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Adjunctive Therapeutic Effects of Forest Bathing Trips on Geriatric Hypertension: Results from an On-Site Experiment in the *Cinnamomum camphora* Forest Environment in Four Seasons

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Abstract: Forest bathing is receiving increased attention due to its health benefits for humans. However, knowledge is scarce about the adjunctive therapeutic effects of forest bathing in different seasons on geriatric hypertension. The aim of the current study was to evaluate the antihypertensive effects of forest bathing in a *Cinnamomum camphora* (*C. camphora*) forest environment in four seasons. One group of participants with geriatric hypertension was sent to a *C. camphora* forest to experience a 3 day trip, while, as a control, another group was sent to the urban center. The participants' blood pressure, blood routine, and blood biochemistry were assessed. The profile of the mood states (POMS) of the participants was assessed before and after the experiment. The air quality, atmospheric environment, and content of volatile organic compounds (VOCs) at the two experimental sites were monitored during the experiment. This experiment was repeated across four seasons. The advantages of the urban forest groups over the control groups were mainly represented by reductions in diastolic blood pressure (DBP), systolic blood pressure (SBP), and heart rate (HR), as well as increased oxygen saturation (SpO_2). The antihypertensive effects of forest bathing in the *C. camphora* forest environment changed with the seasons. Compared with the baseline level, SBP and DBP declined after forest bathing across the whole year, except during winter, whereas SpO_2 increased. The effect of forest bathing on lowering blood pressure was particularly pronounced during summer and autumn. The antihypertensive effects of forest bathing in the four seasons were highly consistent with the seasonal dynamics of VOCs and negative air ions (NAIs), which implies that the effect of forest bathing may be attributed to alterations of the atmospheric environment. The antihypertensive effects of *C. camphora* forest were confirmed in our study, and the results can provide a reference for scheduling bathing trips.

Keywords: geriatric hypertension; forest bathing; *Cinnamomum camphora* forest; four seasons; adjunctive therapy

Citation: Huang, R.; Li, A.; Li, Z.; Chen, Z.; Zhou, B.; Wang, G. Adjunctive Therapeutic Effects of Forest Bathing Trips on Geriatric Hypertension: Results from an On-Site Experiment in the *Cinnamomum camphora* Forest Environment in Four Seasons. *Forests* **2023**, *14*, 75. https://doi.org/10.3390/f14010075

Academic Editors: Qing Li, Won Sop Shin and Christos Gallis

Received: 27 October 2022
Revised: 26 December 2022
Accepted: 27 December 2022
Published: 30 December 2022

1. Introduction

Due to the rapid development of urbanization, an increasing number of humans are living in urban areas and have stressful daily lives. Many studies have indicated that long-term living in urban artificial environments negatively impacts urban residents' physical and mental health, increasing stress anxiety, fatigue, and overweight and obesity [1,2]. Ashworth [3] estimated that more than 75% of all patients suffer from stress-related diseases, and that chronic stress is linked to the six leading causes of death, i.e., heart disease, cancer, lung disease, accidents, cirrhosis of the liver, and suicide. The forest environment features extensive functional resources, such as abundant phytoncides, higher negative air ions (NAIs), higher oxygen content, and comfortable microclimates, which are beneficial for health promotion [4–7]. A forest bathing trip, called "Shinrinyoku" in Japanese, is defined as a visit to a forest or field for the purpose of relaxation and recreation [8]; this practice has been developed with the increase in people's demand for forest recreation.

A growing number of studies have reported that the forest environment decreases blood pressure. Ochiai et al. [9] showed that urinary adrenaline, serum cortisol, and systolic and diastolic blood pressure were significantly lower than the baseline following forest bathing in September 2013. Song et al. [10] provided scientific evidence suggesting that the HRV was increased while the heart rate was reduced in middle-aged hypertensive individuals after a brief forest bathing trip, compared with those who walked in an urban environment. Li et al. [11] found that the pulse rate, urinary adrenaline, and urinary dopamine were significantly lower after forest bathing than after walking in an urban area, whereas serum adiponectin was significantly greater. Li et al. [12] investigated the effects of walking in a forest environment on cardiovascular and metabolic parameters, revealing that habitual walking in forest environments could lower blood pressure by reducing sympathetic nerve activity, in addition to beneficial effects on blood adiponectin, DHEA-S levels, and NT-proBNP levels.

However, there are still many unanswered questions, and further research is needed to comprehensively understand the applications of forest bathing for human health. Firstly, what is the optimal duration and frequency (i.e., dose) of forest therapy to obtain optimal benefits for participants? The results of the studies conducted by Mao et al. [6] and Sung et al. [13] demonstrated that the protective benefits for patients with chronic heart failure (CHF) and hypertension may last only 4 weeks. However, Li et al. [14] reported that the activities of natural killer (NK) cells could remain high for 1 month. Additional evidence showed that forest bathing could increase NK cell activity and improve immunity, with the effects lasting for at least 7 days [8].

Second, it is reasonable to speculate that forest bathing activities may have different effects in different seasons. Some studies have demonstrated that taking a brief forest bathing trip, involving walking, sitting, meditating, and/or viewing the scenery in a forest, could reduce the pulse rate [15–18], heart rate [19], blood pressure [15,17], salivary cortisol level [15,16,18,20], LF/(LF + HF) components of heart rate variability (HRV) [15,17], cerebral activity in the prefrontal area [20], sympathetic nervous activity [19], and negative emotions [18]. Furthermore, it could enhance active emotions [18,19], while HF components of HRV tended to be increased [15–17]. Jia et al. [21] elucidated the effects of a forest bathing trip on the health of elderly patients with chronic obstructive pulmonary disease (COPD), reporting decreases in perforin and granzyme B expression, as well as levels of proinflammatory cytokines and stress hormones, after forest bathing. Mao et al. [22] indicated that taking a 4 day forest bathing trip during summer had a beneficial effect on CHF patients, including a reduction in inflammatory cytokines and oxidative stress levels in CHF participants. Song et al. [23] demonstrated that walking in urban parks during fall enhanced relaxation in the participants via stimulation of the parasympathetic nervous system, whereas sympathetic nervous system stimulation was decreased. A study exploring the effects of *Cinnamomum camphora* forest bathing in early fall on elderly patients with hypertension demonstrated that the DBP and inflammatory levels were significantly decreased, the mood state of participants was improved, and autonomic activity was balanced, implying that *C. camphora* forest bathing might work as an adjunctive therapy for hypertensive patients [24]. The four seasons are distinct in subtropical regions, with significant differences in environmental conditions such as air temperature, humidity, and radiation. Accordingly, there are large changes in forest phenology and diverse changes in forest environments; as a consequence, the effects of forest bathing on human health may differ across seasons, but little is known about this aspect of the effects. Therefore, this study on the effect of the *C. camphora* forest environment on hypertensive patients in different seasons is significant in bridging this considerable knowledge gap.

