Journal of Herbal Medicine 29 (2021) 100471

Contents lists available at ScienceDirect

Journal of Herbal Medicine

journal homepage: www.elsevier.com/locate/hermed

Review article

The effect of Hibiscus sabdariffa (sour tea) compared to other herbal teas and antihypertension drugs on cardiometabolic risk factors: Result from a systematic review and meta-analysis

Maryam Shafiee [a], Vida Mohammadi [b], Asma Kazemi [c], Hajar Davarpanah [c], Seyedeh Maryam Tabibzadeh [d], Siavash Babajafari [c], Hosein Rostami [e,*], Seyed Mohammad Mazloomi [c]

[a] Nephro-Urology Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
[b] Department of Nutrition, Sepidan Bagherololoom Health Higher Education College, Shiraz University of Medical Sciences, Shiraz, Iran
[c] Nutrition Research Center, Department of Food Hygiene and Quality Control, Faculty of Nutrition and Food Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
[d] Anesthesia and Critical Care Research Center, Shiraz University of Medical Sciences, Shiraz, Iran
[e] Health Research Center, Baqiyatallah University of Medical Sciences, Tehran, Iran

ARTICLE INFO

Keywords:
Hibiscus sabdariffa
Systolic blood pressure
Diastolic blood pressure
Lipid profiles

ABSTRACT

Introduction: Hibiscus sabdariffa is a common ingredient in herbal tea blends. Several properties such as antihypertensive and antioxidant activities have been attributed to this plant. The aim of this systematic review and meta-analysis was to synthesize the knowledge about the effect of Hibiscus sabdariffa (sour tea) compared to other herbal teas and antihypertensive drugs on cardiometabolic risk factors.

Methods: PubMed, Web of Sciences (ISI), Embase, and Scopus (Elsevier) databases were searched to identify related articles published up to 12 December 2019. All clinical trials which investigated the effect of Hibiscus sabdariffa (sour tea) consumption on systolic blood pressure (SBS), diastolic blood pressure (DBP), LDL-C (low-density lipoprotein cholesterol), HDL-C (high-density lipoprotein cholesterol), TC (total cholesterol), TG (triglyceride), FBS (fasting blood sugar), BW (body weight) and BMI (body mass index) for more than one week were included. Twenty-two studies (24 effect sizes) were included in the analysis; weighted mean differences for each were estimated using random-effects models.

Results: The pooled data suggested that however Hibiscus sabdariffa consumption reduced the SBP levels (weighted mean difference [WMD]: −7.14, 95 % CI: −11.16, −3.12, $p < 0.001$), and DBP levels (WMD: −3.54, 95 % CI: −5.02, −2.06, $p < 0.001$), the changes in lipid profiles, FBS, BMI and BW were not significant.

Conclusion: In conclusion, this meta-analysis indicated that Hibiscus sabdariffa consumption could efficiently reduce SBP and DBP levels.

1. Introduction

Tea is one of the most popular beverages in the world. There are many different types of tea such as black, white, green and sour that are used in different parts of the world (Mozaffari-Khosravi et al., 2014). Sour tea with the scientific name of Hibiscus sabdariffa is known as sudan tea, karkade, bissap, roselle and red sorrel (Mahadevan and Kamboj, 2009).

Hibiscus sabdariffa is a hardy herbaceous shrub which grows well in tropical countries and is used as a common ingredient in herbal tea blends, jam, ice cream, chocolates and in the food industry as a flavoring agent (Mahadevan and Kamboj, 2009; McKay et al., 2009; Wahabi et al., 2010). It contains various ingredients including organic acids (such as citric, ascorbic, oxalic, malic, tartaric, Hibiscus, and hydroxycitric acid),

Abbreviations: ACE I, Angiotensin -converting enzyme I; BMI, Body mass index; BW, Body weight; CIs, Confidence interval; CVD, Cardiovascular diseases; DASH, Dietary approaches to stop hypertension; DBP, Diastolic blood pressure; FBS, Fasting blood sugar; HDL-C, High-density lipoprotein cholesterol; HMG-CoA, 3-hydroxy-3-methylglutarylcoenzyme A; LDL-C, Low-density lipoprotein cholesterol; SBS, Systolic blood pressure; SDs, Standard deviations; SE, Standard error; TC, Total cholesterol; TG, Triglyceride; WMD, Weighted mean difference.

* Corresponding author.
E-mail address: hosein_rostami59@yahoo.com (H. Rostami).

https://doi.org/10.1016/j.hermed.2021.100471
Received 25 November 2020; Received in revised form 22 March 2021; Accepted 18 May 2021
Available online 24 May 2021

anthocyanins (such as anthocyanidin, gossypicyanin, and hibiscin), polysaccharides (such as glucose, arabinose, galactose, and rhamnose) and flavonoids (such as quercetin, luteolin, hibiscitrin, sabdaritrin, gossypitrin, and gossytrin) (Sindi et al., 2014). Several properties have been attributed to sour tea such as antihypertensive (Serban et al., 2015), hepatoprotective, antihyperlipidemic (Chen et al., 2003), anticancer and antioxidant activities (Mahadevan and Kamboj, 2009; Riaz and Chopra, 2018).

The tea is a rich antioxidant source (Riaz and Chopra, 2018), and various studies have been conducted to evaluate the effect of sour tea consumption on cardiometabolic risk factors. Hypertension, is a serious public health concern (https://www.who.int/news-room/fact-sheets/detail/hypertension) as is dyslipidemia (Kelishadi et al., 2012), diabetes (Mancia, 2005) and obesity (Franks et al., 2010). These are the most important concerns that increase the risk of cardiovascular diseases (CVD). Several studies have assessed the effect of Hibiscus sabdariffa consumption on systolic and diastolic blood pressure (Asgary et al., 2016; Gurrola-Diaz et al., 2010; Jalalyazdi et al., 2019; Kafeshani et al., 2017; Nwachukwu et al., 2015), LDL-C (low-density lipoprotein cholesterol) (Kafeshani et al., 2017; Mohagheghi et al., 2011; Sabzghabaee et al., 2013), HDL-C (high-density lipoprotein cholesterol) (Kafeshani et al., 2017; Mohagheghi et al., 2011; Mozaffari-Khosravi et al., 2014), TC (Total cholesterol) (Kafeshani et al., 2017; Lin et al., 2007; Mohagheghi et al., 2011; Sabzghabaee et al., 2013), TG (Triglyceride) (Mohagheghi et al., 2011; Sabzghabaee et al., 2013), FBS (fasting blood sugar) (Asgary et al., 2016; Chang et al., 2014; Gurrola-Diaz et al., 2010), BW (body weight) (Chang et al., 2014; Morales-Luna et al., 2019) and BMI (body mass index) (Chang et al., 2014; Morales-Luna et al., 2019) but their results are inconsistent.

The authors designed and implemented the present meta-analysis to review and scrutinize the published clinical evidence that assessed the effect of Hibiscus sabdariffa (sour tea) compared to other herbal teas and antihypertensive drugs on cardiometabolic risk factors.

2. Materials and methods

The present study was conducted in accordance with the recommendations outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2015).

2.1. Study selection

Studies were included by following criteria: 1) the clinical trials (parallel or crossover design); 2) Studies with controlled and placebo design 3) the desired parameters before and after the intervention with standard deviations(SDs), standard error (SE), or 95 % confidence interval (CIs) were available for each group in the study; 4) individuals consumed sour tea for at least 1 weeks; and 5) subjects were adults (age $\geq$18 years). Lack of sufficient information at baseline or endpoint was considered as an excluding criterion.

2.2. Search strategy

All articles were searched in the following databases: PubMed, Web of Sciences (ISI), Embase, and Scopus (Elsevier) up to 12 December 2019, using the following terms in every possible combination: (Hibiscus [MeSH Terms]) OR Hibiscus[Title/Abstract]) OR "Hibiscus sabdariffa"[Title/Abstract]) OR Roselle[Title/Abstract]) OR Roselles[Title/Abstract]) OR "Hibiscus cannabinus"[Title/Abstract]) OR Kenaf[Title/Abstract]) OR "red tea"[Title/Abstract]) OR "sour tea"[Title/Abstract])). The reference lists of included articles and also review articles published previously were searched by hand evaluating the effect of sour tea on blood pressure and considered additional articles. Each article was assessed separately by two reviewers (VM and AK).

2.3. Quality assessment

The Cochrane tool was used for assessing the methodological quality of included articles, which includes the following items: random description, allocation concealment, blinding, incomplete data outcome and protocol registration. (Table 2). In the case of all criteria being met or one criteria unclear the quality was judged as good, one criterion not met or two criteria unclear was fair quality, and two or more criteria not met or more than two unclear poor quality.

2.4. Data extraction

Eligible studies were assessed by two reviewers (VM and AK). Any discrepancies were resolved via consensus-based discussions between the reviewers. The following information was extracted: first author's name, publication year, sample size, type and dose of intervention and placebo, study design, duration of the intervention, patient's status and other data including age and sex. Mean and SD of systolic and diastolic blood pressure levels at before and after intervention were recorded.

2.5. Data items

All variables for which the data were assessed included the following: systolic blood pressure (SBP, mmHg), diastolic blood pressure (DBP, mmHg), low-density lipoprotein cholesterol (LDL-C, mg/dl), high-density lipoprotein cholesterol (HDL-C, mg/dl), total cholesterol (TC, mg/dl), triglyceride (TG, mg/dl), fasting blood sugar (FBS, mg/dl), body weight (BW, kg) and body mass index (BMI, kg/m2).

2.6. Quantitative data synthesis and statistical analysis

Statistical analysis of data was carried out using Stata software version 13 (Stata Corp LP, College Station, TX, USA). The effect of sour tea was evaluated on the changes in the following outcomes: (i) SBP (mmHg), (ii) DBP (mmHg), LDL-C (mg/dl), HDL-C (mg/dl), TC (mg/dl), TG(mg/dl), FBS (mg/dl), BW (kg) and BMI (kg/m^2). The WMD and corresponding 95 % CIs were calculated using the DerSimonian and Laird method (DerSimonian and Laird, 1986) random effects model, which takes the between-study variation into account. The mean and SD of the mentioned parameters were extracted before and after intervention. The mean change was computed as follows: (amount at end of the follow-up in the treatment group – amount at baseline in the treatment group) - (amount at end of the follow-up in the control group – amount at baseline in the control group). If SD of the mean difference was not reported, it was computed as follows: SD = square root [(SD pre-treatment)^2 + (SD post-treatment)^2 - (2 R—SD pre-treatment - SD post-treatment)], assuming a correlation coefficient of 0.5, as a conservative estimate for R which ranges between 0 and 1 (Higgins et al., 2008). In the case of the median and range or 95 % CIs being reported, mean and SD values were estimated using Hozo et al.'s procedure (Hozo et al., 2005). Plot digitizer software was used to extract the data when the outcome variable was demonstrated only in the graphic form. Cochran's Q-test was used for assessing the heterogeneity (with significance set at $p < 0.1$) and for computing the percentage of heterogeneity (I^2 value $\geq$50 % indicating significant heterogeneity) the I^2 test and a random effect model was used. The leave-one-out method (i.e. removing a single trial each time and repeating the analysis) was used for sensitivity analysis to determine the effect of each study on the overall effect size (Sahebkar, 2014). For evaluating the association between the effect size and potential adjuster variables including duration of the intervention and dose of Hibiscus sabdariffa meta-regression was carried out. The funnel plot and also Begg's rank correlation and Egger's weighted regression tests were used for recognizing any possible publication bias. Subgroup analysis was conducted based on the duration of intervention, age, type of control group, duration of intervention and quality of studies for all mentioned factors. Meta-regression was conducted for

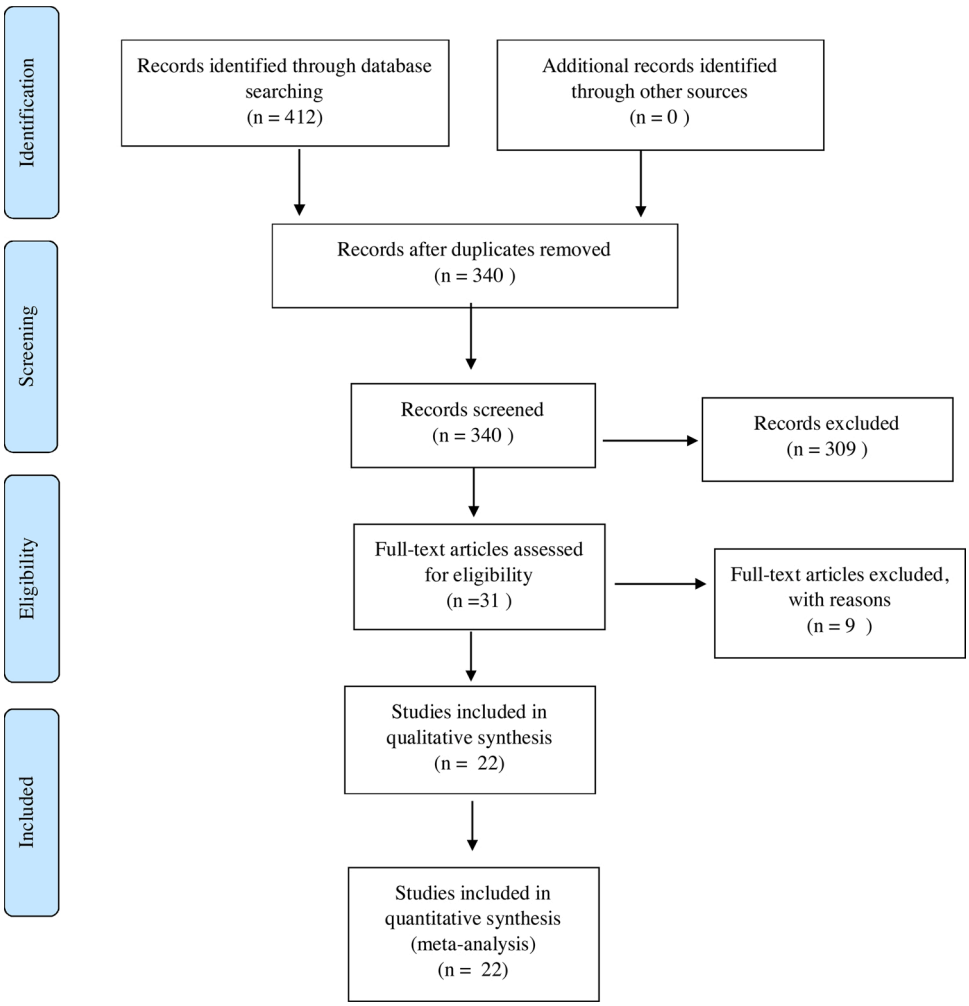


Fig. 1. Flow diagram.

participants' age, duration of the intervention and dose of Hibiscus sabdariffa. Moreover, sensitivity analysis for the small study effect was carried out.

