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ORIGINAL ARTICLE

The effects of sour tea (*Hibiscus sabdariffa*) on hypertension in patients with type II diabetes

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To compare the antihypertensive effectiveness of sour tea (ST; *Hibiscus sabdariffa*) with black tea (BT) infusion in diabetic patients, this double-blind randomized controlled trial was carried out. Sixty diabetic patients with mild hypertension, without taking antihypertensive or antihyperlipidaemic medicines, were recruited in the study. The patients were randomly allocated to the ST and BT groups and instructed to drink ST and BT infusions two times a day for 1 month. Their blood pressure (BP) was measured on days 0, 15 and 30 of the study. The mean of systolic BP (SBP) in the ST group decreased from 134.4 ± 11.8 mm Hg at the beginning of the study to 112.7 ± 5.7 mm Hg after 1 month (*P*-value < 0.001), whereas this measure changed from 118.6 ± 14.9 to 127.3 ± 8.7 mm Hg (*P*-value = 0.002) in the BT group during the same period. The intervention had no statistically significant effect on the mean of diastolic BP (DBP) in either the ST or BT group. The mean pulse pressure (PP) of the patients in the ST group decreased from 52.2 ± 12.2 to 34.5 ± 9.3 mm Hg (*P*-value < 0.001) during the study, whereas in the BT group, it increased from 41.9 ± 11.7 to 47.3 ± 9.6 mm Hg (*P*-value = 0.01). In conclusion, consuming ST infusion had positive effects on BP in type II diabetic patients with mild hypertension. This study supports the results of similar studies in which antihypertensive effects have been shown for ST.
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Introduction

High blood pressure (BP) frequently coexists with diabetes mellitus, occurring twice as frequently in diabetic as in non-diabetic persons. It accounts for up to 75% of added cardiovascular disease risk in people with diabetes, contributing significantly to the overall morbidity and mortality in this high-risk population.[1] It is one of the most important treatable risk factors for cardiovascular diseases because of its high prevalence and lethal outcomes.[2] Different studies have reported the global prevalence of hypertension in adults as 3.4–72.5%. It is estimated that in 2025, there will be 333 million patients in developed countries and 639 million patients in developing countries suffering from hypertension.[3,4] Although it has been most dominant in industrialized countries in the past decades, now it is a challenging issue and its prevalence is rapidly increasing in many developing countries, including Iran.[5–8]

Sour tea (ST; *Hibiscus sabdariffa*) is a genesis of the Malvaceae family. It has been called by different local names in various countries. In Iran, it is mainly known as ST. In English-speaking countries, it is named Roselle or Red Sorrel and in Arabic it is called Karkade. The phytochemical, pharmacological and toxicological properties of *H. sabdariffa* have been investigated in many studies. The calyces of *H. sabdariffa* are used in many parts of the world to make cold and hot drinks. ST contains many chemical constituents including alkaloids, L-ascorbic acid, anisaldehyde, anthocyanin, β-carotene, β-sitosterol, citric acid, cyianidin-3 rutinoside, delphinidin, galactose, gossypetin, hibiscetin, mucopolysaccharide, pectin, protocatechuic acid, polysaccharide, quercetin, stearic acid and wax. In folk medicine, the calyx extracts are used for the treatment of several complaints, including high BP, liver diseases and fever. In view of its reported nutritional and pharmacological properties and relative safety,

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H. sabdariffa and compounds isolated from it could be a source of therapeutically useful products.[9,10]

