

A Review of Field Experiments on the Effect of Forest Bathing on Anxiety and Heart Rate Variability

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Abstract

Many studies have explored the physiological and psychological benefits of the Japanese nature therapy practice of “shinrin-yoku,” known in the West as forest bathing. This review article has narrowed its focus to include the most recent literature about the beneficial effects of forest bathing on heart rate variability, expressed as an increase in lnHF, indicating activation of the parasympathetic nervous system and also its effect on reducing anxiety.

Keywords

forest bathing, shinrin-yoku, anxiety, heart rate variability

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Introduction

Urbanization continues to increase worldwide, and by 2050, 68% of the population is projected to live in an urban environment.¹ This trend has a negative impact on physical and emotional health. “Overall, urbanicity seems to be linked to a higher risk of mental health disorders.”²

Anxiety disorders are the most prevalent psychiatric disorders. According to epidemiological surveys, one-third of the population is affected by an anxiety disorder during their lifetime. They are more common in women. During midlife, their prevalence is highest. These disorders are associated with a considerable degree of impairment, high health-care utilization and an enormous economic burden for society.³

This review aims to consider if the practice of forest bathing may be a valuable intervention to treat anxiety and boost parasympathetic responses.

Background

Forest bathing is a nature therapy originally developed in Japan as shinrin-yoku, a term coined in 1982 by Tomohide Akiyama of the Japanese Forestry Agency.⁴ This therapeutic technique can be described as “bathing in the forest atmosphere, or taking in the forest through our senses.”⁵ Clifford notes “the Japanese emphasize the

scientific rationale for forest walks. Most of the guided walks I’ve been on in Japan begin and end with measurements of blood pressure and salivary amylase, which are indicators of stress and relaxation.” For the purposes of this article, the forest bathing model entails an average of 2 to 4 hours in a forest and includes a combination of various activities such as walking, standing, lying, sitting, and deep breathing. This practice is facilitated by a trained forest bathing guide to focus participants’ attention with meditative concentration on sensory experiences, engaging sight, sound, touch, smell, and sometimes taste to explore the surrounding forest.⁶ Forest bathing can be defined as immersion in nature with mindful use of all 5 senses; studies on physical and mental health benefits report reduced stress, anxiety, and depression symptoms as well as improved mood and relaxation.⁷

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Methods

A broad review of the available literature was conducted using the PubMed and ScienceDirect databases with the keywords: “shinrin-yoku,” “forest therapy,” “forest walking,” and “nature therapy”; 631,953 references were found with this search. The results were narrowed to recent field experiments with dates ranging from 2008 to 2018 that also used a formalized forest bathing program affecting anxiety levels and heart rate variability; however, other studies using similar methods of exposure to natural settings were also included due to the limited amount of recent research specifically related to a formalized forest bathing program. Inclusion criteria for these additional field experiments are defined as walking in a forest for a determined amount of time. Some studies were excluded in which surveys were given or lab experiments were conducted where participants were presented with images or other natural stimuli versus actually walking in natural surroundings. Nine articles were selected for this review.

Effects on Parasympathetic Nervous System Activity

Research observing the effects of forest bathing/forest therapy on the autonomic nervous system (measuring an increased heart rate variability as an indicator) were found with 2 studies.

The first study analyzed the heart rate variability (HRV) of 485 young male participants while walking in forest versus urban environments. HRV data were obtained while groups walked “in a forest or an urban environment for approximately 15 minutes. On the second day, the participants switched field sites.”⁸

During forest walking, larger parasympathetic indicator of HRV (InHF) and smaller sympathetic indicator of HRV (In(LF/HF)) were observed compared with those walking in urban environments. As the InHF and In(LF/HF) are indicators of parasympathetic and sympathetic activity, the results implied that the autonomic relaxation occurred during walking in forest environments. Parasympathetic activation (using HRV as an autonomic nervous system indicator) while walking in forest environments has been established in previous field experiments by the same authors and are confirmed by this study. It is important to note that increased InHF indicates an increase in parasympathetic activation response: lowered heart rate and blood pressure, and a calm mood state. Conversely, increased In(HF/LF) indicates a heightened state, or “fight or flight” response. In addition, previous studies suggest that InHF differs between viewing and walking, with an increase in InHF evident with walking.⁸

In the second study, “autonomic responses to urban and forest environments were studied in 625 young male subjects.”⁹ The participants were randomly divided into 2 groups that viewed either a forest or urban landscape for 15 minutes each in a seated position. HRV was monitored continuously. “The experiment was performed at each experimental site over 2 consecutive days.”⁹ On day 2, the subjects switched environments, repeating the protocol from the first day.