The meta-analysis was caried out using STATA software version 13 (Stata Corp LP, College Station, TX, USA). We considered probability value (p value) < 0.05 as statistically significant.

2.7. Studies identified and selection process

Fig. 1 indicates the flowchart of the selection process in the meta-analysis. A total of 412 reports were firstly identified; after eliminating the duplicates (n = 72), 340 articles remained. Of the 340 articles, 309 were excluded because they were either not human clinical trials or didn't meet the inclusion criteria, after an accurate review of the titles and abstracts. 31 potentially pertinent articles were chosen for full text assessment and detailed examination. Furthermore 9 articles were excluded for one or more of the following reasons: not randomized placebo-controlled studies (n = 3) (Al-Shafei and El-Gendy, 2013; Harrison et al., 2009; Lin et al., 2007), conference paper (n = 1) (Camille et al., 2018), duplicate report (n = 1) (Nwachukwu et al., 2017), use of sour tea in combination with other components without an appropriate control group (n = 2) (Boix-Castejón et al., 2018; Herranz-López et al., 2019), participants younger than 18 years old (n = 1) (Sabzghabaee et al., 2013), and intervention duration less than 1 week (n = 1) (Abubakar et al., 2019). After ultimate evaluation, 22 eligible studies satisfied the inclusion criteria and were qualified for the final meta-analysis. Quality assessment of studies are presented in Table 2. Nine studies reported the method used for random sequence generation to put participants in the intervention and control groups (Herrera-Arellano et al., 2007; Kafeshani et al., 2017; McKay et al., 2009, 2010; Mozaffari-Khosravi et al., 2013, 2014; Mozaffari-Khosravi et al., 2009; Nwachukwu et al., 2015; Seck et al., 2018; Soleimani et al., 2015) while the other studies didn't report any explanation in this regard. Only three studies reported allocation concealment (Asgary et al., 2016; Nwachukwu et al., 2015; Seck et al., 2018). However, eight trials were not blind (Faraji and Tarkhani, 1999; Gurrola-Diaz et al., 2010; Hajifaraji et al., 2018; Herrera-Arellano et al., 2007; Lin et al., 2014; Mohagheghi et al., 2011; Sari et al., 2018; Soleimani et al., 2015), the other studies clarified the blindness. None of the studies revealed attrition bias. All of the studies were judged at low risk for selective reporting. Finally, five studies were judged as having good quality (Asgary et al., 2016; Kafeshani et al., 2017; McKay et al., 2010; Nwachukwu et al., 2015; Seck et al., 2018), twelve poor quality (Chang et al., 2014; Faraji and Tarkhani, 1999; Gurrola-Diaz et al., 2010; Hajifaraji et al., 2018; Herrera-Arellano et al., 2004, 2007; Jalalyazdi et al., 2019; Kuriyan et al., 2010; Lin et al., 2014; Mohagheghi et al., 2011; Sari et al., 2018; Soleimani et al., 2015) and three fair quality (Mozaffari-Khosravi et al., 2013, 2014; Mozaffari-Khosravi et al., 2009).

2.8. Features of included studies

The features of the eligible studies are shown in Table 1. Data was obtained from 22 eligible studies with 24 effect sizes with 724 and 733 participants in the control and intervention group respectively. The

Table 1
Characteristic of studies that evaluated the effect of sour tea on the mentioned parameters.

Study, Year	location	gender	Age (years)	study Population	Participants (control group, intervention group)	Duration (weeks)	Sour tea group	Control group	Hibiscus sabdariffa dose (gr/d)	Outcome
Gurrola-Diaz et al., 2010	Mexico	Both	49	metabolic syndrome	27, 20	4	Extract powder + Diet	Diet	0.1	SBP, DBP, LDL-C, HDL-C, TC, TG, FBS
Chang et al., 2014	Taiwan	Both	37.32	Obese with liver steatosis	17, 19	12	Extract capsule	Starch	2.7	BW, BMI, WC, LDL-C, HDL-C, TC, TG, FBS
McKay et al., 2010	Nigeria	Both	54.2	mild to moderate hypertension	30, 35	6	tea	placebo	3.75	SBP, DBP
Hajifaraji et al., 2018, (a)	Iran	Both	47.76	polygenic dyslipidemia	22, 21	6	tea	lifestyle modifications	4	LDL-C, HDL-C, TC, TG,
Hajifaraji et al., 2018, (b)	Iran	Both	47.76	polygenic dyslipidemia	21, 20	12	tea	lifestyle modifications	4	LDL-C, HDL-C, TC, TG,
Jalalyazdi et al., 2019	Iran	Both	49.87	stage 1 hypertension	23, 23	4	tea	nonmedical treatment advices	2.5	SBP, DBP
Kafeshani et al., 2017, (a)	Iran	Men	20.71	healthy adult men	16, 17	6	tea	maltodextrin	0.45	SBP, DBP, LDL-C, HDL-C, TC, TG
Kafeshani et al., 2017, (b)	Iran	Men	20.71	healthy adult men	16, 17	6	tablet	Green tea	0.45	SBP,DBP LDL-C, HDL-C, TC, TG
Kuriyan et al., 2010, (a)	India	Both	45.7	hyperlipidemic Indians	29, 28	6.4	extract	maltodextrin	1	BW, BMI, WC, LDL-C, HDL-C, TC, TG, FBS
Kuriyan et al., 2010, (b)	India	Both	45.7	hyperlipidemic Indians	29, 28	12	extract	maltodextrin	1	BW, BMI, WC, LDL-C, HDL-C, TC, TG, FBS
Asgary et al., 2016	Iran	Both	47.66	metabolic syndrome	17, 18	4	powder	starch	0.5	BMI, SBP, DBP LDL-C, HDL-C, TC, TG, FBS
Lin et al., 2014	Taiwan	Both	NR	Patients with Long-term Urinary Catheterization	17, 10	24	tea	placebo	3	TC, TG, FBS
DC Nwachukwu et al., 2015, (a)	Nigeria	Both	49.92	mild to moderate hypertension	25, 25	4	beverage	placebo	10.5	SBP,DBP
DC Nwachukwu et al., 2015, (b)	Nigeria	Both	49.92	mild to moderate hypertension	25, 25	5	beverage	placebo	10.5	SBP,DBP
DC Nwachukwu et al., 2015, (c)	Nigeria	Both	49.92	mild to moderate hypertensive	25, 25	4	beverage	Hydrochlorothiazide	10.5	SBP,DBP
DC Nwachukwu et al., 2015, (d)	Nigeria	Both	49.92	mild to moderate hypertensive	25, 25	5	beverage	Hydrochlorothiazide	10.5	SBP,DBP
Sari et al., 2018	India	Men	42.6	Obese Adult Men	11, 14	6	beverage	placebo	1	BW, BMI, WC, LDL-C, HDL-C, TC, TG
Mozaffari-Khosravi et al., 2013	Iran	Both	45	mildly hypertensive patients with diabetes	48, 46	4	Tea bag	Green tea	3	BW, BMI, SBP,DBP, FBS
Mozaffari-Khosravi et al., 2009,	Iran	Both	55.37	diabetic patients	26, 27	4	Tea bag	Black tea	2	LDL-C, HDL-C, TC, TG
Mozaffari-Khosravi et al., 2009, (a)	Iran	Both	55.37	diabetic patients	26, 27	4	sachet	Black tea	2	BW, BMI, SBP,DBP
Mozaffari-Khosravi et al., 2009, (b)	Iran	Both	55.37	diabetic patients	26, 27	2	sachet	Black tea	2	BW, BMI, SBP,DBP
Mozaffari-Khosravi et al., 2014	Iran	Both	45	type 2 diabetes patients	48, 46	4	Tea bag	Green tea	3	

(*continued on next page*)

Table 1 (*continued*)

Study, Year	location	gender	Age (years)	study Population	Participants (control group, intervention group)	Duration (weeks)	Sour tea group	Control group	Hibiscus sabdariffa dose (gr/d)	Outcome
										LDL-C, HDL-C, TC, TG
Mohagheghi et al., 2011	Iran	Both	50	hypertensive patients	45, 45	2	Tea bag	Black tea	0.5	LDL-C, HDL-C, TC, TG, FBS
M. Faraji and Tarkhani, 1999	Iran	both	52.6	essential hypertension patient	23, 31	2	powder	Black tea	150	SBP,DBP
Sidy Mohamed Seck et al., 2017, (a)	Africa	both	53.2	hypertension paitient	41, 42	4	powder	Ramipril	0.65	SBP,DBP, TC, FBS
Sidy Mohamed Seck et al., 2017, (b)	Africa	both	53.2	hypertension paitient	41, 42	2	powder	Ramipril	0.65	SBP,DBP
Sidy Mohamed Seck et al., 2017, (c)	Africa	both	53.2	hypertension paitient	42, 42	4	powder	Kinkeliba	0.65	SBP,DBP, TC, FBS
Sidy Mohamed Seck et al., 2017, (d)	Africa	both	53.2	hypertension paitient	42, 42	2	powder	Kinkeliba	0.65	SBP,DBP
Soleimani et al., 2015	Iran	Both	53.3	hypertension paitient	20, 20	6	pill	captopril	1	SBP,DBP
Herrera-Arellano et al., 2004	Mexico	both	51.13	hypertension paitient	37, 53	4	solution	captopril	10	SBP,DBP
Herrera-Arellano et al., 2007, (a)	Mexico	both	43	hypertension paitient	93, 100	1	envelope	lisinopril	0.25	SBP,DBP
Herrera-Arellano et al., 2007, (b)	Mexico	both	43	hypertension paitient	93, 100	2	envelope	lisinopril	0.25	SBP,DBP
Herrera-Arellano et al., 2007,(c)	Mexico	both	43	hypertension paitient	93, 100	3	envelope	lisinopril	0.25	SBP,DBP
Herrera-Arellano et al., 2007, (d)	Mexico	both	43	hypertension paitient	93, 100	4	envelope	lisinopril	0.25	SBP,DBP

Table 2
Quality assessment of the studies according to Cochrane tool.

Study	Sequence generation	Allocation concealment	Blinding of participants or personnel	Blinding of outcome assessment	Incomplete outcome data	Selective outcome reporting	Quality
Gurrola-Diaz et al., 2010	?	?	?	?	✓	✓	Poor
Chang et al., 2014	?	?	✓	?	✓	✓	Poor
L. McKay et al., 2010	✓	?	✓	✓	✓	✓	Good
Hajifaraji et al., 2018	?	?	?	?	✓	✓	Poor
Jalalyazdi et al., 2019	?	?	✓	?	✓	✓	Poor
Kafeshani et al., 2017	✓	?	✓	✓	✓	✓	Good
Kuriyan et al., 2010	?	?	✓	?	✓	✓	Poor
Asgary et al., 2016	?	✓	✓	✓	✓	✓	Good
Lin et al., 2014	?	?	?	?	✓	✓	Poor
Nwachukwu et al., 2015	✓	✓	✓	?	✓	✓	Good
Sari et al., 2018	?	?	?	?	✓	✓	Poor
Mozaffari-Khosravi et al., 2013	✓	?	✓	?	✓	✓	Fair
Mozaffari-Khosravi et al., 2009	✓	?	✓	?	✓	✓	Fair
Mozaffari-Khosravi et al., 2014	✓	?	✓	?	✓	✓	Fair
Mohagheghi et al., 2011	?	?	?	?	✓	✓	Poor
Faraji and Tarkhani, 1999	?	?	?	?	?	✓	Poor
Sidy Mohamed Seck et al., 2017	✓	✓	✓	?	✓	✓	Good
Soleimani et al., 2015	✓	?	?	?	✓	✓	Poor
Herrera-Arellano et al., 2004	✓	?	?	?	✓	✓	Poor
Herrera-Arellano et al., 2007	?	?	✓	?	✓	✓	Poor

number of participants in these trials ranged from 20.7 (Kafeshani et al., 2017) to 55.3 (Mozaffari-Khosravi et al., 2009). The included studies were published between 1999 and 2019 and conducted in Iran (Nine studies) (Asgary et al., 2016; Faraji and Tarkhani, 1999; Hajifaraji et al., 2018; Jalalyazdi et al., 2019; Kafeshani et al., 2017; Mohagheghi et al., 2011; Mozaffari-Khosravi et al., 2013, 2009; Soleimani et al., 2015), Nigeria (two studies) (McKay et al., 2010; Nwachukwu et al., 2015), Mexico (three studies) (Gurrola-Diaz et al., 2010; Herrera-Arellano et al., 2004, 2007), Taiwan (two studies) (Chang et al., 2014; Lin et al., 2014), India (two studies) (Kuriyan et al., 2010; Sari et al., 2018) and Africa (one study) (Seck et al., 2018). The participants mean age alternated from 20.71 to 55.37 years. Only two studies were carried out particularly on men (Kafeshani et al., 2017; Sari et al., 2018), and the remaining trials were performed on both sexes. The duration of the

Table 3
Results of subgroup analysis of included randomized controlled trials in meta-analysis of sour tea and cardiometabolic risk factors.

