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The Efficacy of Forest Therapy on Negative Emotions, Oxidative Stress, and Cardiovascular Disease Risk in Elderly Hypertensive Patients

ABSTRACT

Background: This study aims to explore the effects of forest therapy on negative emotional states, oxidative stress levels, and the risk of cardiovascular disease among elderly patients with hypertension.

Methods: A total of 120 eligible elderly hypertensive participants were randomly assigned to either a control group or an intervention group, utilizing a random number table, with each group comprising 60 individuals. The control group engaged in urban walking, while the intervention group underwent forest therapy. Following a 4-week intervention period, comparisons were made between the 2 groups regarding blood pressure, emotional well-being, and oxidative stress levels. Participants were subsequently followed for 12 months to evaluate the incidence of cardiovascular events.

Results: After the intervention, both groups exhibited significant reductions in systolic blood pressure and diastolic blood pressure, with the intervention group showing markedly greater improvements compared to the control group. Furthermore, the intervention group demonstrated a significantly greater increase in superoxide dismutase levels and a more pronounced decrease in malondialdehyde levels than the control group. Assessments of emotional health indicated that the intervention group had significantly lower scores in Tension-Anxiety, Anger-Hostility, Fatigue-Inertia, Depression-Dejection, and Confusion-Bewilderment, while scores for Vigor-Activity were significantly higher. The intervention group also exhibited a significantly reduced risk of cardiovascular events (hazard ratio = 0.340, P = .018, 95% CI: 0.120-0.950).

Conclusion: Forest therapy is an effective intervention for managing blood pressure, enhancing emotional well-being, and reducing oxidative stress levels in elderly hypertensive patients, ultimately contributing to a lower risk of cardiovascular events.

Keywords: Elderly hypertension, forest therapy, negative emotions, oxidative stress

ORIGINAL INVESTIGATION

INTRODUCTION

An estimated 7.5 million fatalities worldwide, or roughly 13% of yearly mortality rates, are attributed to hypertension, making it a significant risk factor for cardiovascular complications and mortality.[1,2] Apart from its high prevalence and multifaceted adverse effects, hypertension is also regarded as a preventable condition, underscoring the importance of blood pressure control in the prevention of disease and mortality.[3] The pathogenesis and progression of hypertension are influenced by a myriad of factors, including genetics, neuroendocrine mechanisms, organ dysfunction, lifestyle choices, and environmental factors.[4] Psychosocial stress is a prevalent modifiable risk factor contributing to the onset and exacerbation of hypertension. Stress-related alterations in blood pressure responses are mediated by changes in endothelial function, inflammation, and immune responses, which play a pivotal role in the progression of the disease.[5-7]

With an emphasis on the effects of forest settings on human health, forest therapy is a young multidisciplinary field that combines concepts from environmental medicine, alternative medicine, and preventive medicine.[8] This practice entails immersing individuals in natural settings and fostering connections through sensory engagement—sight, hearing, taste, smell, and touch—thereby bridging the

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divide between the human body and the natural world.[9] The serene ambiance, picturesque landscapes, mild climates, fresh air, and distinctive fragrances of forest environments are increasingly recognized for their ability to mitigate stress and promote relaxation.[10] Furthermore, volatile organic compounds emitted by plants, including alcohols, ketones, esters, and ethers, can alleviate stress and enhance mood by modulating parasympathetic nervous system activity, thereby improving both physical and mental well-being.[11] A systematic review has demonstrated that forest therapy significantly enhances cardiovascular function, immune response, and antioxidant activity, as well as markedly improving emotional well-being by alleviating anxiety and depression.[12]

In alignment with the Healthy China initiative, which has been established as a national strategic priority, the health industry in China is experiencing rapid growth. As an integral component of the health industry, forest therapy is garnering considerable attention for its potential applications in managing chronic diseases.[13] This study aims to investigate the efficacy of forest therapy in elderly patients with hypertension, providing robust evidence to support the broader implementation of this therapeutic approach.

