyle interventions showed that a DASH adherence index based on intake of fruits and vegetables, dairy, and percentage of calories from saturated fat was associated with lower systolic blood pressure; however, the association was not statistically significant after controlling for weight change.

In a nationally representative study of US adults, a nutrient-based DASH score was associated with older age, a diagnosis of diabetes, and higher education status.

In the present study, the DASH score based on ranking components of diet was a stronger predictor of HF than were other scores that were based on absolute intake. A likely explanation for this is that the food-frequency questionnaire method is designed to rank individuals’ dietary intake rather than determine absolute intake. Although studies of cardiovascular outcomes in the Swedish Mammography Cohort are limited, a healthy dietary pattern constructed using factor analysis and characterized by high intake of fruit, vegetables, whole grains, and legumes, similar to the DASH diet, was associated with a reduced rate of MI.

Research into diet and HF has not been studied adequately to date; however, the relationship between several components of the DASH diet and HF have been investigated in human and animal studies. In prospective studies of free-living individuals, daily consumption of whole-grain breakfast cereals was associated with a 30% lower rate of HF compared with no consumption, consumption of eggs more than twice per day was associated with a 64% higher rate of HF, and daily consumption of 100 mmol/d or more of sodium was associated with a 26% higher rate of HF; nut consumption was not associated with rate of HF. In rat models of HF, macronutrient intake modified the course of cardiac dysfunction. High-fat diets reduced cardiac remodeling and contractile dysfunction; however, animals fed diets high in linoleic acid survived longer than those fed diets high in carbohydrates or lard. When high-starch, high-fructose, and high-fat diets were compared, animals fed the high-fructose diet demonstrated more cardiac remodeling and worse survival.

In the DASH randomized trial of 459 adults with normal or modestly elevated blood pressure, after 2 months with the DASH diet, mean systolic blood pressure was reduced by 5.5 mm Hg and mean diastolic blood pressure was reduced by 3.0 mm Hg. A second trial demonstrated...
that sodium restriction for 1 month led to further reduction in blood pressure. The DASH diet also reduced the low-density lipoprotein cholesterol concentration, which would tend to decrease risk of cardiovascular disease; however, it decreased the high-density lipoprotein cholesterol concentration and may have increased triglyceride levels. Based on data from the Framingham Heart Study, the decrease in systolic blood pressure of 5.5 mm Hg observed in the DASH diet trial might be expected to reduce the rate of HF by approximately 12%.

In addition to the effect on blood pressure, several potential beneficial physiologic effects of the DASH diet have been outlined including estrogenic effects of phytochemicals and decreased oxidative stress. Overabundance of circulating fatty acids and glucose caused by poor diet quality may mediate the association between diet and HF through decreased mechanical efficiency of the heart, increased myocardial triglyceride content, cardiac hypertrophy and fibrosis, and perturbed mitochondrial function.

Because the DASH diet is recommended to the public for the prevention and treatment of hypertension, a metric to measure adherence to this diet may be useful in clinical practice. The scores presented in this study were derived from semiquantitative food-frequency questionnaires, which may be too burdensome for routine clinical use. A shorter instrument may be more useful in this setting but would require validation.

The rate of HF-associated hospitalization or death in this study (18.1 cases per 10,000 women per year) was similar to the age-standardized rate in Sweden as a whole.

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Table 3. Association of DASH Scores With Incident Heart Failure

<table>
<thead>
<tr>
<th>DASH Diet Score</th>
<th>Quartile 1</th>
<th>Quartile 2</th>
<th>Quartile 3</th>
<th>Quartile 4</th>
<th>P Valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>DASH diet component score</td>
<td>9.22-23.24</td>
<td>23.25-25.27</td>
<td>25.28-28.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of cases</td>
<td>162</td>
<td>87</td>
<td>105</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>Person-years</td>
<td>68,296</td>
<td>44,213</td>
<td>66,395</td>
<td>66,231</td>
<td></td>
</tr>
<tr>
<td>Model 1 RR (95% CI)b</td>
<td>1 [Reference]</td>
<td>0.85 (0.86-1.11)</td>
<td>0.89 (0.94-0.88)</td>
<td>0.83 (0.48-0.81)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Model 2 RR (95% CI)c</td>
<td>1 [Reference]</td>
<td>0.88 (0.67-1.19)</td>
<td>0.74 (0.58-0.94)</td>
<td>0.88 (0.62-1.03)</td>
<td>.06</td>
</tr>
</tbody>
</table>

Food and nutrient recommendations

| Range          | 0.5-4.0 | 4.5-4.5 | 5.0-5.5 | 6.0-10.5 |          |
| No. of cases   | 138     | 73      | 126     | 106      |          |
| Person-years   | 69,665  | 38,495  | 77,090  | 59,983   |          |
| Model 1 RR (95% CI)b | 1 [Reference] | 0.82 (0.94-1.23) | 0.73 (0.60-0.97) | 0.63 (0.49-1.01) | .12     |
| Model 2 RR (95% CI)c | 1 [Reference] | 0.83 (0.88-1.08) | 0.69 (0.50-0.95) | 0.80 (0.61-1.07) | .01     |