Dietary Factors	No of studies	WMD	95 % CI	I^2 (%)	Test for Subgroup difference
SBP					
age					
<50 years	7	−4.34	−7.07, -1.60	32.1	0.005
≥50 years	4	−11.62	−21.61, -1.60	93.8	
Type of control group					
Placebo	6	−4.92	−7.88, -1.95	37	0.03
Tea	5	−9.44	−18.32, -0.56	92.5	
duration of intervention					
<4 weeks	7	−7.39	−13.31, -1.47	90.6	0.98
≥4 weeks	4	−6.10	−9.32, -2.88	0	
Dose of sour tea					
< 2 g/d	5	−2.68	−6.30, 0.92	34.3	0.007
≥ 2 g/d	6	−10.67	−17.02, -4.32	90.4	
Quality of studies					
Poor or Fair	5	−8.74	−16.40, -1.08	93.3	0.21
Good	6	−4.59	−7.18, -2	0	
DBP					
age					
<50 years	7	−3.36	−4.92, -1.80	21.3	0.94
≥50 years	4	−3.59	−6.85, -0.33	74.9	
Type of control group					
Placebo	6	−3.39	−4.99, -1.78	19.6	0.99
Tea	5	−3.54	−6.38, -0.70	70	
duration of intervention					
<4 weeks	7	−3.34	−5.21, -1.47	63.7	0.31
≥4 weeks	4	−4.15	−6.63, -1.67	0	
Dose of sour tea					
< 2 g/d	5	−3.72	−6.68, -0.76	57.7	0.66
≥ 2 g/d	6	−3.63	−5.52, -1.75	49.6	
Quality of studies					
Poor or Fair	5	−4.31	−6.69, -1.94	66.7	0.27
Good	6	−2.57	−4.57, -0.60	21.4	
LDL-C					
age					
≥ 45years	7	−5.41	−14.36, 3.55	75	0.21
<45 years	4	−5.13	−13.47, 3.19	0	
Type of control group					
Placebo	7	−11.88	−16.42, -7.33	12.4	<0.001
Tea	4	2.30	−4.32, 8.92	0	
duration of intervention					
≥ 6week	7	−10.92		20.7	<0.001
< 6week	4	2.70	−15.89, -5.95 −4.18, 9.58	0	
Dose of sour tea					
< 2 g/d	7	−5.27	−10.90, 0.36	0	0.47
≥ 2 g/d	4	−6.27	−20.89, 8.29	85	
					0.27
HDL-C					
age					
≥ 45years	7	−1.11	−2.50, 0.26	17.5	0.05
<45 years	4	1.42	−2.45, 5.31	45.4	
Type of control group					
Placebo	7	0.40	−2.09, 2.91	57.1	0.15
Tea	4	−0.11	−2.36, 2.15	0	
duration of intervention					
≥ 6week	7	0.06	−2.3, 2.43	54	0.08
< 6week	4	0.24	−2.05, 2.55	0	
Dose of sour tea					
< 2 g/d	7	0.86	−1.03, 2.75	0	0.004
≥ 2 g/d	4	−2.09	−3.12, -1.07	2.6	
					0.06
TG					
age					
≥ 45years	7	−0.93	−10.44, 8.56	6.7	0.37
<45 years	4	−7.82	−23.98, 8.34	0	
Type of control group					
Placebo	8	−0.51	−8.54, 7.52	0.2	0.76
Tea	4	−3.08	−18.33, 12.17	0	
duration of intervention					
≥ 6week	8	0.08	−7.60, 7.77	0	0.47
< 6week	4	−10.94	−35.04, 13.15	31.7	
Dose of sour tea					
< 2 g/d	7	−7.64	−19.64, 4.36	0	0.18
≥ 2 g/d	5	−1.01	−8.07, 6.04	0	
					0.49
TC					
age					
≥ 45years	8	−4.10	−16.86, 8.64	75.8	0.17
<45 years	4	−5.65	−15.65, 4.33	0	
Type of control group					
Placebo	7	−11.55	−18.01, -5.10	20.6	<0.001
Tea	5	1.22	−14.43, 16.89	57.5	
duration of intervention					
≥ 6week	7	−10.87		26.3	<0.001

(*continued on next page*)

Table 3 (*continued*)

Dietary Factors	No of studies	WMD	95 % CI	I^2 (%)	Test for Subgroup difference
< 6week	5	2.42	−17.38, -4.35 −14.51, 19.35	53	
Dose of sour tea					
< 2 g/d	8	−3.43	−10.78, 3.91	0	0.008
≥ 2 g/d	4	−4.71	−13.42, 4	85.9	0.18
FBS age					
≥ 46 years	4	3.14	−11.76, 18.05	83.9	0.53
<46 years	4	−2.69	−7.06, 1.69	0	
Type of control group					
Placebo	5	−4.75	−11.96, 2.44	41.4	0.01
Tea	3	8.79	−7.19, 24.77	75.9	
duration of intervention					
≥ 6week	5	−5.77	−10.68, -0.85	35.9	0.005
< 6week	4	8.61	−4.87, 22.09	64.5	
Dose of sour tea					
< 2 g/d	5	0.007	−8.83, 8.85	79.6	0.34
≥ 2 g/d	3	2.94	−7.13, 13.02	0	
BMI age					
≥ 45 years	4	−0.05	−1, 0.9	0	0.82
<45 years	2	−0.25	−1.78, 1.28	0	
Type of control group					
Placebo	4	−0.09	−1.07, 0.87	0	0.97
Tea	2	−0.12	−1.57, 1.32	0	
duration of intervention					
≥ 6week	4	−0.08	−0.1, 0.82	0	0.95
< 6week	4	−0.12	−1.17, 0.92	0	
Dose of sour tea					
< 2 g/d	3	−0.08	−1.14, 0.96	0	0.95
≥ 2 g/d	3	−0.13	−1.39, 1.12	0	
Body weight age					
≥ 45 years	3	−0.14	−3.12, 2.83	0	0.84
<45 years	2	−0.73	−5.77, 4.29	0	
Type of control group					
Placebo	3	−0.34	−3.79, 3.10	0	0.96
Tea	2	−0.24	−4.06, 3.59	0	
duration of intervention					
≥ 6week	3	−0.34	−3.79, 3.10	35.9	0.96
< 6week	2	−0.24	−4.06, 3.59	64.5	
Dose of sour tea					
< 2 g/d	2	−0.31	−4, 3.38	0	0.99
≥ 2 g/d	3	−0.28	−3.83, 3.26	0	

Abbreviations: WMD: weighted mean difference, SBP: systolic blood pressure, DBP: diastolic blood pressure, LDL-C: low-density lipoprotein cholesterol, HDL-C: high-density lipoprotein cholesterol, TG: Triglyceride, TC: Total cholesterol, FBS: fasting blood sugar, BMI: body mass index, BW: body weight.

intervention differed from 4 (Asgary et al., 2016; Gurrola-Diaz et al., 2010; Herrera-Arellano et al., 2004; Jalalyazdi et al., 2019; Mozaffari-Khosravi et al., 2013, 2014; Mozaffari-Khosravi et al., 2009; Seck et al., 2018) to 24 (Lin et al., 2014) weeks.

2.9. Publication bias

Begg's test was conducted for assessing publication bias of sour tea consumption on SBP, DBP, LDL-C, HDL-C, TC, TG, FBS, BW and BMI, there was no significant of publication bias with respect to SBP (Begg's test: P = 0.53), DBP (Begg's test: P = 0.11), LDL-C (Begg's test: P = 0.64), HDL-C (Begg's test: P = 06), TC (Begg's test: P = 0.83), TG (Begg's test: P = 0.21), FBS (Begg's test: P = 1) levels; BW (Begg's test: P = 0.22, Egger's test: P = 0.30) and BMI (Begg's test: P = 0.70). Funnel plot for all variables are shown in Fig. 11 (panel A –I).

3. Results

3.1. Meta-analysis and subgroup results

Results of the subgroup analysis are demonstrated in Table 3. Subgroup analysis was conducted based on the duration of intervention, age, type of control group, duration of intervention and quality of studies for all mentioned factors.

A total of 15 studies compared the effect of sour tea with placebo, tea, and antihypertensive drug on SBP and DBP. The studies with placebo or tea as a comparator (ten studies with 11 effect size and 284 patients) were pooled together and the studies in which antihypertensive drug was the comparator (five studies with 240 patients) were analyzed separately.

Fig. 2 panel A and B indicates the pooled outcomes from random-effect model combining the WMD for the impact of Hibiscus sabdariffa on SBP in the study population, revealing that the diminution in SBP levels was significant after consuming Hibiscus sabdariffa compared with the placebo or tea as control group, (WMD: −7.14, 95 % CI: −11.16, −3.12, $p < 0.001$), with significant heterogeneity ($I^2 = 84.7$ %, $p < 0.001$), while its effect was not significant after consuming Hibiscus sabdariffa compared to the drugs as control group (WMD: −4.05, 95 % CI: −9.64, 1.53, $p = 0.15$), with significant heterogeneity ($I^2 = 82$ %, $p < 0.001$).

The results for DBP were the same as SBP; Hibiscus sabdariffa compared with placebo or tea as the control group, led to a significant reduction in the DBP (WMD: −3.54, 95 % CI: −5.02, −2.06, $p < 0.001$), without significant heterogeneity ($I^2 = 48.9$ %, $p = 0.34$), however, reduction in the DBP levels was not significant when compared with drugs as control group (WMD: −0.22, 95 % CI: −2.01, 1.56, $p = 0.8$), without significant heterogeneity ($I^2 = 48$=%, $p = 0.1$) (Fig. 2 panel C and D).

Significant reduction was observed in the subgroup with dose of ≥ 2 g and <2 g; the changes in the subgroup with duration of intervention (<4 and ≥4 week) was significant as well. Age of the participants (<50 and ≥50) and type of control group (tea and placebo) didn't affect the result as the change in both of the subgroups were similar. Quality of the studies didn't affect the result since the change in both of the subgroups (poor or fail and good).

Ten studies (11effect sizes) with 254 subjects investigated the effect of Hibiscus sabdariffa on LDL-C and HDL-C compared to placebo or tea as the control group, Fig. 2 panel E indicates a non-significant decrease of LDL-C in Hibiscus sabdariffa group compared with placebo or tea (WMD: −5.32, 95 % CI: −11.76, 1.13, $p = 0.1$), with significant heterogeneity ($I^2 = 62$ %, $p = 0.003$). The result for HDL_C was also non-significant (WMD: −0.07, 95 % CI: −1.7, 1.56, $p = 0.93$), without significant heterogeneity ($I^2 = 40$ %, $p = 0.08$), (Fig. 2 panel F).