METHODS

Study Design

This research was conducted as a prospective randomized controlled trial involving 120 elderly participants diagnosed with hypertension. Participants were randomly assigned to either a control group or an intervention group, with each group consisting of 60 individuals. The randomization process utilized a random number table to ensure unbiased allocation. Over a period of 4 weeks, both groups engaged in the intervention for 5 days each week, followed by 2 days of rest. The study protocol received ethical approval from the Institutional Ethics Committee, and all procedures were conducted in accordance with the ethical guidelines established in the Declaration of Helsinki for clinical research.

Study Population

Inclusion Criteria

1. Aged between 60 and 80 years, regardless of gender;
2. Systolic blood pressure (SBP) ranging from 140 to 159 mm Hg or diastolic blood pressure (DBP) between 90 and 99 mm Hg, or currently receiving antihypertensive medication;
3. New York Heart Association functional classification I-II; and
4. Capable of performing activities of daily living independently.

Exclusion Criteria

1. Presence of a cold or any acute illness within 2 weeks prior to enrollment or during the study;
2. History of cancer or chronic illnesses affecting the liver, kidneys, brain, heart, or lungs; and
3. Acute myocardial infarction or stroke within the 3 months preceding enrollment.

Intervention Methods

All participants were accommodated in a uniform hotel setting, where dietary intake and physical activity were closely monitored. Following randomization, the control group engaged in walking activities within urban areas, while the study group participated in a guided 2-hour forest walk that incorporated stimuli across the 5 senses: auditory, tactile, olfactory, visual, and gustatory.

To ensure standardization and participant safety, the forest therapy sessions were conducted under the supervision of 2 certified forest therapy guides who had completed accredited training programs in forest medicine and nature-based interventions. They were assisted by 1 physician and 1 nurse, who monitored participants' physiological status and ensured adherence to medical safety protocols.

A standardized forest therapy protocol, developed based on national forest health guidelines and previous research in forest medicine, was followed throughout the study. Each session began with a 5-minute orientation and breathing exercise, encouraging participants to focus on slow, deep breathing and relaxation. The guides provided structured verbal instructions to facilitate sensory engagement—for example: "Pay attention to the sound of leaves rustling and birdsong" (auditory); "Gently touch the surface of tree bark or leaves and notice the texture" (tactile); "Inhale deeply to perceive the scent of the forest air and nearby plants" (olfactory); "Observe changes in light, color, and movement around you" (visual); "If appropriate, taste approved edible leaves or flowers under supervision" (gustatory).

Throughout the walk, guides maintained a calm, reflective pace and encouraged participants to remain silent for parts of the session to deepen sensory perception and mindfulness. The same procedure was implemented for all intervention sessions to maintain consistency and reproducibility.

The total walking duration was approximately 60 minutes, covering about 3 kilometers. Throughout the study, participants were instructed to avoid strenuous exercise, smoking, and the consumption of alcoholic or caffeinated beverages, and to maintain their prescribed antihypertensive medications. The sensory stimulation components are detailed in Table 1.

HIGHLIGHTS

- Forest therapy is a multi-sensory nature-immersion intervention that integrates five sensory engagements to connect humans with natural environments.
- The intervention significantly reduces blood pressure and oxidative stress compared to urban walking in elderly hypertensive patients. It also markedly alleviates negative emotions and lowers the 12-month cardiovascular event risk.
- This work validates forest therapy as a valuable complementary clinical approach for elderly hypertension management and holistic health promotion.

Table 1. Sensory Stimulation Components

Sensory Modality	Main Content
Auditory	Listening to their breathing, the rustling of dry leaves, birdsong, and the sound of the wind.
Tactile	Experiencing the different textures of plants, leaves, rocks, wind, and soil through touch.
Olfactory	Appreciating the aromas provided by leaves, stems, and flowers.
Visual	Observing the landscape, including streams, small animals, rocks, large trees, and shrubs.
Gustatory	Tasting edible species of leaves and flowers.

