ORIGINAL ARTICLE

Effect of *Hibiscus sabdariffa* on blood pressure and electrolyte profile of mild to moderate hypertensive Nigerians: A comparative study with hydrochlorothiazide

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Abstract

Background: *Hibiscus sabdariffa* (HS) is widely consumed in Nigeria as a refreshing beverage and also as an antihypertensive agent. Since three decades ago when its antihypertensive activities were reported in several animal experiments, its consumption has greatly increased.

Aim: The aim of this study is to investigate the effect of HS consumption on blood pressure (BP) and electrolytes of mild to moderate hypertensive Nigerians and compare it with that of hydrochlorothiazide (HCTZ), a diuretic widely used as first-line antihypertensive drug.

Subjects and Methods: Eighty newly diagnosed, but untreated mild to moderate hypertensive subjects attending Medical Out-Patients clinic of Enugu State University Teaching Hospital, Enugu, were recruited for the study. They were randomly divided into three groups: A, B and C. Those in Groups A were given placebo; those in Group B took HCTZ while those in Group C were given HS. Treatment lasted for 4 weeks. BP, serum, and urine electrolytes were measured at baseline, weekly during treatment and 1 week after withdrawal of treatment.

Results: At the end of treatment, both HCTZ and HS significantly ($P < 0.001$) reduced systolic BP, diastolic BP, mean arterial pressure and serum Na^+ compared to placebo. When compared to each other, HCTZ significantly ($P < 0.001$) reduced serum Na^+ and Cl^- compared to HS and significantly ($P < 0.001$) increased K^+ and Cl^- output in urine. After withdrawal of treatment, the fall in BP and serum Na^+ in HS group were significant compared to HCTZ where they returned to baseline values. No side effect was reported during the study.

Conclusion: HS was a more effective antihypertensive agent than HCTZ in mild to moderate hypertensive Nigerians and did not cause electrolyte imbalance. HS showed longer duration of action compared to HCTZ and reduction in serum Na^+ may be another antihypertensive mechanism of action of HS.

Key words: Clinical trial, essential hypertension and electrolytes, *Hibiscus sabdariffa,* hydrochlorothiazide

Date of Acceptance: 27-Feb-2015

Introduction

Hypertension is the most common cardiovascular disease in Nigeria (Ajayi and Akintomide, 1995)[1] and is a major cause of morbidity and mortality worldwide (Catanzaro and Kurtz, 2002).[2] Approximately 20% of the world's adults are estimated to have hypertension. It is responsible for

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Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/1119-3077.163278

over 7.1 million deaths annually (Cooper *et al.*, 1997).[3] Hypertension is more severe and associated with more severe sequelae in blacks when compared with white patients (Whittle *et al.*, 1991; Rayner and Becker, 2006).[4,5] Nigerians are particularly susceptible to hypertension and its complications such as disabling and fatal strokes remain a major cause of morbidity and mortality (Nwosu *et al.*, 1992;[6] Iman and Olorunfemi, 2002; Akinkugbe, 2003).[7-9] Etiologically, hypertension is regarded as a multi-factorial disease condition in which a myriad of physiological mechanisms participate to elevate and maintain blood pressure (BP) (Kaplan, 1994; Beevers *et al.*, 2001).[10,11]

The role of electrolytes in the pathogenesis and maintenance of essential hypertension has received considerable attention, debate and study (Blaustein *et al.*, 1991; Kuller, 1997; Milan *et al.*, 2002).[12-14] These studies have implicated Na^+, K^+, Cl^- in both Caucasians and blacks with their values being higher in black hypertensives (Aderounmu and Salako, 1979; Worthington *et al.*, 1993)[15,16] and have also shown that intracellular and plasma (or serum) Na^+ and Cl^- concentration are significantly higher in hypertensives than normotensives. Human and animal models of hypertension have shown that Na^+ and Cl^- must act in concert to induce BP rise (Whitescarver *et al.*, 1986).[17] In various human population, K^+ is an important predictor of mean arterial pressure (MAP); hypertensives have been reported to have lower plasma (or serum) and total body K^+ as well as lower urinary K^+ excretion levels than normotensives (Kurtz *et al.*, 1987; Morton and Abraham, 1987; Krishna *et al.*, 1989).[18-20]

In spite of the many hypotheses that have been advanced in respect of the possible mechanisms for essential hypertension, it is not clear whether the kidney provides the causative factors or bears the brunt of the vascular disease (Coleman *et al.*, 1981).[21] Kidney regulates electrolyte balance in the body and diseases that adversely affect this balance may lead to hypertension (Blaustein *et al.*, 1991; Beevers *et al.*, 2001; Vikrant and Tiwari, 2001).[11,12,22] Electrolyte imbalance has been reported among Nigerians with essential hypertension (Iyalomhe *et al.*, 2008)[23] and this may be responsible for the susceptibility of Nigerians to hypertension and its complications (Ukoh and Obasohan, 1992).[24]

Several animal studies (Obiefuna *et al.*, 1994; Adegunloye *et al.*, 1996; Mojiminiyi *et al.*, 2000)[25-27] and human studies (Jonadet *et al.*, 1990; Herrera–Arellano *et al.*, 2004; McKay *et al.*, 2010)[28-30] have reported the antihypertensive activities of *Hibiscus sabdariffa* (HS). These studies have suggested several mechanisms of action such as vasodilatory effect, inhibition of Ca^{2+} influx, inhibition of ACE among others. None of these studies have examined the effect of HS on electrolyte balance and its clinical implication. Electrolyte imbalance has been implicated in the pathogenesis of hypertension and the speculation that HS has antihypertensive effect has greatly increased its consumption both at home and social gatherings in Nigeria by hypertensives and nonhypertensives alike (Onyenekwe *et al.*, 1999).[31] This study is designed to investigate the effect of HS on BP and electrolyte profile of mild to moderate hypertensive Nigerians and compare it with that of hydrochlorothiazide (HCTZ), a diuretic widely used in the treatment of hypertension, with a view to determining its therapeutic usefulness.

