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Preworkout Consumption of Chicken Essence Elicits Post-Exercise Hypotension in Prehypertensive Offspring of Hypertensive Parents: A Crossover Randomized Controlled Trial

Sasitorn Nakthong[1], Sauwanit Wutthikrairat[2], Piyaporn Tumnark[3], and Jatuporn Phoemsapthawee[3]

[1]Department of Food Safety Innovation and [2]Research and Development Program, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom 73140, Thailand
[3]Department of Sports Science, Faculty of Sports and Health Science, Kasetsart University, Nakhon Pathom 73140, Thailand

ABSTRACT: Chicken essence (CE) is known for its antihypertensive properties. However, few studies have investigated the effects of CE in prehypertensive individuals. Here, we conducted a randomized crossover clinical trial on prehypertensive offspring of hypertensive parents to evaluate the effects of preworkout CE consumption (CEC) on post-exercise hypotension (PEH) and cardiac autonomic and vascular responses. Ten prehypertensive males participated in three randomly ordered sessions: a resting control (REST) condition and two exercise conditions involving CEC and an exercise control (CON). The participants in the CEC condition consumed CE daily for seven days prior to the experimental sessions. Measurements were taken before and after each intervention. The results showed that the CEC condition resulted in significantly lower systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) at night compared with the CON and REST conditions ($P<0.05$ and $P<0.01$, respectively). This reduction in SBP and MAP in the CEC condition was observed as early as 10 min and persisted for up to 12 h after a single exercise session. Only the CEC condition showed significantly higher root mean square of successive differences at night ($P<0.05$) and across a 24-h period ($P<0.05$). Moreover, we observed a significantly lower brachial-ankle pulse wave velocity 30 min post-exercise ($P<0.05$). These findings support the efficacy of CE in promoting PEH, particularly with greater reductions in SBP, DBP, and MAP at night, while also enhancing post-exercise vagal activity and reducing vascular stiffness. Thus, CEC may be an effective strategy for preventing hypertension.

Keywords: ambulatory blood pressure monitoring, carnosine, hypertension, post-exercise hypotension, pulse wave analysis

INTRODUCTION

Prehypertension has emerged as a global health concern that particularly affects young adults and poses a significant threat to their overall well-being (Senthil and Krishndasa, 2015). It is associated with an increased risk of developing clinical hypertension (HT), which in turn increases the likelihood of cardiovascular diseases (CVDs) (Chobanian et al., 2003). In Thailand, about one-third of individuals aged 15 years and older are affected by prehypertension, with males being more susceptible than females (Aekplakorn et al., 2008).

Autonomic abnormalities, including increased sympathetic tone (Lopes et al., 2000) and/or vagal withdrawal (Pal et al., 2011), have been observed in young normotensive individuals with hypertensive parents. These abnormalities significantly contribute to the sympathovagal imbalance observed in prehypertensive offspring (Lopes et al., 2000; Pal et al., 2011). In young adults, increased sympathetic tone and peripheral vascular resistance are commonly responsible for the early onset of high blood pressure (BP), leading to arterial stiffness (Li et al., 2004). High arterial stiffness is a key factor in the development of HT, especially in individuals with hypertensive parents (Yasmin et al., 2004). Therefore, reducing sympathetic activity and arterial stiffness in prehypertensive young adults may decrease their risk of developing HT.

Chicken essence (CE), or chicken meat extract, has long been used in Asia as a health promoter and preventive measure against chronic diseases (e.g., hyperglycemia and HT) owing to its nutritional benefits (Li et al., 2012). CE is rich in essential amino acids, including threonine, methionine, lysine, tryptophan, phenylalanine, and branched-chain amino acids (e.g., isoleucine, leucine, and valine)

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Correspondence to Jatuporn Phoemsapthawee, E-mail: jatuporn.w@ku.th

(Huang et al., 2018). It also contains minerals; trace elements; vitamins; and histidine-containing peptides, such as carnosine (β-alanyl-L-histidine) and anserine (β-alanyl-1-methyl-L-histidine) (Geissler et al., 1996; Zain and Jamalulail, 2003). These peptides exhibit strong antioxidant, antiglycemic, and antihypertensive properties (Tanida et al., 2005; Kubomura et al., 2010; Tanida et al., 2010; Nagai et al., 2012; Baye et al., 2016; Artioli et al., 2019).

In Thailand, Kasetsart University developed Betong chicken (KU line), which is characterized by superior meat quality with lower carcass fat and leaner meat compared with other native Thai chickens (Sopannarath and Bunchasak, 2015). Moreover, the meat of Betong chicken contains high levels of carnosine and anserine, enhancing its overall quality (Charoensin et al., 2021; Wutthikrairat et al., 2023). The high concentrations of functional compounds in Betong chicken make it an attractive option due to its excellent nutritional value.

Animal studies have shown the potential antihypertensive effects of carnosine, primarily through the inhibition of sympathetic activity (Niijima et al., 2002; Tanida et al., 2005). Carnosine also promotes vasodilation independently of the endothelium-mediated production of cyclic guanosine monophosphate (GMP) (Ririe et al., 2000). Furthermore, anserine appears to affect renal sympathetic activity and BP by interacting with the histaminergic nerve (Tanida et al., 2010). Although isolated carnosine and anserine have been extensively studied in animal models, clinical studies involving prehypertensive individuals are notably lacking. The mechanisms behind the beneficial effects of CE are complex and likely result from the combined action of multiple bioactive components (Li et al., 2012). Thus, CE in its natural form may offer better bioavailability and synergistic effects compared with isolated supplements.