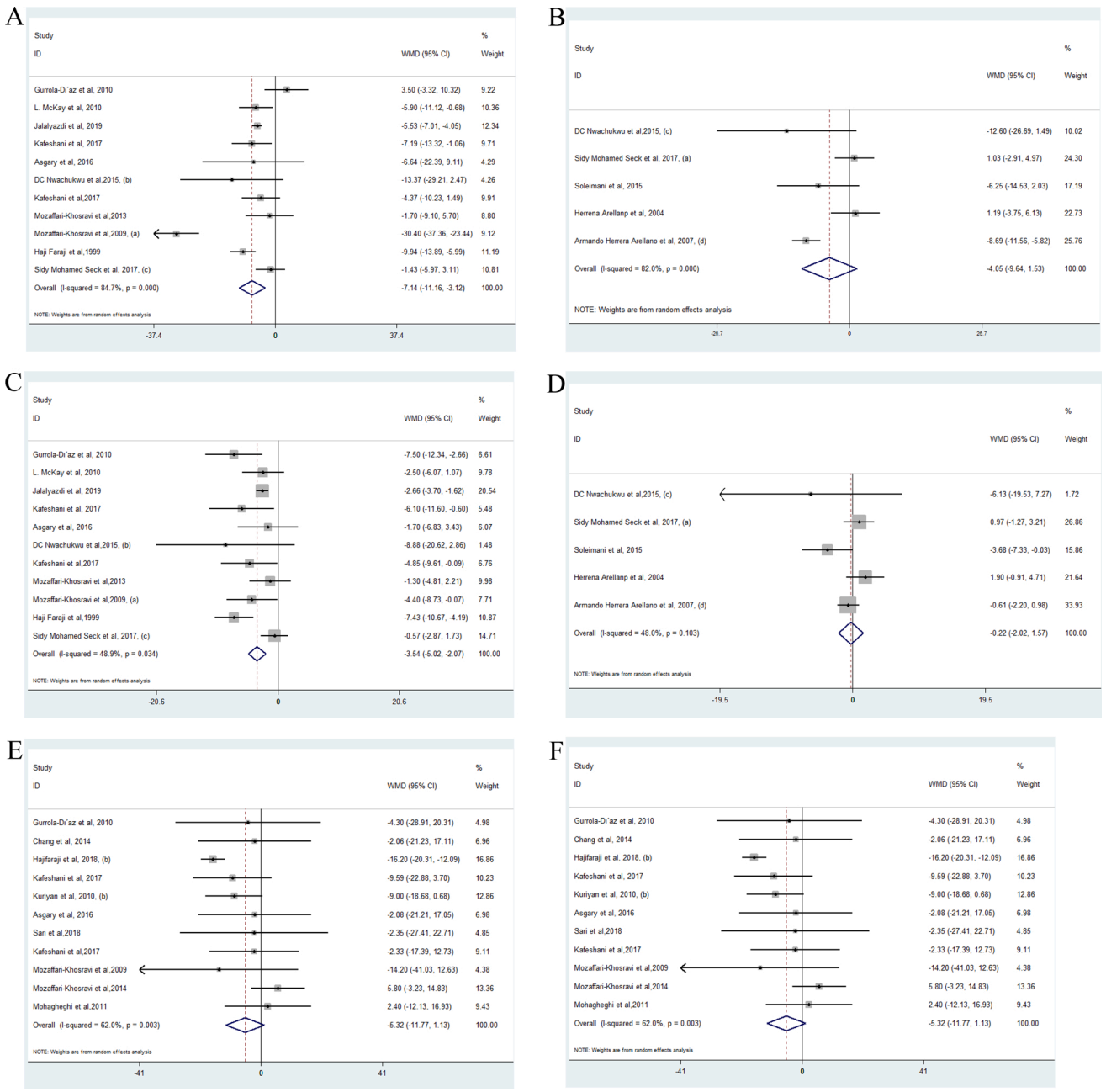


Fig. 2. **Panel A**. Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on SBP levels compared with placebo and tea as control group. **Panel B**. Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on SBP levels compared with drugs as control group. **Panel C**. Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on **DBP** levels compared with placebo and tea as control group. **Panel D**. Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on **DBP** levels compared with drugs as control group. **Panel E**. Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on **LDL_C** levels compared with placebo and tea as control group. **Panel F**. Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on **HDL_C** levels compared with placebo and tea as control group. **Panel G**. Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on **TG** levels compared with placebo and tea as control group. **Panel H**. Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on **TC** levels compared with placebo and tea as control group. **Panel I**. Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on **FBS** levels compared with placebo and tea as control group. **Panel J.** Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on **BMI** levels compared with placebo and tea as control group. **Panel K.** Forest plot displaying weighted mean difference and 95 % confidence intervals for the impact of Hibiscus sabdariffa on **BW** compared with placebo and tea as control group.

In LDL-C case, subgroup analysis by both of sour tea dose (<2 g and ≥2 g) and participants' age (≥ 45 and <45years) indicated a non-significant reduction. In subgroup analysis by type of control group and study duration, a significant reduction was observed in the placebo as control group and duration of study (≥ 6week), however, subgroup analysis by the tea as control group and duration of intervention (< 6week) indicated non–significant increase.

In subgroup analysis by type of participants' age for HDL-C,

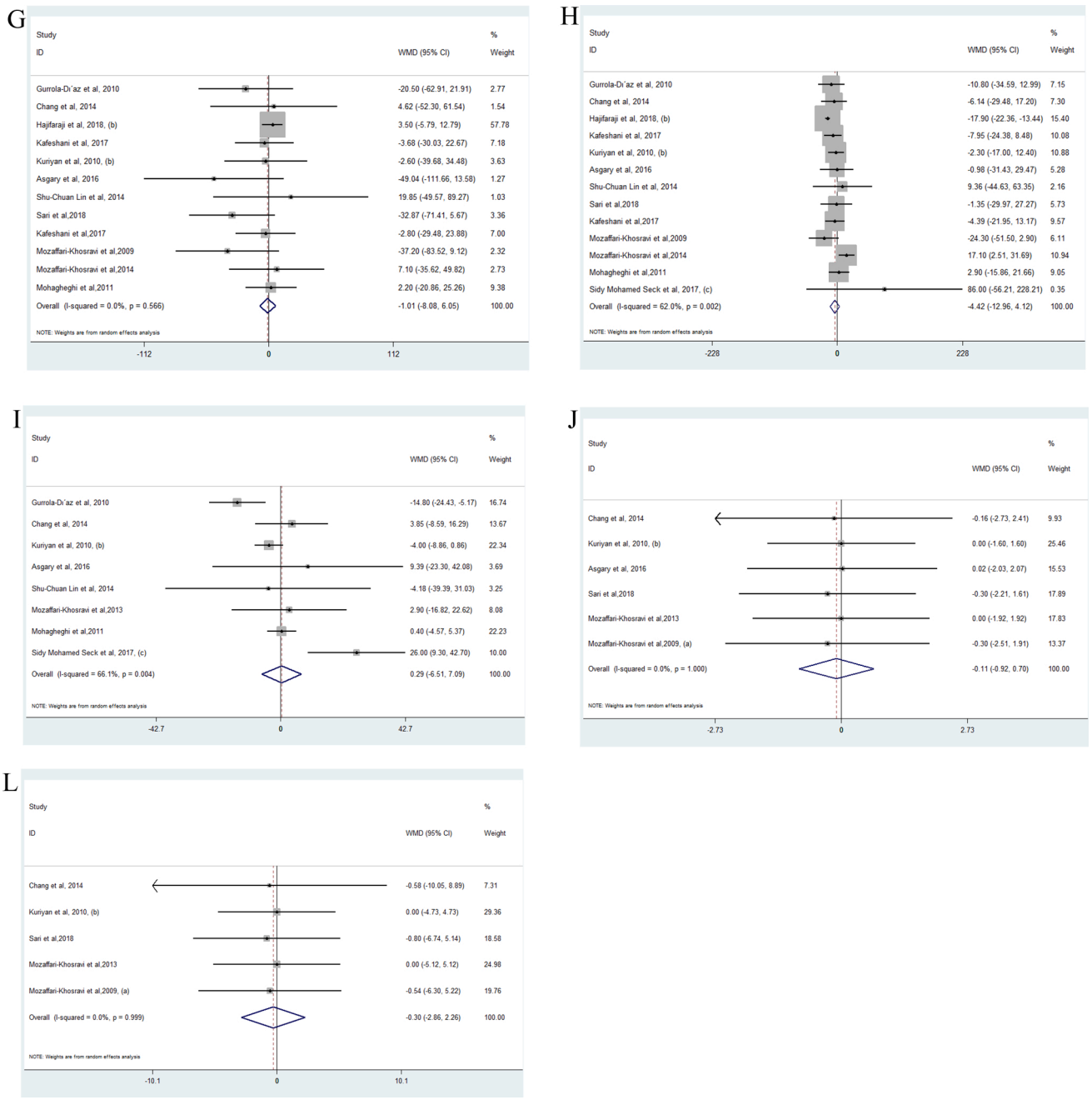


Fig. 2. (*continued*).

reduction in ≥ 45years and increase in <45 years was observed, although the changes were not significant. Non-significant increase and decrease was revealed for subgroup by placebo and tea, respectively. In subgroup analysis by duration of intervention, although a non-significant raise was observed in the both of the subgroups, the increase in duration of < 6 week was greater than the studies with duration of ≥ 6week. However, in subgroup by dose ≥ 2 g the significant reduction was observed, increase in subgroup by dose < 2 g was not significant.

For TG and TC, the results obtained from 12 studies (13 effect size) with 336 patients which compared the effect of Hibiscus sabdariffa with placebo or tea. The effect on TG was non-significant (WMD: −1.01, 95 % CI: −8.07, 6.04, p = 0.77), without heterogeneity (I^2 = 0%), (Fig. 2 panel G). As well the effect of Hibiscus sabdariffa on TC was non-significant too. (WMD: −4.42, 95 % CI: −12.96, 4.11, p = 0.31), with significant heterogeneity (I^2 = 62 %, p = 0.002) (Fig. 2 panel H).

Subgroup analysis by dose of sour tea for TG and TC indicated a non-significant reduction in the subgroup with dose of ≥ 2 g and < 2 g.

In subgroup analysis by age for TG and TC, although a non-significant reduction was observed in both of the subgroups. The reduction in patient with <45 years of age for both of TG and TC was greater than the patient with ≥ 45years. The subgroup analysis by type of control group for TG indicated non-significant reduction in both of the subgroups, However, for TC, the significant reduction was observed in the subgroup using placebo. For the dose of sour tea, non-significant reduction was shown in both of the subgroups (<2 g and ≥2 g) for TG and TC. Subgroup analysis by duration of the studies indicated a significant reduction in the subgroup with ≥ 6week and non-significant increase in the subgroup with <6week for TC, however, the reduction in subgroup by < 6week and increase in subgroup by ≥ 6week was not significant.

In subgroup analysis by quality of study for lipid profiles in both of

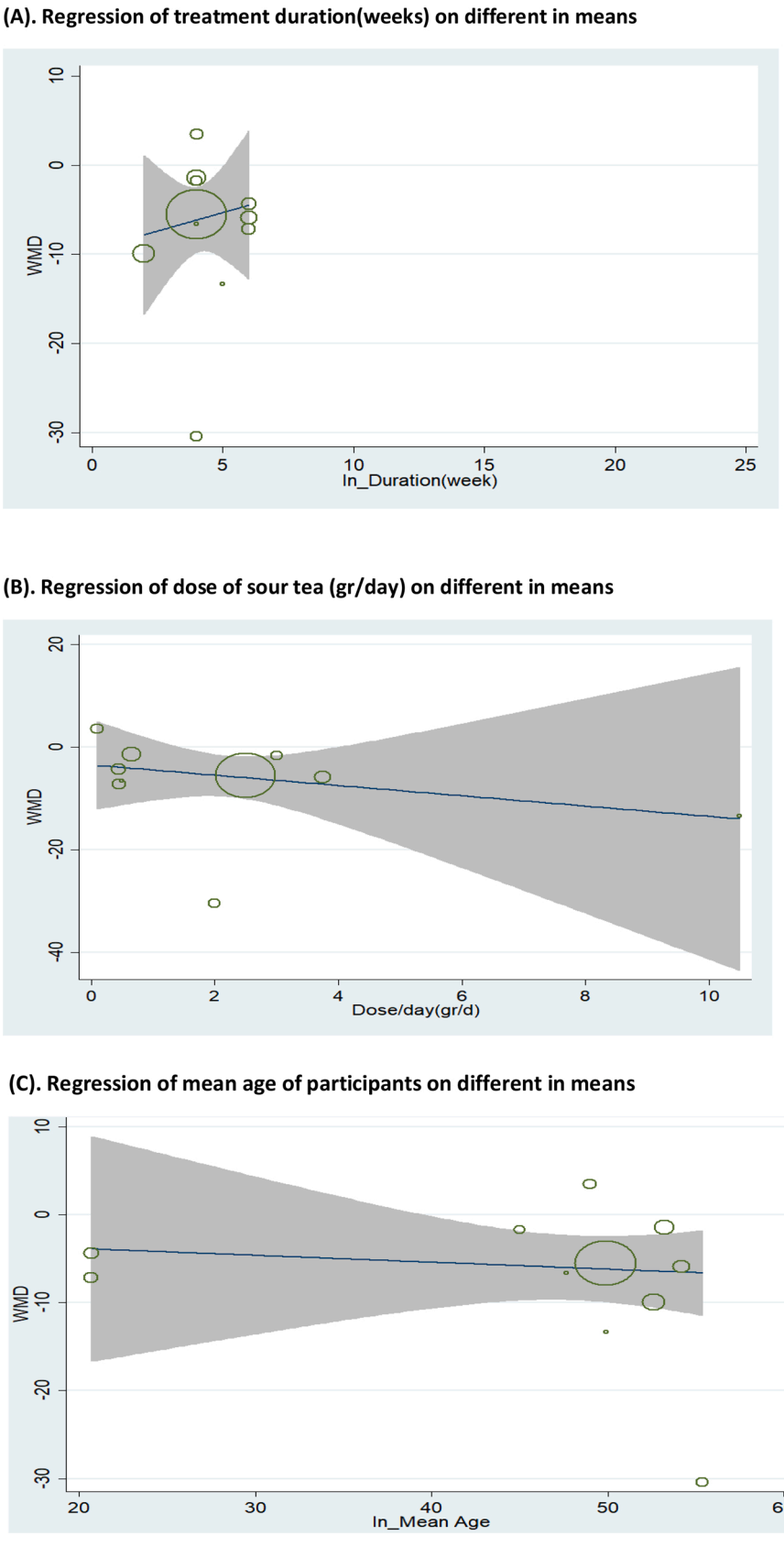
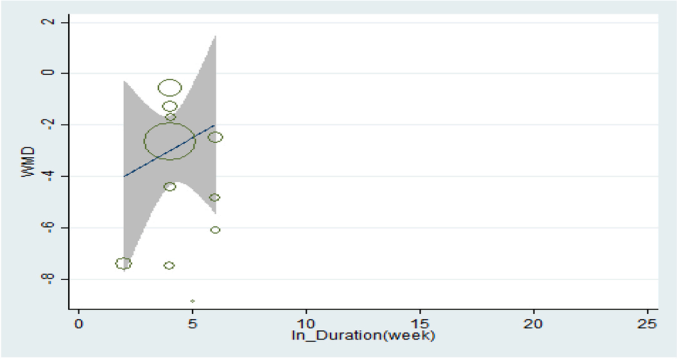
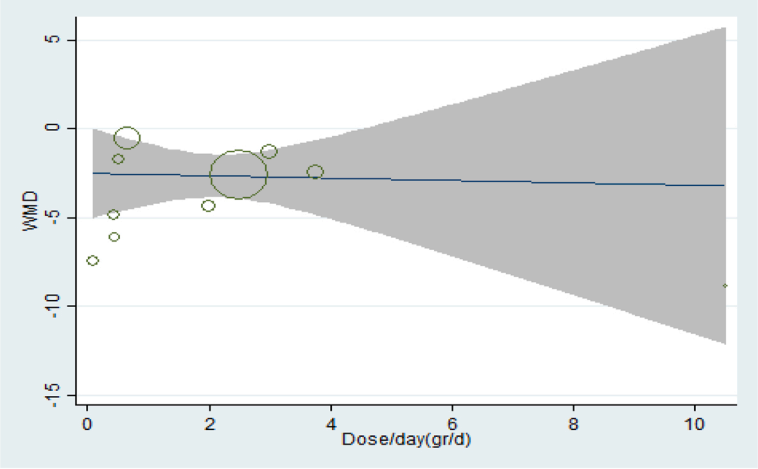


Fig. 3. Meta-regression plots of the association between mean changes in SBP levels with treatment duration (A), dose of sour tea (B) and mean age of participants (C).