Subjects and Methods

Study setting

Enugu is located in the South-East Zone of Nigeria. It is the capital of Enugu State in Nigeria. It is a cosmopolitan city and used to be the regional capital of Eastern Nigeria. It has an estimated population of over one million people, and most of the inhabitants are predominantly civil servants, traders, and artisans. The study lasted for 5 weeks.

Human subjects

Sample size

This was determined using the formula below:

$$N = \frac{(r+1)(Z_{a/2} + Z_{1-b})^2 s2}{rd^2}$$

$Z_{\alpha} = 1.96$ for 5% level of significance

$Z_{1-\beta} = 0.84$ at 80% statistical power

$r = n_1/n_2 = 1$ for equal sample size

σ = common standard deviation

d = difference between mean values in previous study (Herrera-Arellano *et al.*, 2004).[29]

Eighty mild to moderate hypertensive subjects (aged 31–70 years) attending Medical Out-Patient clinic of Enugu State University Teaching Hospital, Parklane, Enugu, were recruited for the study, but only 75 completed it. Five subjects withdrew for nonmedical reasons. The study was carried out in line with the guidelines of the Helsinki Declaration for human studies (as amended) and approved by the Institutional Ethical Committee (EC: ESUTTH/EC/11002).

Inclusion criteria

- Newly diagnosed but untreated mild to moderate hypertension using WHO/ISH (2003) classification [Table 1]
- The subjects were adequately briefed about the study and oral consent obtained.

Exclusion criteria

- Patients with diabetes, nephropathy, cardiopathy, hepatic disease and cancer were excluded from this study
- Pregnant women, individuals with evidence of secondary hypertension, chronic smokers and alcoholics were excluded
- Those who did not complete the study were also excluded.

All participants were prohibited from participating in other clinical studies throughout the duration of the study.

Block randomization was used to divide subjects who met the inclusion criteria into three Groups (A, B and C) using Quickcalcs (GraphPad Software, Armonk, NY: IBM Corp). The group they belong to and the type of treatment given were concealed from the subjects as well as the physicians that took the measurements.

Group A

Subjects were given equivalent dose (150 mg/kg) in volume of placebo taken orally before breakfast daily for 4 weeks.

Group B

Subjects were given 25 mg HCTZ (Esidrex®, Novarvatis, Switzerland) orally once daily before breakfast for 4 weeks.

Group C

Subjects were given HS infusion (150 mg/kg) orally once daily before breakfast for 4 weeks.

All the subjects were given weekly appointments and a week worth of infusion/medication.

Blood pressure, serum and urine electrolytes were measured at baseline, weekly during treatment for 4 weeks and 1-week after withdrawal of treatment. Clinical evaluation and treatment adherence were evaluated weekly via oral submission by subjects and close relatives and by inspection of plastic containers given to them.

Plant collection

Dried calyces of HS were purchased from Ogbete Main Market, Enugu. They were authenticated by Mr. A. Ozioko of the herbarium section of Botany Department, University of Nigeria, Nsukka and a specimen voucher number UNH/314[b] was assigned to it for future reference.

Preparation of *Hibiscus sabdariffa* infusion

The method of Herrara-Arellano *et al.* (2004)[29] was used with two modifications.

20 g of dry calyces were weighed and ground in an electric mill to obtain particles <2 mm. It was used to make an infusion by adding 1 L of boiling clean bottle water (Aquafina, Pepsi Nig. Ltd.) and allowed to stand for 30 min.

The solution was filtered using Whatman's No. 1 filter paper. The filtrates were stored in clean plastic containers at room temperature.

The following two modifications were made:

- Infusions were prepared and given to patients
- Time allowed for extraction was extended from 10 to 30 min.

Placebo preparation

Blackcurrant (Glaxosmithkline®, UK) was used as placebo. It was diluted with clean bottle water (Aquafina, Pepsi Nig. Ltd.) to obtain approximately the same color as HS infusion. Blackcurrant was chosen among other drinks because it has a similar color as the locally prepared "Zobo" drink and preliminary investigation using 20 healthy subjects who were given equivalent dose of it for 2 weeks showed no effect on BP.

Hibiscus sabdariffa dosage calculation

$$Daily\ dose = 150\ mg/kg$$

$$1\,kg = 150\ mg$$

$$Weight\ of\ Patient = W\ kg$$

$$W\ kg = 150 \times W\ mg = 0.15 \times W\ g$$

From extraction,

$$20g = 1L$$

Thus,

$$0.15 \times W\ g = \left(0.15 \times W / 20 \times 1\right)L = \left(0.0075 \times W\right)L$$

150 mg/kg was chosen because it produced approximately the same color as the locally brewed HS ("Zobo") drink and is far below the LD_{50} of HS (>5000 mg/kg).

Hibiscus sabdariffa extract standardization

The HS extract was standardized using the colorimeter method of Fuleki and Francis (1968).[32] This method was based on the ability of anthocyanin (the active component of HS) to produce a color at pH 1.0 that disappears at pH 4.5. This special characteristic is produced by a pH dependent structural transformation of the chromophore. The colored oxonium ion predominates at pH 1.0, while the noncolor hemiketal is presented at pH 4.5. This method ensures accurate and fast determination of total anthocyanins, in spite of the presence of polymeric pigments and other compounds. This procedure was done with 1 ml of the HS solution (20 g of dried HS calyx extracted with 1 L of water). Two samples were gauged to 5 ml solution at pH 1.0 and 4.5, respectively. These solutions were filtered through a 0.45 mm membrane (Gelman acrodisk) and analyzed with a

spectrophotometer at 510 and 700 nm, respectively. The total anthocyanins concentration is obtained using the formula:

Concentration (mg/ml) = A × MW × FD × 1000/(Ɛ × 1).

(A = Absorbance of diluted sample; MW = Molecular weight of anthocyanin; FD = Dilution factor; Ɛ = Molar absorptivity)

From this method, the total anthocyanin contained in 20 g of HS dissolved in 1 L was 10.04 mg.

Measurements

Blood pressure measurement

Sitting BP was measured using Accoson® mercury sphygmomanometer. Systolic BP (SBP) was taken as first appearance of Korotkov sounds and the diastolic BP (DBP) the point of disappearance of the sounds (Phase V). Two consecutive readings were taken from each subject at 5 min interval and the average of these was taken as the mean blood pressure reading. Measurement was taken between 8.00 am and 10.00 am. Any constrictive clothing on the arm was removed before measurement was taken.

