Coffee, Caffeine, and Risk of Type 2 Diabetes

A prospective cohort study in younger and middle-aged U.S. women

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OBJECTIVE — High habitual coffee consumption has been associated with a lower risk of type 2 diabetes, but data on lower levels of consumption and on different types of coffee are sparse.

RESEARCH DESIGN AND METHODS — This is a prospective cohort study including 88,259 U.S. women of the Nurses' Health Study II aged 26–46 years without history of diabetes at baseline. Consumption of coffee and other caffeine-containing foods and drinks was assessed in 1991, 1995, and 1999. We documented 1,263 incident cases of confirmed type 2 diabetes between 1991 and 2001.

RESULTS — After adjustment for potential confounders, the relative risk of type 2 diabetes was 0.87 (95% CI 0.73–1.03) for one cup per day, 0.58 (0.49–0.68) for two to three cups per day, and 0.53 (0.41–0.68) for four or more cups per day compared with nondrinkers (*P* for trend <0.0001). Associations were similar for caffeinated (0.87 [0.83–0.91] for a one-cup increment per day) and decaffeinated (0.81 [0.73–0.90]) coffee and for filtered (0.86 [0.82–0.90]) and instant (0.83 [0.74–0.93]) coffee. Tea consumption was not substantially associated with risk of type 2 diabetes (0.88 [0.64–1.23] for four or more versus no cups per day; *P* for trend = 0.81).

CONCLUSIONS — These results suggest that moderate consumption of both caffeinated and decaffeinated coffee may lower risk of type 2 diabetes in younger and middle-aged women. Coffee constituents other than caffeine may affect the development of type 2 diabetes.

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High coffee consumption has been associated with better glucose tolerance and a substantially lower risk of type 2 diabetes in diverse populations in Europe, the U.S., and Japan (1–3). However, it remains unclear what coffee components may be responsible for the apparent beneficial effect of coffee on glucose metabolism. In rats, intakes of the coffee components chlorogenic acid (4,5), quinic acid (6), trigonelline (7), and the lignan secoisolariciresinol (8) improved glucose metabolism. Short-term metabolic studies in humans have shown that caffeine can acutely lower insulin sensitivity (9–11). However, the long-term effects of caffeine intake on glucose metabolism are unknown, and beneficial effects on insulin sensitivity through increased expression of uncoupling proteins have also been suggested (12).

In most of the populations in which the relation between coffee consumption and type 2 diabetes has been studied, drip-filtered caffeinated coffee was the predominant type of coffee consumed (1). Data on decaffeinated coffee and various methods of coffee preparation in relation to risk of type 2 diabetes are sparse (3,13,14). In addition, in previous studies consumption of five or more cups of coffee per day was consistently associated with a lower risk of type 2 diabetes, but results for lower levels of consumption have been mixed (1). We therefore examined the consumption of different types of coffee and the intake of caffeine in relation to risk of type 2 diabetes in a large cohort of younger and middle-aged U.S. women.

RESEARCH DESIGN AND METHODS

— We used data from the prospective Nurses' Health Study II. This cohort included 116,671 female U.S. nurses at study initiation in 1989. Information has been collected using biennial-mailed questionnaires, and response rates have been ~90% for each questionnaire. For the current analysis, follow-up began at the return of the 1991 questionnaire because diet was first assessed in that year. Participants were aged 26–46 years at the start of follow-up. We excluded women if they did not complete a dietary questionnaire in 1991; if >70 items were left blank or if the reported total energy intake was implausible (<500 kcal/day or >3,500 kcal/day); if they had a history of diabetes (including gestational diabetes), cancer (except nonmelanoma skin cancer), or cardiovascular disease at baseline; or if they had not provided data on physical activity in 1991. A total of 88,259 women remained for the current analysis. The study was approved by the human research committees at the Harvard School of Public Health and Brigham and Women's Hospital.

