Coffee consumption in relation to Type 2 Diabetes Mellitus

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May 5, 2011

Abstract

Scientific data has reported an inverse association in which higher coffee consumption may lower the risk of type 2 diabetes mellitus. This review discusses the correlation of coffee consumption with type 2 diabetes and plausible mechanisms that may be involved. Higher coffee consumption was found to decrease the risk for type 2 diabetes in several diverse populations of both genders of all ages in multiple studies. This correlation held strong with caffeinated and decaffeinated coffee, suggesting that compounds other than caffeine are providing health benefits. Constituents of coffee that are of interest to have anti-diabetic effects could be chlorogenic acid, quinides, antioxidants or magnesium. Some studies have shown chlorogenic acids and quinides to lower blood glucose concentrations, possibly by the inhibition of glucose-6-phosphatase or by increasing glucagon-like 1 peptide. Antioxidants present in coffee may help the prevention of oxidative stress associated with beta-cell dysfunction, insulin resistance and impaired glucose tolerance. Data on magnesium has not shown promising results on decreasing the risk for type 2 diabetes. Further research is needed to determine the source or sources of coffee providing the inverse association between coffee consumption and type 2 diabetes. Long term studies have shown high habitual coffee consumption to be associated with a reduced risk for type 2 diabetes.

Introduction

Type 2 diabetes is a chronic disease, which accounts for approximately 90-95% of those with diabetes and encompasses individuals who have insulin resistance or relative insulin deficiency.[1] The prevalence of diabetes is growing at a rapid rate globally. Within 10 years, from 2000 to 2010, the number of people diagnosed rose from 151 million to 285 million,

representing 6.6% of the world's adult population. At this rate, by 2030 the prediction will have risen to 438 million people. These numbers are significant, considering type 2 diabetes is associated with a high morbidity and premature mortality rate. Diabetes is ranked among the leading causes of blindness, renal failure and lower limb amputation. In addition, diabetes is now one of the leading causes of death due to a greatly elevated risk of other chronic illnesses, including cardiovascular disease, which more than doubles the risk of having a heart attack or stroke.[2] Many factors impact the risk for type 2 diabetes; with key determinants being diet and personal lifestyle factors. Excess weight, obesity, physical inactivity, smoking, diets rich in high glycemic load foods and trans fatty acids and low in fiber and polyunsaturated fatty acids are factors consistently reported to increase the risk for type 2 diabetes. While physical activity and a balanced diet can reduce the risk of type 2 diabetes, it is still important to recognize the role of other lifestyle factors that may contribute to the prevention and protection from the development of diabetes.

Coffee is a common brewed beverage consumed daily around the world. Coffee contains numerous substances; among them, caffeine, antioxidants, chlorogenic acid, quinides and magnesium.[3] To allow individuals to make informed choices regarding coffee consumption, knowledge on positive and negative effects of coffee consumption is important.[3] Scientific studies have shown coffee to have beneficial health effects for many medical conditions. Some of these conditions include Alzheimer's disease, Parkinson's disease, heart disease, cirrhosis of the liver and gout. In addition, recent scientific studies have also reported a correlation between coffee consumption and a decreased risk for type 2 diabetes. However, not all studies have found a significant inverse relationship between coffee consumption and type 2 diabetes. An American study and Finnish study showed no significant protective effects.[4,5] Moreover, as

additional research has been performed, the vast majority of studies are detecting a strong correlation. The mechanism behind coffee and its anti- diabetic effects is unclear, but the research is currently ongoing. Based on scientific data, coffee consumption may reduce the risk of developing of type 2 diabetes.

