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ORIGINAL CONTRIBUTION

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Effects of black and green tea consumption on blood glucose levels in non-obese elderly men and women from Mediterranean Islands (MEDIS epidemiological study)

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Abstract *Background* Obesity and diabetes are metabolic disorders that affect a large amount of the elderly population and are related to increased cardiovascular risk. Tea intake has been associated with lower risk of mortality and morbidity in some, but not all studies. We evaluated the association between tea intake, blood glucose levels, in a sample of elderly adults. *Methods* During 2005–2006, 300 men and women from Cyprus, 142 from Mitilini and 100 from Samothraki islands (aged 65–100 years) were enrolled. Dietary habits (including tea consumption) were assessed through a food frequency questionnaire. Among various factors, fasting blood glucose and body mass index (BMI) were measured. *Results* Fifty-four percent of the participants reported that they consume tea at least once a week (mean intake 1.6 ± 1.1 cup/day). A significant interaction was observed between tea intake, obesity status on glucose levels ($P < 0.001$). After adjusting for various confounders, tea intake was associated with lower blood glucose levels in non-obese (P for trend <0.001), but not in obese people ($P = 0.24$). Multiple logistic regression analysis revealed that moderate tea consumption (1–2 cups/day) was associated with 88% (95% CI 76–98%) lower odds of having diabetes among non-obese participants, irrespective of age, sex, smoking, physical activity status, dietary habits and other clinical characteristics. *Conclusion* Tea consumption is associated with reduced levels of fasting blood glucose only among non-obese elderly people.

Key words diabetes – obesity – cardiovascular risk factors – tea – elderly

Introduction

Diabetes and obesity are common metabolic disorders, especially in the elderly, and they have been associated with the development of cardiovascular disease. Moreover, presence of obesity may lead to the development of diabetes, while the opposite may also occur. During the past years scientific research has proposed several pharmacologic and non-pharmacologic means (i.e., diet and exercise) to prevent from the development of these conditions [6]. Tea is a part of dietary habits in many countries around the world, and especially in Asia. Although there are several types of tea (green, black, oolong and white), the most significant effects on human health have been found with the moderate consumption of green tea [2, 5, 8, 9, 13, 21, 23, 27, 29]. Bio-chemical analyses revealed that green tea contains significant amounts of vitamins and minerals, such as ascorbic acid (vitamin C),

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several B vitamins, such as riboflavin, niacin, folic acid, pantothenic acid, and magnesium, potassium, manganese and fluoride [5, 9, 13, 21, 27]. Many epidemiological studies and clinical trials showed that green tea (black and oolong teas to a lesser extent) may reduce the risk of many chronic diseases, including cardiovascular disease [8, 23] and cancer [14, 29]. This beneficial effect has been mainly attributed to the presence of high amounts of polyphenols that are potent antioxidants. In particular, green tea may lower blood pressure and thus, reduce the risk of stroke and coronary heart disease [28]. Some animal studies suggested that green tea may protect against the development of coronary heart disease by reducing blood glucose levels, and body weight [6, 7, 12, 24, 26]. However, most of these data are based on middle-aged populations, where the disease burden is not high, while among the elderly, where the burden of disease is high since the nutritional status tends to be more adversely influenced by age-related biological and socio-economic factors [15], information about the effect of tea consumption on health is sparse. Therefore, in the context of the Mediterranean Islands (MEDIS) study [16, 20], we evaluated whether tea consumption is associated with fasting blood glucose levels. The MEDIS epidemiological study is a cross-sectional health and nutrition survey that aims to evaluate the association between various socio-demographic, bio-clinical, dietary and other lifestyle habits and the prevalence of the common cardiovascular disease risk factors (i.e., hypertension, dyslipidemia, diabetes and obesity), among elderly people without history of chronic disease, living in Mediterranean Islands.

Methods

Participants

A random, population-based, multistage sampling (age group: three age levels; 65–75, 75–85, 85+ and sex: two levels; males, females) method was used to select men and women, 65 years of age or older, from several Cypriot cities (Arsos, Lemessos, Pachna, Pafos, Empa, Kallapia and Yeroskipu), as well as from Mitilini and Samothraki islands, in Greece. Individuals residing in assisted-living centers, as well as those with a clinical history of cardiovascular disease or cancer, were not included in this research. Of the initially selected people, 234 men and 308 women ($n = 542$) agreed to participate (Cyprus, $n = 300$, Mitilini, $n = 142$ and Samothraki, $n = 100$). The participation rate was 79%. A group of scientists (i.e., dietitians, nurses and physicians) with previous experience in field investigation (i.e., the MEDIS study group) collected all the required information, using standard procedures. The obtained data were confidential, and the study followed the ethical consideration that provided by the World Medical Association (52nd WMA General Assembly, Edinburgh, Scotland, October 2000). Before the interview, participants were informed about the aims and methods of the study and signed an informed consent.

