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ARTICLE

The Effect of Green Tea and Sour Tea on Blood Pressure of Patients with Type 2 Diabetes: A Randomized Clinical Trial

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ABSTRACT. *Introduction:* The use of herbal medicines including different types of tea is among the different strategies for preventing and controlling the side-effects of diabetes. The aim of the present study was to compare the effect of sour tea and green tea on mildly hypertensive patients with diabetes. *Methods:* The present study was a randomized clinical trial in which 100 mildly hypertensive patients with diabetes were randomly assigned into sour tea group (ST) and green tea group (GT). They were instructed to drink sour tea and green tea infusion, respectively, three times a day 2 hr after each meal for 4 weeks. The participants' blood pressure was measured at days 1, 15, and at the end of study. *Results:* The systolic pressure of both groups statistically decreased at the end of the study; it decreased from 123.1 ± 15.5 to 116.8 ± 16.3 mmHg in the ST and from 119.4 ± 15.1 to 114.8 ± 15.9 mmHg in the GT. The diastolic pressure of both groups statistically decreased by the end of the study; it decreased from 79.4 ± 11.1 to 74.5 ± 9.3 mmHg in the ST and from 78.9 ± 8.3 to 75.3 ± 7.7 mmHg in the GT. The therapeutic effectiveness of tea drinking by the end of intervention was 43.5% in the ST and 39.6% in the GT compared to the beginning. *Conclusions:* The present study revealed that mildly hypertensive type 2 diabetic individuals who drink three glasses of green or sour tea daily for 4 weeks show significant decreased systolic and diastolic blood pressures.

KEYWORDS. blood pressure, diabetes mellitus, green tea, sour tea

INTRODUCTION

Diabetes mellitus is one of the most common chronic metabolic disorders (Shaw, Sicree, & Zimmet, 2010). The prevalence of this disorder is progressively increasing around the world (zimi-Nezhad et al., 2008). About 6.4% or 285 million individuals in the adult population (20–79 years) were affected by diabetes in 2010.

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It is estimated that by 2030, this rate will increase by 7.7% or 439 million persons, and during 2010–2030, about 69% of the increase will belong to developing countries and 20% to developed ones (Shaw et al., 2010). The incidence of diabetes in the adult population of Iran in 2005 is reported to be 7.7% or 2 million people (Esteghamati et al., 2008). Hypertension is one of the complications of diabetes so that the probability of its incidence in diabetic persons is twice that of patients without diabetes (El-Atat, McFarlane, & Sowers, 2004). It is estimated that in 2025, 333 million people in developed countries and 639 million people in developing countries will be affected by hypertension (Kearney, Whelton, Reynolds, Whelton, & He, 2004; Kearney et al., 2005).

The use of herbal medicines including different types of tea is among the different strategies for preventing and controlling the complications of diabetes. Different types of tea contain many chemical constituents including flavonoids, anthocyanin, delphinidin, hibiscetin, etc. These compounds are thought to be effective in controlling the metabolic and vascular complications of diabetes. On the other hand, tea is one of the most common drinks used in various societies (Sharma & Rao, 2009). It has been used in Asia for more than 4,000 years (Gardner, Ruxton, & Leeds, 2007) and is of different types including green tea, black tea, white tea, yellow tea, and Olong tea (Yuerong, Jianliang, Lingyun, Shan, & Ying, 2003).

Green tea with the scientific name of *Camellia Sinesis* is one of the richest sources of flavonoids. This substance is rich with polyphenols of catechin, epicatechin, epigallocatechin, and epigallocatechin-3-gallate (Crespy & Williamson, 2004). A number of studies have investigated the effect of green tea on different diseases. It has been known that the consumption of green tea decreases fasting blood sugar (FBS) and improves the glucose balance in patients with diabetes (Bose et al., 2008). It also prevents cardiovascular diseases, cancers, and type II diabetes and improves the indices of metabolic syndromes (Brown et al., 2009).