“Approximately 80% of the subjects showed an increase in the parasympathetic activity”⁹ in a forest setting and the urban subjects exhibited the opposite effect. The measured variations in InHF between forest and urban locations measured reveal that 79.2% of the 625 subjects experienced an increase in InHF when exposed to a forest setting; conversely, 20.8% of the 625 subjects experienced a decrease in InHF. In addition, difference in the InHF mean values is statistically significant, although minute. Similar results were found for In(LF/HF) values, indicating HRV may be a more sensitive tool for measuring parasympathetic activation in this experiment.⁹

In this third study evaluating the cardiovascular effects of nature on women, 36 female subjects, aged 30 to 50 years, were selected. In randomly changing groups of fours, the subjects were exposed to an urban area, an urban park, or an urban forest. Seated exposure time was 15 minutes and walking exposure time was 30 minutes. Measurements gathered include blood pressure, heart rate, and electrocardiogram to determine HRV. Breathable particulate matter and noise levels were also recorded in each setting. Substantially reduced levels of particulate air pollution and noise levels were recorded in natural areas, while higher levels of noise and breathable particulate matter were found with city exposures. The data analysis revealed that exposure to natural settings shows increased high frequency (HF) power and a lower heart rate, indicating an increase in parasympathetic nervous activity. Viewing natural settings compared to viewing city areas yields similar results as well as reduced systolic blood pressure.

In general, the results of this study indicate that even brief exposure to a natural setting may result in reduced cardiovascular risk. Furthermore, high noise levels and increased levels of air pollution outdoors appear to have a negative effect on cardiovascular benefit. The authors noted that the combined measures of HRV and heart rate are a more sensitive measure of stress response in short-term field experiments in comparison to similar studies using cortisol levels as a stress indicator. Limitations noted in this field experiment include a small sample size and the absence of male subjects in this study.¹⁰

Effects on HRV and Anxiety Levels

Several other articles consider the effects of forest bathing/forest therapy on anxiety-tension using The Profile of Mood States (POMS) subscale scores and the semantic differential (SD) method.

One such study measured changes in autonomic nervous system activity and emotions after a 2-hour forest bathing program in 128 middle-aged and elderly participants. Physiological measurements were taken; pulse rate, blood pressure, HRV, and POMS subscale scores were recorded.

The POMS “subscale scores for ‘tension-anxiety’, ‘anger-hostility’, ‘fatigue-inertia’, ‘depression-dejection’, and ‘confusion-bewilderment’ were significantly lower, whereas the positive mood subscale score of ‘vigor-activity’ was higher.”¹¹ In addition, participants reported significantly lower levels of anxiety using the Spielberger State-Trait Anxiety Inventory. This study determined that a forest bathing program causes significantly lower pulse rate, systolic, and diastolic blood pressure after a 2-hour walk. In addition, reduced tension, anger, fatigue, depression, confusion, anxiety and improved positive emotions were reported. Surprisingly, sympathetic and parasympathetic nerve activity measures revealed no significant changes. In summary, a 2-hour forest bathing program appears to yield physiological and psychological benefits with middle-aged and elderly individuals.

In another study, 20 Japanese men were screened and 10 were selected for 2 groups of 5. Each participant had been diagnosed with stage 1 hypertension (having a systolic 140–159 mm Hg or diastolic 90–99 mm Hg) and 5 had stage 2 hypertension (having a systolic 160–179 mm Hg or diastolic 100–109 mm Hg). Each group alternated walking in a forest setting for 17 minutes one day followed by walking for 17 minutes in an urban setting the next day. Heart rate and HRV were used to quantify autonomic nervous system responses. Subjects completed 2 questionnaires measuring mood states using the modified SD method referencing 3 pairs of adjectives on 13 scales: “comfortable to uncomfortable,” “relaxed to awakening,” and “natural to artificial.” A modified 30-question POMS was set for 6 subscales: “tension-anxiety,” “depression,” “anger-hostility,” “fatigue,” “confusion,” and “vigor.”