Outcome Measures

Blood pressure and heart rate measurements, as well as fasting venous blood samples, were collected by qualified healthcare personnel between 7:00 and 7:30 AM, following an overnight fast, both before and after the intervention. After a 30-minute rest period, seated blood pressure was measured according to standardized operating procedures using a sphygmomanometer. All subjects were instructed to empty their bladders before measurement and were prohibited from consuming coffee or smoking. Blood pressure was measured 3 times consecutively, with a 30-second interval between measurements. If the differences between the readings exceeded 5 mm Hg, participants were asked to rest for an additional 5 minutes before repeating the measurements. The average of the 3 consecutive blood pressure readings was used. Concurrently, fasting venous blood samples were collected to assess oxidative stress markers, including superoxide dismutase (SOD) and malondialdehyde (MDA).

Post-intervention, the Profile of Mood States-Short Form (POMS-SF) was employed to evaluate emotional and mood states before and after the intervention. This assessment included 5 negative emotions: tension, anger, fatigue, depression, and confusion, as well as 2 positive emotions: vigor and self-esteem.

Following the intervention, all participants were followed up monthly for a total duration of 12 months to record the occurrence of cardiovascular adverse events, including angina pectoris, acute myocardial infarction, chronic heart failure, stroke, and cardiovascular mortality.

Statistical Methods

Statistical analyses were performed using R version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria) and SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Data were first tested for normality using the Shapiro–Wilk test. Normally distributed continuous variables are presented as mean ± SD, while non-normally distributed variables are presented as median (interquartile range).

For blood pressure and oxidative stress indicators (SBP, DBP, SOD, and MDA), paired-sample t-tests were applied to assess within-group differences before and after the intervention, and independent-sample t-tests were used for between-group comparisons of changes. For the analysis of POMS subscale scores, a two-way repeated-measures analysis of variance (repeated-measures ANOVA) with 1 between-subject factor (group: control vs. study) and 1 within-subject factor (time: pre- vs. post-intervention) was conducted to evaluate both within-group (time) and between-group (group) differences, as well as their interaction. When significant interaction effects were observed, post hoc pairwise comparisons were performed to determine which specific between-group and within-group measurements differed. Categorical variables were expressed as frequencies and percentages, and analyzed using the chi-square (χ^2) test or Fisher's exact test.

For the analysis of cardiovascular event incidence, Kaplan–Meier survival curves were constructed and compared between groups using the log-rank test. Hazard ratios (HRs) with 95% CIs were calculated using the Cox proportional hazards model. A two-sided $P < .050$ was considered statistically significant. Graphical representations were generated using R packages ggplot2 and survminer.

RESULTS

Baseline Characteristics

Demographic data, including gender, age, body mass index, and duration of illness, as well as baseline clinical indicators such as SBP, DBP, MDA, and SOD, were well balanced (Table 2) (all *P*-values >.050).

Table 2. Baseline Characteristics

Characteristic	Control, n = 60	Study, n = 60	Statistic	*P*
Age (years)	66.57 ± 1.91	65.93 ± 2.35	1.62	.108
Gender			0.04	.850
Female	22 (36.7%)	23 (38.3%)		
Male	38 (63.3%)	37 (61.7%)		
BMI	23.68 ± 2.08	24.18 ± 2.35	−0.78	.439
Course of disease	7.62 ± 1.83	8.03 ± 1.84	−1.23	.222
Heart rate	74 ± 10	76 ± 11	−0.83	.411
Smoking, n (%)			0.03	.855
No	31 (51.7)	32 (53.3)		
Yes	29 (48.3)	28 (46.7)		
Drinking, n (%)			1.82	.178
No	43 (71.7)	36 (60.0)		
Yes	17 (28.3)	24 (40.0)		
SBP baseline	146 ± 10	166 ± 185	−0.82	.417
DBP baseline	86 ± 10	84 ± 11	0.67	.503
SOD baseline	44.9 ± 14.9	42.9 ± 15.1	0.73	.466
MDA baseline	10.04 ± 1.46	10.09 ± 1.50	−0.16	.871

BMI, body mass index; DBP diastolic blood pressure; MDA, malondialdehyde; SBP, systolic blood pressure; SOD superoxide dismutase.