Sour tea bears the scientific name of *Hibiscus Sabdariffa* of the Malvaceae family. Various constituents as ascorbic acid, anisaldehyde, anthocyanin, β-carotene, β-sitosterol, citric acid, cyianidin-3 rutinoside, delphinidin, galactose, gossypetin, hibiscetin, mucopolysaccharide, pectin, polysaccharide, and stearic acid are present in the petals of this herb. That is why it possesses anticancer, antioxidant, anti-inflammatory, and hypocholesterolemic properties (Mahadevan, Shivali, & Kamboj, 2009; Mozaffari-Khosravi, Jalali-Khanabadi, fkhami-Ardekani, & Fatehi, 2009a).

The consumption of various kinds of tea is very high in many countries including Iran, and people attribute various therapeutic effects to them. Few studies have so far compared the effect of green and sour tea on the blood pressure of patients with type 2 diabetes and mildly hypertensive patients. The aim of this intervention was to compare the effect of drinking these two teas on mildly hypertensive patients with diabetes.

METHODS AND MATERIALS

Design and Participants

The present study was a randomized clinical trial conducted on 100 patients with diabetes supported by Yazd Diabetes Research Center in 2011. The

inclusion criteria were: (a) an age range of 30–60 with a 5-year history of diabetes; (b) a blood pressure of 120–139/80–89 mmHg; (c) absence of nephropathic and other expressive symptoms; (d) lack of use of insulin; (e) absence of consumption of antioxidant complements, vitamins, minerals, and fish oil 6 months prior to intervention; and (f) a negative history of renal, thyroid, hepatic, and cardiovascular disorders. The exclusion criteria included: (a) a radical change in diet during intervention; (b) sensitivity to the consumption of green and sour tea; (c) a change in the treatment course of the patient (a dosage change of glucose-lowering, far-lowering, and antihypertension drugs, a shift from tablets to insulin); and (d) reluctance for the continuation of intervention.

Patients qualifying for inclusion in the study received some explanation and clarification of the course of the study and signed the informed written consent to participate in the research project. The participants were randomly assigned to the sour tea group (ST) and the green tea group (GT) using the random numbers table.

Intervention Method

Similar green and sour teabags of equal weight were given to the participants in both groups. The participants prepared the tea at home as they were instructed by the researcher and consumed it three times a day. The consumption period was 4 weeks three times a day 2 hr after each meal.

Instructions for making the tea, the amount of drinking, and other necessary information were given to the patients at the beginning of the study. The participants in the GT were asked to boil the 3-g green teabags in 150 ml of 60–70°C water and wait for 5 min and then drink the tea. The participants in the ST were asked to boil the 3-g sour teabags in 150 ml of 60–70°C water and wait for 10–15 min and then drink the tea. The participants drank this amount of tea wholly at one time. They were allowed to use one ripened date to make the tea consumption easier and enjoyable. The participants were asked not to use any other type of tea during the study, change their diet and physical activity, or use polyphenol-rich food items as chocolate and coffee.

The amount of tea consumed by participants could be determined by counting the number of unused teabags. Also, participants' sensitivity to tea and possible complications during the intervention were studied in direct interviews. The green and sour teas were bought from reliable herbal shops and were approved by the naturist practitioners.

Measurements

Overnight fasting blood samples were obtained before and after intervention. Levels of FBS were measured by glucose oxidase method. Demographic information was recorded in the first visit. The body measurement parameters were recorded and repeated at the end of 4-week intervention. The body measurements included weight measured by digital scales with the least amount of clothes on with an accuracy of 0.1 kg, and height measured in the standing position without shoes using a tape measure with an accuracy of 0.1 cm. Body mass index (BMI) was calculated by dividing weight by the square root of height in meters. The participants' systolic pressure (SBP) and diastolic pressure (DBP) were measured in the morning on days 1, 15, and at the end of study with an accuracy of 2 mmHg in the sitting position