(A). Regression of treatment duration(weeks) on different in means



(B). Regression of dose of sour tea (gr/day) on different in means



(C). Regression of mean age of participants on different in means

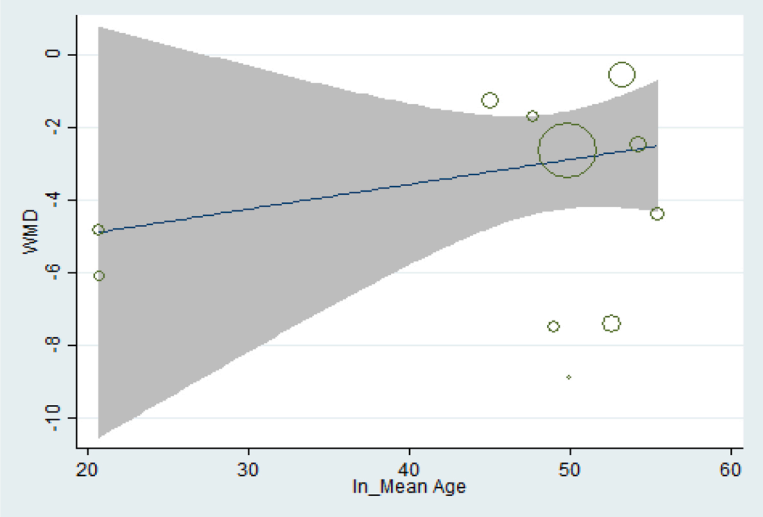
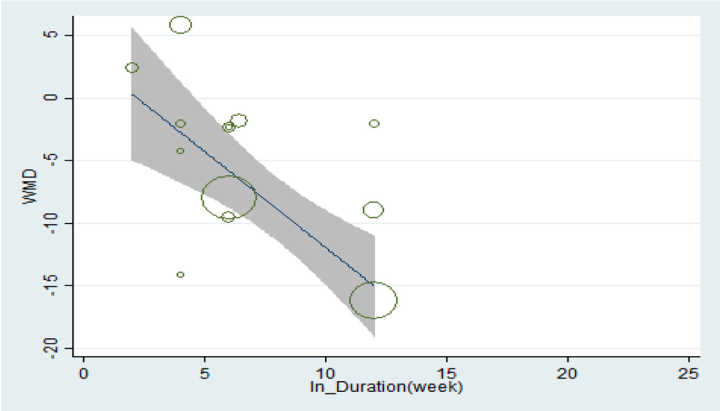
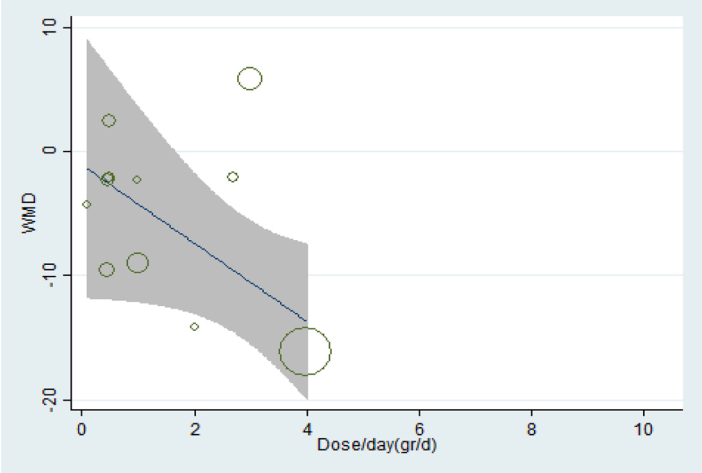


Fig. 4. Meta-regression plots of the association between mean changes in DBP levels with treatment duration (A), dose of sour tea (B) and mean age of participants (C).

(A). Regression of treatment duration(weeks) on different in means



(B). Regression of dose of sour tea (gr/day) on different in means



(C). Regression of mean age of participants on different in means

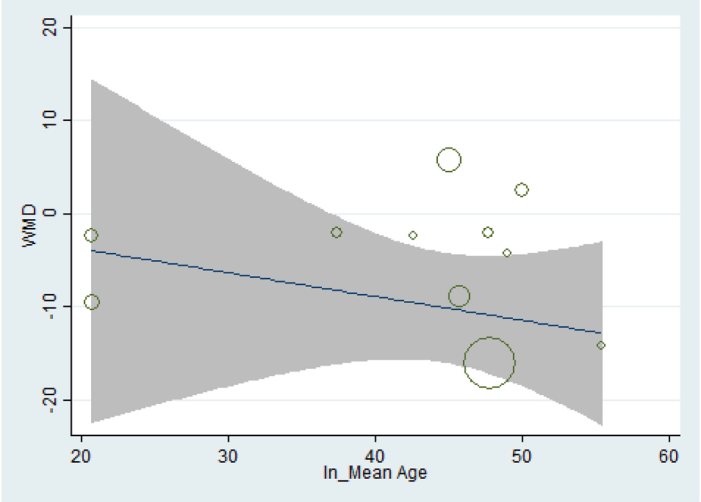
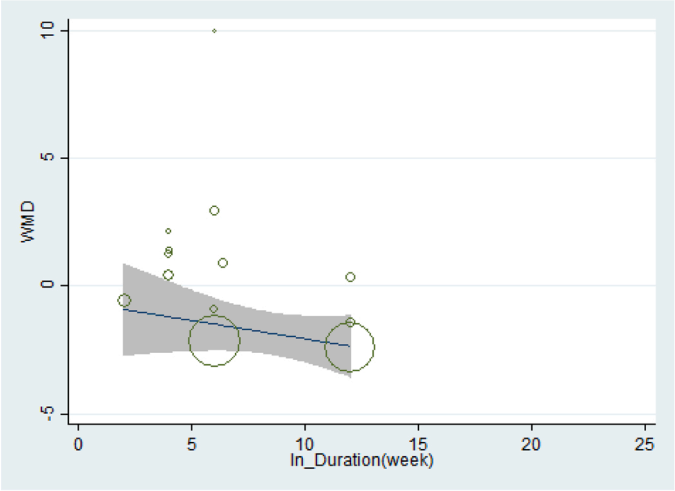
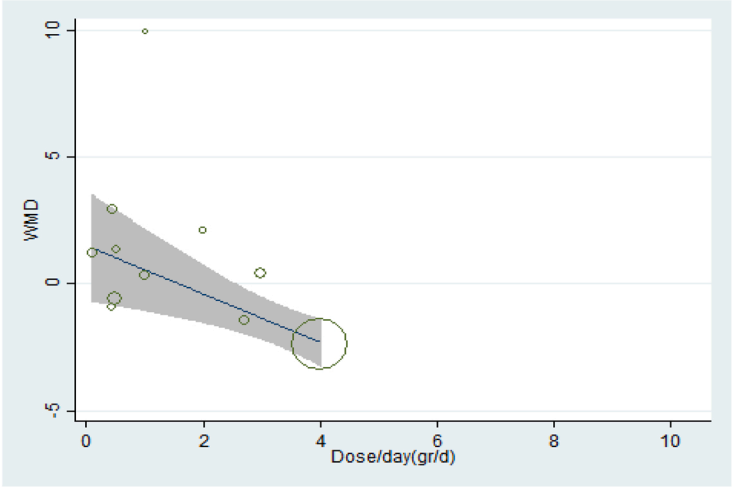


Fig. 5. Meta-regression plots of the association between mean changes in LDL-C levels with treatment duration (A), dose of sour tea (B) and mean age of participants (C).

(A). Regression of treatment duration(weeks) on different in means



(B). Regression of dose of sour tea (gr/day) on different in means



(C). Regression of mean age of participants on different in means

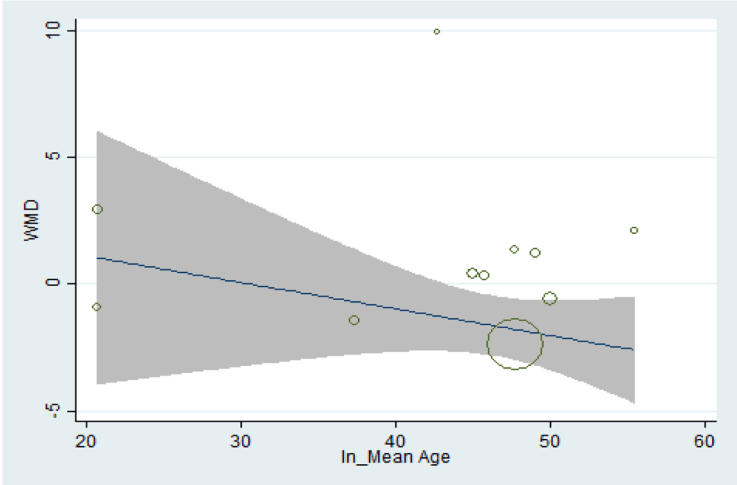
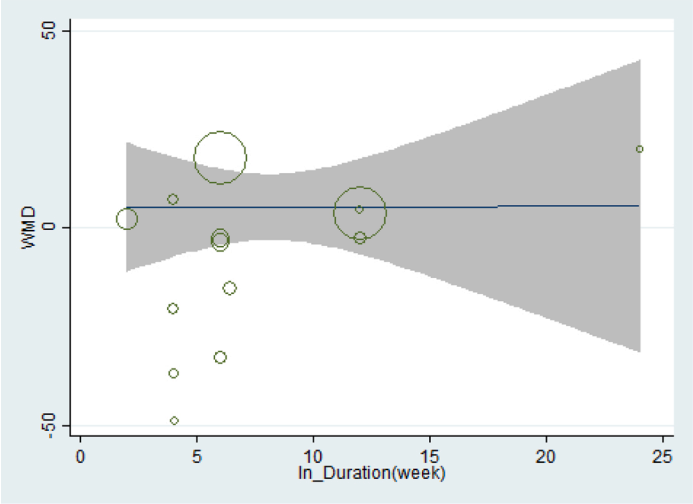
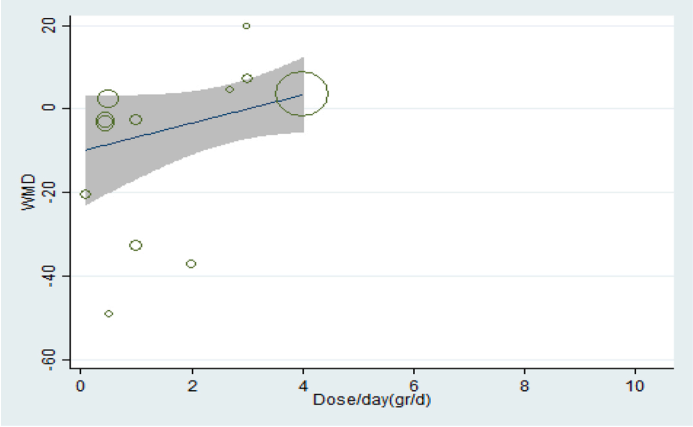


Fig. 6. Meta-regression plots of the association between mean changes in HDL-C levels with treatment duration (A), dose of sour tea (B) and mean age of participants (C). Meta-regression plots of the association between mean changes in TG levels with treatment duration (A), dose of sour tea (B) and mean age of participants (C).

(A). Regression of treatment duration(weeks) on different in means



(B). Regression of dose of sour tea (gr/day) on different in means



(C). Regression of mean age of participants on different in means

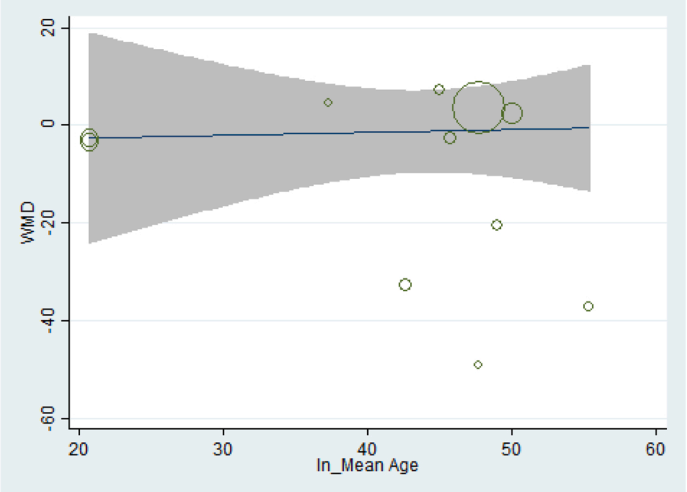
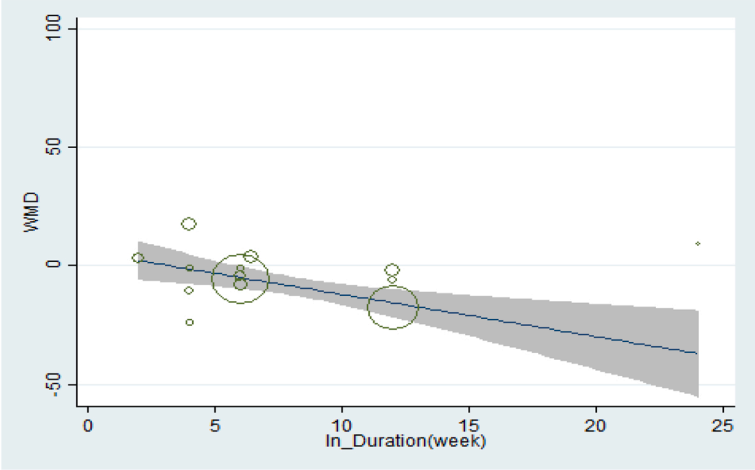


Fig. 6. (*continued*).