Nutrient recommendations

| Range          | 2.0-4.7 | 4.8-5.0 | 5.5-6.1 | 6.2-9.5 |          |
| No. of cases   | 157     | 100     | 105     | 81      |          |
| Person-years   | 60,666  | 61,308  | 61,453  | 61,708  |          |
| Model 1 RR (95% CI)b | 1 [Reference] | 0.71 (0.55-0.92) | 0.78 (0.61-1.00) | 0.69 (0.53-0.90) | .008    |
| Model 2 RR (95% CI)c | 1 [Reference] | 0.70 (0.55-0.91) | 0.76 (0.59-0.98) | 0.69 (0.52-0.90) | .007    |

Abbreviations: CI, confidence interval; DASH, Dietary Approaches to Stop Hypertension [Study]; RR, rate ratio.

aP for linear trend.
bModel 1: Cox proportional hazards models with baseline hazard allowed to vary by age.
cModel 2: Model 1 additionally adjusted for physical activity (linear), energy intake (linear), education status (< high school, high school, or university), family history of myocardial infarction at age younger than 60 years (yes or no), cigarette smoking (current, past, or never), living alone (yes or no), postmenopausal hormone use (yes or no), self-reported history of hypertension and high cholesterol concentration, body mass index (linear), and incident myocardial infarction (time varying: no myocardial infarction, myocardial infarction in the previous year, or myocardial infarction > 1 year previously).

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Figure 1. Rate of heart failure. The solid line represents the incidence rate ratio of heart failure, and dashed lines represent 95% confidence intervals. Penalized cubic splines with 3 d.f. were used to flexibly model the shape of the association. Cox proportional hazards models that enable the baseline hazard to vary by age and adjusted for physical activity (linear), education status (less than high school, high school, or university), family history of myocardial infarction before age 60 years (yes or no), cigarette smoking (current, past, or never), living alone (yes or no), postmenopausal hormone use (yes or no), self-reported history of hypertension and high cholesterol concentration, body mass index (linear), and incident myocardial infarction (time varying: no myocardial infarction, myocardial infarction in the previous year, or myocardial infarction more than 1 year previously). DASH indicates Dietary Approaches to Stop Hypertension [Study].
Cardiovascular Health Study (146 cases per 10 000 women per year); however, 44% of the patients in Olmsted County were not hospitalized at the time of diagnosis and the Cardiovascular Health Study participants were all aged 65 years or older (mean age, 73 years) at enrollment.37,38 In the present study, rates of HF were higher in women with major risk factors for HF including older age, cigarette smoking, and hypertension, as expected.

There are several important limitations of this study. Heart failure is a heterogeneous syndrome, and risk factors may not be identical for all HF subtypes.39 We were unable to determine the cause or subtype of HF. Although Swedish inpatient and cause-of-death registers are almost complete and the accuracy of HF diagnosis is high,13,40 the registers capture only cases of HF that result in hospitalization or death. Therefore, our results may not be generalizable to less severe cases of HF treated exclusively on an outpatient basis. In addition, this study did not include populations with known high rates of hypertensive heart disease and HF, for example, African Americans.1 Hypertension was measured by self-report, which is inherently less reliable than clinical measurement. The DASH diet scores have not been validated against an external standard, however, the food-frequency questionnaire used in this population has been validated against diet records and 24-hour recall.41 Correlations between food-frequency questionnaires and diet records ranged between 0.5 and 0.7 for fruit items,42 0.4 and 0.6 for vegetable items,42 0.5 and 0.7 for whole grain items,43 0.4 and 0.6 for dairy items,44 and 0.6 for sweetened beverages.45 Using food-frequency questionnaires resulted in some exposure misclassification. If the misclassification of diet was unrelated to HF incidence, the results would likely be biased toward the null. However, this assumption was not verifiable with available data. In conclusion, greater consistency with the DASH diet as measured using food-frequency questionnaires was associated with lower rates of HF in middle-aged and elderly women living in Sweden.

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Author Contributions: Dr Wolk had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Levitan, Wolk, and Mittleman. Acquisition of data: Wolk. Analysis and interpretation of data: Levitan, Wolk, and Mittleman. Drafting of the manuscript: Levitan. Critical revision of the manuscript for important intellectual content: Wolk and Mittleman. Statistical analysis: Levitan and Mittleman. Obtained funding: Levitan and Wolk. Study supervision: Wolk and Mittleman.

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REFERENCES

Blood Pressure With DASH. Rockville, MD: National Heart, Lung, and Blood Institute, National Institutes of Health; 2006.
34. Most MM. Estimated phytochemical content of the Dietary Approaches to Stop Hypertension (DASH) diet is higher than in the Control Study Diet. J Am Diet Assoc. 2004;104(11):1725-1727.