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Interaction effect of green tea consumption and resistance training on office and ambulatory cardiovascular parameters in women with high-normal/stage 1 hypertension

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Abstract

This study aimed to investigate the chronic effects of green tea (GT) extract and resistance training (RT) on ambulatory and office blood pressure (BP), heart rate (HR), and rate-pressure product (RPP) in a sample of Iranian women with high-normal/stage 1 hypertension. Forty-four middle-aged sedentary women participated in this randomized, double-blind, placebo-controlled study. They were randomly assigned to one of four groups: GT and RT (GR, $n = 11$), RT ($n = 10$), GT ($n = 10$), or control ($n = 13$). Three weeks of GT consumption were followed by six weeks of the interaction with RT. GR and RT groups performed two circuits of RT at %50 of 1RM two days per week. RT and control groups also received placebo (maltodextrin) with the same timing. The changes of each variable from baseline to post-intervention were compared between the groups using the ANOVA test, and effect size (ES) statistic was also calculated. In comparison with the control group, significant reductions were found for office systolic BP (SBP, 8%, ES = 1.22), and 24 h-SBP (5%, ES = 1.2) in the RT group. However, GR group showed significant decreases in office SBP (10.5%, ES = 1.45), mean BP (8%, ES = 1.11), RPP (13%, ES = 1.47), 24 h-SBP (5%, ES = 1.21), and 24 h-RPP (10%, ES = 1.15). The interaction of regular RT and GT consumption seems to induce more beneficial effects on some important parameters including MBP and RPP when compared to RT or GT alone.

1 | INTRODUCTION

High blood pressure (BP) or hypertension, defined on the basis of BP ≥ 140/90 mmHg,[1] is a multifactor disease leading to the development of cardiovascular disease worldwide. Hypertension affects about 30%-50% of Iranian population,[2] and the importance of controlling HTN in the prevention of future cardiovascular events has been emphasized in most studies.[3]

Resistance training (RT) found to reduce BP within minutes to hours after exercise in women with hypertension.[2,4,5] However, there have been controversies regarding the chronic effects of RT on resting BP in subjects with hypertension.[6-11] For example, two studies[6,11] reported significant reductions in both systolic (SBP) and diastolic (DBP) BP, but no significant reductions were found in other studies.[7,9] Nevertheless, it has been concluded that both dynamic and static RT have a beneficial effect on resting BP in adults with optimal pressure and/or prehypertension.[12] Overall, more recent meta-analyses in this regard have shown that RT programs alone can reduce SBP and DBP in adults with hypertension.[13-15] Therefore, it seems that dynamic RT should be considered as an effective stand-alone antihypertensive lifestyle therapy.

In addition to BP, heart rate (HR) and rate-pressure product (RPP) are two accessible indicators of heart work. Resting HR, as a familiar clinical biomarker reflecting the sympathetic and parasympathetic nerve control, is inversely associated with cardiovascular morbidity and mortality.[16] RPP is also recognized as a very reliable and widely used measure of myocardial workload based on the product of HR and SBP.[17] Therefore, similar to SBP, HR should be taken into account in patients with hypertension, which in turn helps to keep RPP under control and to prevent future cardiovascular events.

Green tea (GT), a product made from the *Camellia sinensis* plant, is the major source of antioxidant polyphenols such as catechins and flavonols.[4] Epigallocatechin-3-gallate (EGCG) is the primary catechin species in GT, and it seems that the beneficial effects of GT are mainly related to its antioxidant activity owing to higher EGCG content.[18] Some studies have been reported that the prolonged consumption of GT or GT components resulted in a decrease in BP.[19–22] In an epidemiological study, daily GT consumption for at least 1 year appeared to reduce the risk of developing hypertension in 1507 Taiwanese subjects who were previously normotensive.[19] Likewise, Garcia and colleagues concluded that short-term treatment with GT may decrease BP.[20] However, some other data do not support the hypotensive effect of GT consumption over a period of 3 weeks,[23] 6 weeks,[24] or 8 weeks.[25]

Collectively, the pooled data demonstrate that RT program and GT supplementation may be beneficial for the cardiovascular parameters. Nonetheless, the interaction effect of these two separate factors has been received less attention. Although the combination of RT with GT intake resulted in a significant improvement in body composition and several blood lipids,[26] it has been reported that the addition of GT consumption to an aerobic training protocol was not effective to modify other cardiovascular risk factors such as HR.[27] In contrast, our previous results showed that three weeks consumption of GT have a favorable effect on RPP and MBP responses to an acute session of RT.[4] Considering that a short period of GT consumption could change RPP and BP responses, the interaction of RT and GT consumption may have positive effects on cardiovascular health in hypertensive adults beyond the separate effects of each. The main purpose of this study, therefore, was to examine whether a longer period of simultaneous GT consumption and RT would alter ambulatory and office BP, as well as HR and RPP in women with high BP. The initial hypothesis of the study was that regular RT together with GT consumption might have additional effects on the cardiovascular parameters compared with RT or GT alone.

2 | MATERIALS AND METHODS

2.1 | Participants

Women aged between 35 and 55 years old referred to the hospital of the Heshmat Educational & Remedial Center of Rasht, Guilan province, were eligible for the present study. Women with diagnosed hypertension were consecutively included over this period. In all women included, hypertension was diagnosed using consecutive measurements of BP in standard condition. However, some women had a history of hypertension and were taking antihypertensive medications (Table 1). The participants had either mean SBP of >120 to 160 mmHg or mean DBP of >80 to 100 mmHg. The average baseline BP is presented in Table 1. These values are considered as high-normal BP to stage 1 essential hypertension.[28] Moreover, all participants had a 24 h ambulatory BP higher than 120/80 and lower than 160/100 mmHg.

