


SHORT COMMUNICATION

Effect of cocoa consumption on postprandial blood pressure in older adults with untreated hypertension: A randomized crossover clinical trial

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Abstract

Cocoa powder is an important dietary source of flavanols that modulate elevated blood pressure (BP). This study aimed to investigate the acute effects of cocoa beverage co-consumption with a high-fat-high-salt meal (HFHSM) on postprandial systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate in older adults living with uncontrolled hypertension. The study was a randomized crossover trial and involved older adults (aged 52.50 ± 9.36 years) ($n = 28$) living with hypertension. Participants, following an overnight fast, consumed either an HFHSM and cocoa beverage comprising 15 g cocoa powder in 250 mL water (HFHSM + CB; intervention) or HFHSM and 250 mL water (HFHSM + W; control). Resting SBP, DBP, and the heart rate of participants were measured at baseline (-5 min and 0 min) and 15, 30, 45, 60, 90, and 120 min following the consumption of either HFHSM + CB or HFHSM + W using an automated BP monitor. Repeated measures linear mixed model was used to compare the effect of cocoa beverage and water on postprandial outcomes over a 2-h period. A significant reduction (-3.8 ± 0.6 mmHg, $p < .05$) in resting SBP was observed postprandially following the intake of the HFHSM + CB over the 120-min period compared to the HFHSM + W. The effect was more prominent during the 90- and 120-min time points of the trial duration. No significant change in the DBP and heart rate following the consumption of HFHSM + CB compared to the HFHSM + W was observed. Cocoa beverage co-consumption with HFHSM improved postprandial SBP in older adults living with hypertension.

KEYWORDS

cocoa beverage, diastolic blood pressure, heart rate, hypertension, systolic blood pressure

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1 | INTRODUCTION

Hypertension, characterized by systolic blood pressure (SBP) ≥ 140 mmHg and/or diastolic blood pressure (DBP) ≥ 90 mmHg (WHO, 2021), has increased in prevalence globally. A recent meta-analysis of data pooled from 1201 studies involving 104 million individuals aged 30–79 years showed a doubling number of individuals living with hypertension, from 648 million in 1990 to 1.278 billion in 2019 (NCD Risk Factor Collaboration [NCD-RisC], 2021). Notably, countries in the Southeast Asia, Oceania, and Sub-Saharan Africa region including Ghana recorded the majority of hypertension cases (Mills et al., 2016; Zhou et al., 2021). In Ghana, the prevalence of hypertension in adults was 27%, of which a concerning 65% of cases were undiagnosed (Bosu & Bosu, 2021). Furthermore, of those treated with antihypertensive medications, less than 25% achieved an optimal blood pressure (BP) control of $<140/90$ mmHg (Bosu & Bosu, 2021). Since hypertension was ranked as the leading cause of mortality in Ghana (Owusu et al., 2021), it underscores the urgent need for interventions.

Efforts to mitigate hypertension through salt reduction have faced challenges. Many Ghanaian staple foods, including rice, are traditionally cooked with salt (Annor et al., 2016), contributing to the persistently high salt intake in the population. The WHO-SAGE Ghana Wave 3 study revealed that 77% of the population exceeded the WHO's recommended salt intake of ≤ 5 g/day, with a median salt intake of 8.3 g/day (Menyanu et al., 2020). Excessive salt intake has been associated with adverse vascular function. For example, an acute study showed that a high sodium meal, equivalent to 3.5 g salt, could impair vascular function in healthy individuals over a 2-h postprandial period (Dickinson et al., 2011). The high salt meal is hypothesized to increase BP by adversely increasing oxidative stress (Dickinson et al., 2011), alterations in the renin-angiotensin system (RAS) (Drenjancevic-Peric et al., 2011), and inactivation of endothelial nitric oxide synthase (eNOS) activity. Consequently, the decreased eNOS activity lowers nitric oxide (NO) production, resulting in endothelial dysfunction (Dickinson et al., 2011; Grillo et al., 2019; Jaques et al., 2021). Longitudinal studies have also provided evidence that salt reduction is linearly associated with BP reduction (Filippini et al., 2021). However, changing deeply ingrained cultural traditions, such as the culinary use of salt in cooking staple foods, poses a considerable challenge and is likely to require substantial time and effort.