Assessment of coffee consumption

Validated dietary questionnaires were sent to the Nurses' Health Study participants in 1991, 1995, and 1999. Participants were asked how often on average during the previous year they had consumed caffeinated and decaffeinated coffee ("one cup"), tea ("one cup or glass"), different types of caffeinated soft drinks ("one glass, bottle, or can"), and chocolate products (e.g., "bar or packet"). The participants could choose from nine re-

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A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

sponses (never or less than one per month, one to three per month, one per week, two to four per week, five to six per week, one per day, two to three per day, four to five per day, and six or more per day). In 1991, we also asked about the usual method of preparing coffee with the answer categories "mainly filtered," "mainly instant," "mainly espresso or perculator," and "no usual method/don't know/don't use." We assessed the total intake of caffeine by summing the caffeine content for a specific amount multiplied by a weight proportional to the frequency of its use. Using U.S. Department of Agriculture food composition data supplemented with other sources, we estimated that the caffeine content was 137 mg per cup of coffee, 47 mg per cup of tea, 46 mg per bottle or can of cola beverage, and 7 mg per serving of chocolate candy. In a validation study in the original Nurses' Health Study, we found high correlations between intake of coffee and other caffeinated beverages assessed with food frequency questionnaire and with four 1-week diet records (coffee, $r = 0.78$; tea, $r = 0.93$; and caffeinated sodas, $r = 0.85$) (15).

Assessment of type 2 diabetes

Women who reported a diagnosis of diabetes on a biennial follow-up questionnaire were sent a supplementary questionnaire asking about diagnosis and treatment of diabetes and history of ketoacidosis to confirm the self-report and to distinguish between type 1, type 2, and gestational diabetes. In accordance with the criteria of the National Diabetes Data Group (16), confirmation of diabetes required at least one of the following for cases that were diagnosed through 1997: *1*) an elevated glucose concentration (fasting plasma glucose ≥7.8 mmol/l [140 mg/dl], random plasma glucose ≥11.1 mmol/l [200 mg/dl], and/or plasma glucose ≥2 h after an oral glucose load ≥11.1 mmol/l) plus at least one classic symptom (excessive thirst, polyuria, weight loss, or hunger), 2) no symptoms but elevated plasma glucose concentrations as described above on at least two different occasions, or 3) treatment with insulin or oral hypoglycemic medication. For cases that were diagnosed after 1998, we changed the cutoff for fasting plasma glucose concentrations to 7.0 mmol/l [126 mg/dl] in accordance with the 1997 American Diabetes Association criteria (17). In a validation study in the original Nurses' Health Study, 98% of the cases ascertained by the same supplementary questionnaire were confirmed by medical record review (18).

Assessment of medical history, anthropometry, and lifestyle

On the baseline questionnaires, we requested information about age; weight and height; smoking status; physical activity; history of diabetes in first-degree relatives; use of postmenopausal hormone therapy; use of oral contraceptives; and personal history of diabetes, cardiovascular diseases, and cancers. This information has been updated every 2 years, with the exception of physical activity (only updated in 1997) and height and family history. BMI was calculated as weight in kilograms divided by the square of height in meters, and physical activity was assessed in metabolic equivalents per week. Validation studies for the assessment of body weight and physical activity have been previously reported (19,20).

Statistical analyses

Person-years of exposure were calculated from the date of return of the baseline questionnaire to the date of diagnosis of type 2 diabetes, death, or 1 July 2001, whichever came first. Cox proportional hazards regression models stratified by 5-year age categories and 2-year time periods were used to examine the association between coffee consumption and risk of type 2 diabetes. To reduce within-subject variation and to best represent long-term exposure, we used the cumulative average of coffee consumption and other dietary variables from all available dietary questionnaires up to the start of each 2-year follow-up interval (21). We stopped updating diet at the beginning of the time interval during which individuals developed cancer (except nonmelanoma skin cancer), cardiovascular diseases, or gestational diabetes because changes in diet after development of these conditions may confound the relationship between diet and diabetes (21). Nondietary covariates were also updated during follow-up using the most recent data for each 2-year interval. To test for linear trends across categories, we modeled the median of each category of coffee consumption as a continuous variable. For analyses that examined the association between coffee consumption and risk of type 2 diabetes for women who used a certain method of preparing coffee, we excluded coffee consumers who used other methods or did not report what method they used. All reported *P* values were two tailed, and *P* values <0.05 were considered statistically significant. All analyses were performed using SAS software, version 8.2 (SAS Institute, Cary, NC).

RESULTS — During 866,118 person-years of follow-up, we documented 1,263 cases of type 2 diabetes. Characteristics of the study population according to consumption of caffeinated and decaffeinated coffee and caffeine intake are presented in Table 1. Higher caffeinated coffee consumption, but not decaffeinated coffee consumption, was strongly associated with cigarette smoking and higher alcohol consumption. Both higher caffeinated and higher decaffeinated coffee consumption were associated with older age and lower consumption of sugar-sweetened soft drinks and tea. Women who did not consume caffeinated or decaffeinated coffee tended to have a higher BMI compared with women who did consume either type of coffee. Pearson correlations with caffeine intake were 0.83 for total coffee, 0.94 for caffeinated coffee, −0.05 for decaffeinated coffee, and 0.09 for tea consumption.