Exclusion criteria were smoking, any musculoskeletal or renal diseases, cancer, regular physical activity (2 ≥ exercise sessions/week) prior to the study for a minimum period of six months, pregnancy, and menopause or any disturbances in the menstrual cycle. To ensure the cardiovascular health, all participants received a resting 12-lead electrocardiogram and a cardiac stress test. A total of 49 women volunteered to complete the study. After initial dropout, the remaining participants (n = 44) were randomly assigned to one of four groups: GT consumption and RT (GR), RT (RT protocol plus placebo consumption), GT (GT consumption without exercise training), and control (placebo consumption without exercise training). In order to a more accurate randomization, 44 bottles containing GT supplement or placebo capsules (22 bottles of GT and 22 bottles of placebo) were placed in a non-transparent bag and the participants were asked to take one bottle. The bottles were prepared and coded as A (GR group, bottles containing GT), B (RT group, bottles containing placebo), C (GT group, bottles containing GT), and D (control group, bottles containing placebo) in a double-blind manner by an expert pharmacist who was not involved in the study procedures. This study was conducted in accordance with the Declaration of Helsinki. Each participant received a comprehensive verbal and written description of the study and signed an informed consent form approved by the institutional review board of the University of Guilan (DRT-7971) (Figure 1).

2.2 | Nutritional controls and supplementation

The participants were asked to maintain their current activity and dietary routines throughout the study. To maintain consistency, dietary intake was monitored by self-report through a 3-day food diary over one week (2 working days and 1 weekend day) prior to pre-test measurements. In order to obtain more accurate reports, both written and verbal instructions including portion sizes by household measures, exact brand names, and preparation technique were given to the participants. The participants then received some recommendations on how to observe a 2200-2500-cal diet (reflecting typical energy intake according to their food diary reports) and were asked to not modify their diet until the end of the study. They have also been instructed to refrain from consuming any products containing GT and limiting the intake of caffeine-containing drinks (especially black tea) to one cup per day.

TABLE 1 Different characteristics of the participants

	GR (n = 11)	RT (n = 10)	GT (n = 10)	Control (n = 13)	p
Age (years)	47.63 ± 4.75	45.3 ± 5.94	49.5 ± 5.6	46.15 ± 5.33	.32
Height (cm)	161.27 ± 5.71	163.1 ± 5.6	166.8 ± 5.45	164.84 ± 4.39	.11
Weight (kg)	71.63 ± 8.2	72.2 ± 4.41	74.3 ± 8.84	73.3 ± 6.54	.83
BMI (kg/m^2)	27.6 ± 3.47	27.2 ± 2.26	26.66 ± 2.43	26.98 ± 2.18	.86
Body fat (%)	27.13 ± 4.63	26.32 ± 4.31	26.45 ± 1.83	26.25 ± 3.98	.94
VO$_{2max}$ (ml kg^{-1} min^{-1})	19.52 ± 4.3	18.27 ± 2.41	20.91 ± 6.41	19.76 ± 4.82	.66
Dietary intake					
Energy intake (Cal)	2343 ± 256	2420 ± 221	2384 ± 275	2397 ± 245	.91
Sodium (g)	2.41 ± 0.52	2.85 ± 0.49	2.77 ± 0.7	2.66 ± 0.62	.36
Potassium (g)	3.46 ± 0.78	3.67 ± 0.93	3.58 ± 0.98	3.84 ± 0.87	.76
Hemodynamic parameters					
Systolic BP (mmHg)	133.18 ± 5.6	135 ± 8.16	130 ± 14.71	136.15 ± 10.03	.51
Diastolic BP (mmHg)	87.27 ± 6.06	85 ± 7.45	81.5 ± 8.83	86.53 ± 6.57	.27
Mean BP (mmHg)	102.57 ± 4.9	101.66 ± 6.28	97.66 ± 10.21	103.07 ± 7.06	.32
Heart rate (b.min^{-1})	79.72 ± 5.69	78.2 ± 8.4	73.7 ± 8.26	78.23 ± 6.46	.27
RPP (mmHg.b.min^{-1})	106.16 ± 8.88	105.5 ± 12	96.39 ± 19.67	106.93 ± 15.7	.32
Concomitant diseases					
Hyperlipidemia	2 (18%)	3 (30%)	3 (30%)	3 (23%)	
Diabetes mellitus	4 (36%)	3 (30%)	2 (20%)	3 (23%)	
Family history of CVD	3 (27%)	2 (20%)	2 (20%)	4 (31%)	
Sleep disorders	2 (18%)	1 (10%)	3 (30%)	2 (15%)	
Antihypertensive medication					
Beta-blocker	3 (27%)	4 (40%)	4 (40%)	5 (38%)	
ACE inhibitor	5 (46%)	4 (40%)	3 (30%)	2 (16%)	
Calcium channel blocker	3 (27%)	2 (20%)	3 (30%)	6 (46%)	

Note: Data are presented as mean ± standard deviation.

Abbreviations: ACE, angiotensin-converting enzyme; BP, blood pressure; CVD, cardiovascular disease; GR, green tea and resistance training; GT, green tea; RPP, rate-pressure product; RT, resistance training.
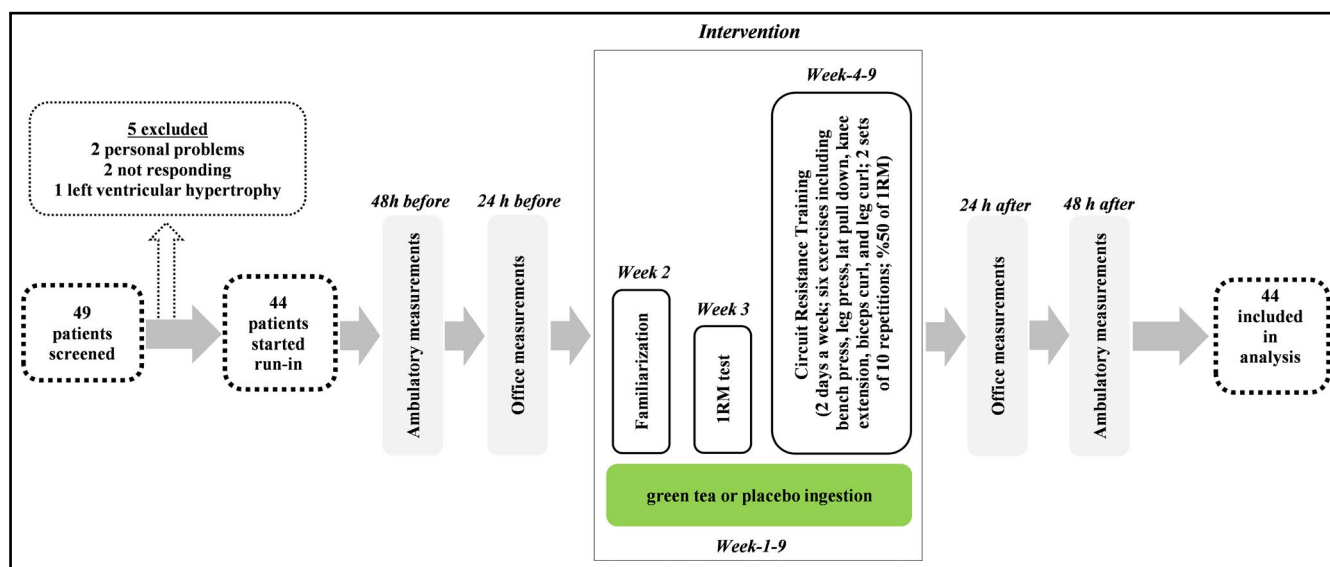