Results indicated that walking in a forest elicited both physiological and psychological relaxation for middle-aged individuals with hypertension; there was a significant increase in parasympathetic nerve activity and a significant decrease in heart rate. In addition, a significant increase in “comfortable,” “relaxed,” and “natural” mood, and reduced “tension-anxiety,” “depression,” “anger-hostility,” “fatigue,” “confusion,” and “vigor” were reported. The authors point out this study’s

limitations, including an inability to generalize these results for the female population and for people of varying ages, and thus a more comprehensive study is recommended in the future.¹²

A third article investigated the influence of forest therapy on cardiovascular effects. “Forty-eight young adult males participated in the two-day field research”¹³ comparing physiological and psychological changes during forest walking and urban walking. Changes in HRV, heart rate, and blood pressure were measured and questionnaires recorded changes in mood states following walking. Subjective measures such as “comfortable-uncomfortable,” “natural-artificial,” and “soothed-aroused” were recorded using a 13-scale SD method. The modified 30-question version of the POMS questionnaire was used to measure mood. Anxiety was measured using the Spielberger State-Trait Anxiety Inventory questionnaire. Each group walked for 14 minutes in each environment.

The study found forest walking significantly increased $\ln(\text{HF})$ values and significantly decreased $\ln(\text{LF}/\text{HF})$ values compared to urban walking. Heart rate during forest walking was significantly lower than the urban walking control group. Reported subjective measures indicated that “negative mood states and anxiety levels decreased significantly by forest walking compared with urban walking.”¹² “Walking in a forest environment may promote cardiovascular relaxation by facilitating the parasympathetic nervous system. In addition, forest therapy may be effective in reducing negative psychological symptoms.”¹³

Another study examined the effects of walking in a forest on HRV and mood states, comparing natural settings to city environments. Over the course of 2 years, 24 field experiments were done with 280 Japanese male participants to compare the findings regarding the physiological effects of forest walking with corresponding results from previous research. Each experiment was comprised of 12 subjects divided into 2 groups of 6. One group was assigned to walk in a city while the alternate group walked in a forest environment. Each group walked approximately 14 minutes. On the following day, the groups alternated settings. Blood pressure, heart rate, HRV, and salivary cortisol levels were recorded prior to and following each walk. All cardiac data were collected with a portable electrocardiograph, and both HF and low frequency (LF) power level components were calculated each minute during walking. Psychological status was measured using the POMS recording 6 dimensions of mood: tension-anxiety, depression-dejection, anger-hostility, fatigue, confusion, and vigor.

Results indicated reduced salivary cortisol levels after walking or viewing natural environments, with a 2.4% decrease when walking is compared to viewing.

Significantly lower average pulse rates were recorded in a natural setting versus a city environment, and walking resulted in lower rates than viewing. Comparable results were also seen in the reduced average diastolic blood pressure after walking in versus simply viewing nature. In addition, a 102% increase in InHF after walking and a 56% increase after viewing with a corresponding reduction in In(LF/HF) were measured. POMS score results indicate that natural settings (versus urban environments) reduce tension/anxiety, depression, anger, confusion, as well as increase vigor, and that walking in nature yields significantly greater effects as compared with viewing natural settings.

In summary, exposure to forest bathing, when compared to exposure to urban settings, may reduce heart rate, cortisol levels, blood pressure, and increase parasympathetic nervous system activity indicating a lower stress response. These findings, along with past studies, establish a strong case that exposure to nature has a positive impact on human physiology and mental health.¹⁴

Effects on Anxiety

Additional studies considered the influence of forest bathing/forest therapy on anxiety levels in participants.

One study recorded the effects of forest bathing on cardiovascular function and mood states in 19 middle-aged hypertensive subjects while walking in a forest versus during urban walking. Forest park walking for 80 minutes “significantly reduced the pulse rate in middle-aged males with higher blood pressure, compared with walking in an urban area.”¹⁵ Pulse rate is an index of autonomic nervous system activity indicating a state of relaxation.

Results included decreased pulse rate, a decrease in urinary dopamine, tendency toward decreased urinary adrenaline, a decrease in adiponectin in serum, in addition to a significantly increased score for vigor, and decreased scores for depression, anxiety, fatigue, and confusion (using POMS). In contrast, urban walking significantly increased scores for fatigue and reduced scores for vigor. As found in previously discussed studies, the cumulative effect suggests a forest bathing program induces a significant physiological and psychological state of relaxation.¹⁵

Two studies authored by Ochai et al. explored the physiological effects of a forest therapy program on middle-aged females and males, respectively. In the first study, 17 middle-aged Japanese females were selected to determine the effects of a formalized forest therapy regimen on both physiological and psychological status. Subjects took a 4-hour 41-minute walk; systolic, diastolic BP, and pulse rates were recorded, and salivary samples were taken to obtain a reliable measure of cortisol levels, as an increase in cortisol indicates stress.

