Chocolate Intake and Incidence of Heart Failure
A Population-Based Prospective Study of Middle-Aged and Elderly Women

Elizabeth Mostofsky, MPH; Emily B. Levitan, ScD; Alicja Wolk, DrMedSci; Murray A. Mittleman, MD, DrPH

Background—Randomized clinical trials have shown that chocolate intake reduces systolic and diastolic blood pressure, and observational studies have found an inverse association between chocolate intake and cardiovascular disease. The aim of this study was to investigate the association between chocolate intake and incidence of heart failure (HF).

Methods and Results—We conducted a prospective cohort study of 31 823 women aged 48 to 83 years without baseline diabetes or a history of HF or myocardial infarction who were participants in the Swedish Mammography Cohort. In addition to answering health and lifestyle questions, participants completed a food-frequency questionnaire. Women were followed from January 1, 1998, through December 31, 2006, for HF hospitalization or death through the Swedish inpatient and cause-of-death registers. Over 9 years of follow-up, 419 women were hospitalized for incident HF (n=379) or died of HF (n=40). Compared with no regular chocolate intake, the multivariable-adjusted rate ratio of HF was 0.74 (95% CI, 0.58 to 0.95) for women consuming 1 to 3 servings of chocolate per month, 0.68 (95% CI, 0.50 to 0.93) for those consuming 1 to 2 servings per week, 1.09 (95% CI, 0.74 to 1.62) for those consuming 3 to 6 servings per week, and 1.23 (95% CI, 0.73 to 2.08) for those consuming ≥1 servings per day (P=0.0005 for quadratic trend).

Conclusions—In this population, moderate habitual chocolate intake was associated with a lower rate of HF hospitalization or death, but the protective association was not observed with intake of ≥1 servings per day. (Circ Heart Fail. 2010;3:612-616.)

Key Words: diet ■ epidemiology ■ heart failure
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Ingelsson and colleagues20 found that 95% of persons given these
codes were hospitalized for HF for the first time (n = 379) or died of HF
(n = 40), corresponding to a rate of 15.1 cases per 10 000 person-years.
Women with higher levels of chocolate intake had higher levels of total calorie intake and were more likely
to have com-

Statistical Analysis
Chocolate intake was categorized as no regular chocolate intake, 1 to 3 servings of chocolate per month, 1 to 2 servings per week, 3 to 6 servings per week, and ≥ 1 servings per day. Because some of the participants were missing data on BMI (1.3%) and physical activity (19.7%), we used Markov chain Monte Carlo multiple imputation to simulate 5 complete data sets, as previously described.14,21 All statistical analyses described were performed in each data set separately. The results were averaged, and CIs and P values were calculated, accounting for the uncertainty in the imputed estimates.21
We reported baseline characteristics stratified by category of chocolate intake as mean±SD or as counts with proportions, as appropriate, and the corresponding P value for the ANOVA or χ² test. We used Cox proportional hazards models to compute multivariable-adjusted rate ratios with corresponding 95% CIs, with participants in the lowest category of chocolate intake as the reference group. For the Cox proportional hazards models, we chose covariates a priori that we considered potential confounders on the basis of their association with both chocolate intake and development of HF. We accounted for the effect of age by allowing the baseline rate to vary with age and adjusted for total energy intake (linear term). A second model was additionally adjusted for education (less than high school, high school, university), BMI (linear term), physical activity (linear term), cigarette smoking (current, past, never), living alone (yes, no), postmenopausal hormone use (yes, no), alcohol consumption (linear term), family history of MI before age 60 (yes, no), self-reported history of hypertension (yes, no), and self-reported history of high cholesterol (yes, no).
To examine whether the inverse association between chocolate intake and HF was mediated through blood pressure, the rate ratios for chocolate intake in the multivariable-adjusted model were contrasted with the estimates for chocolate intake when an indicator variable for hypertension was removed from the model.
We conducted a test for the quadratic component of trend by assigning an ordinal score (0, 1, 2, 3, or 4) for each level of chocolate intake and determined the statistical significance of its squared value in the multivariable model. To examine the possibility that participants reporting lower intake of chocolate had undiagnosed risk factors placing them at immediate HF risk, we conducted a sensitivity analysis that excluded individuals with a follow-up time of <2 years.
Because milk consumption may inhibit the intestinal absorption of flavonoids, which may be responsible for the cardioprotective effects of chocolate,23 we examined the association between chocolate intake and HF above and below the median milk consumption. We performed formal tests of interaction by conducting a likelihood ratio test of nested models with and without all interaction terms of the product of indicator variables for chocolate intake and milk consumption above or below the median. We also examined whether the association varied by regular physical activity, an indicator of general health, by performing a similar test of interaction. We calculated the product of indicator variables for chocolate intake and for physical activity (metabolic equivalent of task×hours per day) above or below the median and tested the significance of this term in the multivariable model using a likelihood ratio test.
Finally, we tested whether intake of other snack foods is associated with HF risk by creating a variable for total servings per day of biscuits, pastries, candy, ice cream, and chips and popcorn. We tested the proportional hazards assumption by including product terms of the predictors and the log of survival time, and we found no significant violations. Statistical analyses were performed using SAS version 9.2.
Two-sided P<0.05 was considered statistically significant.