Higher coffee consumption was associated with a lower risk of type 2 diabetes (Table 2). Adjustment for potential confounders weakened this association, mainly due to adjustment for BMI and alcohol consumption. After multivariate adjustment, the relative risk (RR) of type 2 diabetes was 0.87 (95% CI 0.73–1.03) for one cup per day, 0.58 (0.49–0.68) for 2–3 cups per day, and 0.53 (0.41–0.68) for four or more cups per day. Additional adjustment for magnesium, high- and low-fat dairy consumption, tea consumption, or sucrose intake; adjustment for BMI as a continuous variable; use of baseline coffee consumption instead of cumulative updated coffee consumption; use of baseline coffee consumption with exclusion of the first 4 years of follow-up; and exclusion of women who developed gestational diabetes during follow-up did not substantially change the association between coffee consumption and risk of type 2 diabetes (RR for four or more cups per day versus no cups per day ranged from 0.51 to 0.60; all *P* values <0.0001). Both higher caffeinated coffee and higher decaffeinated coffee consumption were associated with a lower risk of type 2 diabetes (Table 2). Tea consumption was not substantially associated with risk of type 2 diabetes after adjustment for potential confounders (0.88 [0.64–1.23] for

Table 1—*Baseline characteristics of the study population by level of caffeinated and decaffeinated coffee consumption*

	Caffeinated coffee					Decaffeinated coffee			
	No cups per day	Less than one cup per day	One cup per day	Two to three cups per day	Four or more cups per day	No cups day	Less than one cup per day	One cup per day	Two or more cups per day
Median	0	0.40	1.1	2.5	4.5	0	0.14	1.0	2.5
n (participants)	33,375	14,020	11,292	21,672	7,900	56,728	19,605	5,999	5,927
Age (years)	35.6	35.4	36.2	36.8	37.6	35.8	36.2	37.1	38.2
BMI (kg/m^2)	24.9	24.6	24.2	24.1	24.6	24.8	24.1	24.0	24.2
Physical activity (MET h/week)	20.3	20.6	22.0	21.8	21.4	20.6	21.2	22.2	22.3
Current smoker (%)	6.7	7.7	10.0	16.9	35.6	13.7	9.0	8.7	13.3
Family history of diabetes (%)	16.1	15.6	15.4	15.7	17.6	16.3	15.0	15.7	15.7
Hypertension (%)	3.6	3.6	3.1	2.6	2.5	3.4	2.8	3.1	2.5
Hypercholesterolemia (%)	9.6	9.3	8.9	8.6	9.7	9.3	9.1	9.3	8.6
Ever hormone replacement therapy (%)	7.3	6.9	7.1	6.5	6.9	7.1	6.6	6.9	7.0
Current oral contraceptive use (%)	10.7	12.1	12.1	10.6	8.2	11.7	9.7	8.2	7.8
Dietary intake									
Total energy (kcal/day)	1,777	1,781	1,787	1,788	1,832	1,768	1,822	1,819	1,829
Alcohol consumption (g/day)	1.8	2.8	3.5	4.7	4.6	3.0	3.4	3.0	3.6
P:S ratio	0.52	0.53	0.53	0.52	0.51	0.52	0.53	0.54	0.53
Cereal fiber (g/day)	5.6	5.7	5.8	5.6	5.3	5.4	5.9	6.1	6.0
Glycemic index	54.6	54.1	53.7	53.2	52.5	54.1	53.7	53.3	52.6
Processed meat (servings/day)	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2
Sugar-sweetened soft drinks (servings/day)	0.4	0.3	0.3	0.2	0.2	0.3	0.2	0.2	0.2
High-fat dairy (servings/day)	0.8	0.9	1.0	1.1	1.2	0.9	1.0	0.9	1.0
Low-fat dairy (servings/day)	1.4	1.4	1.3	1.3	1.2	1.3	1.5	1.5	1.5
Tea (cups/day)	0.8	0.8	0.6	0.5	0.5	0.8	0.6	0.6	0.6
Decaffeinated coffee (cups/day)	0.3	0.5	0.4	0.3	0.2				
Caffeinated coffee (cups/day)						1.2	1.4	1.1	1.0
Magnesium (g/day)	302	312	318	327	344	307	324	335	346
Caffeine (mg/day)	80	118	204	415	747	253	249	205	198

Data are means, unless otherwise indicated. Data, except age, were directly standardized to the age distribution of entire cohort. MET, metabolic equivalent, P:S ratio, ratio of polyunsaturated and saturated fat intake.

four or more versus no cups per day; *P* for trend = 0.81).