Different studies, both in animal[11–14] and human models,[15,16] have shown that an extract or infusion of ST influences the atherosclerosis process, blood sugar and lipids, and BP. Lin *et al.*[17] reported that ST infusion reduces cholesterol by 8.3–14.4% after 4 weeks.[18] Chen *et al.*[19] showed that ST extracts reduce triglyceride, cholesterol, low-density lipoprotein cholesterol (LDLc) and LDLc/HDLc in hyperlipidaemic rats. Haji Faraji and Haji Tarkhani[20] and Herrera-Arellano *et al.* showed that ST infusion reduce BP in patients with hypertension.[16] Although the mechanism of lowering BP is not proven as yet, different studies have reported a direct effect on the vascular muscles, the affecting sympathetic nervous system, calcium channels, cholinergic and histaminic mechanisms and rennin–angiotansin system. The antioxidative and diuretic effects are the most important mechanisms suggested for their hypotensive effects.[18,21]

The prevalence of diabetes mellitus in Iran is higher than in many other countries, and one of its common complications is hypertension, which intensifies other risk factors. We could not find any study investigating the results of drinking ST on diabetic complications including hypertension.[22–24]

As the general perception in Iran and many other countries is in favour of drinking tea and the people know it as a safe herbal drug, also knowing that herbal drugs do not have the adverse reactions as chemical drugs have, this study was designed to assess the short-term effects of consuming ST infusion on BP in patients with type II diabetes and to compare it with those of black tea (BT). Regarding the chemical composition of ST, in this study our hypothesis was that drinking ST infusions, as is prescribed in traditional medicine, would effectively change the diabetic patients' BP.

Materials and methods

Study description

This sequential randomized controlled clinical trial was conducted on 60 diabetic patients in Yazd Diabetes Research Centre from December 2006 to November 2007. Inclusion criteria were having type II diabetes mellitus for more than 5 years, showing mild hypertension according to JNC-VI criteria[25] (systolic BP (SBP) <160 mm Hg and diastolic BP (DBP) <100 mm Hg), and not taking antihyperlipidaemic or antihypertensive drugs. In addition to these criteria, the patients were allowed to receive oral hypoglycaemic agents and insulin drugs as their routine treatment. Exclusion criteria were existing secondary hypertension, history of allergy to tea, preferring not to drink tea, or suffering from other diseases that required the intake of medicines.

After obtaining informed consent from all patients, they were randomly assigned to one of these two groups: ST group or BT group. Assignment to the two groups was made by using a sequential list prepared on the basis of randomized numbers table. Patients in the ST group were given ST sachets and those in the BT group were given BT sachets that were similar in shape and weight. Instructions for preparation and usage of black and ST were given. The patients were instructed to use one glass of the tea decoction two times a day for 1 month.

Tea preparation directions

According to various studies, drinking tea was continued for 1 month, two times a day, one in the morning and the other in the afternoon, between the main meals. The patients were asked to pour the contents of one tea sachet, weighing 2 g, in a tea pot, add 240 ml of boiling water and drink it after a steeping time of 20–30 min with one cube of sugar (5 g). They were prohibited from drinking any other type or amount of tea during the study, and their medications and diet were kept unchanged. The ST, which was imported from Saudi Arabia, was obtained from the local market and verified by agricultural experts. The BT was imported from Sri Lanka. Both types of tea were purchased as bulks of loose tea and packaged in 2 g sachets.

Measurements

On days 1, 15 and 30 of the study, the patient's BP was measured by a general physician on their right hand in seated position. BP was measured twice at 5–10 min intervals and the average was recorded. 3M Littmann stethoscope (3M Health Care, St Paul, MN, USA) and Panalife mercury sphygmomanometer (Panasonic, Japan) with a 14×50 cm cuff were used for measuring BP. The hypotensive effect was calculated as the difference between basal BP at the beginning and at the end of each follow-up stage of the study. The positive therapeutic effectiveness in each stage was achieved when the DBP diminution was $\geqslant10$ mm Hg.[16,18] The body mass index (BMI) was calculated as weight in kilograms (kg) divided by height in metres (m) squared. Obesity was defined as a BMI of 30 and above. Pulse pressure (PP) was calculated as the difference between SBP and DBP. Patient's compliance was measured by counting the empty sachets on 15 and 30 days of the study.