Thus, we conducted an experiment concerning the seasonal effects of forest bathing on hypertensive patients. Two groups of participants with hypertension were sent either to an urban forest site or to an urban center for a 3 day trip to evaluate the effects of the *C. camphora* forest environment on hypertension across four seasons. The specific research aims for the study were (1) to clarify the antihypertensive effect of the *C. camphora* forest environment, (2) to explore the optimal season for forest therapy (*C. camphora* forest bathing) in elderly hypertensive patients, and (3) to explore the favorable influencing factors, i.e., the levels of NAIs and volatile organic compounds (VOCs), for forest bathing.

2. Materials and Methods

2.1. Study Sites

The forest bathing experiment was conducted at an urban forest and an urban center in different four seasons; the study periods occurred once a season for 3 days at a time, as per the experimental methods of Li et al. [8] and Wu et al. [25], in order to determine the influence of forest bathing on elderly patients with hypertension. Forest bathing was undertaken in a *C. camphora* forest in the Changle Forestry Center, 42 km away from Hangzhou. The coverage area of the forest was about 86,658 m^2, containing 230 various camphor tree species. For comparison, the urban center in Jingshan town (119°86′ E, 30°37′ N) was used as the control; this center is located in the northwest of Hangzhou, Zhejiang Province, Southeast China, and has a total area of 157.08 km^2. The population of local city dwellers totaled 36,438 in 2017. Hereafter, the two groups are called the urban forest group (FG) and the urban center group (CG).

2.2. Participants

Non-hospitalized hypertensive patients in a stable condition were openly recruited from the community by Zhejiang Hospital as participants in this study. Participants needed to meet the following criteria over a period of up to four seasons: (1) diagnosed with essential hypertension; (2) aged 60 to 75 years; (3) BP, with or without medical control, less than 180/110 mmHg; (4) class I–II cardiac function, according to the criteria of the American New York Heart Association; (5) self-care capability in daily life. Participants were excluded if they (1) caught a cold or suffered other acute diseases 2 weeks prior to the trial or during the trial process, (2) had a history of chronic illness, including cancer, or serious diseases of the liver, kidney, brain, heart, lung, etc., and (3) had experienced acute myocardial infarction or a cerebrovascular accident within 6 months of the experiment.

The recruitment procedure undertaken in this study was in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards, and this study was approved by the ethics committee of Zhejiang Hospital. The study is registered in the Chinese Clinical Trial Registry (registration number: ChiCTR-IOR-17011799). All participants provided informed consent.

2.3. Procedure

In this study, 30 participants were recruited, of which 20 served as the urban forest group (FG) and 10 served as the urban center group (CG). This was because more subjects wished to go to the forest bathing group; accordingly, a 2:1 test was more efficient from a statistical point of view. The field experiment was performed from 22–24 August and from 19–21 October in 2017, as well as from 10–12 January and from 18–20 April in 2018, representing summer, autumn, winter, and spring, respectively. Before the forest bathing experiment, we referred to previous studies and determined that the forest bathing time was 3 h for 1 day [6,13,18]. The experimental procedure for this study is shown in Table 1; the schedule, diet, and activities (such as walking and sitting) of participants were the same for the urban forest group and urban center group.

Table 1. The experimental procedure for participants in the urban forest and urban center groups.

Time	Urban Forest Group	Urban Center Group
Day 1		
6:30–7:30	Drawing of blood samples drawn and blood pressure measurement	Drawing of blood samples drawn and blood pressure measurement
7:30–8:30	Breakfast	Breakfast
9:00–11:30	Trip to the urban forest	Trip to the urban center
11:30–12:30	Lunch at hotel	Lunch at hotel
12:30–15:00	Noon break or free activities	Noon break or free activities
15:00–16:30	Walking along a predetermined course	Walking along a predetermined course
16:30–17:30	Free time	Free time
17:30–18:30	Dinner at hotel	Dinner at hotel
18:30–19:30	Walking or free time at hotel	Walking or free time at hotel
19:30–22:00	Free time at hotel	Free time at hotel
22:00	Sleeping	Sleeping
Day 2		
7:30–8:00	Blood pressure measurement	Blood pressure measurement
8:00–8:30	Breakfast	Breakfast
8:30–10:00	Walking along a predetermined course	Walking along a predetermined course
11:30–12:30	Lunch at hotel	Lunch at hotel
12:30–15:00	Noon break or free activities	Noon break or free activities
15:00–16:30	Walking along a predetermined course	Walking along a predetermined course
16:30–17:30	Free time	Free time
17:30–18:30	Dinner at hotel	Dinner at hotel
18:30–19:30	Walking or free time at hotel	Walking or free time at hotel
19:30–22:00	Free time at hotel	Free time at hotel
22:00	Sleeping	Sleeping
Day 3		
6:30–7:30	Drawing of blood samples and blood pressure measurement	Drawing of blood samples and blood pressure measurement
7:30–8:30	Breakfast	Breakfast
9:00–11:30	Return to Zhejiang hospital	Return to Zhejiang hospital

2.4. Measurement

Systolic and diastolic blood pressure (SBP and DBP), heart rate (HR), oxygen saturation (SpO_2%), and heart rate variability (HRV) were measured using a portable digital sphygmomanometer (OMRON HEM-7000); all participants had an empty bladder before the measurements. Two or three measurements were taken, depending on the difference in blood pressure between the measurements. All participants were assessed on the basis of a routine blood panel, and blood biochemical examinations were measured using an automatic biochemistry analyzer before and after the experiment. An ELISA test was used to obtained endothelin-1 (ET-1), renin, and angiotensinogen (AGT). The profile of mood states (POMS) assessment was used to assess the mood changes of all participants before and after the experiment, with a 65-item self-administered rating scale that measures six dimensions of mood.