Coffee & Type 2 Diabetes

The correlation of coffee consumption and decreased risk for type 2 diabetes produced significant results when 17,111 Dutch men and women participated in a 5 year follow up questionnaire and physical examination. Dutch men and women between the ages of 30-60 years old who drank at least seven cups of coffee a day were 0.50 (95% CI 0.35-0.72, p=0.0002) times as likely as those who drank ≤ 2 cups to develop type 2 diabetes. The inverse association remained significant after adjustments for potential confounders. The results supported a substantially lower risk for type 2 diabetes with higher amounts of coffee consumption.[6] With the findings of this early study, more studies followed to further support the relationship of coffee and diabetes. Coffee consumption and risk of type 2 diabetes without the consideration of decaffeinated or caffeinated coffee was also assessed by 3 surveys in middle aged Finnish men and women. The combined cohorts were adjusted for potential confounders and statistically analyzed with SPSS version 11.0 (SPSS Inc, Chicago, Ill). There was a significant relationship in the multivariate-adjusted comparison of coffee consumption and diabetes with men and women. The hazard ratio for development of type 2 diabetes in men and women combined were 0.76 (95% CI 0.57-1.01) for 3-4 cups per day, 0.54 (95% CI 0.40-0.73) for 5-6 cups, 0.55 (95% CI 0.37-.081) for 7-9 cups and 0.39 (95% CI 0.24-0.64) for > 10 cups (Table 2). [7] Since both Dutch and Finnish studies[6,7] did not consider whether coffee consumed was caffeinated or decaffeinated, it cannot be determined if caffeine was associated with diabetes prevention.

However, it can be gathered that there is a definite relationship between habitual coffee consumption and development of type 2 diabetes.

Table 2. Development of Type 2 Diabetes by Volume of Coffee Consumption

	Daily Coffee Consumption, Cups					*P* Value for Trend
	≤2	3-4	5-6	7-9	≥10	
Men						
No. of new cases	41	48	67	28	19	
Person-years	14 191	20 054	25 704	11 480	10 426	
Adjustment for age and study year, HR (95% CI)	1.00	0.83 (0.54-1.25)	0.88 (0.60-1.30)	0.86 (0.53-1.39)	0.69 (0.40-1.19)	.74
Multivariate adjustment, HR (95% CI)*	1.00	0.73 (0.47-1.13)	0.70 (0.45-1.05)	0.67 (0.40-1.12)	0.45 (0.25-0.81)	.12
Women						
No. of new cases	46	68	48	13	3	
Person-years	15 821	30 367	32 036	10 523	4980	
Adjustment for age and study year, HR (95% CI)	1.00	0.72 (0.49-1.04)	0.49 (0.32-0.73)	0.47 (0.25-0.87)	0.26 (0.08-0.85)	.002
Multivariate adjustment, HR (95% CI)*	1.00	0.71 (0.48-1.05)	0.39 (0.25-0.60)	0.39 (0.20-0.74)	0.21 (0.06-0.69)	<.001
Men and Women Combined†						
No. of new cases	87	116	115	41	22	
Person-years	30 112	50 421	57 740	22 003	15 406	
Adjustment for age and study year, HR (95% CI)	1.00	0.79 (0.59-1.04)	0.67 (0.50-0.88)	0.66 (0.46-0.96)	0.53 (0.33-0.85)	.02
Multivariate adjustment, HR (95% CI)*	1.00	0.76 (0.57-1.01)	0.54 (0.40-0.73)	0.55 (0.37-0.81)	0.39 (0.24-0.64)	<.001

Abbreviations: CI, confidence interval; HR, hazard ratio.
*Adjusted for age, study year, body mass index, systolic blood pressure, education, occupational physical activity (light, moderate, and active), walking or cycling to or from work (0, 1-29, and ≥30 min/d), leisure time physical activity (low, moderate, and high), cigarette smoking (never, past, and current smoking of 1-19 or ≥20 cigarettes/d), alcohol consumption (0, 1-100, 101-300, and >300 g/wk), and tea consumption (none, 1-2, and ≥3 cups/d).
†Also adjusted for sex.

To determine whether there's a difference in caffeinated or decaffeinated coffee and a reduced risk for type 2 diabetes; a prospective cohort study consisting of 88,259 young and middle aged US women participated in a 10 year follow up study. Preceding the study, consumption of both, decaffeinated and caffeinated coffee was found to be associated with a lower risk for type 2 diabetes. When the results were adjusted for potential confounders, the association was weakened slightly; primarily from BMI and alcohol consumption but still remained significant. In caffeinated coffee, the adjusted relative risk (RR) of type 2 diabetes was 0.87 (95% CI 0.73-1.03) for 1 cup per day, 0.58 (95%CI 0.49-0.68) for 2-3 cups per day and 0.53 (95% CI 0.41-0.98) for > 4 cups per day. The decreasing trend continued with the consumption