Measurement of serum electrolytes

Venous blood (5 ml) was withdrawn from medial cubital vein into a vacutainer and allowed to stand undisturbed for 25 min. The clot formed was removed by centrifuging at 2000 rpm for 10 min. The resulting supernatant (serum) was transferred to a clean polypropylene tube using Pasteur pipette. Serum electrolytes (Na^+, K^+ and Cl^-) were determined by ion selective electrode using Audicom automated electrolyte analyzer (AC9000 series) China.

Measurement of urine electrolytes

Urine samples were collected and Na^+, K^+ and Cl^- were measured with an ion-selective electrode analyzer; Audicom automated Electrolyte analyzer (AC9000 Series), China.

Statistical analysis

Results were presented as mean ± standard error of mean data was classified by groups and weeks of treatment and analyzed using SPSS Version 20 by IBM Corp. One-way analysis of variance was used to compare differences between groups, and further analysis was carried out using Bonferroni test. $P \leq 0.05$ was considered significant.

Results

Blood pressure changes

At the end of treatment (week 4), SBP decreased by 12.9 ± 4.31 mmHg and 17.08 ± 5.12 mmHg in HCTZ and HS group respectively; similarly, DBP decreased by 9.50 ± 2.06 mmHg and 11.12 ± 3.12 mmHg respectively. The percentage decline in SBP in HCTZ group was 8.55 ± 1.64% while that of HS was 11.38 ± 2.53%. DBP decreased by 9.59 ± 1.60% and 12.13 ± 2.48 in HCTZ and HS groups respectively [Table 2]. These changes were significant ($P < 0.001$) in both treatment groups when compared with of placebo. MAP followed a similar pattern with HS group recording a higher percentage decrease of

Table 1: WHO/ISH (2003) classification of hypertension

Category	SBP (mmHg)	DBP (mmHg)
Optimal	<120	<80
Normal	<130	<85
High normal	130–139	85–89
Mild (grade 1) hypertension	140–159	90–99
Moderate (grade 2) hypertension	160–179	100–109
Severe (grade 3) hypertension	≥180	≥110

SBP=Systolic blood pressure; DBP=Diastolic blood pressure

Table 2: Clinical characteristics of subjects

Parameter	Placebo *n*=25	HCTZ *n*=25	HS *n*=25
Age (years)	48.90±5.06	51.55±10.88	49.92±3.40
Body mass index (BMI) (kg/m²)	27.27±1.50	27.72±0.57	28.10±2.48
Basal SBP (mmHg)	152.50±4.18	154.20±2.75	150.88±7.33
SBP (mmHg) at week 4	150.40±2.37	141.30±2.39*	133.80±1.77***
SBP (mmHg) at week 5	152.75±2.18	149.72±2.29	137.76±1.92***
Basal DBP (mmHg)	99.70±3.16	99.75±4.81	100.20±5.96
DBP (mmHg) at week 4	99.30±1.30	90.25±1.54***	88.08±1.12***
DBP (mmHg) at week 5	99.50±1.10	96.80±1.45	91.12±1.23***
Basal MAP (mmHg)	117.65±3.14	118.04±1.70	116.96±4.17
MAP (mmHg) at week 4	116.70±1.50	109.32±1.78**	103.28±1.3***
MAP (mmHg) at week 5	117.26±1.32	114.10±1.67	106.66±1.42***

Results presented as mean±SEM. *=*P*<0.05 with respect to placebo; **=*P*<0.01 with respect to placebo; ***=*P*<0.001 with respect to placebo

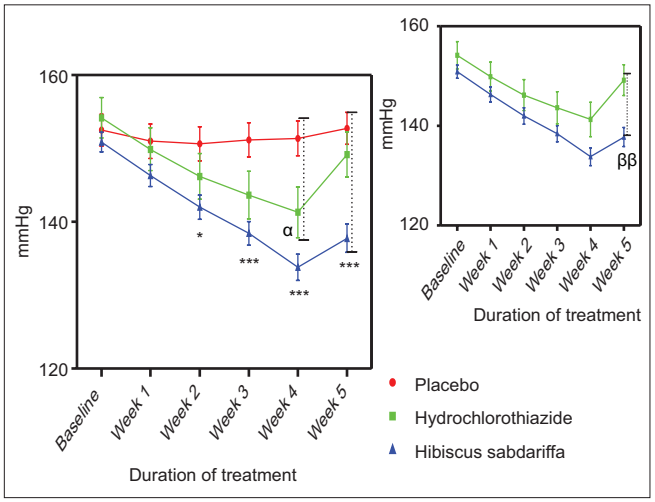

Figure 1: Systolic blood pressure measurements following the administration ofplacebo (control), hydrochlorothiazide andHibiscus sabdariffa on mild to moderate hypertensive subjects. Each point on the graph represents the average of atleast 25 independent measurements. Error bars are SEM; *P<0.05, **P<0.01, ***P<0.001, $^{\alpha}P$<0.05, $^{\beta\beta}P$<0.01 (two way ANOVA with Bonferroni posttest, using Graphpad prism 5.0). Inset is a comparison of thetreatment groups

11.74 ± 2.12% than HCTZ where 9.14 ± 1.62% decrease was obtained [Table 2]. 1-week after withdrawal of treatment, the fall in SBP, DBP and MAP in HS group were still significant ($P < 0.001$) compared to those of placebo while BP returned to baseline levels in HCTZ group.

When compared to HCTZ, there was significant difference in the reduction in SBP ($P < 0.01$), DBP ($P < 0.01$) and MAP ($P < 0.01$) in HS group at week 5 [Figures 1-3].