Table 3. Blood Pressure

	SBP		DBP	
	Follow-Up	Mean Difference (95% CI)[a]	Follow-Up	Mean Difference (95% CI)[a]
Control group	142.2 ± 7.79	−13.94 (−16.80, −11.09)	82.3 (8.92)	−2.49 (−5.02, 0.04)
Study group	134.3 ± 13.83	−21.57 (−24.42, −18.72)	76.0 (10.69)	−8.83 (−11.36, −6.30)
Study - Control		−7.63 (−11.63, −3.63)		−6.34 (−9.89, −2.80)
P		<.001		<.001

DBP, diastolic blood pressure; SBP, systolic blood pressure. Note: "a" represents the change in the difference between post-intervention and pre-intervention values.

Blood Pressure

One month post-intervention, SBP and DBP were recorded and compared between the 2 groups, as detailed in Table 3. In the control group, the least squares mean change in SBP was −13.94 (−16.80, −11.09), and for DBP it was −2.49 (−5.02, 0.04). In the study group, the mean difference in SBP post-intervention was −21.57 (−24.42, −18.72), while for DBP it was −8.83 (−11.36, −6.30). Improvements in both SBP and DBP in the study group were more notable than in the control group.

Oxidative Stress

After 1 month of intervention, SOD and MDA levels were presented in Table 4. In the control group, the mean difference for SOD was 10.03 (7.20, 12.86), and for MDA it was −1.47 (−1.67, −1.27). In the study group, the mean difference for SOD was 21.12 (18.29, 23.95), while for MDA it was −1.95 (−2.15, −1.75). The increase in SOD and the decrease in MDA in the study group were both significantly greater than those in the control group.

Adverse Emotions

One month post-intervention, the POMS was employed to assess the emotional and mood states of the participants, with results depicted in Figure 1 and summarized in Table 5. A two-way repeated-measures ANOVA (group × time) demonstrated significant main effects of time and group, as well as significant group × time interaction effects for all POMS subscales (all *P*-values <.050). Compared with baseline, both groups showed reductions in negative emotion scores over time, but the study group exhibited markedly greater pre–post improvements in Tension-Anxiety, Anger-Hostility, Fatigue-Inertia, Depression-Dejection, and Confusion-Bewilderment. In contrast, Vigor-Activity increased to a significantly greater extent in the study group than in the control group. Post hoc comparisons further confirmed that, at post-intervention, all negative emotion scores were significantly lower and the Vigor-Activity score was significantly higher in the study group than in the control group.

Cardiovascular Events

All participants were followed up for 1 year post-intervention to document the occurrence of cardiovascular events. During the follow-up period, 16 individuals from the control group and 11 from the study group were lost to follow-up. By the end of the follow-up, 13 cardiovascular events were recorded in the control group, including 10 cases of angina pectoris, 2 strokes, and 1 myocardial infarction. In contrast, the study group reported 5 cardiovascular events, comprising 4 cases of angina pectoris and 1 stroke. In comparison to the control group, the study group saw a significantly decreased incidence of cardiovascular events (χ^2 = 5.557, *P* = .018). The association between cardiovascular events and time was assessed using Kaplan–Meier analysis; the findings are shown in Figure 2. Cardiovascular events were considerably less likely to occur in the study group (HR = 0.340, *P* = .018, 95% CI: 0.120-0.950).