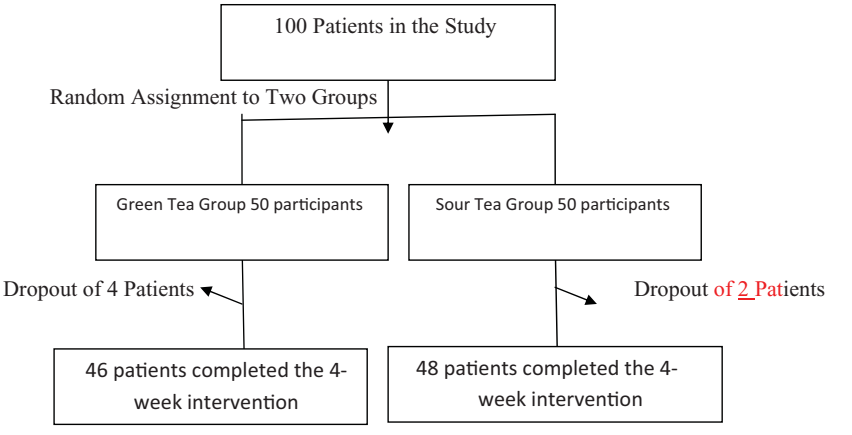

FIGURE 1. Steps in intervention.

on a chair 5 min after resting in the right arm using a mercury sphygmomanometer (Samsung, Japan). The positive therapeutic effects in each stage were achieved when the DBP decrease was ≥10 mmHg (Mozaffari-Khosravi, Jalali-Khanabadi, fkhami-Ardekani, Fatehi, & Noori-Shadkam, 2009b).

In order to estimate the individuals' daily dietary intake, use was made of the 24 hr dietary recall questionnaire. The data were analyzed using the Nutritionist IV (Nutritionist IV Diet Analysis, First Data Bank Division, Hearst Corp., San Bruno, CA, USA).

Ethical Considerations

Patients' confidential data were coded and not published. The teabags were given free of charge to the participants. Informed written consent was obtained from the patients before the study after clarification. The statement of the Bioethics Committee of Yazd Shahid Sadoughi University of Medical Sciences was given. It has been registered in the website of Iranian Clinical Trial (www.irct.ir) with the code of IRCT201107317161N1.

Data Analysis

The data were analyzed using SPSS software version 11 (SPSS Inc., Chicago, IL, USA). Descriptive statistics as mean, standard deviation (SD), frequency, and frequency percentages, as well as tests such as paired *t*-test, student *t-test*, Chi-square test, Fischer's exact test, and Friedman test were used. The significance of *p*-value was set at $<.05$.

RESULTS

There were 100 participants at the beginning of the study, of whom 94 remained until the end of the trial (Figure 1). Of the participants who dropped out, 4 were in the ST and 2 in the GT. They discontinued their participation due to factors as sensitivity to tea, disliking tea, traveling, and lack of interest for cooperation. Based

TABLE 1. Frequency Distribution of Qualitative Variables in Both Groups before Intervention

	Sour Tea Group		Green Tea Group		
Variable	*N*	%	*N*	%	*p*-Value
Gender					
Male	9	19.6	12	25	*.3
Female	37	80.4	36	75	
Education					
Illiterate	8	17.4	10	20.8	**.2
Primary	25	54.3	18	37.5	
High school	7	15.2	15	31.3	
Higher education	6	13	5	10.4	
Taking oral hypoglycemic agents					
Yes	42	19.3	43	89.6	*.5
No	4	8.7	5	10.4	
Taking antihypertensive drug					
Yes	21	45.7	16	34	*.2
No	25	54.3	31	66	
Having a special diet					
Yes	6	13	10	20.8	*.2
No	40	87	38	79.2	
Systolic blood pressure (mmHg)					
Less than 140	44	95.7	46	95.8	*.9
More than 140	2	4.3	2	4.2	
Diastolic blood pressure (mmHg)					
Less than 85	30	65.2	36	75	*.3
More than 85	16	34.8	12	25	
Body mass index (kg/m^2)					
25 – 18.5	7	15.2	19	39.6	**.01
30 – 25	26	56.5	15	31.3	
More than 30	13	28.3	14	29.2	

*Fisher's exact test, **Chi-square test.

on the follow ups by the researcher, the compliance rate was 89% in the ST, and 91% in the GT. None of the participants in the two groups reported any adverse effects.

The baseline data are given in Tables 1 and 2. As these tables show, except for BMI classification (not mean), no significant differences in any variables between the two groups were seen. The sex distribution, a special diet, taking diabetes tablets, and blood pressure were equal in both groups and were not statistically significant.