FIGURE 1 Graphical description of study timeline. Office and ambulatory cardiovascular variables were measured before and after the intervention

A randomized, double-blind, placebo-controlled design was employed over a 9-week intervention. The bottles and capsules with the same colors, shapes, and sizes were used to assure the content of the bottles (GT or placebo) was remained indiscernible to the participants and researchers. All the capsules were also scorched with GT to minimize any differences between them. The participants ingested 2 capsules (500 mg) per day[18] containing either GT extract (~245 mg total polyphenols; ~75 mg EGCG; and ~25 mg caffeine) or placebo (~490 mg maltodextrin) after lunch and dinner besides their usual medication. Furthermore, daily doses, types, and timings of medications did not change during the study period. We ensured about the ingestion of the GT capsules through regular and repeated contact with the participants. They were not taking any capsules on the measurement days and were instructed to avoid the consumption of caffeine-containing items (tea, coffee, chocolate, and energy drinks) for at least 3 h before the measurements.

2.3 | Familiarization sessions and RT protocol

Anthropometric data were collected on the initial visit to the laboratory. The body fat percentage was determined by measuring skinfolds thickness at three sites[29] using a standard skinfold caliper (Lafayette Instrument Co). The participants were familiarized with RT machines and devices, correct technique, the normal range of motion and suitable breathing in two separate days. In these sessions, they performed 2 sets of 15 repetitions without load. The upper- and lower-body 10-repetition maximum (10RM) tests were carried out 72 h after the familiarization days, in the same order. 1RM records were calculated using the Equation (1) below.[30]

$$1RM = \frac{weight\,(kg)}{1.0278 - (0.0278 \times number\,of\,repetitions)} \quad (1)$$

The exercise protocol was designed according to the American College of Sports Medicine (ACSM) recommendations[31] and recent meta-analysis results.[14,15] The program consisted of six weeks of circuit RT with resistance machines and was performed 2 days a week in the afternoon (4-6 PM). In each RT session, six exercises including bench press, leg press, lat pull-down, knee extension, biceps curl, and leg curl were carried out after 10 min of warm-up consisting of walking and static stretching. In these sessions, they performed 2 sets of 10 repetitions with the intensity of %50 of 1RM. Rest intervals between the sets and circuits were 2 min.

2.4 | Office measurements and experimental procedure

Office BP (standard mercury sphygmomanometer; ALP K2; 300-V-EU) and HR (automatic HR monitor; Beurer; PM80) were assessed 24 h before and after the first and final session of RT, respectively. In these sessions, after seated rest for at least 5 min, BP and HR were measured manually at the brachial artery. Each measurement was performed three times at 5 min intervals, and the average value of them was calculated. The first and fifth Korotkoff sounds were used for SBP and DBP, respectively. Additionally, an appropriate-sized cuff (cuff bladder encircling two-thirds of the circumference of the upper arm) was used to ensure accuracy.[32]

The participants were familiar with the measurement environment, procedure, and equipment to reduce stress during study days. All the measurements were performed in a sound-attenuated, temperature-controlled (21-24°C) room, at the same time of the day (4-6:30 PM) and the same order for each participant. All the study variables were measured by the same observer who was masked to the treatment the participant received. All participants were instructed to refrain from eating or ingesting caffeine 3 h before the tests. During the preliminary session, the participants received their GT or placebo capsules in a randomized order and were asked to take them for three weeks to ensure there was no problem in taking the capsules. In the third and fourth sessions, the 1RM test was carried out and the six-week RT protocol began days later.

2.5 | Monitoring ambulatory BP

Twenty-four-hour SBP, DBP, MBP, and HR were tracked in the non-dominant arm by the Oscar 2 oscillometric ambulatory BP monitor (SunTech Medical®, Model 222) 48 h before the initiation of the RT program and 48 h after the final session of training protocol. The cuff size was adapted to the circumference of the upper arm of each patient according to the manufacturer's instructions. The cardiovascular parameters were measured every 30 min throughout the daytime (8:00 AM-11:00 PM) and every 60 min throughout the nighttime (12:00 AM-7:00 AM).[33] The values were then averaged and were expressed as mean 24 h, daytime, and nighttime ambulatory BPs. All participants received instructions to maintain their normal daily activities and to stop moving the arm and relax it during measurements. The cardiovascular measurements were considered invalid for statistical analysis if >30% of the measurements were missing, or if the values were missing over a period of >2 h.