Statistical analyses

Results are given as mean ± s.d. Using the Kolmogrov–Smirnov test, we found that SBP and DBP variations, age and BMI showed normal distribution, whereas the other variables, including SBP, DBP and duration of diabetes, did not show normal distribution. For comparing the mean of the BPs during the study, we used Friedman's test, as the samples were dependent and the data were not

normally distributed. Mann–Whitney test was used to compare the BPs between the two groups in each phase of the study, as they showed non-normal distribution. In contrast, independent Student's *t*-test was used for comparing BP variations in each phase between the two groups. To compare the overall variation (0–30 days) of BPs between the two groups, we used the analysis of covariance test adjusted by the variables, which were statistically different at the beginning of the study including SBP, DBP and age. Categorical data were analysed by χ^2 and Fisher's exact test. Data were analysed by SPSS software (SPSS Inc., Chicago, IL, USA). The *P*-value <0.05 was considered as significant. All *P*-values were two-tailed.

Ethical considerations

An informed consent was obtained from each patient. Patients could quit the study freely, if they liked. All the patients were continuing their medical treatment and no interruptions were made. The research ethics committee of the Shahid Sadoughi University of Medical Sciences approved the methodology of the study.

Results

There were 60 patients in two groups at the beginning of the study, of which 53 patients concluded the study. Three patients from the ST group and four patients from the BT group stepped out on grounds of travelling, illness or other reasons. These 53 patients included 45 female (84.9%) and eight male (15.1%). Despite the majority of females among the patients, the sex distributions in these two groups did not show a statistically significant difference. Eighty-three percent of patients were on oral antihyperglycaemic agents, 13.2% on insulin therapy and 20.8% on diet only as their treatment. Regarding the treatment method, there was no statistically significant difference between the two groups. Twenty-one percent of the participants had normal weight, 51% were overweight and 28% were obese. Regarding obesity and overweight, there was no statistically significant difference between the two groups. At the beginning of the study, the distribution of participants based on DBP and SBP classification in both groups was not significantly different (Table 1).

Comparisons between the means of quantitative variables at the beginning of the study are shown in Table 2. The Means of weight, duration of diabetes and BMI were not statistically different between the two groups, but the means of DBP, SBP and PP were significantly different.

The means of quantitative variables in the baseline, on days 15 and 30 of the intervention, are compared using Friedman's test separately in each group, and these variables were compared between the two groups using Student's *t*-test. The means of BMI and weight did not show statistically significant difference throughout the intervention separately in both groups and between the groups in each phase.

In the ST group, the means of SBP and PP showed statistically significant difference throughout the study, as SBP decreased from 134 ± 11.8 mm Hg at the beginning to 112.7 ± 5.79 at the end of the study, and in the same period of time, PP decreased from

Table 1 Qualitative variable of the sour tea group and black tea group at the beginning of the study

Variable	*Sour-tea group no. (%)*	*Black-tea group no. (%)*	P-*value*
Sex			
Male	6 (22.2)	2 (7.7)	0.1[a]
Female	21 (77.8)	24 (92.3)	
Insulin therapy			
Yes	2 (7.4)	5 (19.2)	0.1[a]
No	25 (92.6)	21 (80.8)	
Oral antihyperglycaemic			
Yes	22 (81.5)	22 (84.6)	0.5[a]
No	5 (18.5)	4 (15.6)	
Diet only			
Yes	8 (29.6)	3 (11.5)	0.09[a]
No	19 (70.4)	23 (88.5)	
DBP (mm Hg)			
<85	19 (70.4)	23 (88.5)	0.09[a]
85–100	8 (29.6)	3 (11.5)	
SBP (mm Hg)			
<140	23 (85.2)	24 (92.3)	0.3[a]
140–160	4 (14.8)	2 (7.7)	
BMI (Kg/m²)			
18.5–24.9	6 (22.2)	5 (19.2)	0.9[b]
25–29.9	13 (48.1)	14 (53.8)	
$\geqslant 30$	8 (29.6)	7 (26.9)	

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure.
[a]Fisher's exact test.
[b]χ^2-test.