The final number of enrolled participants is high enough for standardized difference evaluation between the investigated parameters greater than 0.5, achieving statistical power >0.80 at the <0.05 probability level (*P*-value).

Measurements

The survey included basic demographic information, such as age, gender, financial status (average annual income during the past 3 years), education level (years of school) and various clinical and biological characteristics. In particular, blood samples were collected from the antecubital vein after 12 h of fasting. Diabetes mellitus (type 2) was defined by fasting plasma glucose tests and was classified in accordance with the American Diabetes Association diagnostic criteria (i.e., fasting blood glucose levels greater than 125 mg/dl or use of special medication, indicated the presence of diabetes). Blood lipids (total, HDL, LDL-cholesterol and triglycerides) were also measured. Hypercholesterolemia was defined as total serum cholesterol levels >200 mg/dl or the use of lipid-lowering agents. Weight and height were measured to attain body mass index (BMI) scores (kg/m^2). Obesity was defined as a BMI > 29.9 Kg/m^2. Moreover, participants' blood pressure levels retrieved from their medical records. Individuals who had systolic/diastolic blood pressure levels ≥140/90 mmHg or used antihypertensive medications were classified as hypertensive.

Regarding dietary habits, consumption of 15 food groups and beverages (i.e., meat and products, fish and fisheries, poultry, milk and other dairy, fruits, vegetables, greens, legumes, cereals and non-refined cereals, coffee and tea, and soft-drinks) was measured through a semi-quantitative food-frequency questionnaire, in times of weekly consumption (never, rare, 0–1, 1–2, 3–5 times and daily). Particularly for tea consumption all participants were asked about the type of tea (green, black, oolong and white) and the frequency they consume a cup (of 150 ml) within a week (i.e., never or <1 cup per week, 1–2 cups/day, 3–5 cups/day and >5 cups/day). Coffee consumption was also recorded through the same way. Consumption of various alcoholic beverages (wine, beer, etc.) was measured in terms of wineglasses adjusted for ethanol intake (e.g., one 100 ml glass of wine was considered to be 12% ethanol). Furthermore, overall assessment of dietary habits was evaluated through a special diet score (MedDietScore, range 0–55) that assess adherence to the Mediterranean dietary pattern [18, 19]. Higher values of the score indicate greater adherence to this pattern and, consequently healthier dietary habits [18].

Physical activity was evaluated using the shortened version of the self-reported, international physical activity questionnaire (IPAQ) for the elderly [4]. Frequency (times per week), duration (minutes per time) and intensity of physical activity during sports, occupation and/or free-time activities were assessed. Participants who did not report any physical activity were defined as sedentary. Current smokers were defined as those who smoke at least one cigarette per day or have stopped cigarette smoking during the past 12 months. Former smokers were defined as those who previously smoked, but have not done so in a year or more. The remaining participants were defined as rare- or non-smokers.

Further details about the aims, sampling procedure and methods used in the MEDIS Study have been presented elsewhere [16, 17, 20].

Statistical analyses

Continuous variables are presented as mean values ± standard deviation. The categorical variables are presented as absolute and relative (%) frequencies. After controlling for equality of variances, associations between continuous variables and group of participants are evaluated with analyses of variance (ANOVA). Correlations between continuous variables are tested with Spearman's correlation coefficient. Multiple linear regression was applied to evaluate the relationship between blood glucose levels and tea consumption, after adjusting for various potential confounders. The interaction between tea intake variable with potential confounding factors, like obesity status, was also assessed. The assumptions of linearity for the continuous independent variables and constant variance of the standardized residuals were assessed through plotting the residuals against the fitted values. We also calculated the R^2 in order to find how well each fitted model predicts the dependent variables. Moreover, multiple logistic regression analysis by the calculation of odds ratio and the corresponding 95% confidence intervals, evaluated the association between tea intake and the presence of diabetes. P-values < 0.05 from two-sided hypotheses are considered as statistically significant. All statistical calculations are performed on the SPSS version 14.0 software (SPSS Inc, Chicago, IL, USA).