Serum and urine electrolytes

Both HCTZ and HS reduced serum Na^+ and their effect were significant ($P < 0.001$) compared to that of placebo; HCTZ also reduced serum Na^+ significantly ($P < 0.01$) compared to HS at weeks 3–5 [Figure 4]. Both HCTZ and HS produced significant decrease ($P < 0.01$) in serum K^+ and Cl^- at the end of treatment when compared to placebo [Figures 5 and 6]. HCTZ produced the highest percentage change of −12.83% ± 0.48%, −14.71% ± 1.825% and −15.80% ± 0.65% in

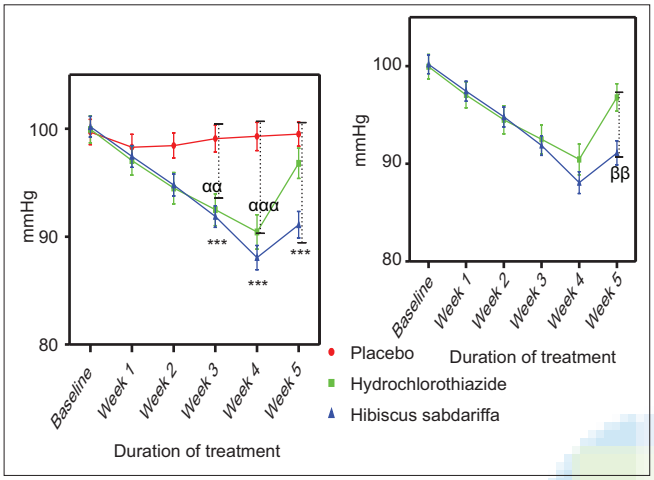

Figure 2: Diastolic blood pressure measurements following the administrationofplacebo (control), hydrochlorothiazide andHibiscus sabdariffaon mild to moderatehypertensive subjects. Each point on the graphrepresents the averageof at least 25 independent measurements.Error bars are SEM; $^{***}P<0.001$,$^{\alpha\alpha}P<0.01$, $^{\alpha\alpha\alpha}P<0.001$, $^{\beta\beta}P<0.01$(two way ANOVA with Bonferroni posttest, using Graphpad prism 5.0). Inset is a comparison of the treatment groups

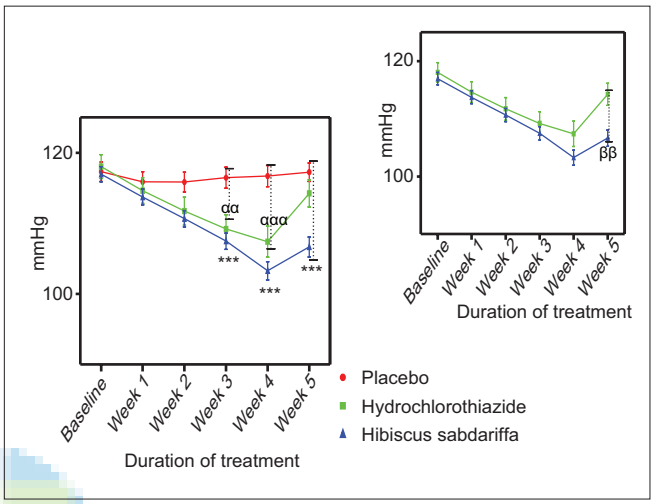

Figure 3: Mean arterial blood pressure measurements following the administration of placebo (control), hydrochlorothiazide and Hibiscus sabdariffa on mild to moderate hypertensive subjects. Each point on the graph represents the average of at least 25 independent measurements. Error bars are SEM; $^{***}P<0.001$, $^{\alpha\alpha}P<0.01$, $^{\alpha\alpha\alpha}P<0.001$, $^{\beta\beta}P<0.01$ (two way ANOVA with Bonferroni posttest, using Graphpad prism 5.0)

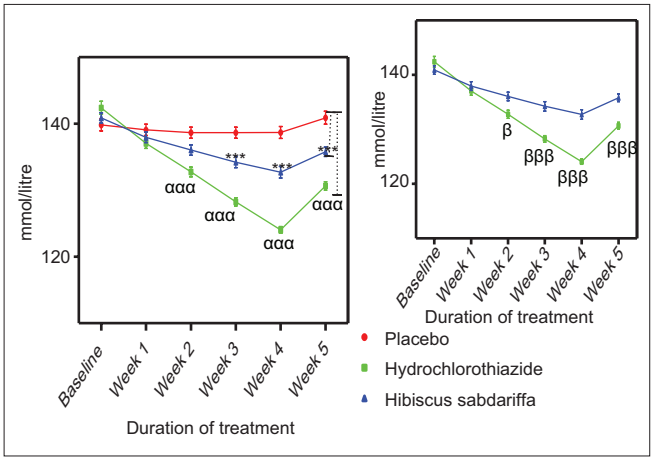

Figure 4: Serum Na^+ concentration measurements following the administration of placebo (control), hydrochlorothiazide and Hibiscus sabdariffa on mild to moderate hypertensive subjects. Each point onthe graph represents the average of at least 25 independent measurements. Error bars are SEM, $^{***}P<0.001$, $^{\alpha\alpha\alpha}P<0.001$, $^{\beta}P<0.05$, $^{\beta\beta\beta}P<0.001$ (two way ANOVA with Bonferroni posttest, using Graphpad prism 5.0). Inset is a comparison of the treatment groups

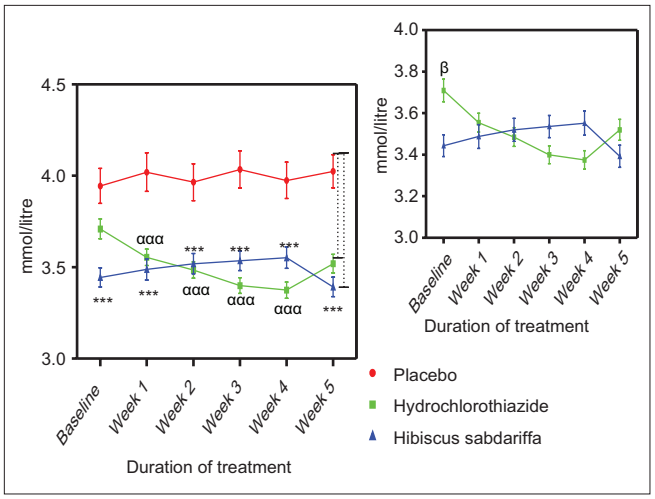

Figure 5: Serum K^+ concentration measurements following the administration ofplacebo (control), hydrochlorothiazide andHibiscus sabdariffa on mild to moderate hypertensive subjects. Each point on the graph represents the average of at least 25 independent measurements. Error bars are SEM; $^{***}P<0.001$, $^{\alpha\alpha\alpha}P<0.001$, $^{\beta}P<0.05$ (two way ANOVA with Bonferroni posttest, using Graphpad prism 5.0). Inset is acomparison of the treatment groups

serum Na^+, K^+ and Cl^- respectively. At the end of treatment, HS produced a change of −10.36% ±0.32% in serum Na^+ which was significant ($P < 0.001$) compared to placebo but not to HCTZ. 1-week after withdrawal of treatment, the change in serum Na^+ produced by HS (−6.71% ± 0.31%) was still significant ($P < 0.001$) compared to placebo but serum electrolytes returned to their baseline levels in HCTZ group.