DISCUSSION

This study explored the effects of forest therapy on improving adverse emotional states, oxidative stress levels, and the prevention of cardiovascular events in elderly patients with hypertension. The findings substantiate that forest therapy is effective in enhancing blood pressure regulation, reducing oxidative stress, alleviating negative emotions, and decreasing the incidence of cardiovascular events. These results underscore the potential of forest therapy as a complementary approach for managing hypertension and promoting overall health in older adults.

Both groups demonstrated significant improvements in blood pressure. Previous research indicates that walking interventions lasting 20-40 minutes, conducted 3-5 times per week over a duration of approximately 15 weeks (in both indoor and outdoor environments), can lead to substantial reductions in blood pressure and heart rate.[14] Furthermore, walking offers numerous health benefits, including enhanced

Table 4. Oxidative Stress

	SOD		MDA	
	Follow-Up	Mean Difference (95% CI)[a]	Follow-Up	Mean Difference (95% CI)[a]
Control group	56.5 ± 6.46	10.03 (7.20, 12.86)	8.6 ± 0.64	−1.47 (−1.67, −1.27)
Study group	67.4 ± 13.80	21.12 (18.29, 23.95)	8.1 ± 0.91	−1.95 (−2.15, −1.75)
Study - Control		11.09 (7.05, 15.14)		−0.48 (−0.76, −0.20)
P		<.001		<.001

MDA, malondialdehyde; SOD superoxide dismutase. Note: "a" represents the change in the difference between post-intervention and pre-intervention values.

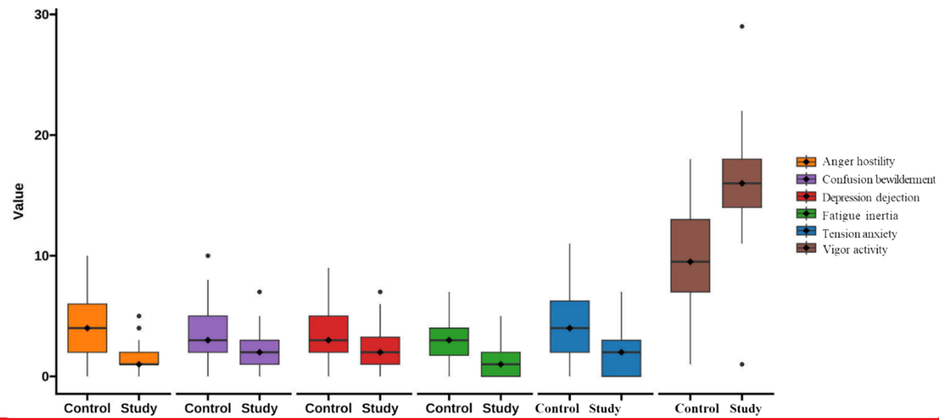

Figure 1. Changes in adverse emotions.

cardiovascular health, reduced risk of cardiovascular diseases, improved bone health, and effective weight management, all while posing a relatively low risk of adverse events.[15,16] The role of walking in mitigating negative emotional states has also been validated; a meta-analysis encompassing 75 randomized controlled trials revealed that various walking modalities effectively alleviate symptoms of depression and anxiety, with outcomes comparable to those of active therapeutic interventions.[17] Forest therapy may amplify the benefits associated with walking; for example, Ochiai et al[18] reported significant reductions in both systolic and DBP in middle-aged men with prehypertension following forest therapy. This study identifies similar effects in an elderly hypertensive cohort, suggesting that the beneficial impacts of forest environments on blood pressure regulation extend across different age demographics and levels of hypertension severity. The dual regulation of blood pressure by both the sympathetic and parasympathetic nervous systems may imply that forest therapy exerts its effects by attenuating sympathetic nervous system activity.[19,20]