Higher caffeine intake was associated with a lower risk of type 2 diabetes (Table 2). Because coffee and caffeine intake were correlated, we attempted to identify their possible independent effects by examination of cross-categories of coffee and caffeine intake in relation to risk of type 2 diabetes. Higher total coffee consumption was associated with a lower risk of type 2 diabetes in each category of caffeine intake. In contrast, higher caffeine intake was not substantially associated with risk of type 2 diabetes within categories of total coffee consumption (Table 3). We also included total coffee consumption and caffeine intake simultaneously in the multivariate model as continuous variables. The association between total coffee consumption and risk of type 2 diabetes remained similar: the RR for a one-cup increment in consumption was 0.86 (95% CI 0.82–0.89) after multivariate adjustment and 0.84 (0.79–0.91) after further adjustment for caffeine intake. In contrast, the association between caffeine intake and risk of type 2 diabetes disappeared after adjustment for coffee consumption (1.01 [0.96–1.07] for a 100 mg per day higher intake). Consistent with this observation, the strength of the inverse association with risk of type 2 diabetes was similar for decaffeinated (multivariate RR 0.81 [95% CI 0.73–0.90]) and caffeinated coffee consumption (0.87 [0.83–0.91]) when expressed for a one-cup increment in consumption per day and simultaneously included in the multivariate model.

We also examined whether the used method of preparing coffee affected the association between coffee consumption and risk of type 2 diabetes. The multivariate RR of type 2 diabetes associated with a one-cup increment in coffee consumption per day was similar for filtered coffee (RR 0.86 [95% CI 0.82–0.90]) and instant coffee (0.83 [0.74–0.93]). In contrast, consumption of espresso/perculator coffee was not substantially associated with a lower risk of type 2 diabetes (0.97 [0.85–1.10]), but the number of women who regularly consumed espresso/perculator coffee was relatively low (number of diabetes cases for consumption of two or more cups per day: 254 for filtered coffee, 27 for instant coffee, and 18 for perculator/espresso coffee).

CONCLUSIONS — In this study of U.S. women aged 26–46 years at baseline, consumption of two or more cups of coffee per day was associated with a substantially lower risk of type 2 diabetes during 10 years of follow-up. This association was similar for caffeinated and decaffeinated coffee and for filtered and instant coffee. The inverse association between coffee consumption and risk of type 2 diabetes was independent of caffeine intake.

The prospective design and high rate of follow-up in this study minimizes the possibility of recall bias or bias due to loss

Table 2—*Relative risk of type 2 diabetes according to coffee and tea consumption and caffeine intake*

	Categories of intake					
	No cups per day	Less than one cup per day	One cup per day	Two to three cups per day	Four or more cups per day	*P* value for trend
Total coffee						
Median (cups/day)	0	0.43	1.2	2.5	4.6	
n (cases)	479	280	199	227	78	
Person-years	235,047	155,431	140,041	253,351	82,248	
Age-adjusted RR	1	0.82 (0.71–0.95)	0.59 (0.50–0.70)	0.36 (0.31–0.43)	0.39 (0.30–0.49)	<0.0001
Multivariate RR*	1	0.93 (0.80–1.09)	0.87 (0.73–1.03)	0.58 (0.49–0.68)	0.53 (0.41–0.68)	<0.0001
Caffeinated coffee						
Median (cups/day)	0	0.40	1.0	2.5	4.5	
n (cases)	549	285	184	185	60	
Person-years	291,336	166,146	139,048	208,945	60,643	
Age-adjusted RR	1	0.81 (0.71–0.94)	0.60 (0.51–0.71)	0.41 (0.34–0.48)	0.48 (0.36–0.62)	<0.0001
Multivariate RR	1	1.00 (0.86–1.17)	0.89 (0.75–1.07)	0.62 (0.52–0.74)	0.61 (0.46–0.81)	<0.0001
Decaffeinated coffee						
Median (cups/day)	0	0.14	1.0	2.5		
n (cases)	841	313	77	32		
Person-years	503,799	253,866	65,122	43,332		
Age-adjusted RR	1	0.62 (0.55–0.71)	0.58 (0.46–0.73)	0.39 (0.27–0.55)		0.0001
Multivariate RR	1	0.86 (0.74–0.99)	0.87 (0.68–1.11)	0.52 (0.36–0.74)		0.005
Tea						
Median (cups/day)	0	0.21	1.0	2.5	4.5	
n (cases)	271	586	222	142	42	
Person-years	213,433	415,827	123,772	89,878	23,209	
Age-adjusted RR	1	0.90 (0.78–1.05)	1.18 (0.99–1.41)	1.07 (0.87–1.31)	1.32 (0.95–1.83)	0.005
Multivariate RR	1	0.97 (0.83–1.12)	1.17 (0.97–1.40)	0.98 (0.79–1.20)	0.88 (0.64–1.23)	0.81
Caffeine	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	
Median (mg/day)	22	93	180	341	528	
n (cases)	281	308	291	218	165	
Person-years	173,758	173,430	172,858	172,867	173,206	
Age-adjusted RR	1	1.05 (0.89–1.23)	0.97 (0.82–1.14)	0.67 (0.56–0.80)	0.51 (0.42–0.62)	<0.0001
Multivariate RR	1	0.88 (0.75–1.04)	0.89 (0.75–1.05)	0.74 (0.62–0.89)	0.55 (0.45–0.67)	<0.0001