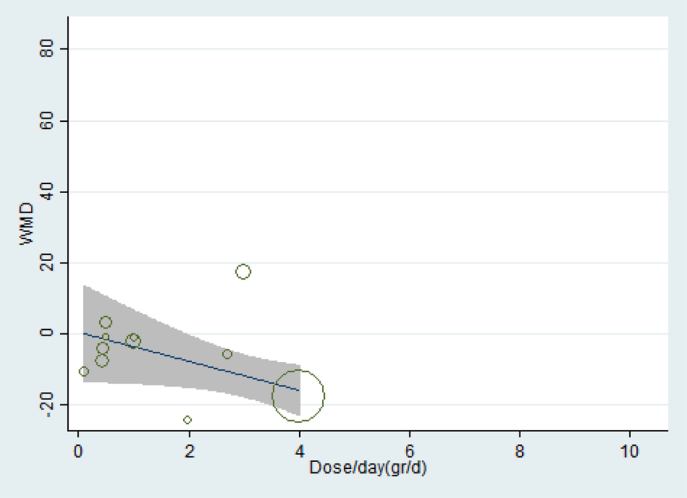
the subgroups (poor or fair and good) none of the changes were significant for lipid profiles.

The FBS data was obtained from 8 studies with 228 subjects. No significant change in FBS level was observed in sour tea group when compared to the placebo or tea (WMD: 0.28, 95 % CI: −6.5, 7.08, p = 0.93), with significant heterogeneity (I^2 = 66 %, p = 0.004), (Fig. 2

(A). Regression of treatment duration(weeks) on different in means



(B). Regression of dose of sour tea (gr/day) on different in means



(C). Regression of mean age of participants on different in means

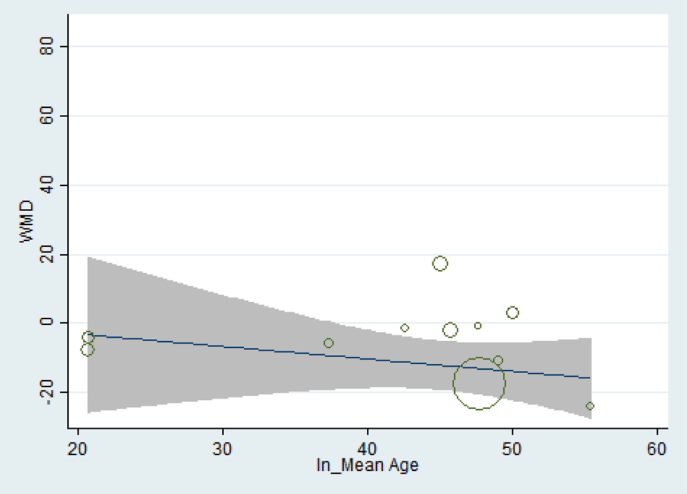
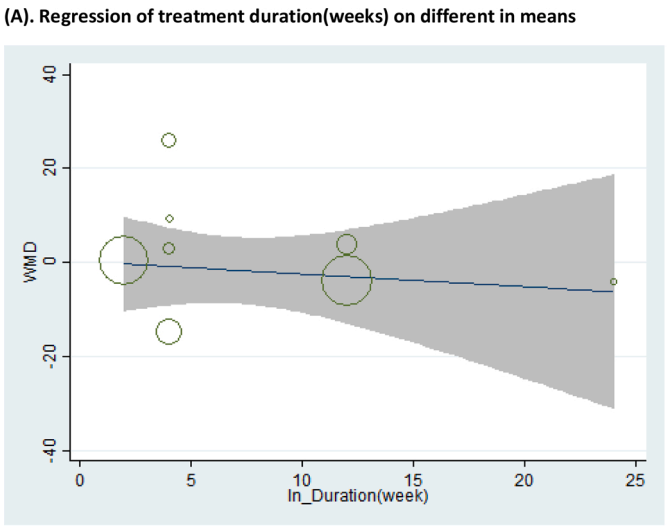
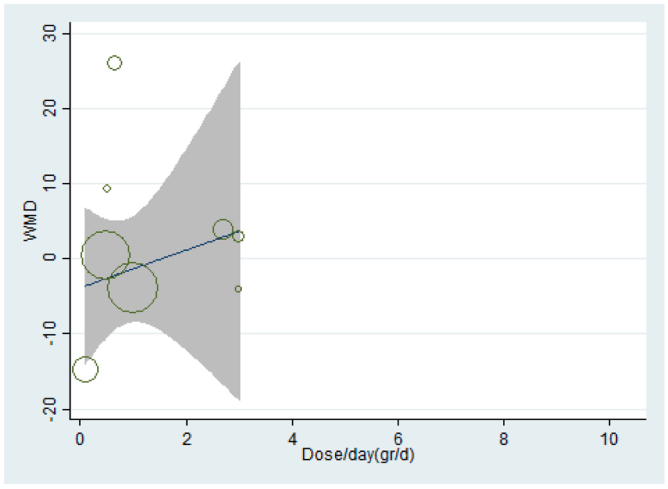


Fig. 7. Meta-regression plots of the association between mean changes in TC levels with treatment duration (A), dose of sour tea (B) and mean age of participants (C).





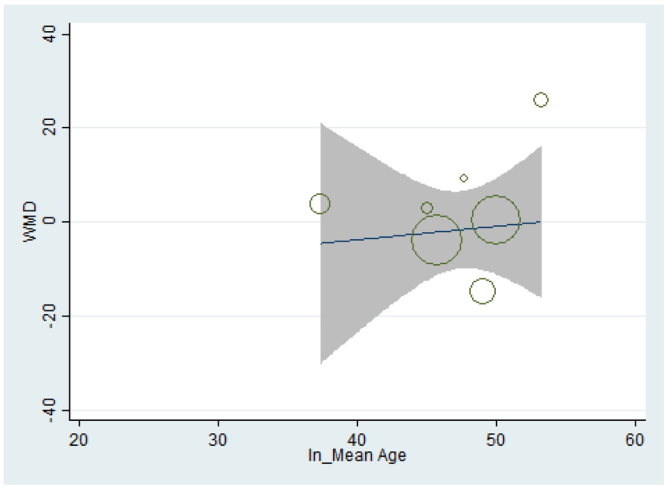
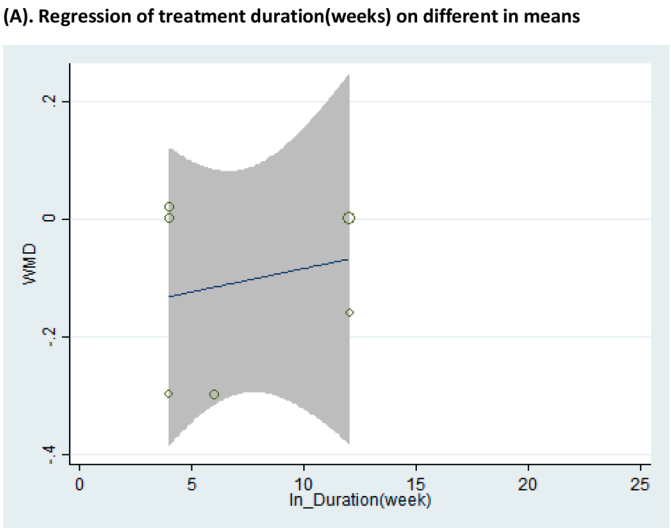
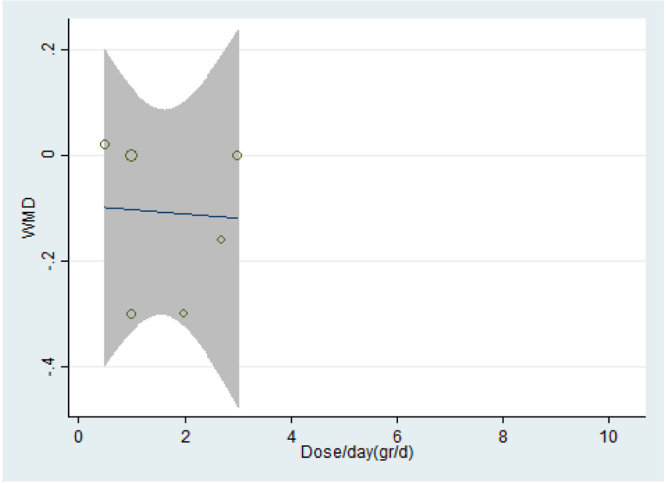


Fig. 8. Meta-regression plots of the association between mean changes in FBS levels with treatment duration (A), dose of sour tea (B) and mean age of participants (C).





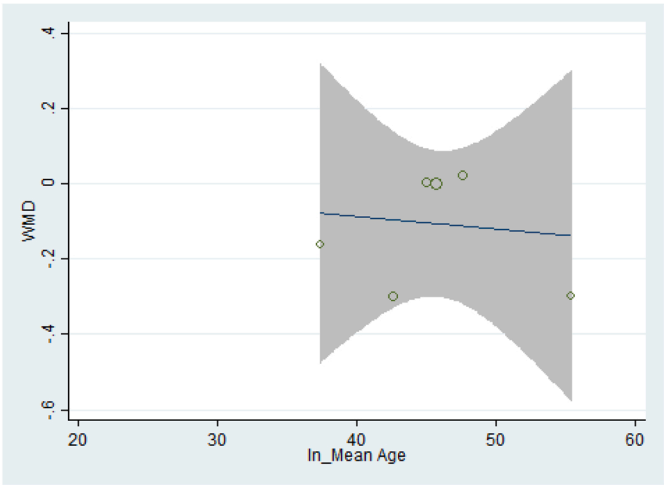


Fig. 9. Meta-regression plots of the association between mean changes in BMI levels with treatment duration (A), dose of sour tea (B) and mean age of participants (C).

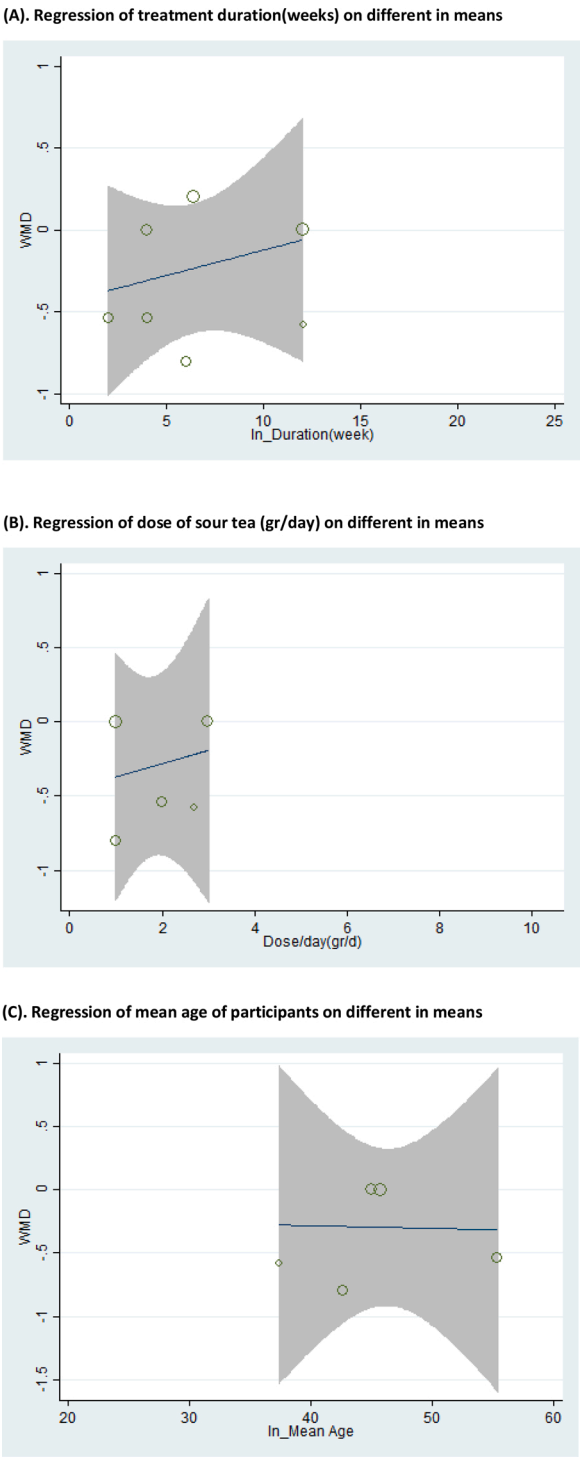


Fig. 10. Meta-regression plots of the association between mean changes in BW levels with treatment duration (A), dose of sour tea (B) and mean age of participants (C).

panel I).

Subgroup analysis by dose of sour tea indicated a non-significant increase in the both of subgroups with dose of ≥ 2 g and < 2 g.

In subgroup analysis by age, although a non-significant reduction was observed in the subgroup with<46 years, the non-significant increases was revealed in subgroup with ≥46 years. Also for the type of control group in spite of non-significant reduction in the subgroup with placebo, a non-significant increase was observed in the subgroup with tea as a control group.