In addition, evidence supporting the use of CE as a natural nutritional supplement for sustained BP reduction following a single exercise session—known as post-exercise hypotension (PEH)—is currently insufficient. PEH can last up to 13 h, suggesting that its effects may accumulate and contribute to long-term adaptations (Kenney and Seals, 1993; Brito et al., 2018). This highlights the potential for PEH to serve as an effective non-pharmacological treatment for HT (Kenney and Seals, 1993). Therefore, the present study aimed to investigate the effects of preworkout Betong CE consumption (CEC) on PEH and cardiac autonomic and vascular responses in young prehypertensive offspring of hypertensive parents.

MATERIALS AND METHODS

Recruitment and screening of participants

Ten prehypertensive males aged 18 to 22 years with a parental history of HT were recruited in this study. Prehypertension was defined as a systolic BP (SBP) of 120 to 139 mmHg or a diastolic BP (DBP) of 80 to 89 mmHg. A parental history of HT was established if the parents had been receiving treatment for essential HT (stage 1 or 2) for at least two years. Participants self-reported their physical activity levels using the International Physical Activity Questionnaire (Hagströmer et al., 2006), and those engaging in less than 1 h of regular physical activity per week were classified as sedentary. A separate self-report questionnaire was used to gather the general health information of participants.

Participants were excluded from the study if they met any of the following exclusion criteria: (1) current smokers, (2) taking any medication that could affect cardiometabolism, (3) having musculoskeletal limitations that restricted physical activity, (4) experiencing psychiatric issues, or (5) having been on a weight loss diet within the previous six months.

This study was approved by the Research Ethics Committee of Kasetsart University (COA no. COA66/007). All participants provided verbal and written informed consent, and all procedures adhered to the guidelines of the Declaration of Helsinki. Participants also granted permission to publish their data. This study was registered on the Thai Clinical Trials Registry public website (TCTR20240330003).

Study design

This study utilized a randomized crossover design, where each participant underwent three experimental sessions in a random order (simple randomization) with a minimum of seven days between each session (Fig. 1). Participants were instructed to maintain their usual routines, including diet and sleep, and to refrain from strenuous exercise during the week between sessions. They were also advised to keep their routines consistent for 24 h prior to each experimental session and to avoid vigorous activities, caffeine, and alcoholic beverages during that same time.

The laboratory temperature was maintained between 23°C and 25°C, and the experimental sessions were conducted between 4:00 p.m. and 7:00 p.m. During each session, participants engaged in either one resting control (REST) condition or two exercise conditions: CEC and exercise control (CON). For the CEC condition, participants were instructed to consume 50 mL of CE after their morning meal for seven consecutive days. Meanwhile, in the CON and REST conditions, participants were asked to maintain their regular diets without consuming CE. Throughout the study, all participants were instructed to avoid commercial vitamins and dietary supplements. Nutrition logs were used to monitor and