2.6 | Data analysis

G*Power software, version 3.1.9.4,[34] was used to calculate the sample size required for the present study. Using a statistical power of 0.85 and an effect size of 0.75, a total sample size of at least 28 participants was necessary to test our hypothesis at $P < .05$. Data analysis was performed using SPSS for WINDOWS software program (version 18®; SPSS Inc, Chicago, IL). Prior to statistical analysis, all data were tested for normality using the Shapiro-Wilk test. Within-group differences were tested using the paired samples t test. Analysis of variance (ANOVA) was also used to compare the study groups at baseline and regarding the changes from pre- to post-intervention (Δ = post–pre). Multiple comparisons by the Tukey

TABLE 2 Cardiovascular variables measured pre- and post-experimental protocol in green tea and resistance training (GR), resistance training (RT), green tea (GT), and control groups

	GR			RT			GT			Control		
	Pre	Post	ES	Pre	Post	ES	Pre	Post	ES	Pre	Post	ES
Clinical measurements												
SBP (mmHg)	133.18 ± 5.6	119.09 ± 8.31**††	1.45	135 ± 8.16	120 ± 11.3**††	1.22	130 ± 14.71	125 ± 11.54*	0.8	136.15 ± 10.03	135.38 ± 7.76	0.13
DBP (mmHg)	87.27 ± 6.06	81.81 ± 8.73	0.64	85 ± 7.45	82.5 ± 11.36	0.18	81.5 ± 8.83	80.5 ± 10.12	0.08	86.53 ± 6.57	87.3 ± 8.8	−0.08
MBP (mmHg)	102.57 ± 4.9	94.24 ± 7.46*†	1.11	101.66 ± 6.28	95 ± 9.55	0.57	97.66 ± 10.21	95.33 ± 8	0.26	103.07 ± 7.06	103.33 ± 6.87	−0.03
HR (b.min^{-1})	79.72 ± 5.69	78.00 ± 9.25	0.21	78.2 ± 8.4	77.9 ± 7.03	0.06	73.7 ± 8.26	74.5 ± 7.48	−0.08	78.23 ± 6.46	79 ± 7.68	−0.17
RPP (mmHg.b.min^{-1})	106.16 ± 8.88	92.62 ± 9.86*†	1.47	105.5 ± 12	93.48 ± 11.91**	1.61	96.39 ± 19.67	93.41 ± 15.54	0.21	106.93 ± 15.7	107.11 ± 13.72	−0.02

Note: Data are presented as mean ± standard deviation.

Abbreviations: DBP, diastolic blood pressure; ES, effect size (Cohen's *d*); HR, heart rate; MBP, mean blood pressure; RPP, rate-pressure product; SBP, systolic blood pressure.

*p < .05 vs pre, **p < .01 vs pre, †p < .05 vs control, ††p < .01 vs control.

method were also used as post hoc when necessary. In addition, effect size statistics were calculated using Cohen's *d* and partial eta squared (η_P^2) for within-group and between-group comparisons, respectively. The magnitudes were considered as small, 0.20; moderate, 0.60; large, 1.2; and very large, 2.0 for Cohen's *d* and small, 0.01; medium, 0.06; and large, 0.14 for η_P^2.[35]

3 | RESULTS

The participants showed optimal adherence (100%) to the RT protocol and GT consumption. The RT protocol and GT consumption were well tolerated by all participants, and no adverse events occurred during the study period. With regard to total training volume (sets × repetitions × load), there was no significant difference between the GR (2125 ± 667.4 kg) and the RT (2162.5 ± 394 kg) groups.

Throughout the study period, 44 eligible women with the average age of 47.09 ± 5.44 years were screened and included in the final statistical analysis (Table 1). Pairwise comparison between the groups revealed that the GT and GR groups had the highest age (49.5 ± 5.6 years) and BMI (27.6 ± 3.47 kg/m^2), respectively, while the control group had the lowest body fat percentage (26.25 ± 3.98) among all the groups. However, these differences did not reach significance in between-group comparisons (p > .05). In addition, the study groups were similar at baseline, with no significant differences noted in SBP (p = .51), DBP (p = .27), MBP (p = .32), HR (p = .27), and RPP (p = .32). Out of 44 hypertensive women included in our research, 11 (25%) participants had hyperlipidemia, 12 (27%) had diabetes mellitus, 11 (25%) had a family history of cardiovascular disease, and 8 (18%) had sleep disorders.

As presented in Table 1, there were no statistically significant differences between the groups in any of the dietary measures (ie, approximate amount of energy, sodium, and potassium) according to the 72-h food records.

No significant alterations in office variables were observed after the study protocol in the control group (Table 2). In comparison with the pre-intervention office values, no significant reductions were found for resting DBP, whereas the decreases observed in resting SBP in the GR (Δ = −14 ± 9.7 mmHg, p = .001, *d* = 1.45), RT (Δ = −15 ± 12.2 mmHg, p = .004, *d* = 1.22), and GT (Δ = −5 ± 6.2 mmHg, p = .03, *d* = 0.8) groups were statistically significant. While resting MBP (Δ = −8.3 ± 7.4 mmHg, p = .004, *d* = 1.11) and RPP (Δ = −13.5 ± 9.1 mmHg.b.min^{-1}, P = .001, *d* = 1.47) levels were decreased significantly after the intervention in the GR group, only RPP decreases were significant in the RT group (Δ = −12 ± 7.4 mmHg.b.min^{-1}, p = .001, *d* = 1.61). HR also did not change in any of the groups.