A comparison of SBP, DBP, pulse pressure, weight, BMI, and FBS in both groups before and after intervention are given in Table 3. As the table shows, the mean FBS concentration, weight, and BMI within and between groups did not show any significant difference. The SBP of both groups statistically decreased at the end of the study compared to the beginning of the study, 123.1 ± 15.5 to 116.8 ± 16.3 mmHg

TABLE 2. Comparing Means of Quantitative Variables in Both Groups at the Beginning of Intervention

Variable	Sour Tea Group (46)	Green Tea Group (48)	*p*-Value*
Age (year)	*6 ± 52.1	6.7 ± 52.2	.9
Age of affliction with diabetes (year)	5.9 ± 48.1	6.6 ± 48.2	.9
Duration of affliction (year)	25.9 ± 3.6	24.9 ± 3.6	.8
Weight (kg)	12.6 ± 73.1	12.8 ± 71.8	.6
Height (cm)	7.9 ± 160.2	10.2 ± 160.6	.8
Body mass index (kg/m^2)	3.8 ± 28.3	5.6 ± 28	.7
Systolic blood pressure (mmHg)	15.5 ± 123.1	15.1 ± 119.4	.2
Diastolic blood pressure (mmHg)	11.1 ± 79.4	8.3 ± 78.9	.8
Pulse pressure (mmHg)	12 ± 43.7	12.6 ± 40.5	.2
Dietary intake			
Energy (Kcal/day)	1555.2 ± 115.9	1503.9 ± 257.3	.4
Carbohydrate (g/day)	248 ± 49	235 ± 40	.3
Protein (g/day)	54.4 ± 16.5	50.3 ± 18.3	.3
Fat (g/day)	38.4 ± 16.6	40.3 ± 12.6	.5
Protein (g/day)	38.4 ± 16.6	40.3 ± 12.6	.5

*Student *t*-test.

TABLE 3. Comparing Means of Systolic, Diastolic, and Pulse Pressure, Weight, Body Mass Index and Fasting Blood Sugar in Both Groups Before and After Intervention

Variable	Beginning	Week 2	Week 4	*p*-Value**
Systolic blood pressure (mmHg)				
Sour tea	15.5 ± 123.1	16.2 ± 120.2	16.3 ± 116.8	<.001
Green tea	15.1 ± 119.4	14.8 ± 117.5	15.9 ± 114.8	<.001
p-Value*	.2	.8	.5	
Diastolic blood pressure (mmHg)				
Sour tea	11.1 ± 79.4	9.8 ± 77.1	9.3 ± 74.5	<.001
Green tea	8.3 ± 78.9	7.7 ± 77	7.7 ± 75.3	<.001
p-Value	.8	.9	.6	
Pulse pressure (mmHg)				
Sour tea	12 ± 43.7	12.7 ± 43	12.5 ± 42.2	.5
Green tea	12.6 ± 40.5	12.5 ± 40.4	13.2 ± 39.5	.4
p-Value	.2	.3	.3	
Fasting blood sugar (mg/dl)				
Sour tea	160.5 ± 49.1	-	162.1 ± 49.6	.6
Green tea	155.3 ± 47.4	-	154.0 ± 48.8	.7
p-Value	.6		.4	
Weight (kg)				
Sour tea	12.6 ± 73.1	-	12.5 ± 72.9	***.1
Green tea	12.8 ± 71.8	-	12.8 ± 71.6	.1
p-Value	.6		.6	
Body mass index				
Sour tea	3.8 ± 28.3	-	3.8 ± 28.2	***.1
Green tea	5.6 ± 28	-	5.5 ± 27.9	.08
p-Value	.7		.7	

*Paired *t*-test, **Friedman test, ***Student *t*-test.