The imbalance between sodium and potassium intake, including a scarcity of potassium in Ghanaian's diet may also partly contribute to elevated BP. Potassium decreases sodium reabsorption from the renal tubule, facilitating its excretion through urine (Wei et al., 2020), in addition to decreasing vascular calcification and stiffness, and improving endothelium-dependent vasodilation (Wei et al., 2020). The INTER-SALT study supported that sodium-to-potassium molar ratio of <1 may protect against elevated BP (Iwahori et al., 2019), and only 7.6% Ghanaians achieved this ratio in the WHO-SAGE Ghana Wave 3 study (Menyanu et al., 2020). This evidence highlights that the Ghanaian population is consuming too much salt but too little fruits and vegetables, which are higher in potassium, hence increasing the risk of hypertension.

Cocoa, an important food crop widely grown in Ghana (FAOSTAT, 2021), has the potential to mitigate the hypertension prevalence. Cocoa powder, obtained through the processing of the dried beans, is rich in flavanols particularly epicatechin and catechin (Febrianto et al., 2022), as well as potassium (Febrianto et al., 2022). Our recent meta-analysis of randomized controlled trials showed that increased consumption of cocoa in the form of beverage and dark chocolate significantly lowered SBP in individuals living with elevated BP (Amoah et al., 2022). In addition to cocoa's high potassium content, it is also speculated that flavanols may inhibit the angiotensin-converting enzyme (Ludovici et al., 2017), stimulate the production of endothelial NO through the activation of eNOS, and reduce oxidative stress (Ludovici et al., 2017), resulting in vasodilation and decreased BP.

Considering the frequent consumption of high-fat-high-salt meal (HFHSM) detrimental to vascular health, this study was set out to determine whether cocoa beverage, which is higher in flavanols and potassium, may help to improve BP in the postprandial state after its co-consumption with HFHSM in older adults living with untreated hypertension.

2 | MATERIALS AND METHODS

2.1 | Trial design

The study employed a randomized crossover design, comparing the acute (120 min) effect of co-consumption of cocoa beverage with an HFHSM (HFHSM + CB; intervention) versus co-consumption of water with the HFHSM (HFHSM + W; control). The study was conducted at the Kwame Nkrumah University of Science and Technology (KNUST) Wellness Centre between February and March 2023. Ethical approval for the study was obtained from the Committee on Human Research, Publication and Ethics (CHRPE/AP/802/22) of KNUST. The study was registered with the Pan African Clinical Trial Registry (www.pactr.org) and granted identification number PACTR202302489428910.

2.2 | Participants

The study was advertised on the KNUST campus. Participants who expressed interests were prescreened to ensure they met the inclusion criteria. Their BP measurements were taken on 2 different days to ensure they were hypertensive as stipulated in the WHO guideline (WHO, 2021). The participants were mainly nonteaching staff recruited from KNUST, Kumasi. All enrolled participants provided written informed consent. The inclusion criteria for the study were as follows: (i) participants who were male or female aged ≥ 19 years, (ii) had a body mass index (BMI) between 18 and 35 kg m⁻², (iii) had hypertension (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg when measured on two separate days; WHO, 2021), and (iv) not taking antihypertensive medication. Exclusion criteria were participants who consumed alcohol more than 2 units/day, took medication for hypertension, smoked cigarette, pregnant women, breastfeeding mothers, had type 1 or type

2 diabetes, had kidney disease, allergic to cocoa, and had dysphagia or digestive disorders such as Chron's disease and irritable bowel syndrome.

2.3 | Trial method

Participants were asked to maintain their usual meals but were restricted from consuming polyphenol-rich food products including cocoa products and tea during the entire study period. On two separate occasions with a washout period of at least 3 days, participants arrived at the KNUST Wellness Centre at 8:00 a.m. following an overnight fast.

Participants were randomly assigned and sequentially allocated a treatment using a computer-generated random number sequence (www.randomizer.org). A researcher independent of the study performed the randomization. The allocation sequence was concealed in opaque envelopes, each labeled with each participant's ID on the front. The envelopes were opened for the participant once the participant had passed the screening. During each visit, in a predetermined randomized order, the participants co-consumed 160 g HFHSM with either cocoa beverage (15 g cocoa powder in 250 mL water) or 250 mL water (control) within 10 min. The participants were requested to remain seated and be sedentary throughout the postprandial period. No further food and drinks were allowed in the postprandial period. Figure 1 shows the flow diagram of the participants' recruitment and presentation of the test meals.

