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Original article

Chocolate intake and diabetes risk

James A. Greenberg*

Department of Health and Nutrition Sciences, Brooklyn College of the City University of New York, 2900 Bedford Avenue, Brooklyn, NY 11210, USA

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SUMMARY

Background & aims: In-vitro and rodent studies, and short-term human trials suggest that compounds in chocolate can enhance insulin sensitivity. Also, a recent prospective Japanese epidemiological analysis found that long-term chocolate consumption was inversely associated with diabetes risk. The objective of the present analysis was to test the epidemiological association between long-term chocolate consumption and diabetes risk in a U.S. cohort.

Methods: Multivariable prospective Cox Regression analysis with time-dependent covariates was used to examine data from 7802 participants in the prospective Atherosclerosis Risk in Communities Cohort. The data included 861 new diabetes cases during 98,543 person-years of follow up (mean = 13.3 years).

Results: Compared to participants who ate 1 oz of chocolate less often than monthly, those who ate it 1–4 times/month, 2–6 times/week and ≥1 time/day had relative risks of being diagnosed with diabetes that were lower by 13% (95% confidence interval: −2%, 25%), 34% (18%, 47%) and 18% (−10%, 38%). These relative risks applied to participants without evidence of preexisting serious chronic disease that included diabetes, heart attacks, stroke or cancer. In conclusion, the risk of diabetes decreased as the frequency of chocolate intake increased, up to 2–6 servings (1 oz) per week. Consuming ≥1 serving per day did not yield significantly lower relative risk.

Conclusions: These results suggest that consuming moderate amount of chocolate may reduce the risk of diabetes. Further research is required to confirm and explore these findings.

1. Introduction

Short-term human trials have shown that daily ingestion of dark chocolate[1,2] and high-flavanol cocoa[3] can improve insulin sensitivity in humans. These findings are consistent with evidence from laboratory and animal studies showing that flavanols in cocoa can improve glucose metabolism.[4] To date there has only been one epidemiological analysis of the association between a long-term chocolate habit and diabetes – by Oba et al.[5] They conducted a prospective Cox Regression analysis using a cohort of 13,540 Japanese community residents. They found a significant inverse association with a 35% lower risk of diabetes incidence in male, but not female, participants during a 10-year follow up.

The objective of the present analysis was to explore the prospective association between a long-term chocolate habit and diabetes risk in the U.S. by using data from the Atherosclerosis Risk in Communities (ARIC) Cohort. The hypothesis was that the association between chocolate intake and the risk of diabetes would be the same as in Oba et al.'s study – inverse and stronger in males than females.

2. Materials and methods

2.1. Data

ARIC is a prospective epidemiologic study made up of 15,732 members aged 45–64 years derived from randomly selected households in four United States communities in North Carolina, Minnesota, Maryland; and Mississippi.[6] ARIC participants were examined at exam 1 between December 1986 and January 1990 and re-examined every three years thereafter (exams 2–4). Exam 2, 3 and 4 occurred in 1990–92, 1993–95, and 1996–98, respectively. Annual follow-up occurred yearly by means of telephone interviews to track health and survival status. The data available for the present analysis covers follow-up to the 15th annual contact, and includes food frequency questions on chocolate consumption, a rich variety of risk-factor variables and sequential assessments of the incidence of diabetes.

Non-standard abbreviations: ARIC, Atherosclerosis Risk in Communities Cohort.

* Tel.: +1 718 951 5000x2736.
E-mail addresses: jamesg@brooklyn.cuny.edu, jamesbronx@gmail.com.

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Response rates among participants who were alive at the time of exam 2, 3 and 4 were 93%, 86% and 80%, respectively. Response rates for each of the 15 annual questionnaires ranged between 87% and 99%.

2.2. Chocolate intake

Participants were asked at exam 1 and 3 via a food-frequency question to specify how often during the past year they ate 1 oz of "chocolate bars or pieces, such as Hershey's, Plain, M&M's, Snickers, Reese's." The consumption frequency was reported in nine levels: almost never, l–3 times/month, 1 time/week, 2–4 times/week, 5–6 times/week, 1 time/day, 2–3 times/day, 6 times/day and >6 times/day. The question did not ask participants to specify which type of chocolate (white, milk, plain) they usually consumed.

The original nine levels of chocolate consumption frequency were combined into three: <1 time/month, 1–4 times/month and ≥1 time/week. The nine levels were also transformed into a continuous variable by converting the consumption frequency at the midpoint of each level into the quantity (oz) of chocolate consumed per day. As an example, the 5th level, 5-6 1-oz servings/week, became 0.79 oz of chocolate per day.

2.3. Outcome variables

Diabetes medication usage, verified by ARIC investigators,[6] was taken as a valid diagnosis of diabetes. As assessed at exam 1, 2, 3 and 4 and at the 15th annual follow up interview, diagnosis of diabetes was the outcome event in all survival analyses. Time to event was the time between exam 1 and the subsequent contact when diabetes was first reported. Participants lost to follow up were censored.