TABLE 4. Mean of Percentage of Blood Pressures Change in Both Groups during Intervention

Variables	Days 0–15	Days 15–30	Days 0–30
Systolic blood pressure (mmHg)			
Sour tea	$+2.3 \pm 5.5$	$+2.6 \pm 5.8$	$+5 \pm 7.3$
Green tea	$+1.4 \pm 5.9$	$+2 \pm 7.1$	$+3.6 \pm 8$
p-Value**	.4	.6	.3
Diastolic blood pressure (mmHg)			
Sour tea	$+2.3 \pm 8.3$	$+3.2 \pm 5.4$	$+5.6 \pm 7.5$
Green tea	$+2.1 \pm 5.4$	$+2.1 \pm 6$	$+4.3 \pm 7.5$
p-Value**	.9	.3	.4

**Student *t*-test, + : decrease, □ : increase

in the ST and from 119.4 ± 15.1 to 114.8 ± 15.9 mmHg in the GT. However, its mean was not statistically different between the two groups at the end of intervention (Table 3).

The DBP of both groups decreased statistically at the end of the study compared to the beginning of the study, it decreased from 79.4 ± 11.1 to 74.5 ± 9.3 mmHg in the ST and from 78.9 ± 8.3 to 75.3 ± 7.7 mmHg in the GT. However, its mean was not statistically different between the two groups at the end of intervention (Table 3).

There was not a statistically significant difference between pulse pressures of both groups at the end of the study. It decreased from 43.7 ± 12 to 42.2 ± 12 mmHg in the ST and from 40.5 ± 12.6 to 39.5 ± 13.2 mmHg in the GT. However, its mean was not statistically different between the two groups at the end of intervention (Table 3).

There was a decrease in weight and BMI in both groups, yet it was not statistically significant. The mean of these two indices was not statistically different between the two groups at the end of intervention (Table 3). The changes in the SBP and DBP during intervention are given in Table 4. In all phases of intervention, both SBP and DBP decreased in both groups but the mean of percentage of changes between the two groups during intervention was not statistically different.

The SBP of the ST decreased $2.3 \pm 5.5\%$ in days 0–15 and $2.6 \pm 5.8\%$ in days 16–30. These changes in SBP in the GT were $1.4 \pm 5.9\%$ and $2 \pm 7.1\%$, respectively. Also, the DBP of the ST decreased $2.3 \pm 8.3\%$ in days 0–15 and $3.2 \pm 5.4\%$ in days 16–30. These changes in DBP in the GT were $2.1 \pm 5.4\%$ and $2.1 \pm 6\%$, respectively.

The therapeutic effectiveness of intervention on the blood pressure of patients in both groups is presented in Table 5. The amount of effect of both types of tea in both groups was almost the same during intervention and was not statistically different. The amount of effectiveness in day 15 of intervention was 23.9% in the ST and 20.8% in the GT. They were 26.1% and 18.8%, respectively, in the second half of intervention. Compared to the beginning of the study, drinking green tea induced a 39.6% decrease in blood pressure. Similarly, drinking sour tea resulted in a 43.5% decrease in blood pressure.

TABLE 5. Therapeutic Effectiveness Effect of Intervention on Blood Pressure in Both Groups

	Days 0–15		Days 15–30		Days 0–30	
Group	Effect	No. (%)	Effect	No. (%)	Effect	No. (%)
Sour tea	Yes	11 (23.9)	Yes	12 (26.1)	Yes	20 (43.5)
	No	35 (76.1)	No	34 (73.9)	No	26 (56.5)
Green tea	Yes	10 (20.8)	Yes	9 (18.8)	Yes	19 (39.6)
	No	38 (79.2)	No	39 (81.3)	No	29 (60.4)
p-Value*	.7		.3		.7	

*Chi-square test.

DISCUSSION

The patients' compliance rate in tea consumption based on the instructions given was about 90% in both groups, which showed their acceptable cooperation. On the other hand, there was no statistically significant difference in sex distribution, special diet, taking diabetes tablets, and hypertension in both groups as they were the same for both groups (Table 1). Also, there was no statistically significant difference between the two groups at the beginning of the study regarding age mean, duration of affliction with diabetes, weight, BMI, and SBP, DBP, and pulse pressures (Table 2). So, the data showed that the random sampling has been proper in both groups regarding the point that there was no statistically significant difference between the two groups at the beginning of intervention.