When compared to HS, HCTZ significantly ($P < 0.001$) reduced serum K^+ at the end of treatment but produced opposite effect on serum Cl^- [Figure 6].

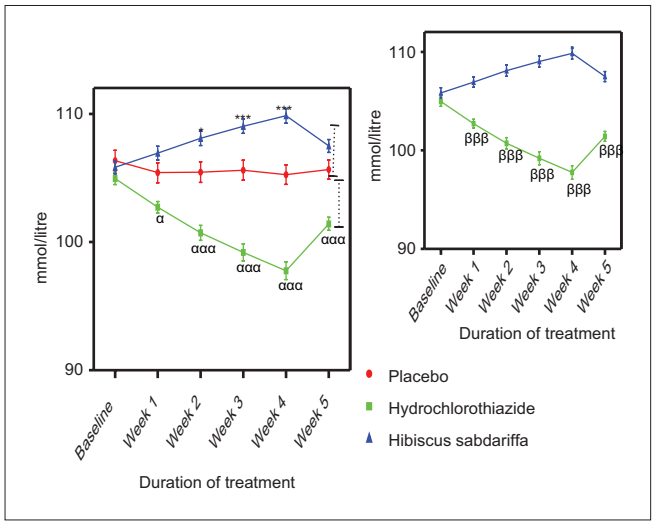

Figure 6: Serum Cl^- concentration measurements following the administration ofplacebo (control), hydrochlorothiazide andHibiscus sabdariffa onmild to moderate hypertensive subjects. Each point on the graph represents the average of at least 25 independent measurements. Error bars are SEM; $^{*}P<0.05$, $^{***}P<0.001$, $^{\alpha}P<0.05$, $^{\alpha\alpha\alpha}P<0.001$, $^{\beta\beta\beta}P<0.001$ (two way ANOVAwith Bonferroni posttest, using Graphpad prism 5.0). Inset is a comparisonof the treatment groups

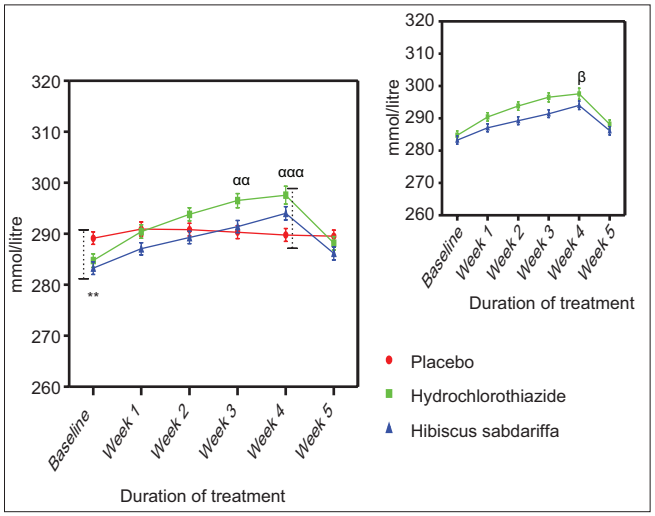

Figure 7: Urine Na^+ concentration measurements following the administration of placebo (control), hydrochlorothiazide andHibiscus sabdariffa on mild to moderate hypertensive subjects. Each point on the graph represents the average ofat least 25 independent measurements. Errorbars are SEM; $^{**}P<0.01$, $^{\alpha\alpha}P<0.01$, $^{\alpha\alpha\alpha}P<0.001$, $^{\beta}P<0.05$ (two way ANOVA with Bonferroni posttest, using Graphpad prism 5.0). Inset is a comparison of the treatment groups

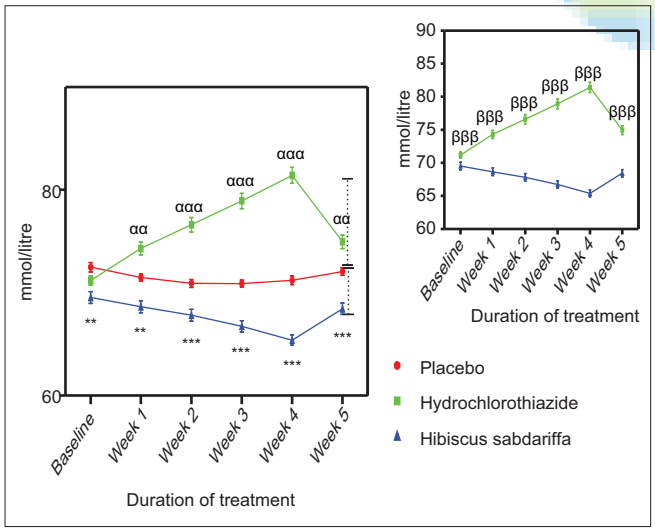

Figure 8: Urine K^+ concentration measurements following the administration of placebo (control), hydrochlorothiazide andHibiscus sabdariffa on mild to moderate hypertensive subjects. Each point onthe graph represents the average of at least 25 independent measurements. Error bars are SEM; $^{**}P<0.01$, $^{***}P<0.001$, $^{\alpha\alpha}P<0.01$, $^{\alpha\alpha\alpha}P<0.001$, $^{\beta\beta\beta}P<0.001$ (two way ANOVA with Bonferroni posttest, using Graphpad prism 5.0). Inset is a comparison of the treatment groups