The ANOVA test showed that the total alterations of DBP (F = 1.12, p = .35, η_P^2 = 0.08) and HR (F = 0.65, p = .58, η_P^2 = 0.05) were not significant among the groups (Table 2). However, significant differences in regard to SBP (F = 7.18, p = .001, η_P^2 = 0.35), MBP (F = 3.52, p = .02, η_P^2 = 0.21), and RPP (F = 3.57, p = .02, η_P^2 = 0.21) were observed. As a result, Tukey post hoc test was used to identify
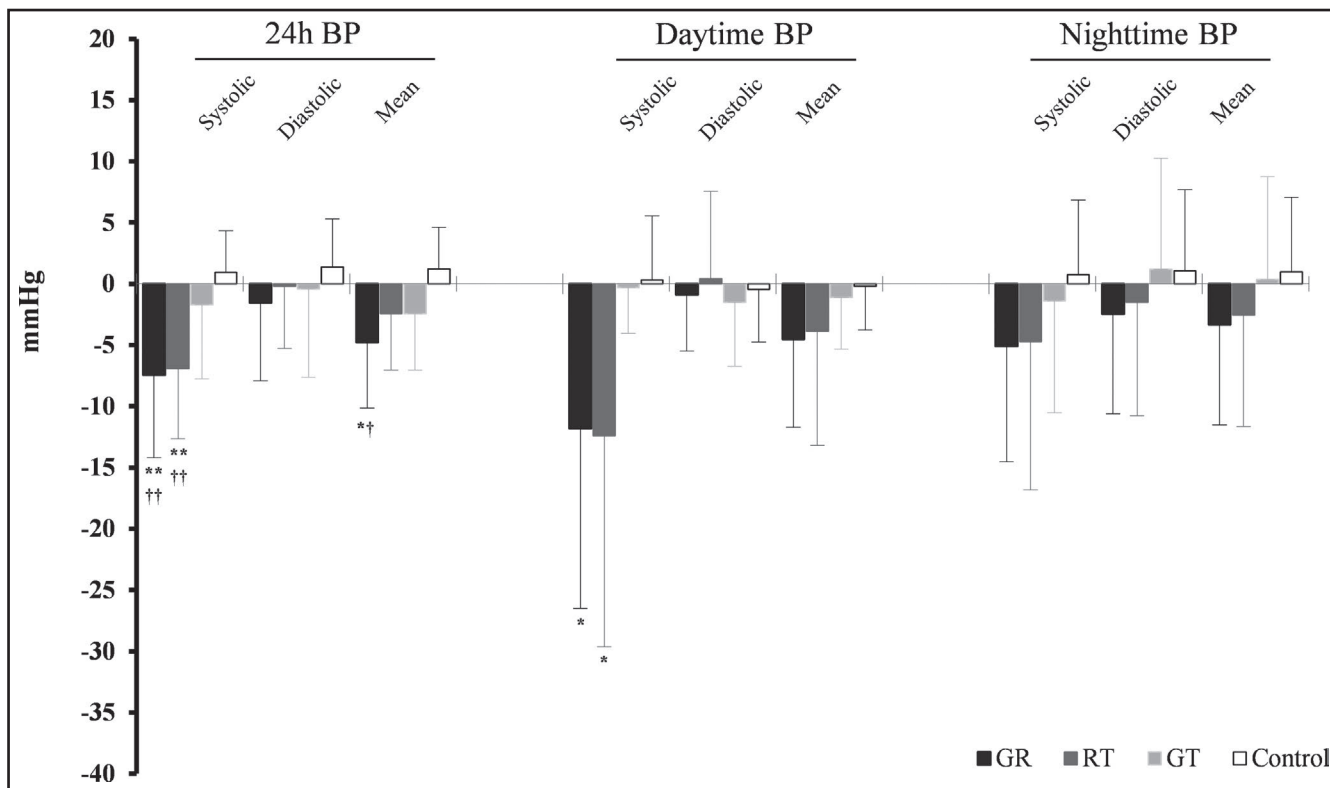
FIGURE 2 Ambulatory blood pressure (BP) differences in green tea and resistance training (GR), resistance training (RT), green tea (GT), and control groups. *$P < .05$ and **$P < .01$ vs pre, †$P < .05$ and ††$P < .01$ vs control
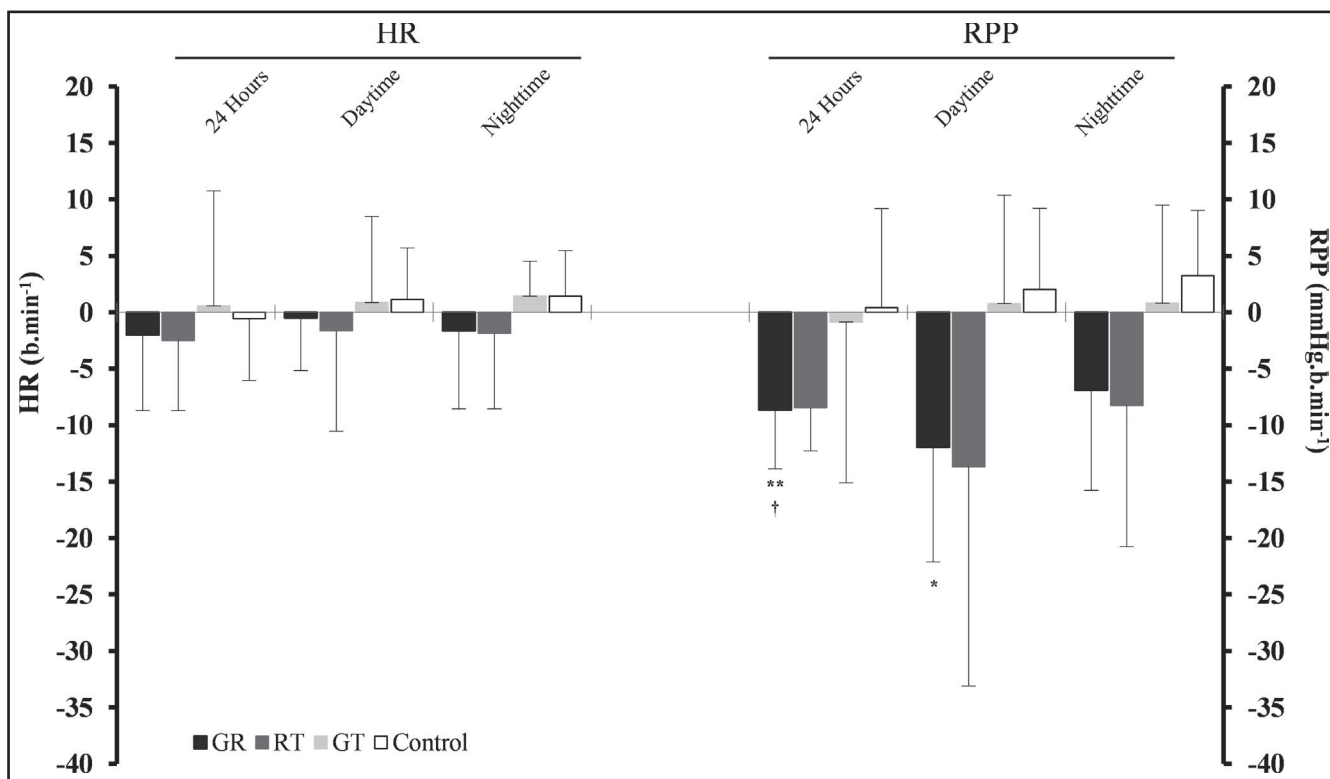