2.4 | Nutritional intervention

The HFHSM recipe delivered as braised rice and consisted of polished white rice, iodized salt, coconut oil, and tap water. A 200-g sample of polished white rice was transferred into a rice cooker; then, 400 mL of tap water, 60 g of cold-pressed coconut oil, and 10 g of iodized salt were added and allowed to cook until ready for serving. A serve of HFHSM weighed 160 g, intended to provide 50 g of available carbohydrate. The nutritional composition of the HFHSM per serve (160 g) was 1683 kJ, 4 g protein, 50 g carbohydrate, 1 g dietary fiber, 20 g total fat, 18 g saturated fat, 1211.6 mg sodium, 77.9 mg potassium, and 9.6 mg magnesium. The cocoa beverage was prepared by reconstituting 15 g of powder in 250 mL warm water and was provided in closed-lid cups and served with the meal. Our 15 g of cocoa powder contained 0.85 g crude fiber, 297.25 mg potassium, and 7.95 g sodium.

2.5 | Measurements

Anthropometric measurements and BP measurements were taken in a fasted state for all study participants at baseline (−5 min and 0 min) and at postprandial time points 15, 30, 45, 60, 90, and 120 min (Figure 2).

Body weight, height, and waist circumference of the participants were measured at their first study visit following the procedure of Dekkers et al. (2008). BMI was recorded to the nearest one decimal places. Hip circumference was measured to the nearest 0.1 cm at the

largest circumference around the buttocks using a flexible narrow non-stretch tape. Waist-to-hip ratio (WHR) was calculated and recorded to the nearest two decimal places.

Total body fat was measured for all study participants using body composition monitor (BF511, Omron), which operates using bioimpedance with participants stepping onto the body composition barefooted. The participants were asked to remove metal objects such as rings, earrings, wristwatches, and coins before measurements were taken.

Participants' SBP, DBP, and heart rate were measured using an approved automated BP device (M7intelli T [HEM-7361T-EBK]; Omron) after 10 min of relaxation at baseline (−5 min and 0 min) and at 15, 30, 45, 60, 90, and 120 min postprandial time points.

2.6 | Sample size

Twenty-eight participants were required to detect a clinically significant mean difference of 5 mmHg in SBP based on a previous meta-analysis (Blood Pressure Lowering Treatment Trialists' Collaboration, 2021) with a statistical power of 0.8, an alpha of 0.05, and assuming a standard deviation (SD) of 9 using G*Power (version 3.1.9.4; Frauz Faul, University of Kiel, Germany) based on a within-participant design.

2.7 | Nutritional analysis of cocoa powder

The fiber, sodium, and potassium contents of the cocoa powder were determined following standard procedures (AOAC, 2000; Jones & Case, 1990) at the Departments of Food Science and Technology and Crop and Soil Sciences Laboratories, KNUST. Flame photometer was used for the mineral analysis.

The cocoa powder contained epicatechin (366.33 µg/g dry weight basis) and catechin (118.33 µg/g dry weight basis) as determined by Todorovic et al. (2017) method at the New Zealand Institute for Plant and Food Research Limited, New Zealand, an internationally ISO accredited laboratory. Approximately 1.0 g of the cocoa powder was extracted three times with 10 mL of n-hexane, in order to eliminate lipids from the samples. Defatted samples were air-dried for 24 h. Polyphenol-rich fraction was extracted from defatted cocoa products with extraction solvent (acetone: distilled water: acetic acid [70:29.8:0.2 v/v/v]). Extractions were carried out twice with 5 mL of solvent for 30 min in FALC ultrasonic bath containing ice water. The mixture was centrifuged for 10 min at 3000 rpm after each extraction, and the supernatants were decanted and combined after filtering through a 0.45-µm syringe filter.