In this investigation, serum MDA levels were significantly lower and SOD levels markedly higher in the study group compared to the control group. Oxidative stress is a critical factor in the pathophysiology of hypertension, and antioxidant therapies have demonstrated promise in both preventing and mitigating hypertension.[21,22] Ssuperoxide dismutase serves as a vital antioxidant enzyme that neutralizes superoxide anion radicals, thereby protecting cellular structures from oxidative damage.[23] Malondialdehyde, a product formed from the reaction between lipids and oxygen free radicals, serves as an indicator of lipid peroxidation levels.[24] Research conducted by Yamada et al[25] further corroborated that regular immersion in forest environments may help to attenuate oxidative modifications of proteins and lipids within the body. Additionally, Zhu et al[26] demonstrated that forest therapy positively influences immune function and overall well-being in patients with chronic fatigue, possibly through the modulation of the

nicotinamide adenine dinucleotide phosphate oxidase 4 (NOX4)/Reactive oxygen species (ROS)/ Nuclear factor kappa-B (NF-κB)

signaling pathway to mitigate chronic stress. According to the POMS questionnaire results, participants reported feeling more "comfortable," "natural," and "relaxed" following forest therapy, with a notable reduction in negative emotional states. Furthermore, when compared to urban walking, forest therapy emerged as an effective stress-reduction intervention, contributing to a decreased risk of psychosocial stress-related illnesses.[27] Importantly, this study included a 12-month follow-up period, thereby confirming the long-term cardiovascular benefits of forest therapy.

Table 5. Profile of Mood States Subscale Scores Before and After Intervention (Mean ± SD) and Between-Group Comparisons at Post-Intervention

Subscale	Control Group (Pre)	Control Group (Post)	Study Group (Pre)	Study Group (Post)	*P* (Between Groups at Post-Intervention)*
Tension-Anxiety	13.5 ± 2.8	11.2 ± 2.6	13.7 ± 2.9	8.6 ± 2.1	<.001
Anger-Hostility	12.8 ± 3.0	10.9 ± 2.5	13.1 ± 2.8	8.4 ± 2.0	<.001
Fatigue-Inertia	14.1 ± 3.1	12.3 ± 2.9	14.3 ± 3.2	9.1 ± 2.3	<.001
Depression-Dejection	15.0 ± 3.2	13.1 ± 3.0	15.3 ± 3.3	10.0 ± 2.4	<.001
Confusion-Bewilderment	12.6 ± 2.7	11.0 ± 2.5	12.8 ± 2.8	8.9 ± 2.2	<.001
Vigor-Activity	11.2 ± 2.6	12.5 ± 2.8	11.3 ± 2.7	15.8 ± 3.0	<.001

**P*-values are derived from post hoc between-group comparisons at post-intervention after a significant group × time interaction in the repeated-measures ANOVA.

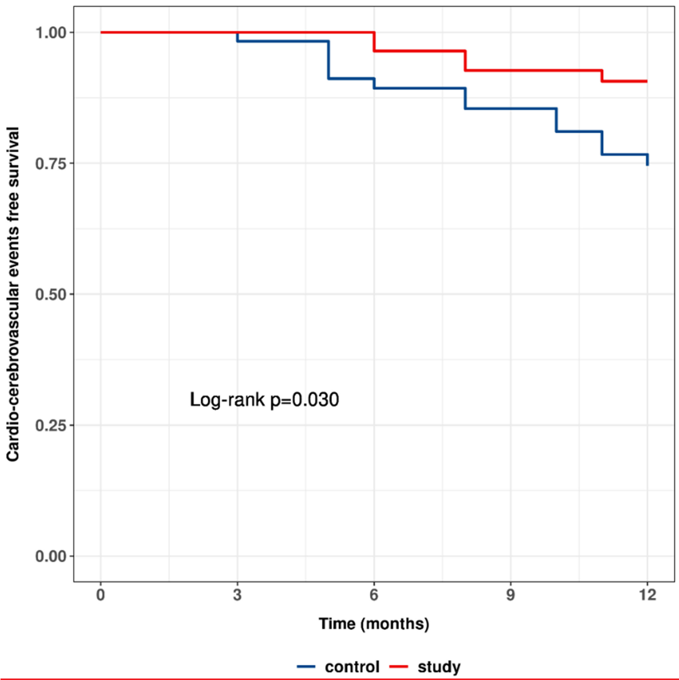

Figure 2. Kaplan–Meier curve of cardiovascular events.