FIGURE 3 Ambulatory heart rate (HR) and rate-pressure product (RPP) differences in green tea and resistance training (GR), resistance training (RT), green tea (GT), and control groups. *$P < .05$ and **$P < .01$ vs pre, †$P < .05$ vs control

where mean differences existed. The GR (p = .001) and RT (p = .003) groups had a lower SBP compared to the control group after the intervention. Moreover, resting values of MBP (p = .03) and RPP (p = .04) were significantly lower for the GR group when compared with the control group. There was also a trend for lower values of MBP and RPP in the RT (p = .07) and GT (p = .09) groups, although this did not reach statistical significance.

The ambulatory variables did not change after the intervention in the control group (Figures 2 and 3). In comparison with the pre-intervention ambulatory values, 24 h-SBP (Δ = −7.4 ± 6.7 mmHg, p = .003, d = 1.21), 24 h-MBP (Δ = −4.7 ± 5.3 mmHg, p = .01, d = 0.89), 24 h-RPP (Δ = −12 ± 10.4 mmHg.b.min^{-1}, p = .003, d = 1.15), daytime SBP (Δ = −11.8 ± 14.6 mmHg, p = .02, d = 0.8), and daytime RPP (Δ = −9.6 ± 11.4 mmHg.b.min^{-1}, p = .02, d = 0.84) were significantly decreased in the GR group. It also seems that six weeks of RT reduced 24 h-SBP (Δ = −6.9 ± 5.7 mmHg, p = .004, d = 1.2) and daytime SBP (Δ = −12.4 ± 17.2 mmHg, p = .044, d = 0.72) in the RT group.

Statistically significant differences were observed when we compared the study groups in the total changes of 24 h-SBP (F = 6.26, p = .001, η_P^2 = 0.32), 24 h-MBP (F = 3.1, p = .03, η_P^2 = 0.19), and 24 h-RPP (F = 4.05, p = .01, η_P^2 = 0.23) at the end of the study (Figures 2 and 3). Post hoc comparisons showed that the values of 24 h-SBP were significantly decreased in the GR (p = .004) and RT (p = .009) groups compared to the control group. The average values of 24 h-MBP (p = .02) and 24 h-RPP (p = .01) also showed significant differences between the GR and control groups. Although the total alterations of daytime SBP (F = 4.08, p = .01, η_P^2 = 0.23) and RPP (F = 3.07, p = .03, η_P^2 = 0.19) were significant among the groups, there was only a tendency toward decreased levels in the GR group compared with the control group (p > .05). Likewise, other differences found among the groups did not reach statistical significance (p > .05).

4 | DISCUSSION

This study investigated the benefits of the regular RT and GT consumption with respect to some of the most important cardiovascular variables in sedentary hypertensive women. We hypothesized that a period of RT might have more positive effects on the office and ambulatory parameters when combined with GT consumption. The results showed that six weeks of low-intensity RT could reduce office resting SBP compared to the sedentary control group, and concurrent consumption of GT had only a small additional effect on these changes (10.5%, d = 1.45% vs 8%, d = 1.22 for the GR and RT groups, respectively) and also decreased resting values of MBP (8%, d = 1.11). Furthermore, although both the GR and RT groups showed a decrease in office SBP and RPP from pre- to post-intervention, there was no significant difference among these two groups.

The findings confirm previous reports showing the benefits of RT in lowering BP among hypertensive individuals.[2,4,6] Collier and colleagues reported that a 4-week RT protocol consisting of three sets of 10 repetitions at 65% of 10RM decreased resting SBP and DBP in pre- and stage-1 hypertensive women and men. Similar studies have also been conducted on obese women. Nascimento and colleagues investigated the variability of BP response to a 10-week RT program among twenty-seven hypertensive and 12 normotensive elderly women. At the end of the study period, both the hypertensive and normotensive women presented a significant decrease in resting SBP.[10]

The average reductions in SBP observed in the present study was 14-15 mmHg, which is clinically relevant because it has been estimated that even a reduction of as little as 3 mmHg in average SBP can lower coronary heart disease by 5%-9%, stroke by 8%-14%, and all-cause mortality by 4%.[28] In contrast to our findings on resting BP, Cononie and colleagues[36] did not find a significant reduction due to regular RT in elderly men and women. However, their subjects were older (aged between 70 and 79 years) when compared to our cohort, and it seems that their exercise intensity (one set to failure) was too strenuous for decreasing BP.[6]

It was also observed that nine weeks ingestion of GT decreased resting SBP in the GT group by 5 mmHg from those at the pre-intervention. To the best of our knowledge, this is the first intervention study to investigate the effects of regular GT ingestion on cardiovascular variables among patients with hypertension. Thus, comparing the present results with relevant findings from previous animal or epidemiological findings is difficult. However, our results are in agreement with some studies. In a more recent trial conducted by Garcia and colleagues, a model of hypertension-induced Wistar rats characterized by sympathoexcitation was treated with GT for one week. Their results showed a significant reduction in BP in the GT group. Epidemiological data have also demonstrated that habitual GT consumption significantly reduces the risk of developing hypertension in human adults.[19] As proposed by previous studies,[20,37] these beneficial effects of GT may be due to the antioxidant properties of its catechin species, especially EGCG. For this reason, the regular consumption of GT is recommended as an interesting alternative to other drinks.