Flavanols content (catechin and epicatechin) were analyzed using a Waters ACQUITY H-Class UPLC system with a photodiode array detector (PDA) and an ACQUITYTM QDa mass spectrometer (Waters). The cocoa extracts were separated on an Acclaim Polar Advantage II C18 RP-LC column (150 × 2.1 mm, 3 µm, Thermo Fisher) using the mobile phases: (A) 0.1% formic acid and (B) acetonitrile + 0.1% formic acid. The flow rate was 0.34 mL/min, and the elution gradient was as follows: 0 min 92% A; 5 min 92% A; 10 min 85% A; 20 min 80% A; 27 min

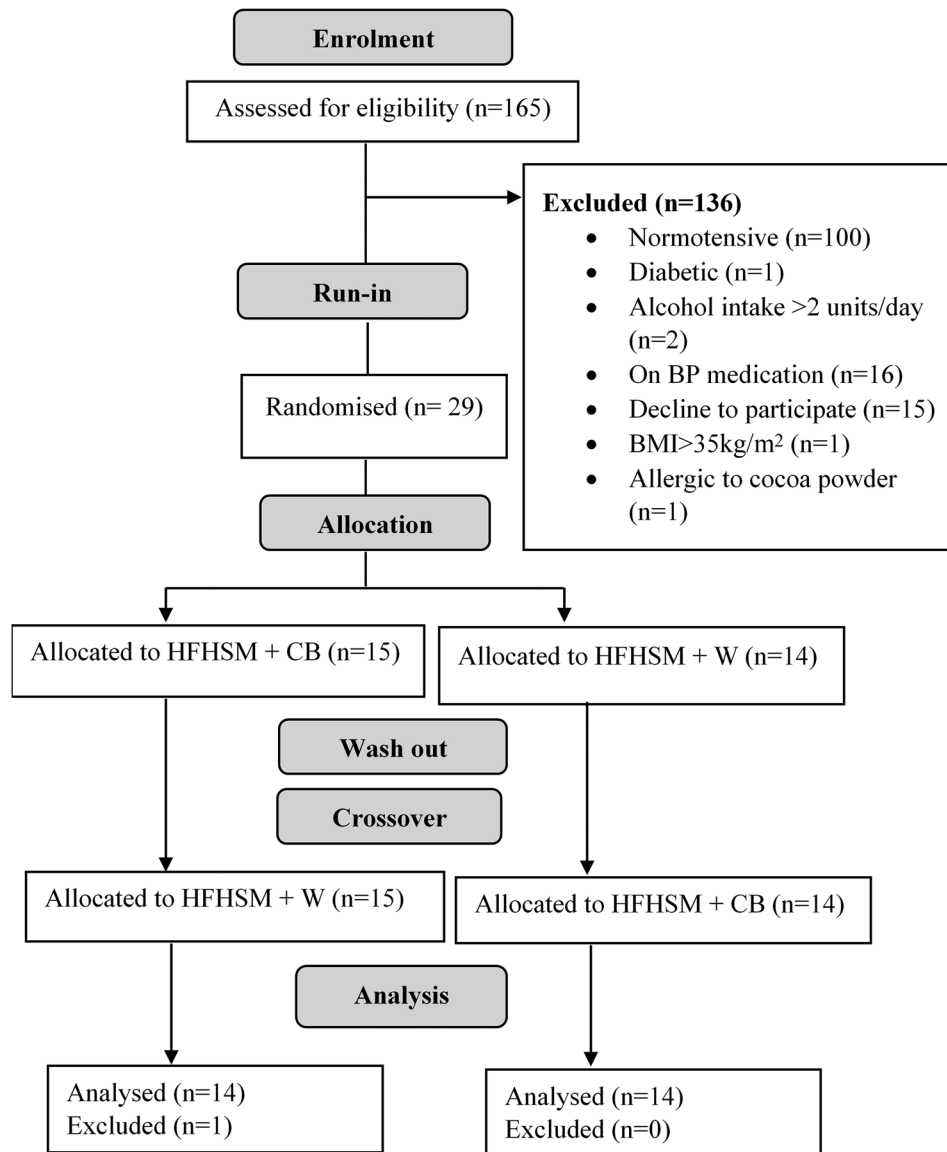


FIGURE 1 Diagram showing the flow of participants of the study. BMI, body mass index; BP, blood pressure; CB, cocoa beverage; HFHSM, high-fat-high-salt meal; n, number of participants, W, water. Participant (n=1) in the HFHSM+W group was excluded for analysis due to fasting blood glucose within the diabetes range and thus meeting the exclusion criteria.