Results

The prevalence of type 2 diabetes mellitus in our sample was 19.2% in men and 20.1% in women ($P = 0.79$), while the prevalence of obesity was 31.7% in men and 48.0% in women ($P = 0.001$). Treatment of diabetes was as follows: all diabetic men and women were on special diet, 84% of men and 82% of women were also taking medication (e.g., sulfonylureas, biguanides, alpha-glucosidase inhibitors etc.) and 2% of men and 13% of women were on insulin treatment.

About one half of the participants (i.e., 54%) reported that they consumed tea at least one time per week (mean intake 1.6 ± 1.1 cup/day). Moreover, the types of tea consumed were mainly (i.e., 98%) green or black. Since the majority of the participants reported that they consumed green or black tea and very few of them (i.e., <2%) reported exclusive consumption of black or green tea, it was decided to use combined tea consumption in all analyses followed on. The participants reported that they had the same habits regarding tea consumption for at least the past 3 decades of their life. Table 1 presents socio-demographic and lifestyle characteristics of the participants by tea consumption group. As it can be seen, no differences were observed between genders and frequency of tea consumption, while people in the higher tea intake consumption group were older, more likely to adhere a Mediterranean diet and less likely to be sedentary. Additionally, no association was observed between tea intake and smoking habits or coffee consumption. Furthermore, no differences were observed regarding socio-demographic variables and consumption of tea between regions of the study ($P > 0.2$).

Table 2 presents biological and clinical characteristics of participants by tea consumption group. As we can see an inverse, dose-response relationship was found between tea intake and fasting blood glucose levels, as well as the prevalence of diabetes mellitus. Moreover, unadjusted analysis revealed that tea consumption was associated with 48% lower likelihood of diabetes (95% CI 20–66%). Moreover, no significant associations were observed between tea consumption and arterial blood pressures, BMI, lipids and triglycerides levels. Moreover, no changes in the aforementioned results were observed when the analysis was stratified by the gender of the participants (data not shown in text or Tables).

Despite the previous analyses, residual confounding may exist. Thus, we also adjusted for age, sex, education status, physical activity and total cholesterol level, as well as for dietary and smoking habits of the participants. It was observed that an increase of

Table 1 Participant's demographic and lifestyle characteristics

	Tea consumption					
	<1 cup/week	1–2 cups/day	3–5 cups/day	> 5 cups/day	Overall	*P*
% of participants	46%	29%	22%	3%	100%	
Age (years)	74 ± 7	77 ± 7	76 ± 6	78 ± 9	75 ± 7	0.01
Male sex (%)	40	48	43	47	43	0.42
Years of school	5.3 ± 2	5.3 ± 3	6.0 ± 3*	5.8 ± 3**	5.5 ± 3	0.10
Current smokers (%)	7	11	7	6	8	0.44
Coffee drinkers (%)	86	88	84	76	86	0.62
Physically inactive (%)	66	61	53	53	61	0.09
MedDietScore (0–55)	26 ± 4	24 ± 4	28 ± 4	30 ± 4	27 ± 4	0.001

Data are expressed as mean ± standard deviation or percentages
*$P < 0.05$ and **$P < 0.01$ (Bonferroni corrected) for the differences between green tea consumption groups vs. no consumption. Probability values derived from ANOVA or *Z*-tests.

Table 2 Participant's biological characteristics by tea consumption group

	Tea consumption					
	<1 cup/week	1–2 cups/day	3–5 cups/day	> 5 cups/day	Overall	*P*
% of participants	46%	29%	22%	3%	100%	
Blood glucose (mg/dl)	121 ± 42	107 ± 24**	105 ± 24**	110 ± 73**	113 ± 37	0.008
Diabetes mellitus (%)	25	18*	9**	29	20	0.001
Body mass index (kg/m^2)	29 ± 5	28 ± 5	30 ± 5	28 ± 5	29 ± 5	0.77
Obese (%)	41	40	47	41	42	0.63
Systolic blood pressure (mmHg)	137 ± 15	140 ± 15	137 ± 16	142 ± 15	138 ± 16	0.28
Diastolic blood pressure (mmHg)	80 ± 8	80 ± 9	81 ± 9	77 ± 11	80 ± 9	0.57
Hypertension (%)	60	68	61	71	63	0.38
Total cholesterol (mg/dl)	221 ± 43	229 ± 45	228 ± 37	233 ± 84	226 ± 44	0.51
Hypercholesterolemia (%)	52	47	52	40	50	0.62
HDL cholesterol (mg/dl)	55 ± 11	56 ± 11	57 ± 9	45 ± 7	55 ± 11	0.23
LDL cholesterol (mg/dl)	143 ± 38	149 ± 37	146 ± 37	120 ± 31	145 ± 38	0.49
Triglycerides (mg/dl)	142 ± 71	138 ± 64	123 ± 40	149 ± 49	136 ± 62	0.19
# CVD risk factors (0–4)†	1.8	1.7	1.6	1.8	1.7	0.88