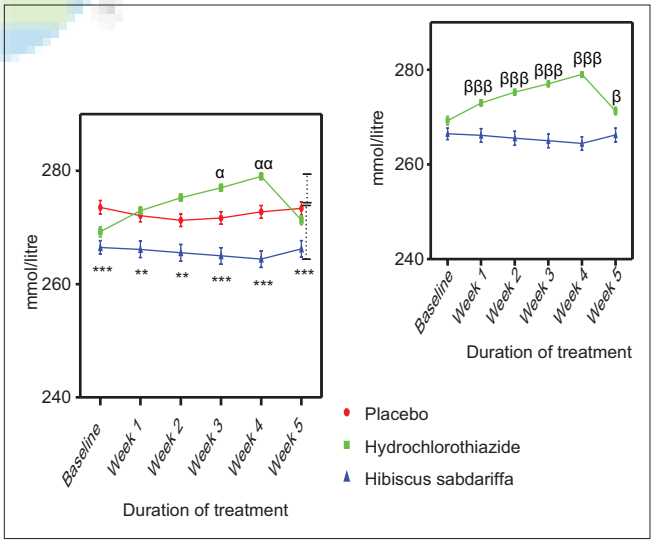

Figure 9: Urine Cl^- concentration measurements following the administration ofplacebo (control), hydrochlorothiazide andHibiscus sabdariffa on mild to moderate hypertensive subjects. Each point on the graph represents the average of at least 25 independentmeasurements. Error bars are SEM; $^{**}P<0.01$, $^{***}P<0.001$, $^{\alpha}P<0.05$, $^{\alpha\alpha}P<0.01$, $^{\beta}P<0.05$, $^{\beta\beta\beta}P<0.001$ (two way ANOVA with Bonferroni posttest, using Graphpad prism 5.0). Inset is a comparison of the treatment groups

At the end of treatment, urinary output of Na^+ increased significantly only in HCTZ at weeks 3 ($P < 0.01$) and 4 ($P < 0.001$) group whereas HS did not produce any significant change in urine Na^+ compared to placebo [Figure 7]. Both HCTZ and HS did not produce any significant change in urine Cl^-. When compared to each other, changes in urine Na^+ produced by HCTZ and HS treatments were not significant but that on urine K^+ was opposite and significant ($P < 0.001$); HCTZ increased K^+ but HS reduced it [Figure 8]. HCTZ increased urine Cl^- while HS reduced it; both effects were significant at week 4 ($P < 0.01$) compared to placebo [Figure 7]; when the effects of both active treatments were compared to each other, they were significant ($P < 0.001$) throughout the duration of study [Figures 1-9].

Discussion

The consumption of botanicals as complimentary/alternative medicine has been encouraged because they are relatively cheap and coupled with the fact that they could significantly contribute to the improvement of human health in terms of cure and prevention of various human disorders in addition to the less frequent side effects reported when compared to modern medicine (Hou *et al*., 2005).[33] In the present study, HS demonstrated a significant BP lowering effect that was higher than that of HCTZ in mild to moderate hypertensive subjects. SBP, DBP and MAP were significantly ($P < 0.001$) reduced compared to placebo in both groups. About 76% therapeutic effectiveness was achieved in the HS group compared to 60% in HCTZ group. Therapeutic effectiveness is a direct measure of therapeutic success that is, those whose BP was reduced to <140 mmHg (SBP) and <90 mmHg (DBP). Thus, HS exhibited greater antihypertensive effect than HCTZ. This result agrees with the previous report by Herrera–Arellano *et al*. (2004)[29] which showed HS producing a therapeutic effectiveness of 78.95% in Mexicans. The higher therapeutic effectiveness obtained in the HS treated group may be due to multiple mechanisms of antihypertensive action by HS in contrast to HCTZ which is a thiazide diuretic whose mechanism of action is inhibition of Na^+-Cl^- symport at the distal convoluted tubule, thereby, depleting the body Na^+.

Results from several studies suggest that aqueous extract of HS achieved its antihypertensive activity by at least four specific mechanisms: Diuretic (Onyenekwe *et al*., 1999; Mojiminiyi *et al*., 2000);[27,31] vasodilatation (Obiefuna *et al*., 1994; Adegunloye *et al*., 1996),[25,26] Inhibition of Ca^{2+} influx (Ajay *et al*., 2007)[34] and ACE inhibition (Jonadet *et al*., 1990; Herrarre–Arellano *et al*., 2004).[28,29] Another possible antihypertensive mechanism of action of HS is by blockage of AT_1 receptors which has been reported in other plant species that has anthocyanins (Caballera-George *et al*., 2002).[35] ACE inhibition and AT_1 receptor blocking were due to the action of anthocyanins present in HS which was also demonstrated in the present study. The vasorelaxant effect of HS are mediated through cholinergic and/or histaminergic mechanisms produced by membrane stabilization and stimulation of vascular Na^+-K^+ ATPase activity and inhibition of Ca^{2+} release from intracellular stores (Adegunloye *et al*., 1996)[26] and may also be mediated by endothelium-dependent and independent mechanisms (Obiefuna *et al*., 1994).[25] The endothelium-dependent vasodilator effect was due to activation of endothelium-derived nitric oxide/cGMP-relaxant pathway (Ajay *et al*., 2007)[34] and that the endothelium-independent effect was possibly due to inhibition of Ca^{2+} influx by the action of quercetin and eugenol present in the HS (Salah *et al*., 2002).[36]

In the present study, HS caused 11.38% and 12.13% decrease in SBP and DBP respectively compared to HCTZ which decreased SBP and DBP by 8.55% and 9.59% respectively. This suggests that apart from diuretic effect via ACE inhibition and AT_1 receptor blocking, that HS possesses other mechanisms of antihypertensive action as earlier stated. These results agree with those from previous study by Haji-Faraji and Haji-Tarkhani (1999)[37] where HS was reported to produce a decrease of 11% in both SBD and DBP.