In the present study, the SBP and DBP of both groups decreased significantly at the end of the study compared to the beginning, yet the final means of SBP and DBP were not statistically significant at the end of the study (Table 3). Also, there was no statistically significance difference between the percent of changes in the SBP and DBP during the intervention in both groups and the pressure decreased equally. The SBP and DBP in the ST decreased averagely, that is, $5 \pm 7.3\%$ and $5.6 \pm 7.5\%$, respectively, and $3 \pm 6.8\%$ and $4.3 \pm 7.5\%$, respectively in the GT (Table 4).

Pulse pressure decreased in both groups in this study at the end of intervention but it was not statistically significant. So, both types of teas decreased the SBP and DBP and they were not different in this regard.

The findings of this study are similar to many other studies. In a study by Haji Faraji, the effect of sour tea on the blood pressure of hypertensives was investigated. It showed that both SBP and DBP decreased significantly at the end of intervention (Haji & Haji, 1999). Another study showed that the SBP and DBP of hypertensive patients decreased by 11.58% and 12.21% at the end of intervention by sour tea, respectively (Herrera-Arellano, Flores-Romero, Chavez-Soto, & Tortoriello, 2004).

In the study by Mozaffari-Khosravi et al. on mildly hypertensive patients with diabetes, the SBP decreased significantly from 134.4 ± 11.8 to 112.7 ± 2.2 mmHg at the end of the study, yet the DBP did not decrease significantly. Also, pulse pressure decreased significantly from 52.2 ± 2.2 to 34.5 ± 9.3 mmHg (Mozaffari-Khosravi et al., 2009b). These results were found in the study by Diane et al. on mildly

hypertensive patients in whom the SBP decreased significantly while the DBP did not (McKay, Chen, Saltzman, & Blumberg, 2010).

Several other studies have investigated the effect of green tea on decreasing blood pressure. In a study on rats, they were divided into three groups. For 12 weeks, one group just received water, and the other two groups received 0.2 g and 1 g of green tea for each kilogram of body weight. The results showed that the SBPs of green tea groups significantly decreased compared to the water group at the end of intervention (Yue-Rong et al., 2011).

Another study investigated the effect of green tea extract on risk factors of cardiovascular disease in fat males and females. The experimental group consumed 583 mg catechin for 12 weeks and the control group consumed 96 mg catechin for the same period. It was observed at the end of the study that the SBP of the experimental subjects decreased significantly compared to the control subjects (Nagao, Hase, & Tokimitsu, 2007). Yet, in another study, polyphenol complements of green tea were given to fat and overweight men. At the end of eighth week of intervention, it was observed that the DBP decreased significantly compared to the placebo group. However, there was no significant decrease in the SBP (Brown et al., 2009).

The recommended mechanism for the effect of green tea on blood pressure is said to be through the polyphenol EGCG. This polyphenol increases the production of nitric oxide (NO) and thereby changes the blood pressure (Wolfram, 2007). Some studies showed that sour tea due to its specific components such as antocianin, exerts an effect on the blood pressure (Mozaffari-Khosravi et al., 2009b). The probable mechanism for decreasing blood pressure by sour tea may be through releasing NO from the endothelium of vessels and preventing calcium penetration to vascular smooth muscle cells (Mahadevan et al., 2009).

Previous studies have not compared the effect of green and sour tea on hypertensive diabetes. The present study surveyed this issue with its own subject inclusion criteria and methodology. The limitations of the study included: lack of a control group to which to compare the two experimental groups, and lack of measurement of concentrations of sodium, potassium, and calcium and the other specific amount of various respective active constituents such as caffeine. Another limitation of this study was that it did not use a double-blind design. Blinding would be difficult to accomplish due to the distinct tastes and smells of the tea. It is recommended that this study be replicated to study the effect of these two types of tea on blood pressure while considering their effects on concentrations of sodium, potassium, and calcium in blood and urine, the effect on heart rate, and clinical signs and symptoms.

The present study revealed that mildly hypertensive type 2 diabetic individuals who drink three glasses of green or sour tea daily for 4 weeks show significant decreased systolic and diastolic blood pressures. Based on this finding and regarding the reported similar useful effects in other studies, it is advised that hypertensive diabetes drink these types of tea daily.

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