Subgroup analysis by duration of intervention indicated a significant reduction in the subgroup with duration of ≥ 6week while the increase in the subgroup with duration lower than 6week was not significant.

The effect of sour tea on BMI was reported by 6 studies including 152 subjects. Hibiscus sabdariffa compared to the placebo or tea, induced no change on BMI (WMD: −0.1, 95 % CI: −0.91, 0.70, p = 0.77), without heterogeneity (I^2 = 0%), (Fig. 2 panel J). Similarly, for the body weight, no significant change was seen (WMD: −0.30, 95 % CI: −2.85, 2.26, p = 0.82), without significant heterogeneity (I^2 = 0%), (Fig. 2 panel K). The result for the weight gathered from 5 studies with 134 subjects.

In subgroup analysis by all, including age (<45 and ≥ 45 years), Type of control group (placebo and tea), duration of intervention (< 6 and ≥ 6week) and dose of sour tea (< 2 and ≥ 2 g) for BMI and BW, a non-significant reduction was observed.

3.2. Sensitivity analysis

Sensitivity analysis for the small study effect was not significant for any of the results.

3.3. Meta-regression

Meta-regression was conducted for participants' age, duration of the intervention and dose of Hibiscus sabdariffa. None of the three factors had significant impact on the effect of Hibiscus sabdariffa on SBP, DBP, LDL-C, HDL-C, TC, TG, FBS levels; BW and BMI. (Figs. 3–10, panel A–C).

4. Discussion

The current systematic review and meta-analysis of twenty-two clinical trials investigated the effect of Hibiscus sabdariffa consumption compared to other herbal teas and antihypertension drugs on SBP and DBP, LDL-C, HDL-C, TC, TG, FBS, BW and BMI as cardiometabolic risk factors. The results indicated that Hibiscus sabdariffa consumption when compared to the placebo or other tea could efficiently reduce SBP and DBP levels, but the changes in lipid profiles, FBS, BMI and BW as cardiometabolic risk factors were not significant. Moreover, Hibiscus sabdariffa was as effective as blood pressure lowering drugs in reducing of hypertension.

Hibiscus sabdariffa belonging to the Malvaceae family is a plant, which often used in traditional medicine. It is rich in phytochemicals like polyphenols especially anthocyanins, organic acids, and polysaccharides. As an antioxidant source, it has an enormous prospective in modern therapeutic uses (Riaz and Chopra, 2018). Several studies have investigated the effect of this plant in the prevention and treatment of chronic and degenerative diseases that are associated with oxidative stress, like hypertension, hyperlipidemia, cancer and other inflammatory diseases of kidney and liver (Asgary et al., 2016; Mahadevan and Kamboj, 2009; Malacrida et al., 2019; McKay et al., 2009; Riaz and Chopra, 2018; Wahabi et al., 2010). Management of hypertension, dyslipidemia and obesity, as the most common risk factors, is an important therapeutic strategy against CVD (Hashemipour et al., 2011; Kafeshani et al., 2017). Indeed, subgroup analysis by dose (dose ≤ 2 g vs. > 2 g) indicated a significant reduction of SBP in the doses > 2 g while the effect in the ≤2 g subgroup was not significant. For DBP the result was not different in subgroup analysis.

The results indicated that Hibiscus sabdariffa was effective in reducing of hypertension compared to the placebo and other tea. In addition, it was as efficient as hypertension medication in alleviating of blood pressure. For SBP, this effect was dose dependent; so that in the dose of >2 g a greater reduction was seen compared to the dose of ≤2 g.

The precise mechanism of blood pressure lowering effects of Hibiscus sabdariffa has not yet been determined but several mechanisms have been proposed. As the authors mentioned previously, Hibiscus sabdariffa contains various anthocyanins and flavonoids (Sindi et al., 2014), both of which have antioxidant properties resulting in cardioprotective

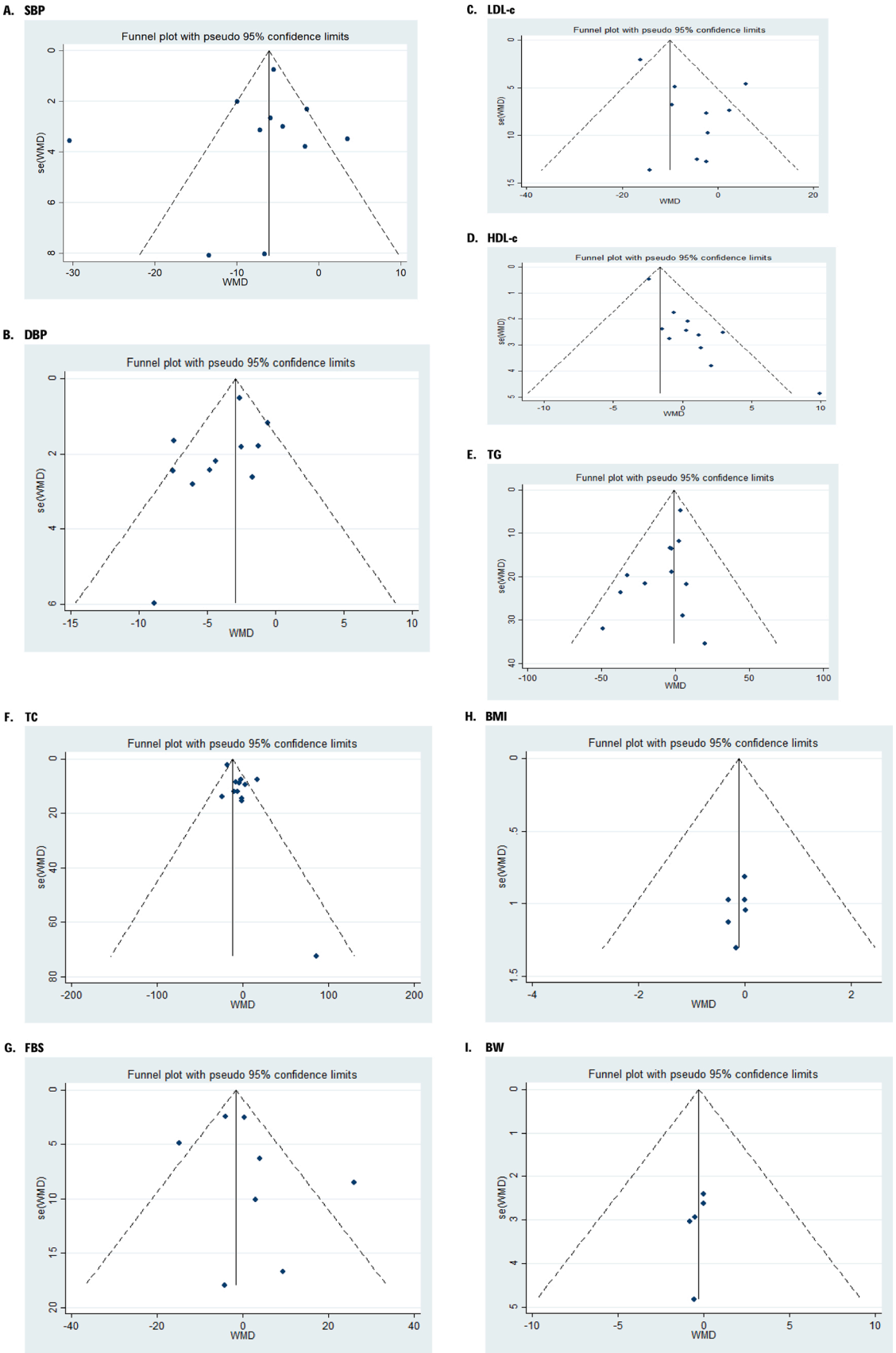


Fig. 11. Funnel plot displaying publication bias in the studies reporting the impact of sour tea on SBP (A) and DBP levels (B); LDL-C(C), HDL-C(D), TG(E), TC(F) and FBS(G) concentration; BMI(H) and BW(I).

effects. Also the anthocyanins can inhibit angiotensin I and angiotensin II converting enzyme (Herrera-Arellano et al., 2004).

In another study, researchers observed that polyphenols from Hibiscus sabdariffa calyces could display potent anti-inflammatory and antioxidant activities, and significantly decrease blood pressure in both humans and rats. In addition to the antioxidant, anti-inflammatory, and endothelium-dependent effects of polyphenols from Hibiscus sabdariffa, they found diuresis and inhibition of the angiotensin -converting enzyme I (ACE I) as less important mechanisms for blood pressure-lowering effect of this plant. Improving nitric oxide production was one of the important mechanisms observed in this study (Joven et al., 2014).

The blood pressure lowering effects of consuming hibiscus sabdariffa observed in our meta-analysis are near to those reported in the Dietary Approaches to Stop Hypertension (DASH) as a large dietary intervention. In a systematic review and meta-analysis of seventeen randomized clinical trials with 2561 participants, they reported that the DASH diet significantly reduced SBP by 6.74 mmHg and DBP by 3.54 mmHg (Saneei et al., 2014). It seems these findings are important for public health because previous studies reported that, a 5-mm Hg decrease in SBP would result in a 14 % overall reduction in mortality due to stroke, a 9% reduction in mortality due to coronary heart disease, and a 7% reduction in all-cause mortality (Chobanian et al., 2003). The dash diet is hard to follow especially for a long time (Kwan et al., 2013), however adding hibiscus sabdariffa to each meal seems simple. Maybe future studies would reveal a greater reduction in blood pressure for a combination of daily hibiscus sabdariffa consumption and DASH diet than either approach alone.

These results did not show any significant effect for 1–12 weeks sour tea consumption on lipid profile, FBS, BW and BMI. Due to the antioxidant properties of sour tea, various studies have examined the effects of its consumption on lipid profile, FBS and obesity but there is no specific proposed mechanism for it (Kafeshani et al., 2017; Mozaffari-Khosravi et al., 2009). However, it was suggested that phenolic and flavonoid components of sour tea may improve glycemic status through alteration of ß cells performance (Shi et al., 2014).

In addition, sour tea can inhibit 3-hydroxy-3-methylglutarylcoenzyme A (HMG-CoA) reductase so reduce cholesterol biosynthesis (Sharma et al., 2011). Moreover, antioxidant components of sour tea can inhibit LDL-C oxidation that reduce atherosclerosis and CVDs, subsequently (Chen et al., 2003).

However, it was suggested that phenolic and flavonoid components of sour tea may improve glycemic status through alteration of ß cells performance (Shi et al., 2014). A most recent met-analysis has investigated the effect of sour tea compared to the placebo on blood pressure, lipid profile and fasting plasma glucose (Najafpour Boushehri et al., 2020).

The novelty of this study for the blood pressure outcome is comparing the effect of sour tea with other tea as well as blood pressure lowering drugs beside the placebo. For the lipid profile outcome, more studies were included in this analysis for the effect of sour tea compared to the placebo which provide more robustness in the results. Finally, the effect of sour tea was assessed on body weight and BMI which has not been assessed previously.

The strength of the current study is the comparison of sour tea with other tea and also with blood pressure lowering drugs. The main limitations of this meta-analysis was the few number of included studies with maximum duration of 12 weeks. Next, the protocol of the study was not registered in the International Prospective Register of Systematic Reviews (PROSPERO) database. Further studies with longer durations are encouraged to warrant the beneficial effect of Hibiscus sabdariffa on cardiometabolic risk factors with greater certainty.

5. Conclusion

In conclusion, this meta-analysis of twenty-two clinical trials indicated that Hibiscus sabdariffa consumption could efficiently decrease SBP and DBP levels and the reduction in SBP was obviously greater in dose of more than 2 g but the changes in lipid profiles, FBS, BMI and BW were not significant.

Author contribution

AK, HR and VM designed the research. AK, VM and MSH evaluated study eligibility and conducted quality assessments. MSH and SB accomplished data synthesis; AK and SMM analyzed the data; VM, MSH wrote the article; SMM, HD and HR revised the article. All authors read and approved the final manuscript; HR and SMM are the guarantors for the study.

Funding/support

Financial support was exclusively provided by the Shiraz University of Medical Sciences, Shiraz, Iran.

Transparency document

The Transparency document associated with this article can be found in the online version.

Declaration of Competing Interest

The authors report no declarations of interest.

References

Abubakar, S.M., Ukeyima, M.T., Spencer, J.P., Lovegrove, J.A., 2019. Acute effects of hibiscus sabdariffa calyces on postprandial blood pressure, vascular function, blood lipids, biomarkers of insulin resistance and inflammation in humans. Nutrients 11 (2), 341.

Al-Shafei, A.I., El-Gendy, O.A., 2013. Effects of Roselle on arterial pulse pressure and left ventricular hypertrophy in hypertensive patients. Saudi Med. J. 34 (12), 1248–1254.

Asgary, S., Soltani, R., Zolghadr, M., Keshvari, M., Sarrafzadegan, N., 2016. Evaluation of the effects of roselle (Hibiscus sabdariffa L.) on oxidative stress and serum levels of lipids, insulin and hs-CRP in adult patients with metabolic syndrome: a double-blind placebo-controlled clinical trial. J. Complement. Integr. Med. 13 (2), 175–180.

Boix-Castejón, M., Herranz-López, M., Gago, A.P., Olivares-Vicente, M., Caturla, N., Roche, E., Micol, V., 2018. Correction: hibiscus and lemon verbena polyphenols modulate appetite-related biomarkers in overweight subjects: a randomized controlled trial. Food Funct. 9 (7), 4037.

Camille, N.N.É., DL, E.M.A., Nga, E.N., Nganou-Gnindjio, C.N., Sobngwi, E., Camille, N. N.É., 2018. A15083 Short-term effects of a standardized beverage from aqueous extracts of Hibiscus sabdariffa and Stevia rebaudiana on diastolic function and circadian blood pressure of Cameroonians with type 2 diabetes patients. J. Hypertens. 36, e231.