The role of serum Na^+ in the pathogenesis and maintenance of essential hypertension has been reported in previous studies (Morton and Abraham, 1987; Ukoh and Obasohan, 1992).[19,24] Serum Na^+ was positively associated with BP (Shailendra *et al*., 2011)[38] thus; agents that lower serum Na^+ may have antihypertensive action. Modest dietary salt restriction employed as a definitive or adjunctive treatment of hypertension has been shown to reduce BP or permitted drug treatment to be substantially reduced or discontinued (Alderman *et al*., 1993; Melander *et al*., 2007).[39,40] Serum Na^+ was significantly reduced in both HCTZ and HS groups with the reduction in HS group being sustained even after withdrawal of treatment. The prolonged reduction in serum Na^+ observed in HS group correlated with fall in BP which underscores the role of Na^+ in the pathogenesis of hypertension and suggests that HS has a longer duration of action compared to HCTZ. Thus, similar to HCTZ, reduction in serum Na^+ may be another significant antihypertensive mechanism of action of HS especially in a population like ours where people habitually consume salt. Unlike HS, a significant reduction in serum K^+ and Cl^- was observed in HCTZ group, suggesting that its treatment may cause electrolyte imbalance.

Both HCTZ and HS caused natriuresis, but HCTZ significantly increased K^+ loss in the urine whereas HS reduced K^+ excretion, which suggests that it may be a K^+ sparing diuretic. The result of the present study agrees with that of

Herrera–Arellano *et al.* (2004)[29] who observed a natriuretic effect in hypertensive Mexicans treated with aqueous calyx extract of HS but contradicted that of Mojiminiyi *et al.* (2000)[27] who reported Na^+ retention in HS treated rats. This difference could be because these workers used animals, consumption of HS was not regulated (*ad libitum*) and the concentration of HS solution was higher in their study. High doses of HS have been shown to affect the structure (Jaiyesimi *et al*., 2002)[41] and functions (Orisakwe *et al*., 2004; Aguwa *et al*., 2004)[42,43] of the kidney. The relative electrolyte stability in the HS group suggests that it has a comparative advantage over HCTZ as an antihypertensive agent.

Conclusion

The results of this study showed that HS was a more effective antihypertensive agent than HCTZ in mild to moderate hypertensive Nigerians. Higher therapeutic effectiveness and longer duration of action were observed in the HS group. In addition to other reported antihypertensive mechanisms of action of HS, reduction in serum Na^+ may be an additional mechanism of action. Unlike HCTZ, HS did not cause electrolyte imbalance and thus demonstrated a comparative advantage over HCTZ. This study also validated the ethno medicinal use of HS as an antihypertensive agent in Nigeria. In spite of the observed antihypertensive effectiveness of HS, the involvement of appropriate government regulatory agencies such as National Agency for Food, Drug Administration and control in regulation of HS consumption is strongly recommended in order to avoid its abuse.

Limitations of the study

- Inability to quantify anthocyanins using high-performance liquid chromatography that is a more sensitive and accurate method due to unavailability of the equipment in our institution
- Reliance on subjects and close relatives for treatment adherence.

References

1. Adegunloye BJ, Omoniyi JO, Owolabi OA, Ajagbonna OP, Sofola OA, Coker HA. Mechanisms of the blood pressure lowering effect of the calyx extract of *Hibiscus sabdariffa* in rats. Afr J Med Med Sci 1996;25:235-8.
2. Aderounmu AF, Salako LA. Plasma and erythrocyte cations and permeability of the erythrocyte membrane to cations in essential hypertension. Afr J Med Med Sci 1979;8:45-9.
3. Aguwa CN, Ndu OO, Nwanma CC, Udeogaranya PO, Akwara NO. Verification of folkloric diuretic claim of *Hibiscus Sabdariffa* L. petal extract. Niger J Pharm Res 2004;3:1-8.
4. Ajay M, Chai HJ, Mustafa AM, Gilani AH, Mustafa MR. Mechanisms of the anti-hypertensive effect of *Hibiscus sabdariffa* L. calyces. J Ethnopharmacol 2007;109:388-93.
5. Ajayi AA, Akintomide AO. The efficacy and tolerability of amlodipine and hydrochlorothiazide in Nigerians with essential hypertension. J Natl Med Assoc 1995;87:485-8.
6. Nwosu CM, Nwabueze AC, Ikeh VO. Stroke at the prime of life: A study of Nigerian Africans between the ages of 16 and 45 years. East Afr Med J 1992;69:384-90.
7. Akinkugbe OO. Current epidemiology of hypertension in Nigeria. Arch Ib Med 2003;1:3-5.
8. Alderman MH, Cushman WC, Hill MN, Krakoff LR, Pecker MS. International roundtable discussion of national guidelines for the detection, evaluation, and treatment of hypertension. Am J Hypertens 1993;6:974-81.
9. Beevers G, Lip GY, Brien EO. The pathophysiology of hypertension. Br Med J 2001;322:912-6.
10. Blaustein MP, Lang S, James-Krakle M. Cellular basis of sodium-induced hypertension. In: Laragh JH, Buhler PR, Seldin D, editors. Frontiers of Hypertension Research. New York: Springer Verlag; 1991. p. 87-102.
11. Catanzaro DF, Kurtz TW. Target organ damage in hypertension: Mechanisms, prevention, and management. Am J Hypertens 2002;15:1117-8.
12. Coleman TG, Hall JE, Norman RA. Regulation of arterial blood pressure. In: Brenner BM, Stein JH, editors. Hypertension. London: Churchill Livingstone Inc.;1981. p. 1-20.
13. Cooper R, Rotimi C, Ataman S, McGee D, Osotimehin B, Kadiri S, *et al.* The prevalence of hypertension in seven populations of West African origin. Am J Public Health 1997;87:160-8.
14. Caballero-George C, Vanderheyden PML, De Bruyne T, Shahat AA, Van den Heuvel H, Solis PN *et al.* In vitro inhibition of angiotensin II binding on human AT1 recptors by proanthocyanidins from guazuma ulmifolia bark. Planta Med. 2002;68:1066-1071.
15. Fuleki T, Francis FJ. Quantitative method s of anthocyanins. 2. Determination of total anthocyanin and degradation index for cranberry juice. J Food Sci 1968;33:78-83.
16. Haji Faraji M, Haji Tarkhani A. The effect of sour tea (*Hibiscus sabdariffa*) on essential hypertension. J Ethnopharmacol 1999;65:231-6.
17. Herrera-Arellano A, Flores-Romero S, Chávez-Soto MA, Tortoriello J. Effectiveness and tolerability of a standardized extract from *Hibiscus sabdariffa* in patients with mild to moderate hypertension: A controlled and randomized clinical trial. Phytomedicine 2004;11:375-82.
18. Hou DX, Tong X, Terahara N, Luo D, Fujii M. Delphinidin 3-sambubioside, a Hibiscus anthocyanin, induces apoptosis in human leukemia cells through reactive oxygen species-mediated mitochondrial pathway. Arch Biochem Biophys 2005;440:101-9.
19. Imam I, Olorunfemi G. The profile of stroke in Nigeria's federal capital territory. Trop Doct 2002;32:209-12.
20. Iyalomhe GB, Omogbai EK, Ozolua RI, Dada FL, Iyalomhe OO. Electrolyte profile in Nigeria patients with essential hypertension. Afr J Biotechnol 2008;7:1404-8.
21. Jaiyesimi AE, Adeyemi AA, Ogunleye DS, Ogundahunsi O, Sanyaolu O. A preliminary toxicological study of the effect of *Hibiscus sabdariffa* (Linn) calyx extract in normal rats. Niger J Pharm Res 2002;1:41-3.
22. Jonadet M, Bastide J, Bastide P, Boyer B, Carnat AP, Lamaison JL. *In vitro* enzyme inhibitory and *in vivo* cardioprotective activities of hibiscus (*Hibiscus sabdariffa* L.). J Pharm Belg 1990;45:120-4.
23. Kaplan NM. Primary hypertension. In: Kaplan NM, editor. Clinical Hypertension. Baltimore, Maryland: Williams and Wikins; 1994. p. 54-282.
24. Krishna GG, Miller E, Kapoor S. Increased blood pressure during potassium depletion in normotensive men. N Engl J Med 1989;320:1177-82.
25. Kuller LH. Salt and blood pressure: Population and individual perspectives. Am J Hypertens 1997;10:295-365.
26. Kurtz TW, Morris RC Jr, Al-Bander HA. Salt-sensitive essential hypertension in men: Is the sodium ion alone important? N Engl J Med 1987;317:1043-8.
27. McKay DL, Chen CY, Saltzman E, Blumberg JB. *Hibiscus sabdariffa* L. tea (tisane) lowers blood pressure in prehypertensive and mildly hypertensive adults. J Nutr 2010;140:298-303.
28. Melander O, von Wowern F, Frandsen E, Burri P, Willsteen G, Aurell M, *et al.* Moderate salt restriction effectively lowers blood pressure and degree of salt sensitivity is related to baseline concentration of renin and N-terminal atrial natriuretic peptide in plasma. J Hypertens 2007;25:619-27.
29. Milan A, Mulatero P, Rabbia F, Veglio F. Salt intake and hypertension therapy. J Nephrol 2002;15:1-6.
30. Mojiminiyi FB, Adegunloye BJ, Egbeniyi YA, Okolo RU. An investigation of the diuretic effect of an aqueous extract of hibiscus sabdariffa. J Med Med Sci 2000;2:77-80.
31. Morton HM, Abraham DW. Cations and hypertension: Sodium, potassium, calcium and magnesium. Med Clin North Am 1987;71:5-8.
32. Obiefuna PC, Owlabi OA, Adegunloye BJ. The petal extract of *Hibiscus sabdariffa*

