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Original article

Breakfast cereals and risk of hypertension in the Physicians' Health Study I

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SUMMARY

Background & aims: Hypertension is a major public health problem. While many dietary factors affect the risk of developing hypertension, limited data are available on the association between consumption of breakfast cereal and incident hypertension. We examined the association between breakfast cereal consumption and the risk of hypertension.

Methods: We prospectively analyzed data from 13,368 male participants of the Physicians' Health Study I. Consumption of breakfast cereals was estimated using an abbreviated food frequency questionnaire and incident hypertension was ascertained through yearly follow-up questionnaires.

Results: The average age of study participants was 52.4 ± 8.9 years (range 39.7–85.9) during the initial assessment of cereal intake (1981–1983). During a mean follow up of 16.3 years, 7267 cases of hypertension occurred. The crude incidence rates of hypertension were 36.7, 34.0, 31.7, and 29.6 cases/1000 person-years for people reporting breakfast cereal intake of 0, ≤1, 2–6, and ≥7 servings/week, respectively. In a Cox regression model adjusting for age, smoking, body mass index, alcohol consumption, fruit and vegetable consumption, physical activity, and history of diabetes mellitus, hazard ratios (95% CI) for hypertension were 1.0 (reference), 0.93 (0.88–0.99), 0.88 (0.83–0.94), and 0.81 (0.75–0.86) from the lowest to the highest category of cereal consumption, respectively (p for trend <0.0001). This association was strongest for whole grain cereals and was observed in lean as well as overweight or obese participants.

Conclusions: The results of this longitudinal cohort study suggest that whole grain breakfast cereal consumption confers a lower risk of hypertension in middle-aged adult males.

1. Introduction

Hypertension (HTN) is a major public health problem.[1] It is an important modifiable risk factor for coronary heart disease, and stroke.[2] The estimated direct and indirect cost of elevated blood pressure for 2010 was $76.6 billion.[1] A range of dietary factors, including potassium, magnesium, fiber, vegetable intake and reducing sodium intake etc. have been shown to decrease the risk of HTN.[2–6] Breakfast cereals are an important meal for many Americans, and have a beneficial effect on various cardio-metabolic disorders like diabetes (DM),[7] obesity[8] and heart failure.[9] In a prospective study of 28,926 female participants of the Women's Health Study, as compared to those who consumed <0.5 whole-grain servings/d, the relative risks (RRs) (95% CIs) of incident HTN were 0.93 (0.87–1.00), 0.93 (0.87–0.99), 0.92 (0.85–0.99), and 0.77 (0.66–0.89), respectively for those consuming 0.5 to <1, 1 to<2, 2 to <4, and 4 whole-grain servings/d.[10] Breakfast cereal was reported as a major source of whole grains in that study. In a randomized controlled trial of 189 participants without history of HTN, anemia, asthma, cancer, or cardiovascular or digestive disease, fortified breakfast cereal significantly decreased plasma homocysteine levels, a known cardiovascular risk biomarker.[11] Folic acid, a vitamin commonly used to fortify breakfast cereals, has been shown to decrease the risk of incident HTN.[12] Thus, although data are available on the association between individual components of breakfast cereals and HTN, it is not known whether consumption of breakfast

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cereal affects the risk of developing HTN. The current study therefore aims to prospectively explore the association between cold breakfast cereal consumption and incidence of HTN among 13,368 US male physicians.

2. Methods

2.1. Study population

This study used data from the Physicians' Health Study (PHS) I, which was a randomized, double blind, placebo-controlled trial to study the effects of low-dose aspirin and beta-carotene for the primary prevention of cardiovascular disease and cancer among US male physicians. A detailed description of the PHS I has been published previously.[13] Briefly, following the run-in period, 22,071 subjects were randomized to low-dose aspirin, beta-carotene, both agents, or placebo. For the current project, we used data on 13,368 after exclusion of subjects with prevalent HTN ($n = 5216$), patients with undefined HTN status ($n = 3242$) missing data on breakfast cereal ($n = 10$) or covariates ($n = 235$). Each participant gave written informed consent and the study protocol was approved by the Institutional review Board at Brigham and Women's Hospital.

