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Effects of Viewing Forest Landscape on Middle-aged Hypertensive Men

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Highlights:
- Physiological effects of exposure to the forest environment were investigated.
- Middle-aged hypertensive men sat on chairs and viewed forest landscapes for 10 min.
- Parasympathetic nervous activity was significantly higher during viewing forest.
- Heart rate was significantly lower during viewing forest.
- Forest landscape produces physiological relaxation effects on hypertensive men.

Abstract: With increasing attention on the health benefits of a forest environment, evidence-based research is required. This study aims to provide scientific evidence concerning the physiological and psychological effects of exposure to the forest environment on middle-aged hypertensive men. Twenty participants (58.0 ± 10.6 years) were instructed to sit on chairs and view the landscapes of forest and urban (as control) environments for 10 min. Heart rate variability (HRV) and heart rate were used to quantify physiological responses. The modified semantic differential method was used to determine psychological responses. Consequently, the high-frequency component of HRV, a marker of parasympathetic nervous activity that is enhanced in relaxing situations, was significantly higher and heart rate was significantly lower in participants viewing the forest area than in those viewing the urban area. The questionnaire results indicated that viewing the forest environment increased “comfortable,” “relaxed,” and “natural” feelings than viewing the urban environment. In conclusion, viewing forest landscape produces physiological and psychological relaxation effects on middle-aged hypertensive men.

Abbreviations
The following abbreviations are used in this manuscript:

HRV: heart rate variability
NK: natural killer
LF: low frequency
HF: high frequency
SD: semantic differential

Keywords: heart rate; heart rate variability; hypertension; middle-aged individuals; preventive medicine; shinrin-yoku
Introduction

In recent years, there has been considerable and increased attention in using the forest environment as a place for recreation and health promotion. This approach was called “Shinrin-yoku” that means “taking in the forest atmosphere” (Selhub and Logan, 2012). It suggests that “forest bathing,” which is a health promotion method and uses proven effects of a forest environment, such as relaxation, can improve the health of the body and mind. In accordance with the accumulation of data, the idea of “forest therapy” has been proposed. It means evidence-based “forest bathing (shinrin-yoku)” and aims to achieve a preventive medical effect by inducing physiological relaxation and immune system recovery.

Previous studies targeting healthy young adults have demonstrated that time spent in a forest environment can decrease cerebral blood flow in the prefrontal cortex (Park et al., 2007) decrease blood pressure (Tsunetsugu et al., 2007; Lee et al., 2009; Park et al., 2009; Park et al., 2010), reduce pulse rate (Tsunetsugu et al., 2007; Park et al., 2008; Lee et al., 2009; Park et al., 2009; Lee et al. 2011), and increase parasympathetic nervous activity that is enhanced in relaxing situations (Tsunetsugu et al., 2007; Park et al., 2008; Park et al., 2009; Park et al., 2010; Lee et al., 2011; Tsunetsugu et al., 2013; Lee et al., 2014). Sympathetic nervous activity that is enhanced in stressful situations is suppressed (Tsunetsugu et al., 2007; Park et al., 2009; Park et al., 2010; Lee et al., 2011; Tsunetsugu et al., 2013; Lee et al., 2014). In addition, the levels of salivary cortisol, a stress hormone, decrease (Miyazaki et al., 1996; Tsunetsugu et al., 2007; Park et al., 2007; Park et al., 2008; Lee et al., 2009; Park et al., 2010; Lee et al., 2011; Tsunetsugu et al., 2013). In other studies, natural killer (NK) cell activity was enhanced and immune function was improved; these effects lasted for 30 days (Li et al., 2007; Li et al., 2008; Li et al., 2008). From the psychological aspect, restorative effects related to psychological stressors or mental fatigue and improved mood states and cognitive function (Miyazaki and Motohashi, 1996; Li et al., 2007; Morita et al., 2007; Shin et al., 2010; Park et al., 2011; Shin et al., 2011) have been reported.

Studies targeting elderly individuals and patients with reversible diseases have also been reported. Walking in a forest environment can improve arterial stiffness and pulmonary function in elderly women (Lee et al., 2014). Furthermore, it can decrease blood glucose levels in patients with non-insulin-dependent diabetes mellitus (Ohtsuka et al., 1998), provide the subjective perception of having less days of pain and insomnia and more days of wellness in patients with fibromyalgia (López-Pousa et al., 2015), and enhance NK cell
activation leading to the production of two anticancer molecules in breast cancer patients (Kim et al., 2015). Other findings have indicated that cognitive behavioral therapy conducted in a forest environment was more successful in achieving depression remission than psychotherapy conducted in a hospital (Kim et al., 2009).