The pronounced reduction in cardiovascular events observed in this study (HR = 0.340, P = .018, 95% CI: 0.120-0.950) likely reflects the cumulative physiological benefits of forest therapy across multiple interconnected domains. First, the significant decrease in both systolic and DBP reduces hemodynamic load on the vascular system, thereby lowering the risk of endothelial injury, a key precursor to atherosclerosis and thrombosis. Second, the observed enhancement of antioxidant capacity, reflected by higher SOD levels and reduced MDA concentrations, suggests attenuation of oxidative stress—a central mechanism in vascular inflammation, arterial stiffness, and plaque instability. Third, the improvement in negative emotional states such as tension, anger, and depression may indirectly contribute to cardiovascular protection by modulating autonomic nervous system balance and reducing sympathetic overactivity, which has been associated with elevated heart rate variability and reduced arrhythmic risk.

Taken together, these physiological and psychological adaptations form a synergistic mechanism that supports vascular homeostasis and reduces the likelihood of cardiovascular events. It is plausible that repeated exposure to restorative natural environments reinforces parasympathetic dominance, dampens systemic inflammation, and promotes endothelial nitric oxide production, collectively translating into tangible clinical benefits over time. Future mechanistic studies incorporating biomarkers of inflammation, autonomic function, and vascular reactivity are warranted to further elucidate these pathways.

Limitations

This study has several limitations that should be acknowledged. First, the sample size was relatively small, with 120 participants in total and only a limited number of cardiovascular events observed during the 12-month follow-up (13 in the control group and 5 in the study group). This small number of events reduces the statistical power of the HR estimation and leads to a wide CI (95% CI: 0.12-0.95). Second, the lack of blinding represents a potential source of bias. Because of the nature of the forest therapy intervention, it was not possible to blind either participants or researchers, which could have introduced expectancy bias, particularly in the subjective assessment of mood states using the POMS questionnaire. Third, this was a single-center study conducted within 1 geographical region, and therefore, the generalizability of the results to elderly populations in other cultural or environmental contexts may be limited. Finally, regarding intervention duration and sustainability, the study only evaluated short-term outcomes after a 4-week intervention. The long-term maintenance of behavioral or physiological benefits remains uncertain, as it is unclear whether participants continued similar activities following the study period. Future multi-center studies with larger sample sizes, longer follow-up durations, and more rigorous control of potential confounding factors are warranted to validate and expand upon these findings.

CONCLUSION

In elderly patients with hypertension, forest therapy effectively manages blood pressure, improves adverse emotional states, reduces oxidative stress levels, and diminishes the risk of cardiovascular events.

Data Availability Statement: The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Committee Approval: The study protocol was reviewed and approved by the Institutional Review Board of The First Affiliated Hospital of Zhejiang University School of Medicine (Acceptance Number: IIT20230086C-R1; Approval Document Number Reference Number: Zhejiang First Affiliated Hospital Lunshen 2023 Research No. 112 - Meeting. Ethical approval date: October 25, 2023).

Informed Consent: Written informed consent was obtained from all participants or their legal representatives prior to enrollment.

Peer-review: Externally peer-reviewed.

Author Contributions: We declare that all the listed authors have participated actively in the study and all meet the requirements of authorship. Dr. SFL designed the study, performed research, managed the literature searches, and wrote the paper; Dr. HJL undertook the data acquisition and analysis; Dr. ZBC contributed to the correspondence and paper revision. All authors reviewed the manuscript.

Declaration of Interests: The authors have no conflicts of interest to declare.

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