Results
Over 9 years of follow-up, 419 of 31 823 women were hospitalized for HF for the first time (n = 379) or died of HF (n = 40), corresponding to a rate of 15.1 cases per 10 000 person-years. Women with higher levels of chocolate intake had higher levels of total calorie intake and were more likely
CI, 0.74 to 1.62) and those who consumed 3 to 6 servings per week (hazard ratio, 1.09; 95% CI, 0.58 to 2.08). Although not materially different when we did not adjust for self-reported physical activity (linear term), cigarette smoking (current, past, never), living alone (yes, no), postmenopausal hormone use (yes, no), and BMI (linear term), physical activity was associated with a lower rate of HF in the high and low dairy intake groups (yes, no), alcohol consumption (linear term), family history of MI before age 60 (yes, no), self-reported history of hypertension (yes, no), and low level of physical activity (P=0.70 for interaction). Finally, the consumption of biscuits, pastries, candy, ice cream, and chips and popcorn, which were all strongly related to chocolate intake, was not associated with HF (P=0.84).

### Discussion
In this prospective study, we found that moderate habitual chocolate intake was associated with a lower rate of HF hospitalization or death, but the protective association was not observed with intake of ≥3 servings per week. Results

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No Intake (n=4705)</th>
<th>1–3 Servings/mo (n=16 912)</th>
<th>1–2 Servings/wk (n=7648)</th>
<th>3–6 Servings/wk (n=2046)</th>
<th>≥1 Servings/d (n=512)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>62.1±9.0</td>
<td>60.4±8.6</td>
<td>60.0±8.6</td>
<td>60.4±8.9</td>
<td>64.7±9.9</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Physical activity, MET h/d</td>
<td>42.6±5.0</td>
<td>42.5±4.7</td>
<td>42.3±4.6</td>
<td>41.8±4.6</td>
<td>41.7±5.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>25.2±4.2</td>
<td>25.0±3.9</td>
<td>24.7±3.7</td>
<td>24.3±3.9</td>
<td>23.9±3.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cigarette smoking*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Never</td>
<td>2437 (51.8)</td>
<td>8819 (52.2)</td>
<td>3954 (51.7)</td>
<td>990 (48.4)</td>
<td>263 (51.4)</td>
<td>---</td>
</tr>
<tr>
<td>Past</td>
<td>1135 (24.1)</td>
<td>4055 (24.0)</td>
<td>1793 (23.4)</td>
<td>458 (22.4)</td>
<td>110 (21.5)</td>
<td>---</td>
</tr>
<tr>
<td>Current</td>
<td>1076 (22.9)</td>
<td>3788 (22.4)</td>
<td>1778 (23.3)</td>
<td>561 (27.4)</td>
<td>127 (24.8)</td>
<td>---</td>
</tr>
<tr>
<td>Living alone</td>
<td>3361 (71.4)</td>
<td>13 057 (77.2)</td>
<td>5899 (77.0)</td>
<td>1495 (73.1)</td>
<td>332 (64.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Postmenopausal hormone therapy</td>
<td>2217 (47.1)</td>
<td>8511 (50.3)</td>
<td>3865 (50.5)</td>
<td>1129 (55.2)</td>
<td>245 (47.9)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Education†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>---</td>
</tr>
<tr>
<td>Less than high school</td>
<td>3624 (77.0)</td>
<td>12 216 (72.2)</td>
<td>5163 (67.5)</td>
<td>1286 (62.9)</td>