No gender differences were observed
*$P < 0.05$ and **$P < 0.01$ (Bonferroni corrected) for the differences between fish consumption groups vs. no consumption. Probability values derived from the ANOVA or the *Z*-test.
†Factors added in this variable were: hypertension, diabetes, hypercholesterolemia and obesity.

one cup of tea per day was associated with 5.9 mg/dl decrease of glucose levels (or 5% reduction of mean glucose levels), independent from the other characteristics of the participants. Comparing the net effect of tea intake on blood glucose levels, using a dummy variable that categorised the frequency of intake (i.e., never or <1 cup per week, 1–2 cups/day, 3–5 cups/day and >5 cups/day) it was revealed that the more prominent results were found in moderate consumption (i.e., 1–2 cups/day, $P < 0.001$) as compared to no intake, while increased consumption did not show any significance. Moreover, BMI and coffee drinking were also positively associated with blood glucose levels, while a decreasing trend in glucose levels was found with greater adherence to the Mediterranean dietary pattern. However, a strong interaction was observed between tea intake and obesity status on blood glucose levels ($P < 0.001$). Thus, we stratified our analysis by obesity status and we observed that tea intake was associated with lower blood glucose levels in non-obese (*P* for trend <0.001), but not in obese people (*P* for trend = 0.24), after adjusting for various potential confounders. No other factors were associated with blood glucose levels in our sample. In addition, an increase of one cup (or 150 ml) per day of tea consumption was associated with 88% lower likelihood of having diabetes among non-obese individuals (95% CI 76% to 98%), but not in obese people.

Discussion

The association between tea intake and blood glucose levels by obesity status was investigated, in a sample of elderly men and women living in Mediterranean islands. This is one of few studies that evaluate this hypothesis in elderly individuals, in whom disease burden is high. It was found that moderate (i.e., 1–2 cups per day) tea consumption is associated with a significant reduction in fasting blood glucose levels among non-obese participants, while no association was observed when we focused our interest in obese men and women. This finding is of great importance for public health, since diabetes is one of main causes of disability and death in the elderly, and tea consumption seems to be an effective non-pharmacologic mean for reducing the burden of diabetes and its consequences.

Several epidemiological and clinical studies have shown that tea may benefit human health through various mechanisms [2, 5, 7, 8, 9, 13, 14, 21, 23, 24, 27–29]. In a recent study of about 17,300 middle aged Japanese men and women, Iso et al., observed that green tea consumption of 1–6 cups per week was associated with 34% lower risk of diabetes after a 5-year follow up even after adjusting for various potential confounders, including coffee intake [11]. The benefits were more prominent in the highest coffee intake group. Moreover, no other type of tea (i.e., black, white or oolong) was associated with the incidence of diabetes within the follow up period. The later findings were similar to the ones observed in the present work. Furthermore, consumption of green or black tea was not related to smoking, BMI, or physical activity status of the participants both in the present as well as the study performed by Iso and colleagues.

There are some potential mechanisms that may explain the benefits of tea consumption on human health. In particular, it has been suggested that polyphenols contained in tea may be responsible for the beneficial actions of tea consumption on various metabolic disorders [2]. The primary polyphenols found in tea are the catechins, which account for 30–40% of dry tea weight. Catechins are strong antioxidants, and hence, may play a crucial role in the prevention of atherosclerosis that is known to be a free radical dependent process. Arts et al., studying elderly men from the Zutphen Study reported that catechins from tea or other sources may reduce the risk for ischemic heart disease, but not for stroke [1]. Other polyphenols found in tea are flavanols, flavanol glycosides, flavandiols, phenolic acids and depsides. All types of polyphenols behave as potent antioxidants and thus, they may prevent tissue damage caused by free radicals [25]. This led to the suggestion that the beneficial actions of tea in the prevention of various chronic diseases, like coronary heart disease and cancer, could be due to its ability to reduce the susceptibility of low density lipoproteins to oxidation, suppress vascular endothelial cell expression of pro-inflammatory cytokines, and consequent up-regulation of adhesion molecules and monocyte adhesion. The aforementioned actions could also be responsible for lower glucose levels seen with green tea consumption [22]. However, there are some studies that did not support our findings [3, 10]. In particular, Hino et al., studied 1900 Japanese men and women over 40-year-old and observed that coffee, but not green tea consumption was inversely associated with metabolic syndrome [10]. It could be speculated that some ingredients contained in coffee, but not in green tea may have favorable effects on blood glucose levels; however, we cannot elucidate the mechanisms for this association, and this issue needs to be investigated further. In our work, we have also observed a strong inverse relationship between coffee intake and blood glucose levels in both obese and non-obese participants (Table 3). Despite the considerations made by Hino and colleagues, the effect of tea consumption among non-obese participants remained significant in our study, irrespective of coffee drinking.