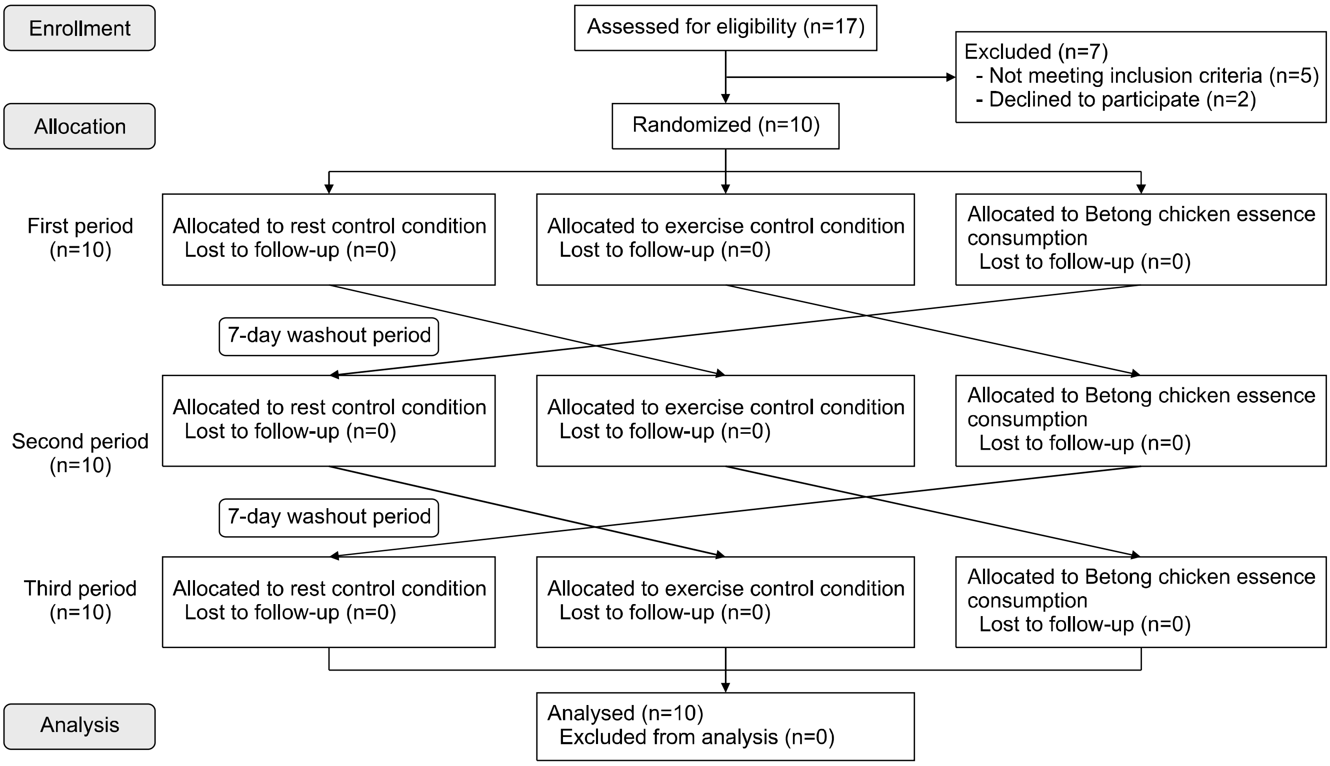

Fig. 1. Flowchart of the overall study design.

record dietary intake. The protocol for each experimental session is shown in Fig. 2.

Prior to the experimental sessions, participants completed baseline measurements over a one-week period. Each session comprised the following phases: preintervention period (20 min of rest), a 45-min intervention period (which included either exercise or non-exercise), and post-intervention period (60 min of rest). Ambulatory blood pressure monitoring (ABPM) and heart rate variability (HRV) were assessed at baseline and over 24 h following each experimental session to evaluate differences in BP and HRV variables among conditions. Moreover, brachial-ankle pulse wave velocity (baPWV) was measured at baseline; immediately after (0 min) each experimental session; and at 30-min, 60-min, and 24-h intervals after the experimental session (Fig. 2).

Exercise and resting protocols

All experimental sessions began at 4 p.m. The exercise session comprised a 5-min warm-up [walking at 50%–60% of maximum heart rate (HRmax)], followed by 40 min of jogging at 70% to 76% of HRmax. The exercise intensity was controlled using an HR monitor (Polar H7, Polar Electro Inc., Kempele, Finland), which recorded the HR every 2 min throughout the session. This protocol has been shown to induce PEH (Forjaz et al., 2004). In the rest control session, the participants remained seated in a chair for the same duration.

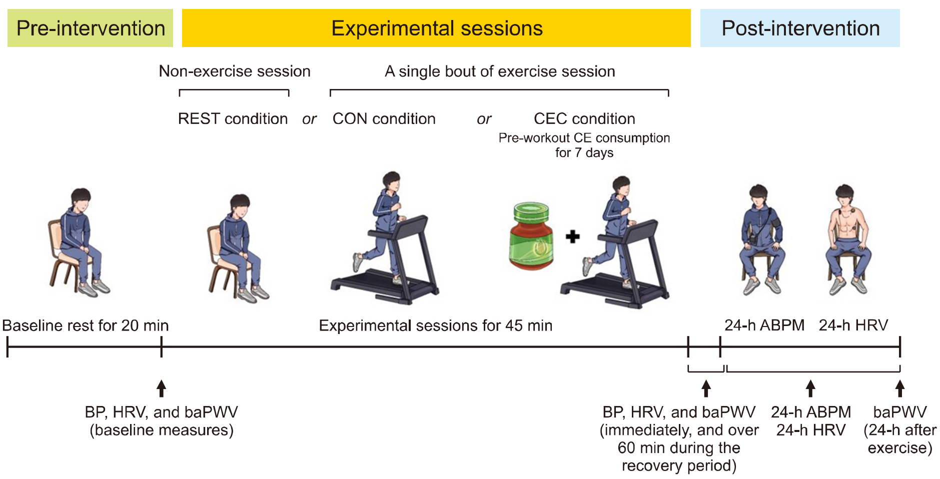

Fig. 2. Overview of the experimental session. REST, resting control condition; CON, exercise control condition; CEC, chicken essence consumption condition; CE, chicken essence; BP, blood pressure; HRV, heart rate variability; baPWV, brachial-ankle pulse wave velocity; ABPM, ambulatory blood pressure.

Preparation and analysis of chicken essence

The Department of Food Safety Innovation, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Kamphaeng Saen Campus, was responsible for providing and conducting the analysis of Betong CE products. Betong CE is produced by extracting water from chicken meat and bones at 100°C for 2 h. Then, the extracted solution was filtered through a cotton sheet and centrifuged to remove fat and cholesterol. The resulting solution was concentrated under vacuum and sterilized at high temperatures and pressures before being packaged. This process yields a low-sugar, low-fat product rich in protein (Wutthikrairat et al., 2023).

In terms of concentration, the five most abundant amino acids in Betong CE include glycine (642.4 mg/100 g), glutamic acid (546.9 mg/100 g), cysteine (414.6 mg/100 g), arginine (236.1 mg/100 g), and alanine (298.9 mg/100 g). A 50-mL bottle of Betong CE contains the active dipeptides carnosine and anserine at concentrations of 168 and 575 mg/50 mL, respectively. The nutritional content of the investigational product in this study, which has been reported previously (Wutthikrairat et al., 2023), is summarized in Supplementary Table 1. The methods for quantifying carnosine and anserine were adapted from the study of Li et al. (2012), and the high-performance liquid chromatography chromatograms for their quantification are shown in Supplementary Fig. 1.