2.2. Assessment of breakfast cereal consumption

Information about consumption of cold breakfast cereals was self-reported using an abbreviated food questionnaire during enrollment (1981–1983). A detailed description of the assessment of breakfast cereal intake in the PHS has been published.[9,13] Briefly, participants were asked to report their average consumption of cold breakfast cereals (1 cup) during the past year. Possible response categories included "rarely/never", "1–3/month", "1/week", "2–4/week", "5–6/week", "daily", and "2+/day". In addition, the brand of cereals consumed was queried at baseline. We used an algorithm developed by Jacobs and colleagues[14] to classify breakfast cereals into whole grain and refined grain. Specifically, breakfast cereals that contain at least 25% of oat or bran were classified as whole grain. Information on breakfast cereal consumption was obtained at baseline, at 18 weeks and 24, 48, 72, 96, and 120 months after randomization.

2.3. Ascertainment of incident HTN

A questionnaire was mailed to each participant every 6 months during the first year and has been mailed annually thereafter to obtain information on incident outcomes including HTN. HTN was defined as systolic blood pressure of 140+, diastolic blood pressure of 90+, or treatment for elevated blood pressure.[15]

2.4. Other variables

Information on age, height, weight, body mass index, cigarette smoking, fruit and vegetable consumption, HTN, history of DM, alcohol consumption, and physical activity was collected at baseline. Incidence of major chronic disease was ascertained through annual follow-up questionnaires.

2.5. Statistical analyses

We used total breakfast cereals as main exposure. However, we conducted stratified analyses by whole grain vs. refined breakfast cereals. Since the distribution of total, refined, and whole grain cereals was skewed to the right, we did not use quintiles to categorize cereal consumption. We grouped adjacent categories to allow sufficient number of person-times per category and to maintain a gradient of exposure as previously described.[9] Thus, we classified each subject into one of the following categories of breakfast cereals: rarely or never, ≤1, 2–6, and 7 + servings/week. We calculated person-time of follow up from baseline until the first occurrence of a) HTN, b) death, or c) date of receipt of last follow-up questionnaire. Within each breakfast cereal group, we calculated the incidence rate of HTN by dividing the number of HTN cases by the corresponding person-time. We used Cox proportional hazard models to compute multivariable adjusted hazard ratios with corresponding 95% confidence intervals using subjects in the cereal category of "rarely/never" as the reference group. Assumptions for the proportional hazard models were tested (by including main effects and product terms of covariates and a logarithmic transformed time factor) and were met (all p values >0.05). We obtained p value for linear trend by treating cereal variable as ordinal (taking values of 0, 1, 2, and 3 from the lowest to the highest category of cereal intake). The initial model controlled for age. Fully adjusted model adjusted for age, smoking (never, past and current smokers), body mass index (BMI) (<25, 25–29.9, ≥30 kg/m^2), alcohol consumption (<1, 1–4, 5–6, 7+ drinks/week), fruit and vegetable consumption (<4, 4–5, 6–7, and 8+ servings/day), physical activity (rarely/never, ≤1, 2–4, and 5+ times per week), and history of DM. To examine the influence of BMI on the cereal-HTN association, we conducted stratified analyses according to BMI Categories (<25, and ≥25). We then repeated the main analysis using updated cereal consumption at 24, 48, 72, 96, and 120 months as time-dependent variable. All analyses were completed using PC SAS, version 9.1 (SAS Institute, NC) and the significance level was set at 0.05.

3. Results

The mean age was 52.4 ± 8.9 (range 39.7–85.9) years among the 13,368 male participants. Higher intake of breakfast cereals was associated with increased physical activity; higher consumption of

Table 1
Characteristics of 13,368 participants according to categories of cereal intake in the Physicians' Health Study.[a]

Variables	Categories of cereal intake			
	None ($n = 4200$)	≤1/week ($n = 3104$)	2–6/week ($n = 3384$)	7+/week ($n = 2680$)
Age (y)	51.8 ± 8.5	51.6 ± 8.9	52.4 ± 8.8	54.0 ± 9.5
Body mass index (kg/m^2)	24.7 ± 2.7	24.8 ± 2.7	24.4 ± 2.5	24.0 ± 2.3
Vegetable intake (servings/day)	2.2 ± 1.2	2.3 ± 1.1	2.5 ± 1.1	2.5 ± 1.2
Current smoking (%)	15.6	11.1	7.9	5.8
Alcohol 1+/week (%)	75.1	73.7	72.9	71.4
Physical activity 1+/week (%)	83.3	89.1	91.3	90.4
History of DM (%)	2.14	2.22	1.65	2.31
Randomized to aspirin (%)	50.4	49.0	49.9	50.0

[a] Continuous variables are shown as mean ± SD; categorical variables as %.