Table 3 Results from multiple linear regression analysis that evaluated the association between tea consumption (in cups/day) and levels of fasting blood glucose (dependent outcome), by obesity status

Non-obese participants (n = 323)	B-coefficient ± Standard error	P
Tea consumption		
<1 cup/day	(reference category)	
1–2 cups/day	−6.86 ± 2.60	0.12
3–5 cups/day	−7.99 ± 4.7	0.02
>5 cups/day	−12.31 ± 3.7	0.004
Age (per 1 year)	0.29 ± 0.45	0.52
Current smoking (yes/no)	12.5 ± 9.9	0.22
Physical activity (yes/no)	2.46 ± 5.01	0.65
Male sex (yes/no)	−6.5 ± 6.1	0.31
Years of school	2.2 ± 1.6	0.41
Coffee drinking (yes/no)	−16.2 ± 6.9	0.02
Systolic blood pressure (per 1 mmHg)	0.19 ± 0.20	0.35
Diastolic blood pressure (per 1 mmHg)	−0.08 ± 0.32	0.81
Total cholesterol (per 1 mg/dl)	−0.07 ± 0.32	0.80
MedDietScore (0–55)	−1.8 ± 0.58	0.10
Adjusted R^2 with/without tea intake variable in the mode		13/9%
Obese participants (n = 219)	**B-coefficient ± Standard error**	**P**
Tea consumption		
<1 cup/day	(reference category)	
1–2 cups/day	−2.16 ± 2.80	0.34
3–5 cups/day	−5.24 ± 4.7	0.12
>5 cups/day	−9.21 ± 5.7	0.18
Age (per 1 year)	0.64 ± 0.68	0.35
Current smoking (yes/no)	−10.3 ± 17.2	0.55
Physical activity (yes/no)	−3.6 ± 7.12	0.61
Male sex (yes/no)	8.15 ± 7.82	0.29
Years of school	2.12 ± 1.8	0.55
Coffee drinking (yes/no)	−27.9 ± 12.8	0.02
Systolic blood pressure (per 1 mmHg)	0.14 ± 0.22	0.54
Diastolic blood pressure (per 1 mmHg)	0.04 ± 0.40	0.93
Total cholesterol (per 1 mg/dl)	0.11 ± 0.08	0.18
MedDietScore (0–55)	−1.04 ± 0.65	0.94
Adjusted R^2 with/without tea intake variable in the mode		8/7%

Furthermore, the present study was not designed to examine whether green tea is better than black or other types of tea, regarding the prevalence of diabetes since, mixed consumption of green and black tea was taken into consideration in the selected sample. Nevertheless, as green tea contains higher amounts of catechin compared to black tea, it is anticipated that a large scale randomised clinical trial could explain whether black tea is as good as green tea in reducing blood glucose levels and prevent atherosclerosis [7].

Limitations

This MEDIS Study is cross-sectional and, consequently, has the potential of recall biases, particularly in the assessment of dietary habits. Thus, the design of this study prohibits causal interpretations. Moreover, people living in Mediterranean islands are not a representative sample of the total population; however, they could be considered as a "closed" cohort for long time, and, therefore the influence of westernised habits may not reach them. Another limitation is that consumption of tea is associated with healthy behaviors, such as increased physical activity, healthier dietary habits and non-smoking. In the present work, these potential confounders were statistically controlled, but, as always the residual confounding cannot be explained. Finally, the IPAQ tool used for the assessment of physical activity status has been validated only for 18–65 years old people, but not for elderly; however, we believe that this does not alter the significance of our findings.

Conclusion

In this work we revealed a beneficial association of tea consumption on fasting blood glucose levels, among non-obese elderly people. However, presence of obesity masked the previous finding. Our results are in agreement with those of previous studies conducted in young or middle-aged samples, but they also state a new research hypothesis regarding the confounding effect of obesity that needs further investigation. Conclusively, tea could be an effective, non-pharmacologic mean for the reduction of blood glucose levels in older adults, and therefore, it should be included in public health strategies.

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