Data collection and measurement

***Preliminary visit*:** Prior to the experimental test day, participants underwent laboratory assessments to evaluate their anthropometrics, body composition, BP, and peak oxygen consumption ($\dot{V}O_2$peak). Body weight and composition were measured using a bioimpedance analysis device (Inbody 720, Biospace Inc.), with participants dressed lightly and without shoes. The body mass index was calculated by dividing weight by height squared. Resting BP and HR were measured using an automated noninvasive BP monitor (Walk200b, Cardioline) between 8:00 a.m. and 10:00 a.m., with participants seated according to standard protocols (Pickering et al., 2005).

$\dot{V}O_2$peak was assessed using a modified Bruce protocol on a treadmill (T-2100 Treadmill, GE Medical Systems), following established exercise testing guidelines (Fletcher et al., 2001). Expired gas samples were collected using a metabolic cart (Vmax Encore Metabolic Cart, Vyaire Medical Inc.) breath by breath, with HR and oxygen saturation being continuously monitored throughout the test. BP was measured using an automatic sphygmomanometer (Tango M2, SunTech Medical Inc.) during the final 30 s of each workload. Participants rated their perceived exertion at the end of each work rate using the Borg scale (6 – 20). $\dot{V}O_2$peak was calculated as the average of the three highest consecutive 10-s oxygen consumption values obtained during the test.

***24-hour ambulatory blood pressure monitoring*:** BP was evaluated 24 h post-condition using an ABPM device (Walk200b, Cardioline), with measurements taken consistently at the same time each day. This device operates on oscillometry with step deflation, and the BP cuff was placed on the nondominant arm using the appropriate cuff size. Participants were instructed to maintain their usual daily routines, avoid exercise, and keep their arms relaxed and straight during the daytime recordings.

SBP and DBP were categorized based on ABPM data for average 24-h, daytime, and nighttime periods. The nighttime period was defined as starting at 10 p.m. for 8 h, whereas the daytime period began at 6 a.m. and continued until the ABPM placement from the previous day, completing the 24-h measurement cycle. The monitor was programed to record the BP every 15 min during the day and every 30 min at night. An examiner who was blinded to the trial conditions analyzed the ABPM data and checked for errors or missing information in the BP readings of each individual.

***24-hour heart rate variability recording and analysis*:** The time between two successive R-waves in the QRS complex on an electrocardiogram (ECG), known as the R-R interval, was recorded 24 h post-condition using an eMotion Faros sensor (eMotion Faros device, Mega Electronics). R-R intervals were analyzed according to the guidelines established by the Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology (1996).

HRV parameters were assessed in time and frequency domains. The time-domain parameters included the standard deviation of normal R-R intervals (SDNN) and root mean square of successive differences of R-R intervals (RMSSD). The frequency-domain parameters included low-frequency (LF) power (0.04 – 0.15 Hz) and high-frequency (HF) power (0.15 – 0.4 Hz), and the LF/HF ratio was calculated to assess sympathovagal balance.

***Brachial-ankle pulse wave velocity*:** baPWV, an indicator of arterial stiffness, was assessed using an oscillometry-based device (BP-203RPE III; Omron Colin Co.), following a standard protocol (Tomiyama and Yamashina, 2010). The oscillometric method has been previously described and validated (Yang et al., 2018). Participants rested for at least 5 min before lying supine, with four occlusion and monitoring cuffs placed around both ankles and upper arms. During this time, the baPWV, BP, ECG, and heart sounds were simultaneously recorded, and the highest bilateral baPWV measurement was selected for analysis.

Statistical analysis

The sample size was determined based on the ability to detect a large effect size (0.86), as reported by de Brito et al. (2015). A minimum of 10 participants was required to achieve 80% power at a significance level of 0.05.

The data are presented as means with standard deviation or standard error of the mean. The Shapiro-Wilk test was used to assess normality. When necessary, logarithmic transformation was applied to the data before conducting analysis of variance (ANOVA) to ensure compliance with the normal distribution criterion. Comparisons between conditions were performed using one-way and two-way ANOVA with repeated measures. Fisher's least significant difference post-hoc test was employed to identify significant differences between mean values, with statistical significance set at $P<0.05$. All statistical analyses were performed using SPSS software version 26.0 for Windows (IBM Corp.).

RESULTS

The characteristics of participants are summarized in Table 1. Ten participants initiated and completed the experiments. Their BP and family history of HT were consistent with the prehypertension range for young men with hypertensive parents. Outside the intervention, the levels of habitual physical activity did not change significantly over time, and no differences were observed between experimental sessions. There were no significant variations in the daily intake of calories, fat, carbohydrates, protein, or sodium. Moreover, no adverse events occurred during any of the experimental sessions. The HRs during exercise were comparable between the CEC and CON conditions (152.4±1.1 and 152.6±1.4 beats/min, $P>0.05$), indicating similar exercise intensities (75.7%±0.5% and 75.8%±0.7% of HRmax, $P>0.05$, respectively). All variables showed similar preintervention values across the three experimental sessions.

The exercise protocol effectively induced PEH, as evidenced by the decreased BP in CEC and CON conditions. Fig. 3 shows the changes in PEH over a 24-h period following exercise or rest control sessions.