To date, the studies regarding the chronic effects of RT on ambulatory cardiovascular parameters have been limited in the hypertensive populations. The current study indicated that RT alone is able to induce favorable effects on 24 h-SBP (5%, d = 1.2) and daytime SBP (8%, d = 0.72). However, nine weeks consumption of GT together with six weeks of regular RT could lead to a decrease in 24 h-SBP (5%, d = 1.21), 24 h-MBP (4.5%, d = 0.89), daytime SBP (8%, d = 0.8), 24 h-RPP (10%, d = 1.15), and daytime RPP (9%, d = 0.84). Our findings are similar to those reported by Montrezol and colleagues[38] who showed significant decreases in 24 h and daytime SBP in the sedentary hypertensive men and women following 16 weeks of low-intensity RT (50% of 1RM). These observations revealed that the addition of GT consumption to regular RT program can induce more desirable effects on ambulatory BP. Therefore, daily GT consumption may be more clinically relevant to those at risk of cardiovascular events.

In the present study, similar to that of Montrezol and colleagues, no significant differences existed among the groups for the

ambulatory DBP. In contrast, Tibana and colleagues[39] reported that a period of regular RT could decrease 24 h and nighttime DBP in women with metabolic syndrome who had high-normal BP. The discrepancy between these findings and ours may be due to the different training variables (3 sessions/week for 8 weeks) compared with our study (2 sessions/week for 6 weeks). We also observed that 24 h-MBP and RPP, and daytime RPP were decreased in the GR group compared with pre-intervention values, indicating that interaction effect of RT program and GT consumption is more effective regarding to the hemodynamic variables. The magnitude of RPP was not calculated in the studies conducted by Montrezol and colleagues and Tibana and colleagues. However, the average reductions of 24 h and daytime RPP in the present study were 12 and 10 mmHg.b.min^{-1}, respectively, which can be important clinically according to the fact that the high RPP levels would develop the risk of cardiovascular disease.[4] These findings also demonstrate that despite the lack of any significant reductions in ambulatory HR, these reductions were enough to reduce RPP in the GR group.

The causal mechanisms responsible for these observations are not clear. However, it is possible that acute post-exercise hypotension induced by RT may generate some vascular adaptations (ie, a reduction in peripheral vascular resistance) in long-term basis.[4,28,40,41] Decreased sympathetic nervous system activity together with increased local release of nitric oxide, prostaglandins, adenosine, and ATP are the main reasons for the fall in peripheral vascular resistance after low-intensity exercise training.[4,40] Moreover, because of having EGCG, GT may increase NO production through phosphoinositide-3-kinase dependent pathways, which is favorable for cardiovascular health.[21]

5 | STUDY LIMITATIONS

The present study encountered several limitations. The patients were selected form the main cardiovascular center in the province, but selecting participants from a single center may have limited generalizability of the results. Sixteen participants were taking beta-blockers with the same dose and timings in the whole investigation period (Table 1). Although the amounts of tea and other dietary intakes were monitored by food diary, the exact amount of catechin intake and other supplements was not controlled separately. Moreover, although all participants were instructed to maintain their routine physical activity levels on the day they had been used the ambulatory BP device and also throughout the training weeks, workload control was not carried out separately.

6 | CONCLUSIONS

The results obtained in the present study allow us to assert that regular low-intensity RT can lead to a reduction in office and ambulatory cardiovascular parameters, and GT ingestion may have additional effects regarding some parameters including MBP and RPP. Thus, it seems that our initial hypothesis was confirmed. However, more research with higher doses of EGCG or more duration of GT ingestion may be helpful in understanding the effects of GT on the ambulatory and office BP and other important cardiovascular factors in humans.

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REFERENCES

1. Mancia G, Fagard R, Narkiewicz K, et al. 2013 ESH/ESC guidelines for the management of arterial hypertension: the Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *J Hypertens*. 2013;22(4):1281-1357.
2. Ghobadi M, Hoseini R, Hoseini Z. Effects of moderate-intensity resistance exercise on blood pressure in hypertensive individuals. *Cent Eur J Sport Sci Med*. 2016;4(16):5-12.
3. Arazi H, Asadi R, Taati B. Exercise training in thermo-mineral spring water has beneficial effects on hemodynamic and health-related factors in young-older hypertensive women: a randomized control trial. *J Women Aging*. 2020;32(3):279-291.
4. Arazi H, Samami N, Kheirkhah J, Taati B. The effect of three weeks green tea extract consumption on blood pressure, heart rate responses to a single bout resistance exercise in hypertensive women. *High Blood Press Cardiovasc Prev*. 2014;21(3):213-219.
5. Faraji H, Dabbagh NS. Effect of concurrent exercise on Post-Exercise hypotension in borderline hypertensive women: influence of exercise intensity. *Kinesiol Int J Fundam Appl Kinesiol*. 2012;44(2):166-172.
6. Collier S, Kanaley J, Carhart R, et al. Effect of 4 weeks of aerobic or resistance exercise training on arterial stiffness, blood flow and blood pressure in pre-and stage-1 hypertensives. *J Hum Hypertens*. 2008;22(10):678-686.
7. Wood R, Reyes R, Welsch M, et al. Concurrent cardiovascular and resistance training in healthy older adults. *Med Sci Sports Exerc*. 2001;33(10):1751-1758.
8. Moeini M, Salehi Z, Sadeghi M, Kargarfard M, Salehi K. The effect of resistance exercise on mean blood pressure in the patients referring to cardiovascular research centre. *Iran J Nurs Midwifery Res*. 2015;20(4):431-435.
9. Shim K-S, Kim J-W. The effect of resistance exercise on fitness, blood pressure, and blood lipid of hypertensive middle-aged men. *J Exerc Rehabil*. 2017;13(1):95-100.

10. Nascimento DDC, da Silva CR, Valduga R, et al. Blood pressure response to resistance training in hypertensive and normotensive older women. *Clin Interv Aging*. 2018;13:541-553.

11. Sarsan A, Ardiç F, Özgen M, Topuz O, Sermez Y. The effects of aerobic and resistance exercises in obese women. *Clin Rehabil*. 2006;20(9):773-782.

12. Cornelissen V, Fagard R, Coeckelberghs E, Vanhees L. Impact of resistance training on blood pressure and other cardiovascular risk factors: a meta-analysis of randomized, controlled trials. *Hypertension*. 2011;58(5):950-958.