Data were gathered the day before the walk and following forest therapy. Urinary adrenaline, noradrenaline, and salivary cortisol levels were measured to determine sympathetic activity. The SD method and short form of the POMS were used to measure psychological status. The SD method used 3 pairs of adjectives on 7-point scales: “comfortable to uncomfortable,” “relaxed to awakening,” and “natural to artificial”. The short form of POMS included 3 subscales: “tension–anxiety,” “fatigue,” and “vigor.”

Pulse rate was shown to be notably lower following forest therapy versus the prior day, while salivary cortisol levels were also significantly lower. Significantly higher SD scores were reported for “comfortable,” “relaxed,” and “natural” following forest therapy than on the prior day. In addition, the POMS scores revealed a significant improvement in mood; the negative subscale “tension–anxiety” was significantly lower and the positive range of the emotional subscale “vigor” was significantly higher following forest therapy. The mean pulse rate was significantly lower as well after forest therapy when compared to the prior day, indicating a state of relaxation. Lab results also revealed that salivary cortisol levels were significantly lower following forest therapy than the day before. The authors conclude that forest therapy also reduces stress in middle-aged females but recognize that this study had the limitation of excluding an urban walk control group in order to compare results with the forest therapy group.¹⁶

In the second study, 9 Japanese males ranging in age from 40 to 72 years were selected as participants in a study to assess the physiological and psychological effects of forest therapy on middle-aged males with high-normal blood pressure (systolic 130–139 mm Hg and/or diastolic 85–89 mm Hg). Each participant engaged in a 4-hour 35-minute forest therapy walk. Blood pressure and several physiological and psychological indicators of stress were measured at the same time of day on the day prior to and following forest therapy. Urine and blood samples were also taken, measuring adrenaline, cortisol, and creatinine. Questionnaires were completed by subjects the day before and following forest therapy. The SD method, POMS subscale scores, and combined POMS Total Mood Disturbance (TMD) score were used to evaluate psychological responses to forest therapy. The SD method used 7-point scales for 3 pairs of adjectives, such as “comfortable to uncomfortable,” “relaxed to awakening,” and “natural to artificial”. The short-form POMS scores used 30 questions with the following 6 subscales: “tension–anxiety,” “confusion,” “anger–hostility,” “depression,” “fatigue,” and “vigor.” The TMD score was calculated by using the POMS 6 subscales values, and a high TMD score correlates with a negative psychological state.

This study demonstrated that forest therapy facilitates a significant decrease in blood pressure and a decrease in serum cortisol levels and urinary adrenaline. Also reported were an increase in “natural” and “relaxed” feelings measured by the modified SD method, “a decrease in POMS negative subscales ‘tension-anxiety’, ‘confusion’, and ‘anger-hostility’, as well as the TMD score in middle-aged males with high-normal blood pressure.”¹⁷ The authors recognize the limitations of this study due to lack of a control group walking in an urban setting.¹⁷ The results of the above discussed studies are summarized in Table 1.

Analysis

It is evident that more research is required to further explore the beneficial health effects of a formalized forest bathing program as only 3 of the 10 articles reviewed here chose an accepted forest bathing model in their experimental design (Yu and Ochiai). One study (Lanki) closely approximated a forest bathing

program, during which subjects were guided through numerous activities engaging the 5 senses. The remaining 6 research articles relied only on walking in and/or viewing a forest environment. A consistent use of a formalized forest bathing program would ensure more reliable outcomes in further research in this area.

Of the reviewed studies, 40% of the researchers selected young participants in their 20s, while the majority chose subjects aged 30 to 69 years. This is a limitation; it will be advantageous for future researchers to include a broader range of ages, equally represented, in order to generalize results across the population.

It is notable that only 1 study included both male and female subjects in their experimental design. This may be of importance as there is evidence there may be physiological differences in how men and women respond to stress.¹⁸ Studies reviewed included 70% male participants, 20% female participants, and 10% mixed group. It is advisable to consider a more heterogeneous sample in the experimental design with regard to gender. It is also of interest to note that 60% of the reviewed studies had sample sizes less than 100 participants.

Table 1. A Summary of Research Studies.