80% A; and 34–36 min 100% B, 36.5–42 min 100% A. The identification of the compounds was performed by comparing UV spectra at 210 nm and retention times of the separated peaks with the retention times of the catechin, and epicatechin standards purchased from Sigma Aldrich. Peaks were also identified using the QDa mass spectrometer in negative ion mode cone with a voltage of 15 V and capillary voltage set to 0.8 kV. Catechin and epicatechin were quantified using the using PDA chromatogram and a five-point calibration curve using the epicatechin and catechin standards.

2.8 | Statistical analysis

All continuous data were checked for normality using the Shapiro–Wilk test. Participant characteristics were summarized using descriptive

statistics, presented as mean \pm SD. Resting BP and heart rate at two separate visits were compared using paired *t*-test. Postprandial BP and heart rate outcomes over the 2-h period were graphically presented as change from baseline, with the error bar representing mean \pm standard error of mean (SEM), plotted using GraphPad Prism (Version 8). Repeated measures linear mixed model was used to compare the effect of CB and water (W) on postprandial BP and heart rate outcomes over the 2-h period. The model included treatment (cocoa beverage or water), time, and treatment \times time as fixed effects; participant as random effect; and resting measurement as covariate. When there was a significant effect of treatment \times time, post hoc pairwise comparisons were conducted following Bonferroni's procedure. Statistical significance was set as $p < .05$. All statistical analyses were carried out using International Business Machines Corporation SPSS Statistics (Version 25).

TABLE 1 Characteristics of study participants.

Measure	Mean	Standard deviation
Age (years)	52.5	9.2
Weight (kg)	70.6	15.2
BMI (kg/m ²)	25.9	4.7
Body fat (%)	30.0	11.6
Visceral fat	8.5	4.0
Waist circumference (cm)	93	12
Hip circumference (cm)	103	11
Waist-to-hip ratio [-]	0.9	0.05

Abbreviation: BMI, body mass index.

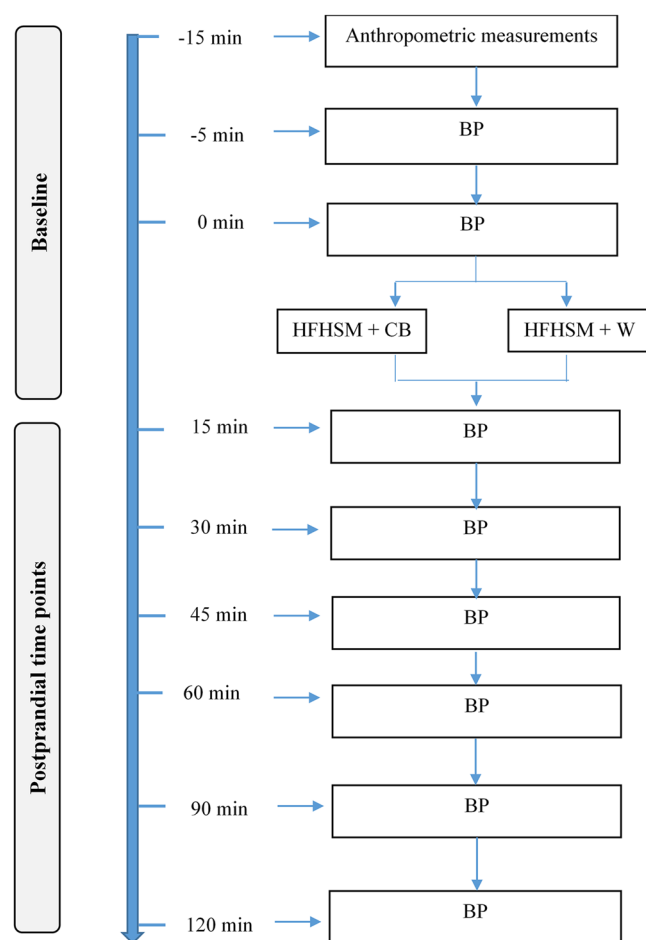


FIGURE 2 Flow chart. BP, blood pressure; CB, cocoa beverage; HFHSM, high-fat-high-salt meal; W, water.