Table 1. Characteristics of participants (total no.=10)

Parameter	Value
Age (years)	18.8±0.8
Height (cm)	174.8±7.2
Body mass (kg)	66.5±6.0
BMI (kg/m^2)	21.7±2.9
Body fat (%)	16.9±3.4
Fat mass (kg)	10.8±3.5
Fat-free mass (kg)	55.8±5.2
SMM (kg)	31.6±3.1
Resting systolic BP (mmHg)	129.5±8.5
Resting diastolic BP (mmHg)	76.2±6.2
Resting MAP (mmHg)	94.0±3.7
$\dot{V}O_2$peak (mL/kg/min)	38.7±1.7
Family history of hypertension	
Father/mother (n)	6/4
Parents' age (years)	54.0±4.0
Parents' age at diagnosis (years)	45.8±3.5

Values are presented as mean±SD.
BMI, body mass index; SMM, skeletal muscle mass; BP, blood pressure; MAP, mean arterial pressure; $\dot{V}O_2$peak, peak oxygen consumption.

Significant differences in SBP reduction were observed among conditions during the day ($F_{2,27}=12.813$; $P<0.001$), at night ($F_{2,27}=7.805$; $P=0.002$), and across the 24-h period ($F_{2,27}=6.201$; $P=0.010$). The CEC condition exhibited significantly lower SBP during the day ($P<0.01$), at night ($P<0.01$), and across the 24-h period ($P<0.01$) compared with the REST condition. Moreover, the CEC condition had lower SBP at night ($P<0.05$) relative to the CON condition (Fig. 3A). Similarly, reductions in DBP showed significant differences between conditions during the day ($F_{2,27}=8.731$; $P=0.001$), at night ($F_{2,27}=6.399$; $P=0.005$), and across the 24-h period ($F_{2,27}=3.769$; $P=0.036$). The CEC condition demonstrated significantly lower DBP during the day ($P<0.01$), at night ($P<0.01$), and across the 24-h period ($P<0.05$) compared with the REST condition. It also showed significantly lower DBP at night ($P<0.05$) compared with

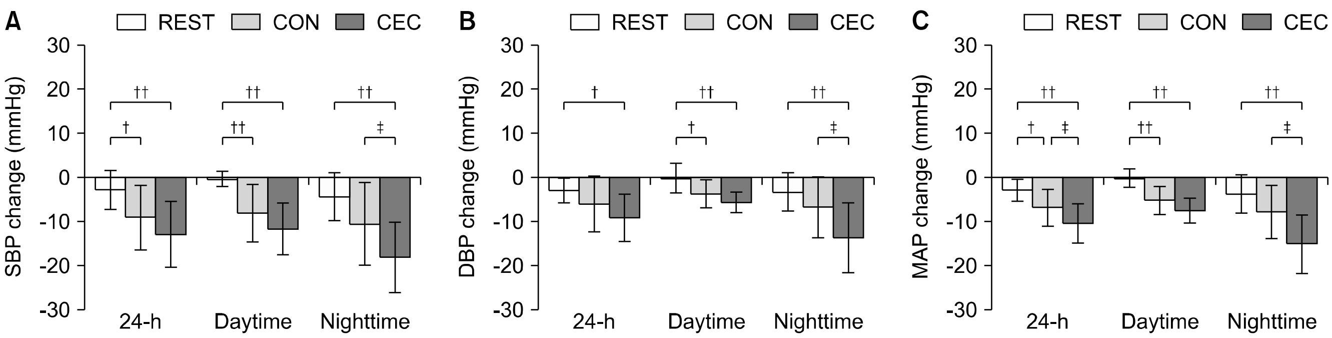

Fig. 3. Changes in 24-h ambulatory systolic blood pressure (SBP) (A), diastolic blood pressure (DBP) (B), and mean arterial pressure (MAP) (C) following the experimental sessions in the REST, CON, and CEC conditions. The values are presented as the mean±SD. †$P<0.05$ and ††$P<0.01$ indicate significant differences in the comparison between the CEC and CON conditions versus the REST condition. ‡$P<0.05$ indicates a significant difference between the CEC and CON conditions. REST, resting control condition; CON, exercise control condition; CEC, chicken essence consumption condition.

the CON condition (Fig. 3B). However, no statistically significant differences in SBP or DBP changes were observed between the CEC and CON conditions during the day or across the 24-h period.

Reductions in the mean arterial pressure (MAP) also varied significantly among conditions during the day ($F_{2,27}$=18.475; P<0.001), at night ($F_{2,27}$=9.833; P=0.001), and across the 24-h period ($F_{2,27}$=9.996; P=0.001). The CEC condition had significantly lower MAP during the day (P<0.01), at night (P<0.01), and across the 24-h period (P<0.01) compared with the REST condition. Moreover, the MAP was significantly lower at night (P<0.05) and across the 24-h period (P<0.05) in the CEC condition than in the CON condition (Fig. 3C). However, there were no statistically significant differences in MAP changes between the CEC and CON conditions during the day.

During the 1-h recovery period, a statistically significant interaction between condition and time was observed for reductions in SBP ($F_{14,189}$=11.489; P<0.001; η^2=0.460) and MAP ($F_{14,189}$=6.876; P<0.001; η^2=0.337). The CEC condition demonstrated a significant decrease in SBP within 10 min (P<0.01) post-exercise, whereas the CON condition did not show a significant reduction until 20 min (P<0.05) post-exercise, when compared with the baseline resting measures. The SBP in the CEC condition was significantly lower than that in the CON condition at 10 min (P<0.05), 40 min (P<0.05), 50 min (P<0.01), and 60 min (P<0.01) after exercise (Fig. 4A).