Data are RR (95% CI), unless otherwise indicated. *Adjusted for age (5-year categories), smoking status (never, past, and current), BMI (13 categories), physical activity (quintiles of metabolic equivalent hours per week), alcohol consumption (0, 0.1–4.9, 5.0–9.9, or ≥10 g/day), use of hormone replacement therapy (ever or never), oral contraceptive use (never, past, or current), family history of type 2 diabetes (yes/no), history of hypertension (yes/no), history of hypercholesterolemia (yes/no), consumption of sugar-sweetened soft drinks (4 categories), consumption of punch (4 categories), and quintiles of processed meat consumption, the polyunsaturated-to-saturated fat intake ratio, total energy intake, the glycemic index, and cereal fiber intake. Caffeinated coffee consumption and decaffeinated coffee consumption were simultaneously included in the multivariate model, and the multivariate model for tea included coffee consumption.

of follow-up. Furthermore, the extensive information on potential confounders allowed us to examine confounding in detail. Self-reported diabetes was confirmed by a supplementary questionnaire, and a validation study of this method to assess type 2 diabetes in older nurses using medical records indicated that reporting of diabetes is accurate for U.S. women of this profession (18). Because screening for blood glucose was not feasible given the size of the cohort, some underdiagnosis of diabetes is likely. However, compared with the general population, the degree of underdiagnosis was probably smaller in this cohort of nurses with ready access to medical care. Moreover, underascertainment of cases, if not associated with exposure, would not be expected to affect the RR estimates (22). Dietary validation studies have indicated that the frequency of coffee consumption reported on a food frequency questionnaire is highly reproducible and agrees well with assessments using diet records (15). Although between-person variation in cup size and strength of the coffee brew have probably contributed to some misclassification with regard to the exposure to relevant coffee constituents, this would have weakened rather than strengthened the observed associations between coffee consumption and risk of type 2 diabetes.

This study agrees with previous findings from a meta-analysis of cohort studies (1). The summary RR of type 2 diabetes was 0.65 (95% CI 0.54–0.78) for six to seven or more cups of coffee per day and 0.72 (0.62–0.83) for four to six cups of coffee per day compared with the reference category (1). In the European studies, coffee consumption was much higher than in the current population, and few participants did not consume coffee. As a result, the lower range could be studied less well, but three to four cups of coffee per day was still associated with a lower risk compared with two or fewer cups per day (1). In previous U.S. studies, consumption of four to five cups of coffee per day, but not of one to three cups per day, was associated with a lower risk of type 2 diabetes compared with no coffee consumption (14). The stronger inverse

Table 3—*Risk of type 2 diabetes by combinations of total coffee consumption and caffeine intake*