Table 2 Quantitative variables of the sour-tea group and black-tea group at the beginning of the study

Variable	*Sour-tea group (n = 27)*	*Black-tea group (n = 26)*	P-*value*
Weight (Kg)	70.44 ± 11.31	69.90 ± 10.11	0.8[a]
Age (years)	55.37 ± 8.6	50.42 ± 8.56	0.04[a]
Duration (years)	9.81 ± 5.81	10.7 ± 5.1	0.27[b]
BMI (Kg/m²)	28.28 ± 3.8	28.35 ± 4.8	0.09[a]
DBP (mm Hg)	80.2 ± 6.1	76.7 ± 7.6	0.01[b]
SBP (mm Hg)	134.4 ± 11.8	118.6 ± 14.9	<0.001[b]
PP (mm Hg)	52 ± 12.2	41.9 ± 11.7	0.003[b]

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; PP, pulse pressure; SBP, systolic blood pressure.
[a]Student's *t*-test.
[b]Mann–Whitney test.

52 ± 12.2 to 34.5 ± 9.3. In this group, the mean of DPB did not show any statistical difference during the intervention. In the BT group, the means of SBP and PP showed statistical difference throughout the study, as SBP increased from 118.6 ± 14.9 to 127.3 ± 8.74 mm Hg during the study and PP increased from 41.9 ± 11.7 to 47.3 ± 9.6 mm Hg in the same period of time. In this group, the mean of DBP did not show significant difference during the intervention. At the end of the intervention, the means of SBP and PP in the BT group were significantly higher than those in the ST group (Table 3).

The means of the variations in SBP, DBP and PP are shown in Table 4. Through the intervention programme, SBP was gradually decreased by 7.76% (days 0–15) and 8.1% (days 15–30) in the ST group, whereas SBP was increased by 2.7% (days 0–15) and 6.2% (days 15–30) in the BT group. The results of SBP were significantly different between the two groups on either day 15 or day 30 (*P*-value <0.001). In total, through the intervention, the SBP variation was increased in the BT group (8.4%) but decreased in the ST group (15.4%), which was significantly different with control of age, SBP and DBP variables, which were different at the baseline using analysis of covariance model (*P*-value <0.001). DBP variation was significantly different between the BT and ST groups. It decreased by 4.8% on day 15 and increased by 1.6% on day 30. However, the variation increased by 0.82 and 3.3% in the ST and BT groups (days 0–15), respectively (*P*-value = 0.3). In total, through the programme, the DBP values increased in the BT group (4.6%) but decreased in the ST group (4.3%), which were significantly different, with the analysis of SBP (*P*-value = 0.009).

The therapeutic effectiveness of BP in both groups is shown in Table 5. The positive therapeutic effects on day 15 of intervention in the ST and BT groups were calculated as 22.2 and 11.5%, respectively (*P*-value = 0.2). For the second half of the study, this measure was calculated as 48.1 and 26.9%, respectively, for the ST and BT groups (*P*-value = 0.09). Regarding the whole 30 days of intervention, the

Table 3 Means of SBP, DBP, PP, BMI and weight of the patients in different stages of follow-up in the study