Similarly, the CEC condition exhibited a significant reduction in MAP within 10 min (P<0.01) after exercise, whereas the CON condition required 30 min (P<0.01) to exhibit a comparable decrease. The MAP was significantly lower in the CEC condition than in the CON condition at 10 min (P<0.01), 20 min (P<0.01), 40 min (P<0.01), 50 min (P<0.05), and 60 min (P<0.01) post-exercise (Fig. 4C).

By contrast, no statistically significant interaction was observed between the condition and time for DBP reduction. The CON condition showed no significant changes in DBP compared with the baseline resting measures, whereas the CEC condition exhibited a decrease in DBP as early as 10 min (P<0.05) after exercise. Moreover, the MAP was significantly lower in the CEC condition than in the CON condition at 10 min (P<0.01) and 20 min (P<0.01) post-exercise (Fig. 4B).

During the 1-h recovery period, the reduction in baPWV significantly differed between conditions at 10 min ($F_{2,27}$=4.142; P=0.027), 30 min ($F_{2,27}$=4.401; P=0.022), and 60 min ($F_{2,27}$=3.936; P=0.032). The CEC condition exhibited significantly lower baPWV compared with the REST condition at 10 min (P<0.01), 30 min (P<0.05), and 60 min (P<0.05) post-exercise. Moreover, the CEC condition showed significantly lower baPWV than the CON condition at 30 min (P<0.05). However, no significant differences in baPWV changes were observed between conditions at 24 h post-exercise (Fig. 5).

Table 2 presents the HRV changes over 24 h following the experimental sessions. A significant difference in the increase of RMSSD was observed between conditions at night ($F_{2,27}$=3.698; P=0.038) and across the 24-h period ($F_{2,27}$=4.755; P=0.017). The CEC condition showed a significant increase in RMSSD at night (P<0.05) and across the 24-h period (P<0.05) compared with the REST condition. However, there were no significant differences with regard to changes in SDNN, HF power, LF power, or LF/HF ratio over 24 h between conditions (Table 2).

DISCUSSION

To the best of our knowledge, this is the first random-

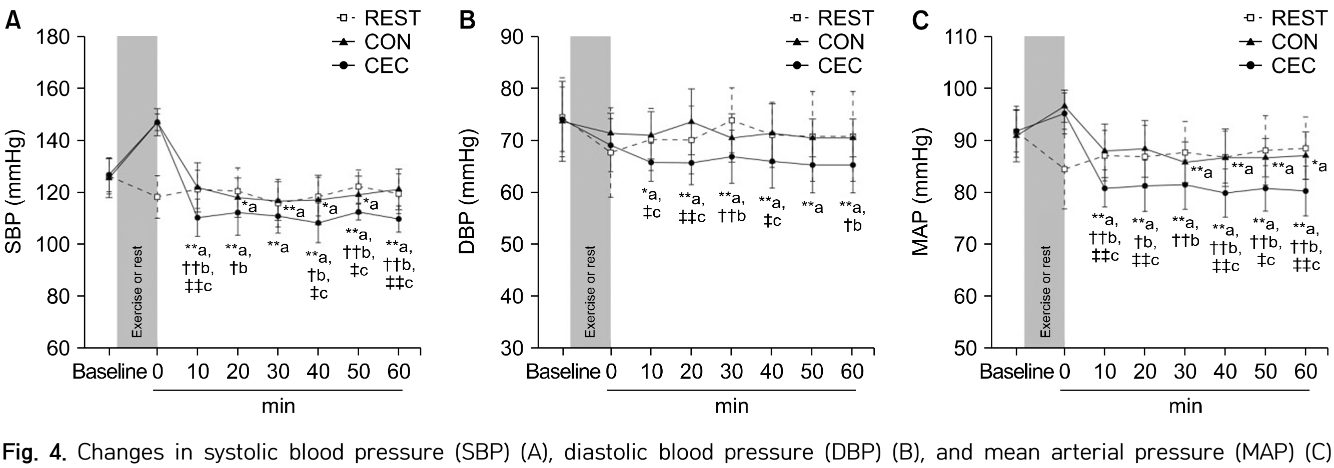

Fig. 4. Changes in systolic blood pressure (SBP) (A), diastolic blood pressure (DBP) (B), and mean arterial pressure (MAP) (C) during the 1-h recovery period following the experimental sessions in the REST, CON, and CEC conditions. The values are presented as mean±SD. *P<0.05 and **P<0.01 (denoted with a) indicate significant differences within the same condition compared with baseline. †P<0.05 and ††P<0.01 (denoted with b) indicate significant differences between conditions compared with the REST condition. ‡P<0.05 and ‡‡P<0.01 (denoted with c) indicate significant differences between conditions compared with the CON condition. REST, resting control condition; CON, exercise control condition; CEC, chicken essence consumption condition.