	Quintiles of caffeine intake		
	Q1–Q2	Q3	Q4–Q5
Total coffee less than one cup per day			
Median coffee consumption (cups/day)	0	0	0
Median caffeine intake (mg/day)	52	173	287
Number of cases/person-years	533/292,658	184/79,183	42/18,638
RR (95% CI)	1 (ref.)	1.02 (0.86–1.21)	0.85 (0.62–1.16)
Total coffee 1.0–1.9 cups/day			
Median coffee consumption (cups/day)	1.1	1.1	1.6
Median caffeine intake (mg/day)	74	186	297
Number of cases/person-years	38/31,550	87/68,142	74/40,348
RR (95% CI)	0.89 (0.63–1.23)	0.88 (0.70–1.10)	0.90 (0.70–1.16)
Total coffee two or more cups per day			
Median coffee consumption (cups/day)	2.5	2.5	2.6
Median caffeine intake (mg/day)	51	189	430
Number of cases/person-years	18/22,979	20/25,533	267/287,087
RR (95% CI)	0.52 (0.32–0.83)	0.50 (0.32–0.79)	0.59 (0.50–0.69)

RRs were multivariate adjusted as described in the legend of Table 2.

association between coffee consumption and risk of type 2 diabetes in the current study may have been related to the more recent start of the study, possibly reflecting secular changes in brew strength or cup size in the U.S., or the younger age of the participants. In a recent prospective analysis of National Health and Nutrition Examination Survey data, decaffeinated coffee consumption was associated with a lower risk of type 2 diabetes only in younger participants (aged ≤60 years) (3). However, individuals may decide to switch from caffeinated to decaffeinated coffee because of health-related conditions. This could weaken the association between decaffeinated coffee consumption and risk of type 2 diabetes, and this bias is more likely to occur in older and less healthy populations than in younger populations.

Caffeine has acutely reduced insulin sensitivity in short-term intervention studies (9–11). However, whether this effect pertains to long-term coffee consumption is unclear because other components of coffee may modify this effect and because tolerance may develop (23). The similar findings for caffeinated and decaffeinated coffee in our study suggest that the detrimental acute effect of caffeine on insulin sensitivity may not substantially affect the relation between long-term caffeinated coffee consumption and incidence of type 2 diabetes. Based on animal studies, beneficial effects of caffeine on insulin sensitivity have also been suggested (12). We observed an inverse association between caffeine intake and risk of type 2 diabetes, but further analyses suggested that this association may have been a result of confounding by coffee consumption. The inverse association between decaffeinated coffee consumption and risk of type 2 diabetes in the current study and in three other U.S. cohorts (3,14) also supports the hypothesis that coffee components other than caffeine may reduce risk of type 2 diabetes. In addition, decaffeinated coffee consumption was associated with lower C-peptide concentrations in U.S. women, which suggests a beneficial effect on insulin sensitivity (24). Furthermore, beneficial effects of coffee components other than caffeine on glucose metabolism are biologically plausible. Coffee has strong antioxidant properties in vivo (25), chlorogenic acid may delay glucose absorption in the intestine (26), and intake of coffee components improved glucose metabolism in rats (4–8).

Our observation that instant coffee consumption was also inversely associated with risk of type 2 diabetes is plausible as the composition is similar to drip-filtered coffee (27,28). In a previous U.S. study, instant coffee was not associated with risk of type 2 diabetes (3). However, the number of participants with substantial instant coffee consumption in that smaller study may have been too low to have adequate power to detect an association with risk of type 2 diabetes. Similarly, consumption of espresso/perculator coffee was not common enough in our study to have sufficient power to exclude an inverse association with risk of type 2 diabetes. Results of one previous study suggested that higher consumption of unfiltered Scandinavian pot-boiled coffee is associated with a lower risk of type 2 diabetes (13). However, high consumption of unfiltered coffee increases plasma LDL concentrations (29) and may thus increase risk of coronary heart disease.

In this population of younger and middle-aged U.S. women, consumption of two or more cups of coffee was associated with a substantially lower risk of type 2 diabetes. This finding suggests that the inverse association between coffee consumption and risk of type 2 diabetes is not limited to very high levels of coffee consumption. However, given the international variation in strength of the coffee brew, cup size, natural composition of coffee beans, and processing of coffee, our findings for specific numbers of cups may not be directly generalizable to other populations. Possible detrimental effects of frequent use of high-caloric additions to coffee on energy balance and body weight should also be considered. Weight management and increased physical activity, which can lower risk of multiple chronic diseases, should be the mainstay of preventive efforts to reduce incidence of type 2 diabetes. For individual choices regarding coffee consumption, the potential effects of coffee consumption on risk of type 2 diabetes may be relevant but should be considered in combination with other health effects of coffee. Consumption of decaffeinated coffee may reduce risk of type 2 diabetes, while avoiding potential

detrimental effects on blood pressure (30) and sleep quality.

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