Variable	*Group*	*Basal*	*Day 15*	*Day 30*	P-*value*[a]
SBP (mm Hg)	Sour tea	134.4 ± 11.8	123.3 ± 10.9	112.7 ± 5.79	<0.001
	Black tea	118.6 ± 14.9	120.7 ± 13.6	127.3 ± 8.74	0.002
	P-value[b]	<0.001	0.4	<0.001	
DBP (mm Hg)	Sour tea	81.6 ± 6.1	83.0 ± 7.8	80.5 ± 8.9	0.5
	Black tea	76.7 ± 7.6	79.0 ± 8.2	80.0 ± 9.3	0.5
	P-value[b]	0.01	0.08	0.8	
PP (mm Hg)	Sour tea	52 ± 12.2	40.9 ± 10.2	34.5 ± 9.3	<0.001
	Black tea	41.9 ± 11.7	41.7 ± 11.4	47.3 ± 9.6	0.01
	P-value[b]	0.003	0.7	<0.001	
BMI (Kg/m^2)	Sour tea	28.3 ± 3.9	28.1 ± 3.9	28.0 ± 3.9	0.1
	Black tea	28.3 ± 4.4	28.4 ± 4.5	28.3 ± 4.2	0.7
	P-value[b]	0.9	0.8	0.7	
Weight (Kg)	Sour tea	70.4 ± 11.3	70 ± 11.4	69.9 ± 11.6	0.1
	Black tea	69.9 ± 10.1	70 ± 10.1	69.9 ± 9.7	0.7
	P-value[b]	0.8	0.1	0.9	

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; PP, pulse pressure; SBP, systolic blood pressure.
[a]Friedman's test.
[b]Student's *t*-test.

Table 4 Mean of blood pressure variations (%)[a] during the study

Variable	*Group*	*Days 0–15*	*Days 15–30*	*Days 0–30*	P-*value*[b]
SBP	Sour tea	−7.76 ± 6.7	−8.1 ± 7.2	−15.4 ± 7.5	<0.001
	Black tea	+2.72 ± 12.6	+6.2 ± 1.8	+8.4 ± 11.0	
	P-value[c]	0.001	<0.001	<0.001	
DBP	Sour tea	+0.82 ± 10.6	−4.8 ± 10.0	−4.3 ± 12.3	0.04
	Black tea	+3.3 ± 9.9	+1.6 ± 11.7	+4.6 ± 11.8	
	P-value[c]	0.3	0.03	0.009	
PP	Sour tea	+20.05 ± 15.7	+11.5 ± 30.1	+30.0 ± 23.9	<0.001
	Black tea	−6.71 ± 44.7	−19.86 ± 33.8	−19.4 ± 34.5	
	P-value[c]	0.007	0.001	<0.001	

Abbreviations: DBP, diastolic blood pressure; PP, pulse pressure; SBP, systolic blood pressure.
[a]+: increase/−: decrease.
[b]Analysis of covariance of total variation (days 0–30) with control of age, basal SBP and basal DBP.
[c]Student's *t*-test.

Table 5 Effectiveness of the intervention on blood pressure in the two study groups

Group	*Days 0–15*		*Days 15–30*		*Days 0–30*	
	Effect	*No. (%)*	*Effect*	*No. (%)*	*Effect*	*No. (%)*
Sour tea	Yes	6 (22.2)	Yes	13 (48.1)	Yes	13 (48.1)
	No	21 (77.8)	No	14 (51.9)	No	14 (51.9)
Black tea	Yes	3 (11.5)	Yes	7 (26.9)	Yes	4 (15.4)
	No	23 (88.5)	No	19 (73.1)	No	22 (84.6)
χ^2 *P*-value	0.2		0.09		0.01	

positive therapeutic effectiveness was calculated as 48.1 and 15.4%, respectively, in the ST and BT groups (*P*-value = 0.01).

Discussion

Out of 60 patients who entered the study, 53 patients (88.4%) completed it. Compliance to tea consumption was 95% for the BT group and 92% in the ST group, which shows satisfactory cooperation. At the beginning of the study, the distribution of participants based on sex, treatment method, DBP and SBP classification in both groups was not significantly different (Table 1). In addition, the means of BMI, weight and duration of diabetes did not show significant difference between the two groups (Table 2).