13. de Sousa EC, Abrahin O, Ferreira ALL, Rodrigues RP, Alves EAC, Vieira RP. Resistance training alone reduces systolic and diastolic blood pressure in prehypertensive and hypertensive individuals: meta-analysis. *Hypertens Res*. 2017;40(11):927-931.

14. MacDonald HV, Johnson BT, Huedo-Medina TB, et al. Dynamic resistance training as stand-alone antihypertensive lifestyle therapy: a meta-analysis. *J Am Heart Assoc*. 2016;5(10):e003231.

15. Naci H, Salcher-Konrad M, Dias S, et al. How does exercise treatment compare with antihypertensive medications? A network meta-analysis of 391 randomised controlled trials assessing exercise and medication effects on systolic blood pressure. *Br J Sports Med*. 2019;53(14):859-869.

16. Hori M, Okamoto H. Heart rate as a target of treatment of chronic heart failure. *J Cardiol*. 2012;60(2):86-90.

17. Ansari M, Javadi H, Pourbehi M, et al. The association of rate pressure product (RPP) and myocardial perfusion imaging (MPI) findings: a preliminary study. *Perfusion*. 2012;27(3):207-213.

18. Wolfram S. Effects of green tea and EGCG on cardiovascular and metabolic health. *J Am Coll Nutr*. 2007;26(4):373-388.

19. Yang Y, Lu F, Wu J, Wu C, Chang C. The protective effect of habitual tea consumption on hypertension. *Arch Intern Med*. 2004;164(14):1534-1540.

20. Garcia M, Pontes R, Nishi E, et al. The antioxidant effects of green tea reduces blood pressure and sympathoexcitation in an experimental model of hypertension. *J Hypertens*. 2017;35(2):348-354.

21. Potenza M, Marasciulo F, Tarquinio M, et al. EGCG, a green tea polyphenol, improves endothelial function and insulin sensitivity, reduces blood pressure, and protects against myocardial I/R injury in SHR. *Am J Physiol Endocrinol Metab*. 2007;292(5):1378-1387.

22. Mahdavi-Roshan M, Salari A, Ghorbani Z, Ashouri A. The effects of regular consumption of green or black tea beverage on blood pressure in those with elevated blood pressure or hypertension: A systematic review and meta-analysis. *Complement Ther Med*. 2020;51:102430.

23. Frank J, George TW, Lodge JK, et al. Daily consumption of an aqueous green tea extract supplement does not impair liver function or alter cardiovascular disease risk biomarkers in healthy men. *J Nutr*. 2009;139(1):58-62.

24. Brown AL, Lane J, Holyoak C, Nicol B, Mayes AE, Dadd T. Health effects of green tea catechins in overweight and obese men: a randomised controlled cross-over trial. *Br J Nutr*. 2011;106(12):1880-1889.

25. Basu A, Sanchez K, Leyva MJ, et al. Green tea supplementation affects body weight, lipids, and lipid peroxidation in obese subjects with metabolic syndrome. *J Am Coll Nutr*. 2010;29(1):31-40.

26. Ghadami A, Abedi B, Abarghoee J, Rarani S. The combined effect of resistance training and green tea supplements on the lipid profile and anthropometric indices of overweight and obese males. *Zahedan J Res Med*. 2018;20(7):e10698.

27. Amozadeh H, Shabani R, Nazari M. The effect of aerobic training and green tea supplementation on cardio metabolic risk factors in overweight and obese females: a randomized trial. *Int J Endocrinol Metab*. 2018;16(4):e60738.

28. Pescatello L, Franklin B, Fagard R, Farquhar W, Kelley G, Ray C. Exercise and hypertension. *Med Sci Sports Exerc*. 2004;36(3):533-553.

29. Pollock M, Jackson A. Research progress in validation of clinical methods of assessing body composition. *Med Sci Sports Exerc*. 1984;16(6):606-615.

30. Brzycki M. Strength testing—predicting a one-rep max from reps-to-fatigue. *J Phys Educ Recreat Dance*. 1993;64(1):88-90.

31. Sorace P, Churilla JR, Magyari PM. Resistance training for hypertension: design safe and effective programs. *ACSMs Health Fit J*. 2012;16(1):13-18.

32. Byrne H, Wilmore J. The effects of resistance training on resting blood pressure in women. *J Strength Cond Res*. 2000;14(4):411-418.

33. Kario K, Shin J, Chen CH, et al. Expert panel consensus recommendations for ambulatory blood pressure monitoring in Asia: the HOPE Asia Network. *J Clin Hypertens*. 2019;21(9):1250-1283.

34. Faul F, Erdfelder E, Lang A, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175-191.

35. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed. L. Erlbaum Associates; 1988.

36. Cononie C, Graves J, Pollock M, Phillips M, Sumners C, Hagberg J. Effect of exercise training on blood pressure in 70-to 79-yr-old men and women. *Med Sci Sports Exerc*. 1991;23(4):505-511.

37. Szulinska M, Stepien M, Kregielska-Narozna M, et al. Effects of green tea supplementation on inflammation markers, antioxidant status and blood pressure in NaCl-induced hypertensive rat model. *Food Nutr Res*. 2017;61(1):1295525.

38. Montrezol F, Antunes H, Almeida V, Gomes R, Medeiros A. Resistance training promotes reduction in blood pressure and increase plasma adiponectin of hypertensive elderly patients. *J Hypertens*. 2014;3(185):1-6.

39. Tibana RA, Pereira GB, De Souza JC, et al. Resistance training decreases 24-hour blood pressure in women with metabolic syndrome. *Diabetol Metab Syndr*. 2013;5(1):27.

40. Iellamo F, Volterrani M. Effect of exercise training in essential arterial hypertension. *Rev Bras Hipertens*. 2010;17(2):68-71.

41. Arazi H, Taati B, Kheirkhah J, Ramezanpour S. Changes in pain following an interaction period of resistance training and green tea extract consumption in sedentary hypertensive women: impact of blood pressure swings. *J Health Popul Nutr*. 2019;38(1):1-8.