Chang, H.-C., Peng, C.-H., Yeh, D.-M., Kao, E.-S., Wang, C.-J., 2014. Hibiscus sabdariffa extract inhibits obesity and fat accumulation, and improves liver steatosis in humans. Food Funct. 5 (4), 734–739.

Chen, C.-C., Hsu, J.-D., Wang, S.-F., Chiang, H.-C., Yang, M.-Y., Kao, E.-S., Ho, Y.-C., Wang, C.-J., 2003. Hibiscus sabdariffa extract inhibits the development of atherosclerosis in cholesterol-fed rabbits. J. Agric. Food Chem. 51 (18), 5472–5477.

Chobanian, A.V., Bakris, G.L., Black, H.R., Cushman, W.C., Green, L.A., Izzo Jr., J.L., Jones, D.W., Materson, B.J., Oparil, S., Wright Jr., J.T., 2003. Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. Hypertension 42 (6), 1206–1252.

DerSimonian, R., Laird, N., 1986. Meta-analysis in clinical trials. Control. Clin. Trials 7 (3), 177–188.

Faraji, M.H., Tarkhani, A.H., 1999. The effect of sour tea (Hibiscus sabdariffa) on essential hypertension. J. Ethnopharmacol. 65 (3), 231–236.

Franks, P.W., Hanson, R.L., Knowler, W.C., Sievers, M.L., Bennett, P.H., Looker, H.C., 2010. Childhood obesity, other cardiovascular risk factors, and premature death. N. Engl. J. Med. 362 (6), 485–493.

Gurrola-Diaz, C., Garcia-Lopez, P., Sánchez-Enríquez, S., Troyo-Sanromán, R., Andrade-González, I., Gómez-Leyva, J., 2010. Effects of Hibiscus sabdariffa extract powder and preventive treatment (diet) on the lipid profiles of patients with metabolic syndrome (MeSy). Phytomedicine 17 (7), 500–505.

Hajifaraji, M., Matlabi, M., Ahmadzadeh-Sani, F., Mehrabi, Y., Rezaee, M.S., Hajimehdipour, H., Hasanzadeh, A., Roghani, K., 2018. Effects of aqueous extracts of dried calyx of sour tea (Hibiscus sabdariffa L.) on polygenic dyslipidemia: a randomized clinical trial. Avicenna J. Phytomed. 8 (1), 24.

Harrison, A.P., Cooper, R.G., Suliman, M.A., Al-Alami, U., 2009. The efficacy of karkadeh tea in controlling post-prandial blood glucose levels. Am. J. Pharmacol. Toxicol. 4 (4), 151–157.

Hashemipour, M., Soghrati, M., Ahmadi, M.M., Soghrati, M., 2011. Anthropometric indices associated with dyslipidemia in obese children and adolescents: a retrospective study in isfahan. ARYA Atheroscler. 7 (1), 31.
Herranz-López, M., Olivares-Vicente, M., Boix-Castejón, M., Caturla, N., Roche, E., Micol, V., 2019. Differential effects of a combination of Hibiscus sabdariffa and Lippia citriodora polyphenols in overweight/obese subjects: a randomized controlled trial. Sci. Rep. 9 (1), 1–12.
Herrera-Arellano, A., Flores-Romero, S., Chavez-Soto, M., Tortoriello, J., 2004. Effectiveness and tolerability of a standardized extract from Hibiscus sabdariffa in patients with mild to moderate hypertension: a controlled and randomized clinical trial. Phytomedicine 11 (5), 375–382.
Herrera-Arellano, A., Miranda-Sánchez, J., Ávila-Castro, P., Herrera-Álvarez, S., Jiménez-Ferrer, J.E., Zamilpa, A., Román-Ramos, R., Ponce-Monter, H., Tortoriello, J., 2007. Clinical effects produced by a standardized herbal medicinal product of Hibiscus sabdariffa on patients with hypertension. A randomized, double-blind, lisinopril-controlled clinical trial. Planta Med. 73 (01), 6–12.
Higgins, J., Green, S., Collaboration, C., 2008. Cochrane Handbook for Systematic Reviews of Interventions. Wiley Online Library.
Hozo, S.P., Djulbegovic, B., Hozo, I., 2005. Estimating the mean and variance from the median, range, and the size of a sample. BMC Med. Res. Methodol. 5 (1), 13. https://www.who.int/news-room/fact-sheets/detail/hypertension.
Jalalyazdi, M., Ramezani, J., Izadi-Moud, A., Madani-Sani, F., Shahlaei, S., Ghiasi, S.S., 2019. Effect of hibiscus sabdariffa on blood pressure in patients with stage 1 hypertension. J. Adv. Pharm. Technol. Res. 10 (3), 107.
Joven, J., March, I., Espinel, E., Fernández-Arroyo, S., Rodríguez-Gallego, E., Aragonès, G., Beltrán-Debón, R., Alonso-Villaverde, C., Rios, L., Martin-Paredero, V., 2014. Hibiscus sabdariffa extract lowers blood pressure and improves endothelial function. Mol. Nutr. Food Res. 58 (6), 1374–1378.
Kafeshani, M., Entezari, M.H., Karimian, J., Pourmasoumi, M., Maracy, M.R., Amini, M. R., Hadi, A., 2017. A comparative study of the effect of green tea and sour tea on blood pressure and lipid profile in healthy adult men. ARYA Atheroscler. 13 (3), 109.
Kelishadi, R., Hashemipour, M., Sheikh-Heidar, A., Ghatreh-Samani, S., 2012. Changes in serum lipid profile of obese or overweight children and adolescents following a lifestyle modification course. ARYA Atheroscler. 8 (3), 143.
Kuriyan, R., Kumar, D.R., Rajendran, R., Kurpad, A.V., 2010. An evaluation of the hypolipidemic effect of an extract of Hibiscus sabdariffa leaves in hyperlipidemic Indians: a double blind, placebo controlled trial. BMC Complement. Altern. Med. 10 (1), 27.
Kwan, M.W., Wong, M.C., Wang, H.H., Liu, K.Q., Lee, C.L., Yan, B.P., Yu, C.M., Griffiths, S.M., 2013. Compliance with the dietary approaches to stop hypertension (DASH) diet: a systematic review. PLoS One 8 (10), e78412.
Lin, T.-L., Lin, H.-H., Chen, C.-C., Lin, M.-C., Chou, M.-C., Wang, C.-J., 2007. Hibiscus sabdariffa extract reduces serum cholesterol in men and women. Nutr. Res. 27 (3), 140–145.
Lin, S.-C., Wang, C.-C., Shih, S.-C., Tjung, J.-J., Tsou, M.-T., Lin, C.-J., 2014. Prevention of asymptomatic bacteriuria with cranberries and roselle juice in home-care patients with long-term urinary catheterization. Int. J. Gerontol. 8 (3), 152–156.
Mahadevan, N., Kamboj, P., 2009. Hibiscus Sabdariffa Linn.–An Overview.
Malacrida, A., Cavalloro, V., Martino, E., Cassetti, A., Nicolini, G., Rigolio, R., Cavaletti, G., Mannucci, B., Vasile, F., Giacomo, M.D., Collina, S., Miloso, M., 2019. Anti-multiple myeloma potential of secondary metabolites from Hibiscus sabdariffa. Molecules 24 (13).
Mancia, G., 2005. The association of hypertension and diabetes: prevalence, cardiovascular risk and protection by blood pressure reduction. Acta Diabetol. 42 (1), s17–s25.
McKay, D.L., Chen, C.O., Saltzman, E., Blumberg, J.B., 2009. Hibiscus sabdariffa L. Tea (tisane) lowers blood pressure in prehypertensive and mildly hypertensive adults. J. Nutr. 140 (2), 298–303.
McKay, D.L., Chen, C.O., Saltzman, E., Blumberg, J.B., 2010. Hibiscus sabdariffa L. Tea (tisane) lowers blood pressure in prehypertensive and mildly hypertensive adults. J. Nutr. 140 (2), 298–303.
Mohagheghi, A., Maghsoud, S., Khashayar, P., Ghazi-Khansari, M., 2011. The effect of hibiscus sabdariffa on lipid profile, creatinine, and serum electrolytes: a randomized clinical trial. ISRN Gastroenterol. 2011.
Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A., Group, P.-P., 2015. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst. Rev. 4 (1), 1.
Morales-Luna, E., Pérez-Ramírez, I.F., Salgado, L.M., Castaño-Tostado, E., Gómez-Aldapa, C.A., Reynoso-Camacho, R., 2019. The main beneficial effect of roselle (Hibiscus sabdariffa) on obesity is not only related to its anthocyanin content. J. Sci. Food Agric. 99 (2), 596–605.
Mozaffari-Khosravi, H., Jalali-Khanabadi, B.-A., Afkhami-Ardekani, M., Fatehi, F., 2009. Effects of sour tea (Hibiscus sabdariffa) on lipid profile and lipoproteins in patients with type II diabetes. J. Altern. Complement. Med. 15 (8), 899–903.
Mozaffari-Khosravi, H., Ahadi, Z., Barzegar, K., 2013. The effect of green tea and sour tea on blood pressure of patients with type 2 diabetes: a randomized clinical trial. J. Diet. Suppl. 10 (2), 105–115.
Mozaffari-Khosravi, H., Ahadi, Z., Fallah Tafti, M., 2014. The effect of green tea versus sour tea on insulin resistance, lipids profiles and oxidative stress in patients with type 2 diabetes mellitus: a randomized clinical trial. Iran. J. Med. Sci. 39 (5), 424–432.
Najafpour Boushehri, S., Karimbeiki, R., Ghasempour, S., Ghalishourani, S.S., Pourmasoumi, M., Hadi, A., Mbabazi, M., Pour, Z.K., Assarroudi, M., Mahmoodi, M., 2020. The efficacy of sour tea (Hibiscus sabdariffa L.) on selected cardiovascular disease risk factors: a systematic review and meta-analysis of randomized clinical trials. Phytother. Res. 34 (2), 329–339.
Nwachukwu, D., Aneke, E., Nwachukwu, N., Obika, L., Nwagha, U., Eze, A., 2015. Effect of Hibiscus sabdariffa on blood pressure and electrolyte profile of mild to moderate hypertensive Nigerians: a comparative study with hydrochlorothiazide. Niger. J. Clin. Pract. 18 (6), 762–770.
Nwachukwu, D.C., Aneke, E.I., Nwachukwu, N.Z., Azubike, N., Obika, L.F., 2017. Does consumption of an aqueous extract of Hibscus sabdariffa affect renal function in subjects with mild to moderate hypertension? J. Physiol. Sci. 67 (1), 227–234.
Riaz, G., Chopra, R., 2018. A review on phytochemistry and therapeutic uses of Hibiscus sabdariffa L. Biomed. Pharmacother. 102, 575–586.
Sabzghabaee, A.M., Ataei, E., Kelishadi, R., Ghannadi, A., Soltani, R., Badri, S., Shirani, S., 2013. Effect of Hibiscus sabdariffa calices on dyslipidemia in obese adolescents: a triple-masked randomized controlled trial. Mater. Sociomed. 25 (2), 76.
Sahebkar, A., 2014. Are curcuminoids effective C-reactive protein-lowering agents in clinical practice? Evidence from a meta-analysis. Phytother. Res. 28 (5), 633–642.
Saneei, P., Salehi-Abargouei, A., Esmaillzadeh, A., Azadbakht, L., 2014. Influence of Dietary Approaches to stop Hypertension (DASH) diet on blood pressure: a systematic review and meta-analysis on randomized controlled trials. Nutr. Metab. Cardiovasc. Dis. 24 (12), 1253–1261.
Sari, F.Y.K., Damayanthi, E., Kustiyah, L., 2018. The effect of rosella beverage intervention on lipid profiles and antropometric in obese adult men. Indian J. Public Health Res. Dev. 9 (12), 644–649.
Seck, S.M., Doupa, D., Dia, D.G., Diop, E.A., Ardiet, D.-L., Nogueira, R.C., Graz, B., Diouf, B., 2018. Clinical efficacy of African traditional medicines in hypertension: a randomized controlled trial with Combretum micranthum and Hibiscus sabdariffa. J. Hum. Hypertens. 32 (1), 75–81.
Serban, C., Sahebkar, A., Ursoniu, S., Andrica, F., Banach, M., 2015. Effect of sour tea (Hibiscus sabdariffa L.) on arterial hypertension: a systematic review and meta-analysis of randomized controlled trials. J. Hypertens. 33 (6), 1119–1127.
Sharma, N.K., Tiwari, S.P., Tripathi, K., Rai, A.K., 2011. Sustainability and cyanobacteria (blue-green algae): facts and challenges. J. Appl. Phycol. 23 (6), 1059–1081.
Shi, C., Karim, S., Wang, C., Zhao, M., Murtaza, G., 2014. A review on antidiabetic activity of Citrullus colocynthis Schrad. Acta Pol. Pharm. 71 (3), 363–367.
Sindi, H.A., Marshall, L.J., Morgan, M.R., 2014. Comparative chemical and biochemical analysis of extracts of Hibiscus sabdariffa. Food Chem. 164, 23–29.
Soleimani, A.-R., Akbari, H., Soleimani, S., Mousavi, S.S.B., Tamadon, M.-R., 2015. Effect of sour tea (Lipicom) pill versus captopril on the treatment of hypertension. J. Renal Inj. Prev. 4 (3), 73.
Wahabi, H., Alansary, L., Al-Sabban, A., Glasziuo, P., 2010. The effectiveness of Hibiscus sabdariffa in the treatment of hypertension: a systematic review. Phytomedicine 17 (2), 83–86.