<td>355 (69.3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>High school</td>
<td>362 (7.7)</td>
<td>1396 (8.3)</td>
<td>719 (9.4)</td>
<td>197 (9.6)</td>
<td>43 (8.4)</td>
<td>---</td>
</tr>
<tr>
<td>University</td>
<td>695 (14.8)</td>
<td>3263 (19.3)</td>
<td>1757 (23.0)</td>
<td>557 (27.2)</td>
<td>113 (22.1)</td>
<td>---</td>
</tr>
<tr>
<td>Family history of MI before age 60</td>
<td>716 (15.2)</td>
<td>2360 (14.0)</td>
<td>944 (12.3)</td>
<td>238 (11.6)</td>
<td>57 (11.1)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>1048 (22.3)</td>
<td>3203 (18.9)</td>
<td>1321 (17.3)</td>
<td>368 (18.0)</td>
<td>92 (18.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>History of high cholesterol</td>
<td>433 (9.2)</td>
<td>1323 (7.8)</td>
<td>535 (7.0)</td>
<td>158 (7.7)</td>
<td>30 (5.9)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Energy intake, kcal/d</td>
<td>1644±532.4</td>
<td>1721.6±490.1</td>
<td>1842.5±500.7</td>
<td>1966.9±517.1</td>
<td>2202.0±681.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Alcohol consumption, g/d</td>
<td>3.7±5.8</td>
<td>4.3±5.1</td>
<td>4.9±5.1</td>
<td>5.6±5.8</td>
<td>5.0±6.7</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Data are presented as mean±SD or no. (%). MET indicates metabolic equivalent of task.
*479 with no data on smoking history.
†23 with no data on education level.

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Table 2. Rate Ratios and 95% CIs Comparing Different Levels of Chocolate Intake to Those Reporting No Chocolate Intake

<table>
<thead>
<tr>
<th>Chocolate Intake</th>
<th>Cases</th>
<th>Person-Years</th>
<th>Model 1*</th>
<th>Model 2†</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>93</td>
<td>40 497.61</td>
<td>1.00 (reference)</td>
<td>1.00 (reference)</td>
</tr>
<tr>
<td>1–3 servings/mo</td>
<td>194</td>
<td>147 768.51</td>
<td>0.71 (0.56–0.91)</td>
<td>0.74 (0.58–0.95)</td>
</tr>
<tr>
<td>1–2 servings/wk</td>
<td>78</td>
<td>66 935.77</td>
<td>0.66 (0.48–0.89)</td>
<td>0.68 (0.50–0.93)</td>
</tr>
<tr>
<td>3–6 servings/wk</td>
<td>36</td>
<td>17 791.75</td>
<td>1.02 (0.69–1.51)</td>
<td>1.09 (0.74–1.62)</td>
</tr>
<tr>
<td>≥1 servings/d</td>
<td>18</td>
<td>4285.00</td>
<td>1.14 (0.68–1.90)</td>
<td>1.23 (0.73–2.08)</td>
</tr>
</tbody>
</table>

P for quadratic trend | 0.0001 | 0.0005 |

*Cox proportional hazards model adjusted for total energy intake (linear term) and accounting for age.
†Additionally adjusted for education (less than high school, high school, university), BMI (linear term), physical activity (linear term), cigarette smoking (current, past, never), living alone (yes, no), postmenopausal hormone use (yes, no), alcohol consumption (linear term), family history of MI before age 60 (yes, no), self-reported history of hypertension (yes, no), and self-reported history of high cholesterol (yes, no).
were similar when we did not adjust for self-reported hypertension and when we restricted the analysis to participants with follow-up times >2 years. Furthermore, consumption of snacks all were strongly related to chocolate intake but was not associated with HF, suggesting a specific association between chocolate and HF incidence.