2.5. Air Quality Measurements

We simultaneously monitored the air quality of the sites where the participants carried out the activities. An air ion counter (KEC-900 Type, Shenzhen Yuan Hengtong Technology Co., Ltd., Shenzhen, China) was used to obtain the level of negative air ions. The temperature, humidity, and wind speed were also recorded using a digital thermometer-hygrometer. The volatile organic compounds (VOCs) in the air were collected and analyzed using a thermal desorption GC–MS. The VOCs were identified by comparing their mass spectra with the standards or reference spectra from databases from the National Institute for Standards and Technology (NIST, 2008). We performed a quantitative analysis of volatile organic components based on peak areas in the total ion chromatographs (TIC) using the area normalization method.

2.6. Data Analysis

Analysis of variance (ANOVA) and multiple comparisons were used to analyze the changes in the human physiological index and mood state after forest bathing across the four seasons; additionally, the correlation between blood pressure (SBP, DBP, HR, and SpO_2) and inflammatory factors (ET-1, renin, and AGT) was analyzed. All statistical analyses were completed using Statistica 12.0, and $p < 0.05$ was considered statistically significant.

In order to compare the effect of forest bathing on hypertension with that of urban center group, we created the index of effect value. The effect value was calculated using the following formula:

$$\text{Effect value} = (\text{RF} - \text{RC})/\text{BP} \times 100\%, \quad (1)$$

where RF is calculated as "$\text{Indicator}_{\text{after}} - \text{Indicator}_{\text{before}}$" of participants in the urban forest environment, RC is calculated as "$\text{Indicator}_{\text{after}} - \text{Indicator}_{\text{before}}$" of participants in the urban center, and BP is the baseline of indicators of participants, in which the indicators are SBP, DBP, HR, SpO_2, Renin, AGT, ET-1, LF, HF, LF/HF, and POMS index.

We used the climatic comfort index to evaluate the intimacy of the human with the external environment. The climatic comfort index (CCI) was calculated as follows [6]:

$$\text{CCI} = (\text{T} - 21.5) + 0.04 \times (\text{RH} - 55) + 0.5 \times (\text{V} - 2), \quad (2)$$

where T is the temperature (°C), RH is the relative humidity (%), and V is the wind speed (m/s).

3. Results

3.1. Baseline Characteristics of Participants

There were no significant differences in the baseline characteristics between the two groups (Table S1); these characteristics included age, body mass index (BMI), SBP, HR, SpO_2, high frequency (HF), ratio of low frequency and high frequency (LF/HF), ET-1, renin, and AGT. No significant differences in the baseline characteristics of DBP and low frequency (LF) were observed between the two groups across the whole year, except in winter (Table S1).

3.2. Effect of Forest Bathing on Blood Pressure and Heart Rate Variability in Different Seasons

After the experiment, the levels of SBP, DBP, and SpO_2 in the FG were significantly different across the four seasons ($p < 0.05$, Table 2). SBP and DBP were significantly higher in winter than in the other seasons, while SpO_2 was significantly lower in winter ($p < 0.05$, Table 2). In addition, DBP was significantly lower in the FG than in the CG in spring, summer, and autumn, but higher in winter. The SpO_2 was significantly lower in the FG than in the CG in autumn and winter, but higher in summer (Table 2).

As shown in Figure 1, forest bathing decreased the levels of LF and LF/HF in different seasons. The levels of LF and LF/HF were lower in the FG than in the CG in autumn, while the HF level was higher in the FG than that in the CG (Figure 1).

Table 2. Blood pressure indicators of participants among different seasons. Mean values ± standard deviation. Lowercase letters (a, b) in the same column indicate significant differences ($p < 0.05$ using Kruskal–Wallis test) among different seasons.

Indicators	Time	Urban Forest	Urban Center	Significance of the Difference between Groups (p)
SBP	Spring	133.15 ± 11.85 b	131.3 ± 15.22	0.7167
	Summer	137 ± 14.75 b	135.7 ± 10.1	0.8045
	Autumn	135.45 ± 9.77 b	144.18 ± 14.17	0.0519
	Winter	145.74 ± 13.47 a	141 ± 13.77	0.396
	Significance of the difference among different seasons (p)	0.0307	0.1556	
DBP	Spring	71.6 ± 5.14 b	80.8 ± 14.66	0.0167
	Summer	67.2 ± 5.85 b	74.3 ± 10.4	0.0229
	Autumn	68.95 ± 7.64 b	77 ± 11.14	0.0239
	Winter	89 ± 8.16 a	79.78 ± 8.07	0.0095
	Significance of the difference among different seasons (p)	0.0000	0.5707	
HR	Spring	69.9 ± 5.13	70.3 ± 6.7	0.8571
	Summer	70.05 ± 8.92	70.7 ± 7.92	0.8469
	Autumn	68.7 ± 5.78	70.45 ± 7.16	0.4637
	Winter	70.11 ± 7.65	68.78 ± 11.83	0.7226
	Significance of the difference among different seasons (p)	0.7383	0.9994	
SpO2	Spring	98.45 ± 0.61 a	98.4 ± 0.52 a	0.8248
	Summer	98.1 ± 0.91 a	96.6 ± 1.35 b	0.0012
	Autumn	98.1 ± 0.72 a	98.18 ± 0.75 a	0.7673
	Winter	96.63 ± 1.98 b	98.44 ± 0.73 a	0.0137
	Significance of the difference among different seasons (p)	0.0054	0.0087	