of decaffeinated coffee. The RR of type 2 diabetes with the consumption of decaffeinated coffee was 0.87 (95% CI 0.68-1.11) for 1 cup per day and 0.52 (95% CI 0.36-0.74) for > 4 cups per day. These data suggested that consumption of 2 or more cups of coffee a day was associated with a substantially lower risk for type 2 diabetes. The notable association in decaffeinated coffee implies that the inverse association between coffee consumption and risk of type 2 diabetes is independent of caffeine intake.[8] Inverse associations between coffee and risk for type 2 diabetes were also reported in an analysis of 28,812 postmenopausal women. The results remained significant after multiple confounders were incorporated; these included age, education, many dietary and lifestyle factors, magnesium and phytate. After adjustments, decaffeinated coffee had a stronger correlation than total coffee intake for a decreased risk for diabetes. Consumption of decaffeinated coffee had a RR of 0.68 (95% CI 0.44-0.80) for > 6 cups of coffee per day and caffeinated coffee had a RR of 0.79 (95% CI 0.61-1.02) for > 6 cups per day.[9] Once again, this study concluded a strong correlation between habitual coffee consumption and decreased risk for type 2 diabetes and caffeine to not be a factor in diabetes prevention. These observations suggest compounds in coffee, other than caffeine are contributing to the beneficial effects of coffee on lowering the risk for type 2 diabetes development.

Coffee consumption on a long term basis was assessed in a prospective 18-year follow up study in Swedish women. Long term consumption of coffee was confirmed to protect from the development of diabetes in women. Analyses performed using SAS statistical software found amongst the women with coffee consumption of < 2 cups per day 475 per 100 000 person-years developed diabetes, 271 for 3-4 cups and 202 for 5-6 cups. The study did not consider men, but

proves that coffee consumption is not based an acute intake of coffee and has a long term benefit in reducing the risk of developing type 2 diabetes.[10]

Encompassing both long term intake of coffee and caffeinated and decaffeinated coffee in relation to the incidence of type 2 diabetes, 41,934 men were followed for 12 years. The results showed a strong correlation of coffee intake with cigarette smoking and alcohol use, in addition to a decreased risk for type 2 diabetes. After adjustments for age, body mass index, dietary and lifestyle factors which included smoking and alcohol use, coffee consumption remained statistically significant with a lower risk for type 2 diabetes. The multivariate relative risks for type 2 diabetes according to consumption of coffee was 0.93 (95% CI 0.84-1.15) for 1-3 cups per day and 0.71 (95% CI 0.53-0.92) for 4-5 cups per day. In decaffeinated coffee consumption, the multivariate relative risk was 0.91 (95% CI 0.76-1.03) for 1-3 cups per day and 0.74 (95% CI 0.48-1.12) for > 4 cups per day.[11] With the adjustment of confounders, the association between coffee intake (caffeinated or decaffeinated) and lower risk for diabetes proved to be independent of body mass index, cigarette smoking, alcohol use and other dietary and lifestyle factors. A considerable amount of magnesium is found in coffee and has been linked to better insulin sensitivity and secretion. The results of this study suggest the lower risk of type 2 diabetes is not associated with a short term mechanism. Also, the data from decaffeinated coffee consumption further verifies that caffeine is not the link for the decreased risk in type 2 diabetes development, but another contributing compound or a host of compounds present in coffee.

Higher habitual coffee consumption was associated with a lower 2 hour post load glucose concentrations, lower incidence of impaired glucose tolerance (IGT) and lower incidence of type 2 diabetes in a population based study of 1,312 older Dutch men and women. However, impaired fasting glucose was not found to be significantly impacted by coffee consumption.