Chocolate is one of the most concentrated sources of flavanoids, which may be responsible for the improvement in cardiovascular risk factors. Some feeding trials suggest that the flavanoids in chocolate may be responsible for the improvement in cardiovascular risk factors. Feeding trials suggest that the flavanoids in chocolate may be responsible for the improvement in cardiovascular risk factors. Feeding trials suggest that the flavanoids in chocolate may be responsible for the improvement in cardiovascular risk factors. Feeding trials suggest that the flavanoids in chocolate may be responsible for the improvement in cardiovascular risk factors. Feeding trials suggest that the flavanoids in chocolate may be responsible for the improvement in cardiovascular risk factors.

Although the association between chocolate intake and HF is not known, there have been observational studies documenting its association with lower blood pressure, lower incidence of stroke and MI, lower incidence of mortality from coronary heart disease, and lower cardiac mortality in patients after their first MI. Furthermore, a recent meta-analysis reported that flavanoid intake is associated with decreased cardiovascular mortality.

There are several limitations of this study that warrant discussion. Although we had extensive data on lifestyle, diet, and comorbidity conditions, we cannot rule out residual or unmeasured confounding. However, our results are robust after using multivariable analyses that adjust for age, socioeconomic status, smoking status, and other potential confounders. Our food-frequency questionnaire was validated in a study comparing 4-7 day open-ended diet records to the food-frequency questionnaire and indicates that intake of sweets was well reported (Spearman correlation, 0.6). Furthermore, if the misclassification of chocolate was unrelated to HF incidence, the results would likely be an underestimate of the protective effect of chocolate. Chocolate consumption and risk factors were only measured at baseline, so we have no information on how changes in chocolate consumption may have affected a participant’s risk of incident HF.

In the European Union, dark chocolate must consist of at least 35% cocoa solids, and in the United States, the minimum is set at 15%. Despite the fact that most of the chocolate consumed in our sample probably contained relatively low concentrations of the potentially protective ingredients (approximately 30% cocoa solids), we still saw a statistically significant trend, suggesting that our findings may underestimate the protective effects of dark chocolate.

Our observed incidence rate of HF of 15.1 cases per 10,000 person-years is similar to the reported incidence rate among women in the national Swedish registers discharged in 2000 (17.1 cases per 10,000 person-years). Although the accuracy of the diagnosis of HF in the Swedish registers was shown to be high, only cases of HF that resulted in hospitalization or death were recorded. In addition, the registers do not contain information on HF etiology or subtype (systolic versus diastolic). Our assessment of hypertension and high cholesterol was based on self-report, which is inherently less reliable than clinical measurement.

On the other hand, this study has many strengths, including a large sample size and long duration of follow-up. Further, the prospective nature of our study reduces the potential for bias caused by differential recall of chocolate intake by cases and noncases of HF.

In conclusion, in this population of middle-aged and elderly Swedish women, moderate habitual chocolate intake was associated with a lower rate of HF hospitalization or death, but the protective association was not observed with intake of ≥1 servings per day. Further studies are needed to confirm or refute these findings, determine the optimal dose and type of chocolate, and clarify the mechanisms involved.

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**Disclosures**

None.

**References**


Although the association between chocolate intake and heart failure (HF) is not known, there have been observational studies documenting its association with lower incidence of hypertension and cardiovascular and overall mortality. Therefore, we evaluated the association between chocolate consumption and incidence of HF using data from the Swedish Mammography Cohort. The study population included 31,823 women aged 48 to 83 years without baseline diabetes or a history of HF or myocardial infarction. Compared with no regular chocolate intake, the multivariable-adjusted rate ratio of HF incidence was 0.74 (95% CI, 0.58 to 1.01) for women consuming 1 to 3 servings per month, 0.68 (95% CI, 0.50 to 0.93) for those consuming 1 to 2 servings per week, 1.09 (95% CI, 0.74 to 1.62) for those consuming 3 to 6 servings per week, and 1.23 (95% CI, 0.73 to 2.08) for those consuming ≥1 servings per day (P=0.0005 for quadratic trend). On the basis of these results, moderate chocolate consumption appears to be protective against HF incidence among women in the Swedish Mammography Cohort. Definitive proof would require a large-scale randomized clinical trial, which is unlikely to occur in the near future.
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