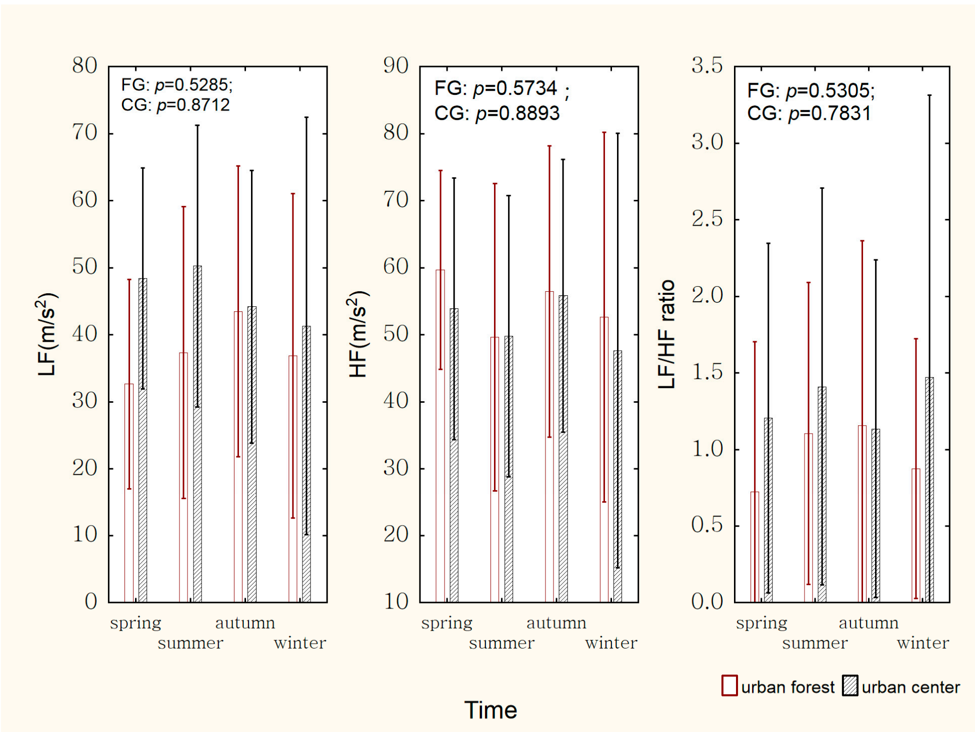

Figure 1. The heart rate variability (HRV) indicators of participants among different seasons with Kruskal–Wallis test. Mean values ± standard deviation.

3.3. Effect of Forest Bathing on Cardiovascular Disease-Related Pathological Factors in Different Seasons

After forest bathing, a significant decrease in ET-1 was observed in the FG in summer compared with that of the CG. As shown in Table 3, ET-1, renin, and AGT of the FG were significantly different across the four seasons. ET-1 of the FG was significantly higher in spring than in other seasons, followed by autumn. Renin of the FG was significantly higher in autumn, followed by spring, and the lowest in winter. AGT of the FG was significantly higher in autumn, followed by spring, and it was significantly higher than in summer and winter ($p < 0.05$, Table 3). Compared with the baseline level, ET-1, renin and AGT decreased in different seasons after forest bathing (Table 3; Table S1).

Table 3. Effect of forest bathing on cardiovascular disease-related pathological factors of participants among different seasons, analyzed by Kruskal–Wallis test. Mean values ± standard deviation. Lowercase letters (a, b, c) in the same column indicate significant differences ($p < 0.05$ using Kruskal–Wallis test) among different seasons.

Indicators	Time	Urban Forest	Urban Center	Significance of the Difference between Groups (*p*)
ET-1	Spring	24.88 ± 22.03 a	12.68 ± 12.99	0.1228
	Summer	5.28 ± 4.84 b	21.13 ± 32.29	0.0426
	Autumn	12.45 ± 11.28 b	5.89 ± 7.91	0.1123
	Winter	12.89 ± 21.62 b	14.99 ± 20.03	0.8071
	Significance of the difference among different seasons (*p*)	0.0029	0.1559	
Renin	Spring	185.67 ± 167.72 b	171.57 ± 108.38 b	0.8134
	Summer	153.39 ± 168.02 b	58.89 ± 49.08 b	0.0956
	Autumn	679.09 ± 275.92 a	753.48 ± 413.01 a	0.5608
	Winter	109.83 ± 155.68 b	251.23 ± 248.48 b	0.0761
	Significance of the difference among different seasons (*p*)	0.0000	0.0001	
AGT	Spring	39.43 ± 34.88 b	14.1 ± 16.72 b	0.041
	Summer	5.75 ± 5.25 c	13.96 ± 19.44 b	0.0916
	Autumn	106.81 ± 57.36 a	144.65 ± 110.46 a	0.2233
	Winter	20.14 ± 25.19 b c	27.07 ± 38.13 b	0.5698
	Significance of the difference among different seasons (*p*)	0.0000	0.0001	

As shown in Table 4, following forest bathing, a significant association was observed for ET-1 with SBP and SpO_2, in winter. Renin was significantly negatively associated with SBP in winter, and AGT was significantly associated with SBP and SpO_2 in spring. However, for CG, no significant association was observed for SBP, DBP, and HR with ET-1, renin, and AGT; the only exception was that SpO_2 was significantly associated with ET-1 and renin in spring and summer (Table 4).

Table 4. The association between changes in biological parameters and blood pressure after forest bathing in different season.