Study Author	Location	Number of Subjects	Gender of Subjects	Age of Subjects (Mean $\pm$ Standard Deviation)	Exposure Time in Minutes	Stimuli vs Control	Follows FB Model	Results
Kobayashi et al. ⁸	Japan	485	M	21.7 $\pm$ 1.6	15	F vs U	No	$\uparrow$ INHF
Kobayashi et al. ⁹	Japan	625	M	21.6 $\pm$ 1.6	15	F vs U	No	$\uparrow$ INHF
Lanki et al. ¹⁰	Finland	36	F	30-60 (age range)	30	F vs U	Closely approximates	$\uparrow$ INHF $\downarrow$ Anxiety $\downarrow$ HR $\downarrow$ BP
Yu et al. ¹¹	Taiwan	43/85	M/F	60.0 $\pm$ 7.44	120	Before FB vs after FB	Yes	$\downarrow$ Anxiety
Song et al. ¹²	Japan	20	M	58.0 $\pm$ 10.6	17	F vs U	No	$\uparrow$ INHF $\downarrow$ Anxiety
Lee et al. ¹³	Japan	48	M	21.1 $\pm$ 1.2	14	F vs U	No	$\uparrow$ INHF $\downarrow$ Anxiety
Park et al. ¹⁴	Japan	280	M	21.7 $\pm$ 1.5	16 $\pm$ 5 14 $\pm$ 2	F vs U	No	$\uparrow$ INHF $\downarrow$ Anxiety $\downarrow$ HR $\downarrow$ SC
Li et al. ¹⁵	Japan	19	M	51.2 $\pm$ 8.8	80	F vs U	No	$\downarrow$ Anxiety $\downarrow$ HR
Ochiai et al. ¹⁶	Japan	17	F	62.2 $\pm$ 9.4	281	FB vs control	Yes	$\downarrow$ Anxiety $\downarrow$ HR $\downarrow$ SC
Ochiai et al. ¹⁷	Japan	9	M	56.0 $\pm$ 13.0	275	FB vs control	Yes	$\downarrow$ Anxiety $\downarrow$ BP $\downarrow$ SC $\downarrow$ UA

Abbreviations: BP, blood pressure; F, forest; FB, forest bathing; HR, heart rate; INHF, average power of the high-frequency component of heart rate variability; SC, salivary cortisol; U, urban; UA, urinary adrenaline.

Another result of this review highlights that the incidence of increased InHF occurred in all 6 articles evaluating the effect of HRV while exposed to a natural environment. These provide strong evidence that forest bathing may elicit parasympathetic nervous activity.

Based on the studies reviewed here, it is evident that forest bathing and exposure to nature approximating this model, even for as little as 15 minutes, may be of benefit in reducing anxiety and stress. However, there were wide variances in exposure time across these studies, from 15 minutes to over 4 hours. Fifteen minutes was the most frequent exposure time used (55% of studies reviewed). It would be of interest if future research could determine if longer times result in stronger results, or perhaps additional health benefits. It is also notable that significant physiological benefits were also found by simply viewing a forest setting; however, the effect has been less than with walking.¹⁴

Limitations

This review raises questions regarding what would be considered a minimal as well as an optimal therapeutic dose for time spent forest bathing in order to maximize physiological and mood benefits. Further field experiments would be justified to determine if longer exposure times would yield even more health benefits yet to be determined. It should be considered whether benefits are dependent on specific amounts of exposure time, as there appears to be no standard used for research purposes currently. In addition, a standardized forest bathing program would improve the reliability of future research studies.

For results to apply to broader populations, it would also be of benefit to select a more heterogeneous mix of participants, as several studies referenced here chose either male or female subjects within a determined age range. Moreover, larger sample sizes would also contribute to more reliable results, improved precision, and a better understanding of the potential benefits of forest bathing.

Conclusions

The field experiments referenced here provide limited but strong and consistent evidence that exposure to forest bathing/forest therapy results in an increase in InHF associated with activation of the parasympathetic nervous system and also reduced anxiety. Additional therapeutic benefits include positive mood states and improved mental coordination, with a reduction in stress levels and lower blood pressure.

Future Studies

The results from the inclusion criteria in this review yielded a very low sample of articles on the effects of

forest bathing/forest therapy on anxiety levels and HRV. Ongoing exploration of the practice of forest bathing is needed in order to better understand the mechanisms activating the parasympathetic nervous system and how this may be used as a safe, economic, and effective method of treating anxiety as an adjunct therapy to medication and cognitive-based therapy. Additional field experiments are recommended to establish a standard for exposure time, a standardized forest bathing program, and appropriate subject selection criteria to be used in future studies.

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