2.4. Statistical methods

Cox Regression analysis[7] was used to calculate the multivariable adjusted hazard ratios in different levels of chocolate intake. In order to account for changes over time in the predictor, chocolate consumption, the chocolate consumption values at exam 1 were updated at exam 3 with available chocolate consumption values. A time-dependent covariates analysis[8] was used to achieve the updating. A sensitivity analyses was conducted using only the actual chocolate intake at exam 1 as predictor – without updating at exam 3.

Exclusion criteria were used to help prevent a bias caused by the tendency of ARIC participants to decrease their chocolate intake after being diagnosed with a serious chronic disease that includes diabetes, heart attack, stroke and cancer.[9] All exam 1 data were excluded for participants who at the exam reported a prior diagnosis of heart attack, stroke or cancer, or who had a diagnosis of diabetes based on verified usage of anti-diabetic medications.

Two regression models were built: 1) one in which the covariates were age, race (non-black, black) and sex (male, female); and 2) another in which the covariates included those in the first model plus additional variables that made a significant contribution to model fit, based on the Log Likelihood test. The additional continuous variables were Key's Index of dietary quality,[10] daily caloric intake and physical activity. The extra categorical variables were family history of diabetes (yes/no), smoking status (never, former, <20/day, ≥20/day), alcohol intake (0, 0–75, 75–150 & ≥150 g/week), educational level (grade school or less; some high school; high school graduate; vocational school; some college; graduate or professional school), and occupational level (managerial, technical, service, agriculture, precision production, laborer, homemaker, retired). The following variables were tested and did not make a significant contribution to model fit: age squared, vitamin D intake, and total fat intake as a % of total caloric intake, determined using the residual method.[11] There were no more than 4.1% of missing cases for predictor or any covariate. A sensitivity analysis investigating the effect of adding several factors in the causal pathway between chocolate intake and diabetes risk is presented in "Sensitivity Analyses."

Two-sided $p < .05$ was considered significant. Time-dependent covariate Cox Regression analyses were conducted with SAS (v. 9.3, SAS Institute Inc., Cary, North Carolina), and the results in Table 1 were produced using IBM SPSS Statistics (v. 20, IBM Corp., Armonk, NY).

2.5. Ethical statement

The study was conducted in accordance with the Helsinki Declaration of 1975 as revised in 1989, and the protocol was approved by the Brooklyn College Institutional Review Board.

3. Results

In the exam 1 (baseline) survey participants who reported eating chocolate more frequently were more likely to be younger, white, thinner and ever smokers (Table 1). They were also more

Table 1
Characteristics[a] of participants in different frequencies of chocolate consumption at exam 1 in the ARIC[b] cohort.

Characteristic[a]	Frequency of eating A 1 oz chocolate serving			
	<1/mo (N = 4822)	1–4/mo (N = 5940)	2–6/wk (N = 2679)	≥1/day (N = 985)
Chocolate Intake (servings/day)	0.00 (0.00)	0.10 (0.04) 0.53 (0.45)	0.50 (0.14)	1.25 (0.72)
Age (yrs)	54.7 (5.8)	53.9 (5.7)	53.8 (5.7)	53.7 (5.6
Race (% Black)	39.1	23.1	15.3	18.3
Sex (% male)	45.5	44.7	48.8	44.8
BMI (Kg/m^2)[c]	27.8 (5.6)	27.7 (5.3)	27.6 (5.2)	27.2 (5.2)
Physical Activity[d]	6.9 (1.5)	7.0 (1.4)	7.1 (1.4)	7.0 (1.5)
Ever smoker (%)	57.4	57.7	60.5	64.5
Education[e]				
Basic	29.3	20.7	18.7	24.4
Intermediate	36.5	41.2	44.2	44.4
Advanced	34.1	38.0	37.1	31.3
Daily Calories (Kcal/day)	1441 (540)	1566 (554)	1848 (621)	2113 (672)
Total Fat (gm/day)	50.3 (23.5)	57.9 (24.1)	72.0 (27.7)	84.9 (29.8)
Carbohydrates (gm/day)	178.3 (77.6)	192.6 (79.5)	226.1 (86.7)	264.1 (98.7)
Keys Index of Dietary Quality[e]	40.7 (10.2)	43.3 (9.0)	44.2 (8.3)	45.9 (8.6)
Alcohol Intake (gm/week)	48.3 (110.1)	41.3 (93.6)	40.3 (85.1)	34.2 (83.2)
Cholesterol Pills (%)	3.4	2.9	1.9	1.9
Hypertension (%)	41.8	33.5	26.9	29.0
Family History of Diabetes (%)	24.3	25.2	24.1	23.6

[a] All characteristics, except Family History of Diabetes, exhibited significant differences across chocolate Consumption levels ($p < .05$) by ANOVA, Kruskal–Wallis or Chi-square test. Data are given as mean (SD) for continuous variables and as percentages for categorical variables. Data are for participants with no missing values for any of the characteristics in this table.

[b] ARIC, Atherosclerosis Risk in Communities Cohort.

[c] BMI, Body Mass Index, calculated as measured weight in kilograms divided by the square of measured height in meters.

[d] Educational and Physical activity were labeled and quantified by ARIC researchers.

[e] Keys Index of Dietary Quality[10] was developed to measure a diet's effect on serum cholesterol, an important diabetes risk factor.