Indicators	Time	Urban Forest			Urban Center		
		ET-1	Renin	AGT	ET-1	Renin	AGT
SBP	Spring	0.385	0.154	0.501 *	−0.159	0.470	−0.165
	Summer	−0.040	−0.003	0.521 *	0.333	0.309	0.091
	Autumn	−0.0053	0.162	−0.023	0.357	−0.345	0.564
	Winter	−0.332	−0.473 *	0.299	−0.092	0.326	0.184

Table 4. *Cont.*

Indicators	Time	Urban Forest			Urban Center		
		ET-1	Renin	AGT	ET-1	Renin	AGT
DBP	Spring	0.297	−0.139	0.294	0.115	0.055	−0.139
	Summer	−0.171	0.125	0.298	−0.036	−0.620	0.182
	Autumn	−0.209	−0.259	0.156	−0.143	0.292	−0.334
	Winter	−0.494 *	−0.131	0.061	0.167	0.550	−0.267
HR	Spring	0.149	−0.442	−0.405	0.195	−0.024	−0.067
	Summer	−0.129	0.121	−0.162	0.067	0.109	−0.292
	Autumn	−0.173	0.049	−0.002	−0.521	0.062	−0.006
	Winter	0.137	−0.021	0.292	−0.268	0.477	−0.636
SpO_2	Spring	0.294	0.275	0.500 *	0.520	−0.260	0.260
	Summer	−0.167	0.194	−0.235	0.764 *	−0.677 *	0.056
	Autumn	0.248	0.047	0.136	−0.179	0.110	0.617
	Winter	0.500 *	0.367	0.299	0.043	0.165	0.381

Note: * correlation is significant at the 0.05 level.

3.4. Evaluation of Mood State Evaluation in Different Seasons

Across the four seasons, significant differences in both positive and negative emotions were observed in the FG. In spring, negative emotions were significantly higher than in the other seasons, and levels of negative emotions were significantly higher in summer than in autumn and winter; meanwhile, no significant difference was observed between autumn and winter. However, the lowest levels of negative emotions were observed in autumn (Table 5). Compared with the CG, the positive emotions were higher in autumn after forest bathing, but lower than those of the CG in spring and summer. However, levels of negative emotions were lower in autumn and summer after forest bathing, compared with the CG (Table 5).

Table 5. Profile of mood state (POMS) evaluation of participants exposed to forest bathing and urban center environments in different seasons. Mean values ± standard deviation. Lowercase letters (a, b, c) in the same column indicate significant differences ($p < 0.05$ using Kruskal–Wallis test) among different seasons.

Indicators	Time	Urban Forest	Urban Center	Significance of the Difference between Groups (p)
Tension/anxiety (T)	Spring	16.3 ± 3.95 a	17.3 ± 4.95 a	0.5525
	Summer	12.9 ± 3.88 b	12.6 ± 2.55 b	0.8268
	Autumn	10.3 ± 2.77 c	11.09 ± 3.65 bc	0.5024
	Winter	11.5 ± 3.87 bc	8.44 ± 0.72 c	0.028
	Significance of the difference among different seasons (p)	0.0000	0.0000	
Depression/dejection (D)	Spring	39.4 ± 5.28 a	38.6 ± 4.45 a	0.6842
	Summer	28.25 ± 5.64 b	30 ± 6.38 b	0.449
	Autumn	19.7 ± 5.08 c	20.82 ± 8.23 c	0.6423
	Winter	20.83 ± 7.19 c	16.78 ± 2.05 c	0.1129
	Significance of the difference among different seasons (p)	0.0000	0.0000	
Anger/hostility (A)	Spring	29.35 ± 3.8 a	29.6 ± 6.35 a	0.8933
	Summer	24.25 ± 4.76 b	24 ± 4.89 b	0.894
	Autumn	16.65 ± 3.67 c	17.91 ± 6.56 c	0.4964
	Winter	17.44 ± 5.54 c	14.33 ± 2.45 c	0.1232
	Significance of the difference among different seasons (p)	0.0000	0.0001	

Table 5. *Cont.*

Indicators	Time	Urban Forest	Urban Center	Significance of the Difference between Groups (*p*)
Vigor/activity (V)	Spring	16.35 ± 3.77 c	18.3 ± 4.32 c	0.2138
	Summer	22.75 ± 2.67 b	23.6 ± 3.37 ab	0.458
	Autumn	27.95 ± 6.39 a	20.82 ± 2.48 bc	0.0014
	Winter	26.06 ± 4.71 a	25.11 ± 5.64 a	0.6494
	Significance of the difference among different seasons (*p*)	0.0000	0.0151	
Fatigue/inertia (F)	Spring	14.4 ± 2.84 a	13.8 ± 2.66 a	0.5818
	Summer	12.65 ± 3.19 a	13.7 ± 3.34 a	0.4104
	Autumn	9.85 ± 2.83 b	10.18 ± 2.36 b	0.7438
	Winter	10.27 ± 3.43 b	10.67 ± 3.5 b	0.7848
	Significance of the difference among different seasons (*p*)	0.0000	0.018	
Confusion/bewilderment ©	Spring	20.15 ± 2.48 a	19.4 ± 1.58 a	0.3921
	Summer	15.55 ± 2.78 b	15 ± 1.83 b	0.5766
	Autumn	13.2 ± 2.42 c	13.45 ± 3.5 b	0.8129
	Winter	13.33 ± 2.43 c	13.11 ± 2.89 b	0.8378
	Significance of the difference among different seasons (*p*)	0.0000	0.0001	

3.5. Relationship between Forest Environment and the Effect Value of Forest Bathing in Four Seasons

The negative air ion concentration in the urban forest was higher than that in the urban center in summer and autumn. Terpenes, the main components of VOCs, differed considerably across the four seasons. Overall, the terpenes of the urban forest were higher than those of the urban center, which is beneficial for human health (Figure 2). The air quality in the urban forest was better than that in the urban center; meanwhile, relative humidity in the urban forest was higher than that in the urban center in summer and autumn. Moreover, the temperature in the urban forest was lower than that of the urban center in summer and autumn, and the CCI of the urban forest was lower than that of the urban center, which indicated that the urban forest was a more comfortable site.