3 | RESULTS

3.1 | Study participants

A total of 28 participants (14 males and 14 females) completed the study. The mean age and BMI of the study participants were 52.50 ± 9.36 years and 25.93 ± 4.72 kg/m², respectively (Table 1). All

participants were not taking hypertensive medication and had no other clinically diagnosed medical conditions.

3.2 | Resting blood pressure

The resting SBP before HFHSM + CB and HFHSM + W intervention were 147.25 ± 14.05 mmHg and 143.57 ± 9.31 mmHg, respectively; the resting DBP before HFHSM + CB and HFHSM + W intervention were 92.38 ± 9.21 mmHg and 91.54 ± 8.13 mmHg, respectively. However, the resting heart rate before HFHSM + CB and HFHSM + W intervention were 72.52 ± 10.52 bpm and 73.09 ± 9.25 bpm, respectively. There were no significant differences in SBP ($p = .112$), DBP ($p = .556$), and heart rate ($p = .632$) at resting state between the two visits.

3.3 | Postprandial blood pressure

Changes in postprandial SBP for participants who consumed cocoa beverage were significantly different from those who consumed W over the 120-min postprandial time points ($p < .05$; Figure 3). The postprandial SBP reduction following the HFHSM + CB treatment was significantly greater compared with the HFHSM + W treatment. Over the postprandial duration, SBP following the HFHSM + CB treatment was on average 3.8 ± 0.6 mmHg ($p < .001$) lower than following the HFHSM + W treatment, with the maximum difference observed at 120 min (HFHSM + CB vs. HFHSM + W: -7.6 ± 0.6 mmHg, $p < .001$, post hoc). For postprandial changes in DBP, there were no significant differences between the two groups at any postprandial time point (Figure 4). A general decrease in DBP was observed at all postprandial time points in both groups. CB supplementation did not significantly influence heart rate (Figure 5).

4 | DISCUSSION

This study has shown that co-consumption of CB with an HFHSM significantly lowered (-3.8 ± 0.6 mmHg) the SBP over a 120-min period

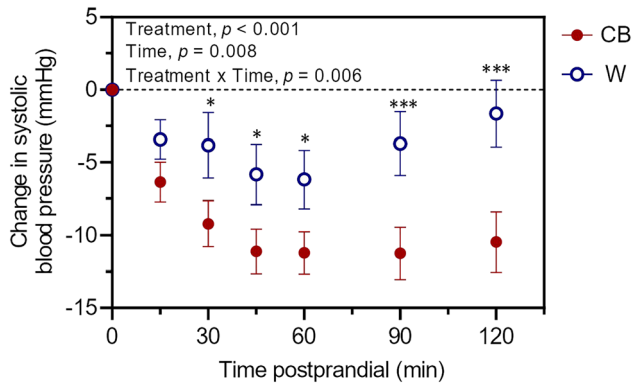


FIGURE 3 Changes in systolic blood pressure from baseline after cocoa beverage (CB) versus water (W) supplementation with a high-fat-high-salt meal in adults living with hypertension. Data are presented as means \pm SEM, $n = 28$. Significant difference by comparison test: Bonferroni between the groups (* $p < .05$; *** $p < 0.001$).

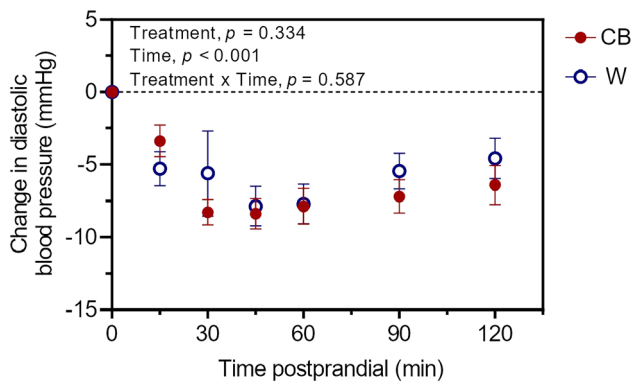


FIGURE 4 Changes in diastolic blood pressure from baseline after cocoa beverage (CB) versus water (W) supplementation with a high-fat-high-salt meal in adults living with hypertension. Data are presented as means \pm SEM, $n = 28$.