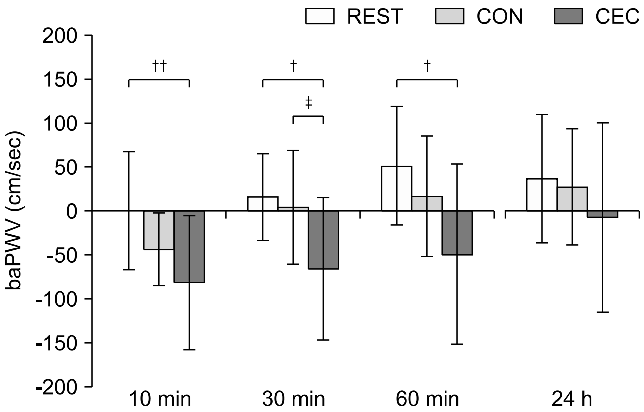

Fig. 5. Changes in baPWV during the 1-h recovery period and at 24 h following the experimental sessions in the REST, CON, and CEC conditions. The values are presented as mean±SD. †*P*<0.05 and ††*P*<0.01 indicate significant differences in the comparison between the CEC and CON conditions versus the REST condition. ‡*P*<0.05 indicates a significant difference between the CEC and CON conditions. baPWV, brachial-ankle pulse wave velocity; REST, resting control condition; CON, exercise control condition; CEC, chicken essence consumption condition.

ized crossover controlled trial that examined the effects of preworkout Betong CEC on PEH and cardiac autonomic and vascular responses in young prehypertensive offspring of hypertensive parents. The main finding of the study was that daily preworkout Betong CEC for seven days could decrease SBP and MAP in young prehypertensive offspring of hypertensive parents. This reduction in SBP, DBP, and MAP was observed as early as 10 min to 12 h after a single exercise session, specifically during nighttime. All participants in the CEC condition exhibited post-exercise SBP and MAP of at least 4 and 3 mmHg, respectively, which were clinically significant. As a result, these findings support the recommendation for the consumption of Betong CE because of its antihypertensive properties. Furthermore, Betong CEC did not result in any adverse effects.

Previous studies have demonstrated a correlation between the magnitude and duration of BP reductions following a single exercise session (known as PEH) and long-term cardiovascular health benefits (Liu et al., 2012; Hecksteden et al., 2013; Wegmann et al., 2018). These findings suggest that the BP reductions observed post-exercise are not merely transient but may reflect a potential for sustained cardiovascular benefits, particularly in individuals with elevated BP or those at risk for HT and other CVDs (Legramante et al., 2002; Pellinger et al., 2010; Franco et al., 2013; Halliwill et al., 2013). Touyz et al. (2004) further found that a 3-mmHg reduction in BP is associated with an 8% reduction in stroke incidence and a 5% reduction in coronary artery disease (CAD). Moreover, data from the Framingham Heart Study indicated that a 2-mmHg reduction in DBP could lead to a 17% decrease in HT prevalence and a 6% reduction in CAD risk (Cook et al., 1995).

Previous clinical trials have reported similar beneficial effects of CE in reducing BP in elderly individuals with cognitive impairment (Szcześniak et al., 2014) and in

Table 2. Changes in heart rate variability over 24 h following the experimental sessions in the REST, CON, and CEC conditions

	REST (n=10)	CON (n=10)	CEC (n=10)	*F*	*P*-value
SDNN (ms)					
24 h	11.1±10.8	20.5±16.6	9.7±9.2	0.218	0.806
Daytime	13.6±16.5	36.5±12.1	10.8±14.4	0.951	0.399
Nighttime	8.7±12.3	4.6±25.0	8.7±5.4	0.021	0.979
RMSSD (ms)					
24 h	−26.0±9.9	12.9±10.8	2.1±6.4*	4.755	0.017
Daytime	−28.1±10.6	21.4±22.0	−4.3±11.7	2.499	0.101
Nighttime	−23.9±9.9	4.4±12.0	8.6±3.4*	3.698	0.038
HF (ms^2)					
24 h	−50.8±129.9	14.7±58.9	15.5±76.4	0.166	0.848
Daytime	−59.8±164.0	−14.5±49.6	−30.2±90.8	0.042	0.959
Nighttime	−41.8±98.5	44.0±84.7	61.1±118.7	0.294	0.747
LF (ms^2)					
24 h	−284.6±252.3	36.5±105.2	−186.2±260.5	0.570	0.572
Daytime	−228.6±279.5	10.2±102.7	−256.8±275.0	0.393	0.679
Nighttime	−340.7±234.0	62.8±134.1	−115.7±271.1	0.839	0.443
LF/HF ratio					
24 h	0.2±0.5	0.2±0.3	−0.4±0.4	0.611	0.550
Daytime	0.7±0.6	0.3±0.4	−0.3±0.4	1.214	0.313
Nighttime	−0.3±0.4	0.0±0.3	−0.4±0.5	0.318	0.730

Values are presented as mean±SEM.
**P*<0.05 indicates significant differences in the comparison between the CEC and CON conditions versus the REST condition.
REST, resting control condition; CON, exercise control condition; CEC, chicken essence consumption condition; SDNN, standard deviation of normal R-R intervals; RMSSD, root mean square of successive differences of R-R intervals; HF, high frequency; LF, low frequency; LF/HF ratio, ratio of absolute LF power to HF power.

those with prediabetes (Liu et al., 2015) and type 2 diabetes (Derosa et al., 2016). However, some studies have found no such effects (Feng et al., 2013; de Courten et al., 2016; Derosa et al., 2016), which may be because of differences in study duration, supplement dosage, and participant characteristics. The present study focuses on a randomized crossover controlled trial to investigate the effects of preworkout Betong CEC on PEH in young prehypertensive offspring of hypertensive parents.