The effect of forest bathing was closely related to air quality and the atmospheric environment, with similar tendencies. As shown in Figure 3, the effect value of forest bathing in terms of SBP, DBP, and HR was decreased in spring, summer, and autumn, while SpO_2 was increased, implying that it had an effect on depressurization and oxygenation. The effect value of forest bathing in AGT was decreased in spring, summer, and autumn, but there was no obvious change in winter, being close to zero. The effect value of forest bathing on ET-1 was declined sharply in summer and rose a little in spring and winter. The effect value of forest bathing in LF and LF/HF decreased sharply in winter, and slightly decreased in spring and summer. The effect value of forest bathing in terms of activity emotion (vigor/activity (V)) increased sharply in autumn, and negative emotions (depression/dejection (D), anger/hostility (A), and confusion/bewilderment (C)) decreased slightly in spring. The seasonal fluctuations in the effect value of forest bathing were highly consistent with the seasonal variations in air quality and the atmospheric environment. Similar trends were observed for air quality and the atmospheric environment, and for the effect of forest bathing; this suggests that the effect of forest bathing may be attributed to changes in air quality and the atmospheric environment.

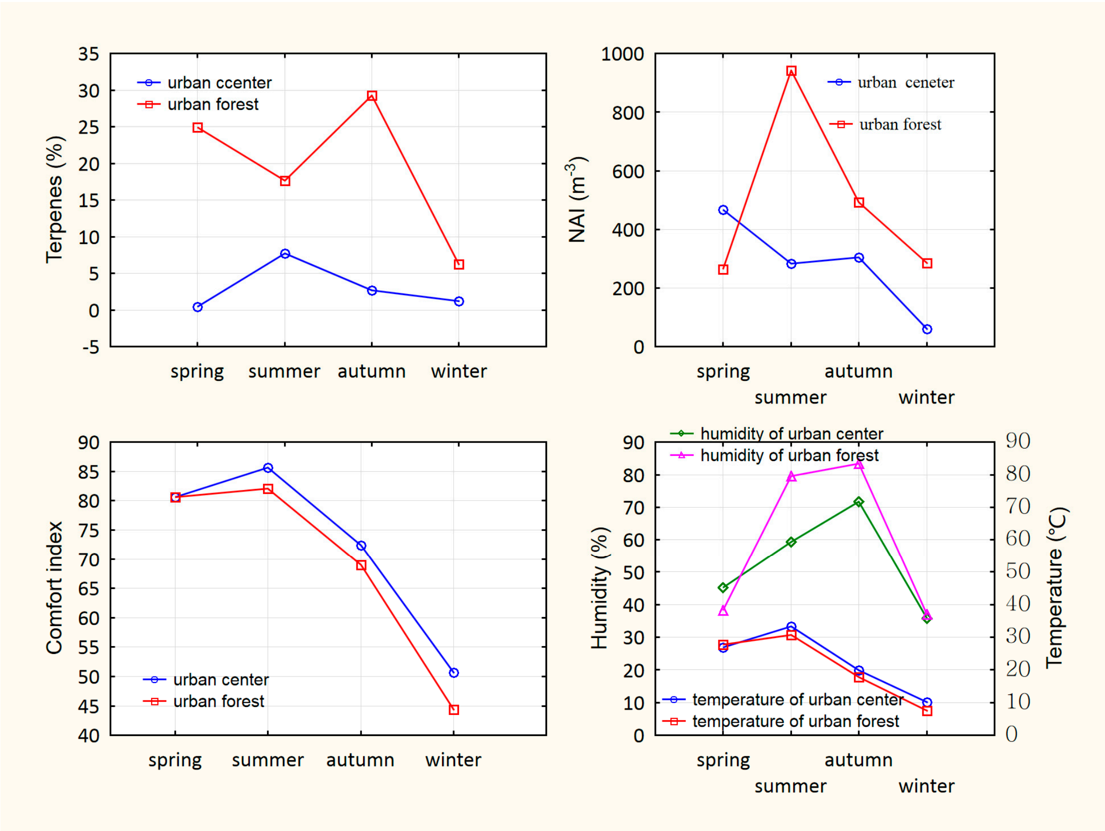

Figure 2. The air quality and atmospheric environment among four seasons, including NAI, temperature, humidity, the comfort index, and terpenes.