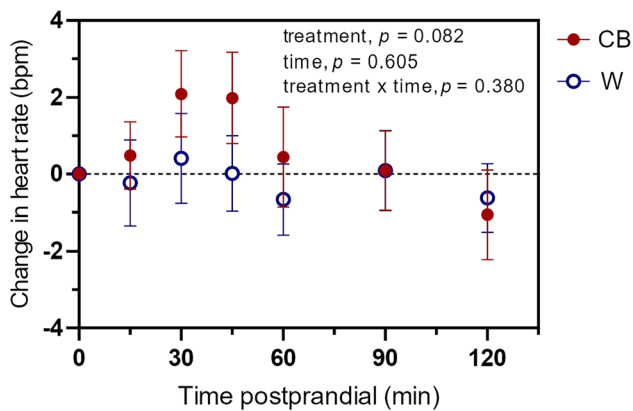


FIGURE 5 Changes in heart rate from baseline after cocoa beverage (CB) versus water (W) supplementation with a high-fat-high-salt meal in adults living with hypertension. Data are presented as means \pm SEM, $n = 28$.

in adults living with untreated hypertension. These findings are consistent with what has been reported in two earlier studies (Buijsse et al., 2006; Monahan et al., 2011). In the Zutphen Elderly Study, which was an extension of the Zutphen study conducted in the Netherlands, a total of 470 older adults were divided into three groups (lowest, middle, and highest tertile) based on their regular intake of cocoa, and cocoa-based products were selected for that study (Buijsse et al., 2006). The mean ages of the lowest, middle, and highest tertile groups were 72.1, 72, and 71.3 years, respectively. The median amount of cocoa consumed by the participants was 2.11 g/day. It was reported that older adults in the highest tertile group recorded a significant reduction in systolic blood pressure of 3.7 mm Hg compared with the lowest tertile group (Buijsse et al., 2006). This closely compares with the reduced systolic blood pressure recorded in this study.

In another randomized, double-blind, placebo-controlled study, 23 healthy older adults with an average age of 63 years consumed 0 (placebo), 2, 5, 13, and 26 g of cocoa (Monahan et al., 2011). The primary outcome of assessment was brachial artery flow-mediated dilation (FMD) measured acutely at baseline, 1 and 2 h after consuming cocoa. The authors found that while the FMD remained constant 1 and 2 h following the placebo intake, significant increases in FMD following 2, 5, 13, and 26 g of cocoa intake were observed at 1 and 2 h (Monahan et al., 2011). The plausible mechanism could be that the polyphenolic compounds epicatechin and catechin, present in the cocoa, stimulated the enzyme eNOS, which results in the production of NO, a vasodilator, from nitrates leading to the lowering of the SBP (Fraga et al., 2010; Maaliki et al., 2019). Whilst a significant reduction in SBP was observed in our study population with uncontrolled BP, a similar reduction in SBP was not observed in Monahan's study population who did not have hypertension (<140/90 mmHg). This is because differences in physiological states impact on different health outcomes. For example, people living with hypertension have impaired renin-angiotensin-aldosterone-system, which is not the case in apparently healthy participants. Thus, the findings of the study must be interpreted with caution.

The study outcome is highly relevant not only to Ghana population but also to other populations with widespread consumption of HFHSM. Specifically in Ghana, hypertension is currently one of the leading causes of death (Owusu et al., 2021). Poor dietary practices including increased consumption of braised rice is an important determinant of hypertension outcomes. A recent review of Ghana's food environment revealed that there is increased availability of processed and ultra-processed foods including white rice (Mockshell et al., 2022). These foods are usually used as carrier medium for dietary salt and sugar delivery, a factor that has contributed toward the surge in Ghana's rise in obesity and comorbidities including hypertension. The consumption of braised rice prepared with oil and salt and fried rice is a common practice in Ghana especially for low-budget consumers especially in urban communities. It has also been established that in regard to genetics, people of African descent are sensitive to sodium (Lindhorst et al., 2007). They have higher sodium accumulation and lower excretion compared to their Caucasian counterparts. Consequently, Black par-