The Betong CE used in this study is rich in amino acids, including glutamic acid, glycine, cysteine, alanine, and arginine. These amino acids may exert antihypertensive effects either directly (Stamler et al., 2009; Vasdev et al., 2009; Dong et al., 2011; Díaz-Flores et al., 2013) or indirectly through their inclusion in angiotensin-converting enzyme (ACE) inhibitory peptides (Saiga et al., 2003; Li et al., 2012), which typically comprise specific amino acids such as glycine, alanine, and cysteine (Saiga et al., 2003; Terashima et al., 2010). ACE, a peptidyl dipeptide hydrolase containing zinc, has active sites that are capable of binding to the guanidine groups of arginine and glutamic acid (Saiga et al., 2003; Terashima et al., 2010). Moreover, CE has been shown to stimulate nitric oxide (NO) production by macrophages (Sim, 2001), which may contribute to its positive effects on vascular function.

Furthermore, the Betong CE used in this study contains high levels of carnosine and anserine. Animal studies have consistently shown that carnosine and anserine supplementation can reduce BP, indicating their potential role in preventing HT (Ririe et al., 2000; Niijima et al., 2002; Tanida et al., 2005; Tanida et al., 2010; Nagai et al., 2012). These studies suggest that carnosine and anserine may exert antihypertensive effects by inhibiting sympathetic activity (Niijima et al., 2002; Tanida et al., 2010; Nagai et al., 2012) and enhancing parasympathetic activity (Kubomura et al., 2010), leading to a reduction in resting BP. In the present study, Betong CEC led to a significant increase in RMSSD, a well-established indicator of parasympathetic activity, with increases of 45% during nighttime and 29% over 24 h following a single exercise session. The abrupt cessation of the central command and activation of the baroreflex enhanced the vagal tone during post-exercise recovery. In addition, a reduction in sympathetic activity contributed to a gradual decrease in BP (Bocalini et al., 2017). However, the association between increased RMSSD and decreased BP did not reach statistical significance.

The present study also examined baPWV, a marker of arterial stiffness (Tanaka et al., 2018). Our results showed a significant reduction in baPWV 1 h after a single exercise session under the CEC condition, whereas no such decrease was observed in the CON condition. Notable differences in baPWV between conditions were observed, especially at 30 min after exercise, but no correlation was observed between baPWV and PEH. The bioactive compounds present in Betong CE likely contribute to its vasodilatory effects. Carnosine has been shown to induce vasodilation through mechanisms independent of the endothelium-mediated production of cyclic GMP (Ririe et al., 2000). Moreover, anserine may facilitate NO release via the PI3K-Akt pathway, thereby promoting vasodilation (Li et al., 2024). Furthermore, the amino acids glycine, cysteine, and arginine, which are abundant in Betong CE, play a role in regulating NO production and enhancing vascular endothelial function by influencing the activity, proliferation, migration, and angiogenesis of endothelial cells (Li et al., 2022). Collectively, these mechanisms contribute to vasodilation, reduce systemic vascular resistance, and result in lower BP.

Another mechanism contributing to BP reduction after a single exercise session involves carnosine, which inhibits glycolytic adenosine 5'-triphosphate (ATP) production while enhancing ATP synthesis in red blood cells (Oppermann et al., 2020; 2021). According to a previous clinical study, a single oral dose of 400 mg of ATP administered 30 min before exercise amplified the effect of PEH in hypertensive women, indicating a potential link between increased ATP levels and PEH (de Freitas et al., 2018). However, further research is needed to explore this mechanism.

Our study has several limitations that should be acknowledged. First, although participants were instructed to avoid vigorous physical activity, caffeinated products, and alcohol 24 h before the experimental sessions and to maintain consistent sleep patterns, we did not objectively verify their adherence to these guidelines. However, we did monitor and track the dietary intake of participants, focusing specifically on sodium consumption throughout the study. Second, our sample consisted exclusively of young, prehypertensive male offspring of hypertensive parents, which may limit our findings' generalizability to other hypertensive populations or to females. Finally, although our study did not include a placebo control, we employed a randomized crossover design, enabling each participant to act as their own control. This approach minimizes bias and clarifies the true effects of Betong CE. Moreover, we implemented single blinding for the researchers analyzing the data to prevent expectation bias, ensuring that the observed effects can be attributed to the intervention itself. Our rigorous analysis of comparisons between Betong CE and control conditions further supports the conclusion that the effects observed in the Betong CE group are likely due to the intervention rather than placebo responses.

In conclusion, the preworkout consumption of Betong CE resulted in a clinically significant post-exercise reduction in SBP and MAP of at least 4 and 3 mmHg, respectively, in young prehypertensive offspring of hypertensive parents. The decrease in BP was noticeable as early as 10 min and up to 12 h after a single exercise session, particularly at night. Based on the findings, the consumption of Betong CE may not only improve vagal reactivation but also reduce the baPWV response to a single exercise session, potentially leading to reduced BP. Taken together, from a nutritional perspective, the long-term consumption of Betong CE may offer potential preventive and therapeutic benefits for HT. Further research should thoroughly investigate the precise mechanistic effects of the long-term consumption of Betong CE on BP.

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AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Concept and design: JP, SN. Analysis and interpretation: JP, PT. Data collection: JP, PT. Product preparation and identification: SN, SW. Writing the article: JP, SW. Critical revision of the article: JP. Final approval of the article: all authors. Statistical analysis: JP, SW. Overall responsibility: JP.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found via https://doi.org/10.3746/pnf.2024.29.4.394

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