The main objective of this study was to evaluate the short-term therapeutic effects of drinking ST on the BP of patients with type II diabetes and to compare the results with those of BT. Our findings showed that the mean of SBP in ST consumers (ST group) decreased from 134.4 to 112.7 mm Hg, which is statistically significant. In the BT consumers (BT group), BP increased from 118.6 to 127.6 mm Hg (Tables 3 and 4). SBP decreased in the ST group but increased in the BT group, and both of them were statistically significant.

Regarding DBP, our findings showed that the consequent changes from the beginning to day 15 of the study and then to day 30 were not significant in either groups (Table 3), though it decreased by 4.3% in the ST group and increased by 4.6% in the BT group (*P*-value = 0.009). In this study, positive therapeutic effectiveness was defined as decreasing 10 mm Hg or more in DBP.[16,18] Evaluating the therapeutic effectiveness of ST on the basis of these findings showed that at the end of the study, the positive therapeutic effectiveness in the ST and BT groups were 48.1 and 15.4%, respectively (*P*-value = 0.01), which indicates significant positive therapeutic effects of ST on DBP (Table 5).

In a study by Haji Faraji and Haji Tarkhani,[20]two groups of patients suffering from hypertension consumed ST and BT for 15 days. This study showed that 12 days after the intervention, SBP and DBP in the ST consumers decreased by 11.2 and 10.7% and after 3 days of withdrawal, the SBP and DBP increased by 7.6 and 5.6%, respectively. Their study showed a significant difference between the two groups.[20]

Herrera-Arellano *et al*. studied the therapeutic effectiveness of ST on hypertensive patients[18]. In their study, two groups of hypertensive patients consumed ST extracts and lisinopril for 4 weeks. The SBP and DBP in ST consuming patients decreased by 11.58 and 12.21%, respectively. In addition, the therapeutic effectiveness of the ST was reported as 65.12%. Finally, they reported that ST is more effective than lisinopril. They also concluded that the plasma level of angiotensin converting enzyme and serum Na concentration decreased significantly by consuming ST.

Herrera-Arellano *et al*. in another study evaluated the effects of captopril with and without ST in mild and moderate hypertensive patients for 4 weeks.[16] The mean SBP in the tea-consuming group decreased from 139.5 to 123.7 mm Hg, and DBP from 90.8 to 79.5 mm Hg. They reported the therapeutic effects of captoril plus ST and captopril only as 0.78 and 0.84, respectively.

Different studies on animals and human models have assessed the effects of ST. Although most of these studies, similar to ours, have evaluated its effects on hypertension, the exact mechanism of its effectiveness remains unknown. Meanwhile, considering the chemical compounds of ST, some mechanisms are predictable. Ajay *et al*.[21] showed its vasodilatation effects, whereas others reported a lowering heartbeat rate.[3] The main effective compounds for BP are antocyanins such as hibiscin, delphinidin-3-glucoside, cyanidin-3-sambubioside and hibiscretin.[10,16]

When comparing the current study with the others, some differences should be considered. In the literature review, we did not find any study of the therapeutic effects of ST on diabetic patients. Different studies used different methodologies, duration of intervention, form and amount of tea and inclusion and exclusion criteria, which should not be overlooked. One of the limitations of this study is the lack of a third group, which did not consume tea, as a control group. BT includes some phytochemicals that may confound the study results. Another limitation of this study is that it ignores changes in other measures of blood chemicals including Na, K, ACE and so on.

Various studies have assessed the effectiveness of ST on BP and lipids, and also the human tolerance for it, but its side effects, safety and sustainability of effects on BP should be evaluated further. As a conclusion, consuming ST infusion two times a day has positive effects on BP in type II diabetic patients. This study supports the results of similar studies in which antihypertensive effects have been shown for ST.

What is known about the topic
- Sour tea has been used as an antihypertensive traditional medicine in many countries
- Sour tea has been shown to be effective in reducing essential hypertension in non-diabetics in some studies

What this study adds
- Sour tea can clinically decrease systolic blood pressure in diabetic patients
- Sour tea can clinically decrease pulse pressure in diabetic patients

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