Represented in Table 3, strong associations between coffee consumption, type2 diabetes, IGT are represented. Data was combined after oral glucose tolerance tests were performed and blood

Table 3. Incidence of type 2 diabetes IGT and IFG according to coffee consumption in the Hoorn Study

	Coffee consumption (cups per day)				
	≤2	3–4	5–6	≥7	*p* value for trend
Type 2 diabetes					
Cases	11.1% (29/261)	10.3% (52/506)	9.2% (36/392)	7.2% (11/153)	
Age- and sex-adjusted OR	1 (referent)	0.95 (0.59–1.55)	0.91 (0.54–1.55)	0.76 (0.36–1.59)	0.11
Multivariate OR[a]	1 (referent)	0.94 (0.56–1.55)	0.92 (0.53–1.61)	0.69 (0.31–1.51)	0.09
IGT					
Cases	17.2% (35/203)	10.7% (46/432)	8.2% (28/343)	6.5% (9/139)	
Age- and sex-adjusted OR	1 (referent)	0.60 (0.37–0.96)	0.50 (0.29–0.87)	0.44 (0.20–0.96)	0.005
Multivariate OR[a]	1 (referent)	0.59 (0.36–0.97)	0.46 (0.26–0.81)	0.37 (0.16–0.84)	0.001
IFG					
Cases	24.1% (53/220)	27.1% (115/425)	25.2% (85/337)	31.3% (42/134)	
Age- and sex-adjusted OR	1 (referent)	1.18 (0.81–1.73)	1.05 (0.70–1.57)	1.42 (0.87–2.32)	0.31
Multivariate OR[a]	1 (referent)	1.18 (0.80–1.75)	1.02 (0.67–1.55)	1.35 (0.80–2.27)	0.49

Values shown for cases are % (*n*/*n* total). The analysis included *n*=1312 without diabetes at baseline for incidence of Type 2 diabetes, *n*=1117 with normal glucose tolerance at baseline and without diabetes at follow-up for incidence of IGT, and *n*=1116 with normal fasting glucose at baseline and without diabetes at follow-up for incidence of IFG. [a] OR adjusted for age (years), sex, BMI (kg/m^2), WHR, physical activity (score), alcohol consumption (none, ≤10, 10–30 or >30 g/day), cigarette smoking (never, past or current), history of cardiovascular disease (yes or no), use of antihypertensive medication (yes or no), and intake of fibre (g/day), total energy (kJ/day), saturated fat (% energy) and polyunsaturated fat (% energy)

samples were collected before and 2 hours after a 75 gram glucose anhydrate load was ingested. Consumption of coffee was associated with a lower incidence of type 2 diabetes (incidence 7.2% for > 7 cups per day and 11.1% for < 2 cups per day). In addition, IGT was also reduced from 6.5% in > 7 cups per day from 17.2% for < 2 cups per day. Adjustment for magnesium intake did not explain the associations and the overall data remained significant after multivariate adjustments for potential confounders were made.[13] From the results of the study, habitual coffee consumption and lower incidence of glucose intolerance and type 2 diabetes were found to be significant. With this data, it can be determined that a compound in coffee is posing an effect on post load glucose concentrations, rather than fasting glucose concentrations. Since coffee contains a considerable amount of magnesium, it has previously been linked to better insulin

sensitivity and secretion.[13] However, adjustments for magnesium intake did not significantly alter data and cannot clarify the association between coffee consumption and diabetes[9,11,12]

Components of coffee like, chlorogenic acid, quinides and antioxidants, are thought to have beneficial effects on glucose tolerance. The association between coffee consumption with type 2 diabetes and impaired glucose tolerance, as well as insulin sensitivity and beta cell function by homeostasis model assessment (HOMA) was investigated in a study of approximately 8000 middle aged Swedish men and women. Decaffeinated coffee was not assessed since it is uncommon in Sweden. The relative risk for type 2 diabetes in men was 0.36 (95% CI 0.18-0.74) with > 5 cups of coffee per day and 0.28 (95% CI 0.12-0.65) with > 5 cups of coffee per day in women. The relative risk for impaired glucose tolerance was reduced by 40% (95% CI 0.38-0.90) in men and 60% (95% CI 0.25-0.63) in women compared to subjects consuming less than 2 cups per day. When potential confounders were included, the relative risk was not influenced. Additionally, there was a reduced relative risk of insulin resistance when > 5 cups of coffee were consumed per day in men and women subjects, but beta cell function did not show a correlation with increased coffee consumption.[14] The study showed an inverse association between coffee consumption and type 2 diabetes, which could may be mediated through improved insulin sensitivity and enhanced insulin response. Since early data has proved caffeine and magnesium to not be true factors in reducing the risk of type 2 diabetes, chlorogenic acid, quinides could be contenders in providing the beneficial effects of coffee.