Participants including Ghanaians are at an increased risk of developing hypertension (Lindhorst et al., 2007). It would therefore be advisable to co-consume these foods with cocoa beverage to help overcome the potential surge in SBP. This is important especially as higher SBP is an important risk factor in predicting cardiovascular event clinically compared to DBP (Zhou et al., 2021). Interestingly, there was no change in DBP following the co-consumption of the HFHSM with CB. In a similar acute randomized crossover study, the participants who were obese adults living with type 2 diabetes were assigned either CB containing 480 mg flavanols or flavanol-free placebo with <0.1 mg flavanols (Basu et al., 2015). These beverages were co-consumed with high-fat fast-food-style breakfast, and cardio-metabolic indices were assessed at time points 0.5, 1, 2, 4, and 6 h postprandially. The authors found that there was no significant difference in the DBP over a 6-h period (Basu et al., 2015). The difference between our study and this study is that while we recorded a significant reduction in SBP over the 2-h period, Basu et al. (2015) recorded no significant reduction in the SBP over the 6-h period. The variation in the SBP outcomes between these two studies could be attributed to the different participant characteristics: those with untreated hypertension compared with obese adults living with type 2 diabetes. These conditions could result in different physiological responses toward polyphenol metabolism. In a similar fashion, heart rate recorded no significant changes following the co-consumption of CB with the high-fat fast-food-style meal.

5 | LIMITATIONS

A limitation of the study is that it was a short-term (2 h) postprandial study. Consequently, it would need long-term studies to establish if the significant improvement in the SBP can be maintained beyond the 2-h period. Another limitation of the study is that other markers of cardiovascular health, for example, flow-mediated dilation, were not assessed.

6 | CONCLUSION AND RECOMMENDATIONS

This acute randomized crossover trial has shown that co-consumption of cocoa beverage with an HFHSM leads to a significant reduction in SBP in adults living with uncontrolled hypertension in a 120-min period. Conversely, no significant effect on DBP and heart rate was observed when cocoa beverage was co-consumed with HFHSM. The widespread use of cocoa in the management of BP is highly recommended to the Ghanaian population due to easy access, sustainable production, high prevalence of undiagnosed or untreated hypertension, and their inherent increased sensitivity to dietary sodium. Future research should investigate the long-term effect of repeated administration of the cocoa beverage on the BP and enzymes involved in BP modulation such as nitric oxide synthase of the same population of participants. Also, an acute study investigating the effect of co-consumption of cocoa beverage and HFHSM in an apparently healthy population living with normal BP should be investigated. This could

highlight the effect of the beverage intake on the physiological state of the participants.

AUTHOR CONTRIBUTIONS

Conceptualization: Emmanuel Ofori Osei, Isaac Amoah, and Jia Jiet Lim. *Methodology:* Emmanuel Ofori Osei, Isaac Amoah, Phyllis Tawiah, Jia Jiet Lim, Andrew Patrick Dare, and Charles Diako. *Validation:* Emmanuel Ofori Osei, Isaac Amoah, Jia Jiet Lim, Andrew Patrick Dare, and Charles Diako. *Formal analysis:* Emmanuel Ofori Osei, Isaac Amoah, and Jia Jiet Lim. *Investigation:* Emmanuel Ofori Osei, Jesse Charles Cobbinah, Andrew Patrick Dare, and Charles Diako. *Data curation:* Emmanuel Ofori Osei, Isaac Amoah, and Jia Jiet Lim. *Writing—original draft preparation:* Emmanuel Ofori Osei, Isaac Amoah, and Jia Jiet Lim. *Writing—review and editing:* all authors. *Supervision:* Isaac Amoah, Jia Jiet Lim, Phyllis Tawiah, Margaret Saka Aduama-Larbi, and Ibok Nsa Oduro. *Project administration:* Emmanuel Ofori Osei and Isaac Amoah. All authors have read and agreed to the published version of the manuscript.

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The study received no external funding.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki. Ethical approval for the study was obtained from the Committee on Human Research, Publication and Ethics (CHRPE/AP/802/22) of the Kwame Nkrumah University of Science and Technology.

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