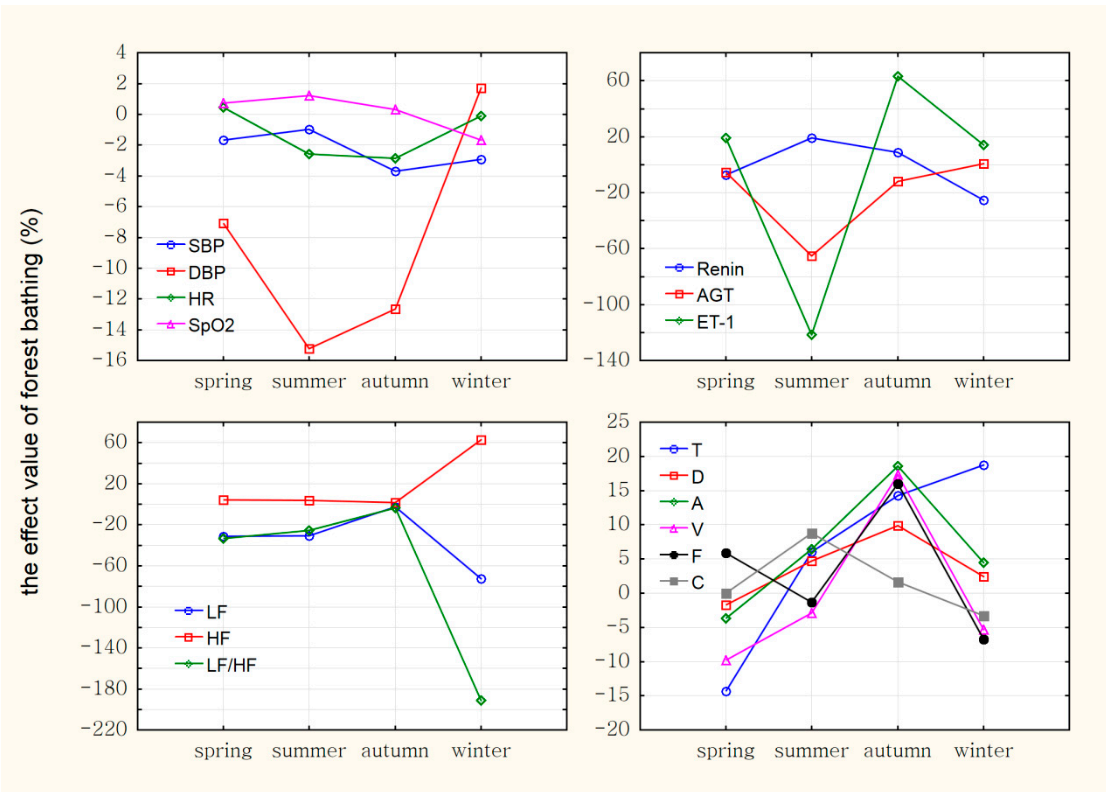

Figure 3. The effect of forest bathing across four seasons.

4. Discussion

4.1. Antihypertensive Effects of C. camphora Forest

This study assessed the physiological and psychological benefits of forest bathing in a *C. camphora* forest on patients with hypertension. The advantages of the FG over the CG were mainly characterized by decreases in DBP, SBP, and HR, a reduction in ET-1, and an increase in SpO_2. In general, our results are consistent with previous studies [10,19], which suggested that subjects in a forest environment had enhanced parasympathetic and lower sympathetic nervous activity, compared to those in a city environment. A similar response is often seen in yoga therapy [26,27]. Our results suggest that taking a brief forest bathing trip attenuated negative emotions and suppressed sympathetic nervous activity, as well as enhanced active emotion; this finding is consistent with many other studies [18,19]. On the basis of a study of middle-aged males with high–normal blood pressure, Ochiai et al. [9] confirmed that forest bathing may significantly reduce negative emotions and enhance feelings of comfort and relaxation. Moreover, forest bathing may reduce serum cortisol, urinary adrenaline, and sympathetic activity [28,29], which regulated the systolic and diastolic blood pressure, in elderly hypertensive patients. Thus, forest bathing may lower the blood pressure of elderly hypertensive patients by regulating biochemical activity and emotional states. A recently published meta-analysis, with 20 trials involving 732 participants, reported that SBP and DBP of the forest environment were significantly lower than that of the non-forest environment, which showed a significant effect of forest bathing on reduction of blood pressure [30]. A recently published review of the literature, with a total of 364 studies identified from the literature search, although only 14 studies were used to assess the quality of the included studies, reported that forest bathing, particularly forest walking and therapy, had physiologically and psychologically relaxing effects on middle-aged and elderly people with hypertension [31].

C. camphora is common evergreen broadleaved tree species found in subtropical environments; it emits phytoncides which have a certain repellent effect on mosquitoes and insects. These volatile organic compounds (VOCs) are continuously accumulated and released into the air, forming a unique forest air environment; this has a direct effect on human physiology and psychology. Many studies have confirmed that *C. camphora* forests have certain health benefits for the human body. Lee et al. [32] suggested that *C. camphora* is an active, oriental herbal medicine, which can exert a significant immunomodulatory effect on various inflammatory responses at the transcriptional level. Wu et al. [24] found that the *C. Camphora* environment significantly decreased DBP and inflammatory levels, balanced autonomic activity, and improved the mood states of participants; these effects might be conducive to the recovery of hypertensive patients. The antihypertensive effect of the *C. camphora* forest environment is attributed to its air quality and to the VOCs released by *C. camphora*. Park et al. [33] found that the psychological responses to physical environments are significantly related to air temperature, relative humidity, radiant heat, and wind velocity. In this study, a similar trend was identified between air quality and the atmospheric environment and the effect of forest bathing, which may, thus, be attributed to air quality and changes in the atmospheric environment. The humidity and NAI of the FG were significantly higher than those of the CG in summer and autumn, while the temperature was lower in the FG. A higher number of NAIs is beneficial for downregulating DBP, as well as improving mental states and performance efficiency [34]. Some studies showed a spatial difference in the concentrations of NAI, with the highest concentrations found in forests (5000 ions$\cdot$cm^{-3}) and the lowest in urban squares and roads (tens to hundreds of ions$\cdot$cm^{-3}) [35,36]; that is, the concentration of NAI increased gradually from the city center to the suburbs [37]. In addition, the components of VOCs were obviously different in the two experimental sites; the *C. camphora* forest accounted for over 80% of the VOCs, including terpenes, aromatics, esters, and aldehydes. It is worth mentioning that terpenes, which are produced by various plants, including *C. camphora* forest, are not only associated with anti-inflammation but also antibacterial. Moreover, terpenes are the main ingredients of the VOCs of *C. camphora*, accounting for 29.26% of the

C. camphora forest atmosphere, in contrast to 50.83% for flowers, 70.75% for leaves, and 78.22% for branches [38]. Terpenes have a potentially beneficial therapeutic effect on the oxidant/antioxidant balance in diseases of the nervous system, as the mechanisms of their antioxidant action appear to involve ROS scavenging [39]. α-Pinene has an anti-inflammatory effect and is, therefore, a potential candidate to treat various inflammatory diseases, which can be attributed to the downregulation of MAPK (ERK and JNK) phosphorylation and the NF-κB signaling pathway [40]. α-Pinene's anti-inflammatory activity is exerted through a decrease in the LPS-induced production of interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), and nitric oxide (NO), and through inhibition of inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2) expression in LPS-stimulated macrophages [40]. Previous studies have demonstrated that *C. camphora* essential oil has antifungal properties and can be used as an antifungal agent for treating Choanephora and other fungi that infect economically important crops [41]. Hansen et al. [42] found that limonene reduced allergic inflammation, possibly because of its antioxidant properties. Therefore, the antihypertensive effects of the *C. camphora* forest can be attributed to the components of the VOCs released by *C. camphora*.