Mechanisms

Currently the mechanisms for positive health effects of coffee on type 2 diabetes are unknown, but there are several plausible mechanisms. Coffee is composed of several compounds, many of which are undergoing research to determine the correlation responsible for

a lower risk for type 2 diabetes. Caffeine, which has also been shown to cause impaired glucose tolerance in humans,[15] has been ruled out as a factor in the association of coffee and diabetes in multiple studies.[8,9,11,14] However, impaired glucose tolerance from caffeine cannot apply to the effects of habitual coffee consumption and type 2 diabetes because the physiological effect of coffee and caffeine together and caffeine alone can differ. Research showed that when caffeine is consumed alone, greater glucose intolerance occurred in response to an oral glucose tolerance test, compared to caffeine and coffee combined.[16] Also, when decaffeinated coffee and water consumed were compared, a blunted rise in blood glucose occurred when decaffeinated coffee was consumed prior to an oral glucose tolerance test.[16] In support of multiple studies, it can be determined that coffee consumption and caffeine have distinct effects and are independent in their role for decreasing the risk for type 2 diabetes. Caffeine, which has also been shown to cause impaired glucose tolerance in humans,[15] has been ruled out as a factor in the association of coffee and diabetes in multiple studies.[8,9,11,14]

The anti-diabetic effect of coffee could be contributed to chlorogenic acid and its constituents in decaffeinated and caffeinated coffee. Upon the roasting of coffee, hydrolysis of some chlorogenic acid yields non acidic quinolactones, or quinides. Chlorogenic acid was shown to significantly lower glucose and insulin concentrations 15 minutes after an oral glucose load, when compared to a trigonelline ingestion.[17] Chlorogenic acid and quinides and their effect on glucose metabolism could be due to their possible inhibition of glucose-6-phosphatase or by increasing glucagon-like peptide-1 concentrations.[18,19] Inhibition of glucose-6-phosphatse, by gluconeogenesis could reduce the hepatic glucose output, possibly lessening hyperglycemia. Increased glucagon-like peptide 1 increases insulin secretion and decreases glucagon, which would help lower post load glucose concentrations. If chlorogenic acid and quinides are acting

in this manner, it would explain their ability to lower the risk for type 2 diabetes. An increase in whole body insulin action with administration quinides was confirmed in experiments performed on conscious rats.[20] The study further confirms that chlorogenic acid and quinides have shown significant results with their association to diabetes. More research needs to be performed to further justify the associations of chlorogenic acid/quinides and type 2 diabetes.

Oxidative stress, producing reactive oxygen species has been proposed to be an underlying cause for the development of insulin resistance, beta cell dysfunction, impaired glucose tolerance and ultimately type 2 diabetes.[21] Generation of reactive oxygen species can be reduced by controlling blood glucose levels. In cases where poor blood glucose occurs, antioxidants could reduce the damaging effects of oxidative stress and possibly the development for type 2 diabetes. Since coffee contains a substantial amount of antioxidants, it could be possible that it is playing a role in reducing the risk for type 2 diabetes. Like other compounds of coffee, more research is needed to evaluate the association.

Conclusion

In conclusion, this review supports the hypothesis that coffee consumption is associated with a lower risk for the development of type 2 diabetes. Long term studies have shown statistically significant anti-diabetic results in both genders of ranging ages with habitual coffee consumption. While the mechanisms are currently unclear, it can be assumed that coffee is providing anti-diabetic effects through antioxidants, inhibition of glucose-6-phostphatase or by increasing glucagon-like peptide 1; or a combination of these compounds or other compounds that have not been discovered yet. Based on data, caffeine has been ruled out as a possible mechanism. Future studies should address different types of coffee and coffee constituents to determine the compound or compounds providing the health benefits; which could lead to the

development of coffees to maximize health benefits towards type 2 diabetes. With too many unknowns for now, it is premature to recommend coffee consumption as a means for decreasing the risk for type 2 diabetes. More research is necessary, but it can be advised that habitual coffee consumption with the addition of a healthy lifestyle could further reduce the risk for type 2 diabetes.

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