produces relaxation of isolared rat aorta. Int J Pharmacogn 1994;32:69-74.
33. Onyenekwe PC, Ajani EO, Ameh DA, Gamaniel KS. Antihypertensive effect of roselle (Hibiscus sabdariffa) calyx infusion in spontaneously hypertensive rats and a comparison of its toxicity with that in Wistar rats. Cell Biochem Funct 1999;17:199-206.
34. Orisakwe OE, Husaini DC, Afonne OJ. Testicular effects of sub-chronic administration of *Hibiscus sabdariffa* calyx aqueous extract in rats. Reprod Toxicol 2004;18:295-8.
35. Rayner B, Becker P. The prevalence of microalbuminuria and ECG left ventricular hypertrophy in hypertensive patients in private practices in South Africa. Cardiovasc J S Afr 2006;17:245-9.
36. Salah AM, Gathumbi J, Vierling W. Inhibition of intestinal motility by methanol extracts of *Hibiscus sabdariffa* L. (*Malvaceae*) in rats. Phytother Res 2002;16:283-5.
37. Shailendra KT, Bhanu PM, Ruchi T, Manish M, Kamlakar T. Serum and urinary electrolytes level in the subjects of two different environmental conditions. J Stress Physiol Biochem 2011;7:20-6.
38. Ukoh VA, Obasohan AO. Salt intake, red cell and plasma electrolytes in hypertensive and normotensive Nigerians. Niger J Physiol Sci 1992;8:42-8.
39. Vikrant S, Tiwari SC. Essential hypertension: Pathogenesis and pathophysiology. J India Acad Clin Med 2001;2:41-8.
40. Whitescarver SA, Ott CE, Holtclaw BJ, Dons JH, Sowers JR, Kotchan TA. Effect of dietary chloride on salt-sensitive and renindependent hypertension. Hypertension 1986;8:56-61.
41. Whittle JC, Whelton PK, Seidler AJ, Klag MJ. Does racial variation in risk factors explain black-white differences in the incidence of hypertensive end-stage renal disease? Arch Intern Med 1991;151:1359-64.
42. WHO/ISH. Statement on Hypertension. Management of Hypertension. J Hypertens 2003;17:151-83.
43. Aguwa CN, Ndu OO, Nwanma CC, Udeogaranya PO, Akwara NO. Verification of folkloric diuretic claim of *Hibiscus Sabdariffa* L. petal extract. Niger J Pharm Res 2004;3:1-8.

How to cite this article: Nwachukwu DC, Aneke E, Nwachukwu NZ, Obika L, Nwagha UI, Eze AA. Effect of *Hibiscus sabdariffaon* blood pressure and electrolyte profile of mild to moderate hypertensive Nigerians: A comparative study with hydrochlorothiazide. Niger J Clin Pract 2015;18:762-70.
Source of Support: Nil, **Conflict of Interest:** None declared.