4.2. Antihypertensive Effects of Forest Bathing across Different Seasons

A previous study by Wu et al. [24] only summarized the antihypertensive impact of *C. camphora* forest bathing in autumn, but did not explore any seasonal differences. Here, our results showed that the antihypertensive effect of forest bathing on elderly hypertensive patients differed significantly across the four seasons. The effects of forest bathing were better in autumn and spring than in summer, while its effects in summer were better than in winter. Our results showed that ET-1, renin, and AGT were significantly higher in spring and autumn than in other seasons after forest bathing. In winter, SBP and DBP were significantly higher than in other seasons after forest bathing, while SpO_2 was significant lower in winter than in other seasons after forest bathing. ET-1 and renin were significantly negatively correlated with SBP and DBP in winter, while ET-1 and renin were significantly positively correlated with SpO_2. Compared with the baseline levels, SBP and DBP declined after forest bathing, except in winter, while SpO_2 increased. Therefore, the antihypertensive effects of forest bathing on were better in spring, summer, and autumn. Mao et al. [6] investigated whether forest bathing had therapeutic effects on human hypertension, whereby they sent participants to a broadleaved evergreen forest to experience a 7 day/7 night trip. They found a significant association between AGT and SBP in participants; it seems that decreased AGT had an inhibitive effect on RAS and, thus, induced a decline in SBP in subjects exposed to the forest environment. ET-1 is the most potent vasoconstrictor and is always involved in the progression of cardiovascular diseases [43]. Our results showed that ET-1 level was significantly associated with the SBP (Table 2). ET-1 was decreased in subjects exposed to the forest environment, which is consistent with Mao's [6] study of the therapeutic effects of forest bathing on elderly hypertensive patients. ET-1 is also an important stimulus for inflammation [44]. Thus, this evidence indicates that a decline in proinflammatory factors in the forest bathing group may be attributed to ET-1 alteration.

On the other hand, *C. camphora* forest bathing can improve participants' emotional states, generally reducing the negative emotions and enhancing the positive emotions of participants, compared with the baseline level. The results of POMS showed differences in the emotional states of participants across the four seasons. This result was confirmed in Wei's [45] study, which used the FireFACE™ software to obtain scores for happy, sad, and neutral expressions, to study a classic scientific question regarding the effect of the forest experience on the emotional state of visitors. Their results suggested that a forest experience can result in more positive emotional expressions on visitors' faces. Rosa et al. [46] obtained similar conclusions, finding that forest therapy can reduce depressive symptoms and improve mood. Similarly, Bielinis et al. [47] showed that taking a short winter forest bathing trip had substantial emotional, restorative, and vitalizing effects on the participants.

Duan et al. [48] investigated spontaneous behavior, body weight, and fecal production in white mice after their entry into urban forest habitats during successive 6 day experiments. Their results suggested that the environmental factors in urban forest, i.e., the NAI and oxygen content, air temperature, and relative humidity, could enhance the physical activity and emotional state of white mice. The antihypertensive effect of *C. camphora* forest bathing on elderly hypertensive patients in different seasons may mainly depend on the air quality and atmospheric environment, in relation to factors such as the high concentration of NAIs, suitable temperatures and humidity, and composition and content of VOCs. Zhou et al. [7] found that there were seasonal variations in the components and the relative contents of VOCs from *C. camphora* forests; the VOC components in spring were more abundant than those in other seasons. Additionally, Zhou et al. [49] found that terpenes were the main components of VOCs released from a *C. camphora* forest in March, and that these were beneficial for regulating blood pressure and reducing inflammation [50]. Pawar et al. [51] investigated the seasonal dynamics of NAI concentration, and they found that it was usually the highest in summer, higher in autumn than in spring, and the lowest in winter; however, the variation coefficient was small. Therefore, the variation in the antihypertensive effects of *C. camphora* forest bathing in different seasons may be related to air quality and the atmospheric environment, i.e., the concentration of NAIs and the content of VOCs, especially terpenes.

In addition, the intake of antihypertensive drugs in each subject was considered in this study due to their potential antihypertensive effects. Because the individual administration of drugs for each participant was carried out in the usual manner during the 3 day experimental periods, the intake of drugs may not have affected the comparison between the pre-experimental levels and post-experimental levels for each group.

5. Conclusions

In summary, our study revealed that forest bathing has remarkable antihypertensive properties, resulting in anti-inflammatory effects, improved emotions and mood, and enhanced antioxidation. The antihypertensive effects of *C. camphora* forest exhibited seasonal differences, with the effect being better in spring, summer, and autumn than in winter. The effect of forest bathing may be attributed to changes in air quality and the atmospheric environment, as it is highly consistent with the seasonal dynamics of VOCs and NAIs. Our findings are of significance in the selection of optimal times for forest tourism.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/f14010075/s1: Table S1. Clinical characteristics of the participants analyzed by variance (ANOVA). Mean values ± standard deviation. Different capital letters in the same line indicate significant differences between treatments.

Author Contributions: Conceptualization, R.H., G.W. and B.Z.; formal analysis, R.H. and A.L.; investigation, R.H., A.L., Z.L. and Z.C.; data curation, R.H., Z.L. and Z.C.; writing—original draft, R.H.; writing—review and editing, A.L., B.Z. and G.W.; supervision, B.Z. and G.W.; project administration, B.Z. and G.W.; funding acquisition, B.Z. and G.W. All authors have read and agreed to the published version of the manuscript.

Funding: This study was funded by Sci-Tech Cooperation Program between Zhejiang Province and Chinese Academy of Forestry (grant number 2020SY06), the Key R&D Program of Zhejiang Province (grant number 2021C02005), and the Science Technology Bureau of Huzhou City (grant number 2021GY68).

Data Availability Statement: Not applicable.

Acknowledgments: We are sincerely grateful to the anonymous reviewers and editors for their valuable suggestions to improve the article.

Conflicts of Interest: The authors declare no conflict of interest.

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