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.

INTRODUCTION

High blood pressure (BP) or hypertension, defined on the basis of BP ≥ 140/90 mmHg, is a multifactor disease leading to the development of cardiovascular disease worldwide. Hypertension affects about 30%-50% of Iranian population, and the importance of controlling HTN in the prevention of future cardiovascular events has been emphasized in most studies. Resistance training (RT) found to reduce BP within minutes to hours after exercise in women with hypertension. However, there have been controversies regarding the chronic effects of RT on resting BP in subjects with hypertension. For example, two studies reported significant reductions in both systolic (SBP) and diastolic (DBP) BP, but no significant reductions were found in other studies. 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. Overall, more recent meta-analyses in this regard have shown that RT programs alone can reduce SBP and DBP in adults with hypertension. 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. RPP is also recognized as a very reliable and widely used measure of myocardial workload based on the product of HR and SBP. 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. 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. Some studies have been reported that the prolonged consumption of GT or GT components resulted in a decrease in BP. Garcia and colleagues concluded that short-term treatment with GT might have additional effects on the cardiovascular 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. 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/m²)          | 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   |
| VO₂max (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%)            | 2 (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.

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**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 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 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.

\[
1\text{RM} = \frac{\text{weight (kg)}}{1.0278 - (0.0278 \times \text{number of repetitions})} \quad (1)
\]

The exercise protocol was designed according to the American College of Sports Medicine (ACSM) recommendations and recent meta-analysis results. 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.

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). 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, 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 (\( \Delta = \text{post-pre} \)). 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 Pre | GR Post | ES Pre | ES Post | GT Pre | GT Post | RT Pre | RT Post | Control Pre | Control Post |
|------------------|--------|---------|--------|---------|--------|---------|--------|---------|-------------|--------------|
| SBP (mmHg)       | 135.20 ± 8.31**†† | 120.13 ± 11.33**†† | 135.20 ± 8.31**†† | 120.13 ± 11.33**†† | 120.13 ± 8.31**†† | 120.13 ± 11.33**†† | 120.13 ± 8.31**†† | 120.13 ± 11.33**†† | 120.13 ± 8.31**†† | 120.13 ± 11.33**†† |
| DBP (mmHg)       | 81.5 ± 8.83  | 81.5 ± 8.83  | 81.5 ± 8.83  | 81.5 ± 8.83  | 81.5 ± 8.83  | 81.5 ± 8.83  | 81.5 ± 8.83  | 81.5 ± 8.83  | 81.5 ± 8.83  | 81.5 ± 8.83  |
| MBP (mmHg)       | 102.57 ± 4.90 | 102.57 ± 4.90 | 102.57 ± 4.90 | 102.57 ± 4.90 | 102.57 ± 4.90 | 102.57 ± 4.90 | 102.57 ± 4.90 | 102.57 ± 4.90 | 102.57 ± 4.90 | 102.57 ± 4.90 |
| HR (b.min⁻¹)     | 78.00 ± 9.25 | 78.00 ± 9.25 | 78.00 ± 9.25 | 78.00 ± 9.25 | 78.00 ± 9.25 | 78.00 ± 9.25 | 78.00 ± 9.25 | 78.00 ± 9.25 | 78.00 ± 9.25 | 78.00 ± 9.25 |
| RPP (mmHg.b.min⁻¹) | 103.07 ± 7.06 | 103.07 ± 7.06 | 103.07 ± 7.06 | 103.07 ± 7.06 | 103.07 ± 7.06 | 103.07 ± 7.06 | 103.07 ± 7.06 | 103.07 ± 7.06 | 103.07 ± 7.06 | 103.07 ± 7.06 |
| Note: Data are presented as mean ± standard deviation. Abbreviations: DBP, diastolic blood pressure; ES, effect size (Cohen's *p* < .05 vs pre, **p* < .01 vs pre, †p* < .05 vs control, ††p* < .01 vs control. 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.

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/m²), 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 in regard to SBP (F = 1.12, p = .35, *p* = 0.08) and HR (F = 0.65, p = .58, *p* = 0.05) were not significant among the groups (Table 2). However, significant differences in regard to SBP (F = 7.18, p = .001, *p* = 0.35), MBP (F = 3.52, p = .02, *p* = 0.21), and RPP (F = 3.57, p = .02, *p* = 0.21) were observed. As a result, Tukey post hoc test was used to identify method were also used as post hoc when necessary. In addition, effect size statistics were calculated using Cohen’s d and partial eta squared (η²p) 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 η²p.

The ANOVA test showed that the total alterations of DBP (F = 1.12, p = .35, *p* = 0.08) and HR (F = 0.65, p = .58, *p* = 0.05) were not significant among the groups (Table 2). However, significant differences in regard to SBP (F = 7.18, p = .001, *p* = 0.35), MBP (F = 3.52, p = .02, *p* = 0.21), and RPP (F = 3.57, p = .02, *p* = 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, $\eta_p^2 = 0.32$), 24 h-MBP (F = 3.1, p = .03, $\eta_p^2 = 0.19$), and 24 h-RPP (F = 4.05, p = .01, $\eta_p^2 = 0.23$) 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, $\eta_p^2 = 0.23$) and RPP (F = 3.07, p = .03, $\eta_p^2 = 0.19$) 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. 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.

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%. In contrast to our findings on resting BP, Cononie and colleagues 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.

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. As proposed by previous studies, 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 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\textsuperscript{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\textsuperscript{-1}, respectively, which can be important clinically according to the fact that the high RPP levels would develop the risk of cardiovascular disease.\textsuperscript{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.\textsuperscript{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.\textsuperscript{4,40} Moreover, because of having EGCG, GT may increase NO production through phosphoinositide-3-kinase dependent pathways, which is favorable for cardiovascular health.\textsuperscript{21}

5 | STUDY LIMITATIONS

The present study encountered several limitations. The patients were selected from 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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CONFLICTS OF INTEREST

The authors declare that they have no competing interest.

AUTHOR CONTRIBUTIONS

Hamid Arazi designed the research. Behzad Taati conducted the research including sample analysis. Behzad Taati, Hamid Arazi, and Jalal Kheirkhah analyzed the data and wrote the paper. All authors read and approved the final manuscript.

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