Several studies have demonstrated the beneficial effects of forest therapy in hypertension. Forest therapy programs such as walking, guided activity, or educational sessions can reduce blood pressure (Mao et al., 2012; Ochiai et al., 2015), urinary adrenaline concentration (Ochiai et al., 2015), and serum and salivary cortisol levels (Sung et al., 2012; Ochiai et al., 2015) in hypertensive individuals. Hypertension is a critical public health challenge worldwide, and the prevention, detection, treatment, and control of this condition have been emphasized (Kearney et al., 2005). Forest therapy is expected to play a key role in this respect. A previous study examined the effects of walking in a forest environment on middle-aged hypertensive men (Song et al., 2015). Walking in a forest environment can enhance parasympathetic nervous activity and decrease heart rate in hypertensive individuals compared with walking on the city streets (Song et al., 2015). However, these findings included not only the impact of forest environment on humans but also incorporated an element of exercise; thus, one must be careful not to over-interpret the health-giving properties of a forest environment alone. Evidence-based research concerning only the influence of exposure to a forest environment while remaining sedentary is lacking. To the best of our knowledge, there are no studies that have examined the physiological and psychological effects of viewing a forest environment in a seated position in hypertensive individuals.

The present study aimed to clarify the effects of viewing forest landscape on the autonomic nervous activity of middle-aged hypertensive men who remained sedentary while viewing the landscape.

**Materials and methods**

**Participants**

Japanese men between the ages of 40 and 75 years and whose blood pressures were above the upper boundary of normal (120/80 mmHg) were recruited. Researchers contacted applicants face-to-face before the start of the study, and those who were taking daily medication for chronic conditions, such as diabetes, hyperlipidemia, and hypertension, were excluded. In total, 20 Japanese men aged 40–72 years (mean age, 58.0 ± 10.6 years; Table 1) participated. Among them, eight participants lived in cities with more than 50,000 residents, nine lived in
towns with more than 8,000 residents, and three lived in villages with less than 8,000 residents.

Of these 20 participants, five had a high-normal blood pressure (systolic, 130–139 mmHg or diastolic, 85–89 mmHg) that was considered to be on the higher range of pre-hypertension. Of the remaining 15 participants, 10 had hypertension stage 1 (systolic, 140–159 mmHg or diastolic, 90–99 mmHg) and five had hypertension stage 2 (systolic, 160–179 mmHg or diastolic, 100–109 mmHg). For classification, the values measured in the morning (8:30–8:45) of the first experimental day at the Nagano Prefectural Kiso Hospital were used. Furthermore, systolic and diastolic blood pressures were measured according to the oscillometric method using a digital blood pressure monitor (HEM1020; Omron Corp., Kyoto, Japan).

At the beginning of the experiment, the participants were informed about the aims and procedures of the study. After receiving a description of the experiment, they signed an agreement to participate in the study. During the study period, the consumption of alcohol, caffeine, and tobacco was prohibited. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committees of the Nagano Prefectural Kiso Hospital, Japan and of the Center for Environment, Health and Field Sciences, Chiba University, Japan (Project identification code number: 5).

Experimental sites
The field experiment was conducted in a natural coniferous forest that included many Japanese cypress trees (Akasawa natural recreation forest) and was located in Agematsu town of Nagano Prefecture, which is situated in central Japan (hereafter referred to as the forest area). In Japan, Japanese cypress is a well-known and common tree, and coniferous forests are typical. The urban environment is used as a control, which is a common exposure in everyday life. The urban areas were downtown near the Japan Railway station (hereafter referred to as the urban area).

The weather was sunny on the days of experiments. During viewing of the forest area, the average temperature was 24.3°C ± 0.1°C with an average humidity of 70.5% ± 0.9%, whereas in the urban area, the average temperature was 29.9°C ± 0.1°C with an average humidity of 52.0% ± 0.8%.

Experimental design
The 20 participants were randomly assigned to two groups of 10 that participated in the experiment over 2 consecutive days. On the first day (September 14), one group moved to the forest area and the other moved to the urban area by car (an approximately 45-min journey). On the second day (September 15), the groups switched experimental areas to eliminate an order effect.

The participants moved within their respective experimental site. After arriving at the site, participants were instructed to sit on a chair. After resting for 5 min, they viewed each landscape for a period of 10 min in the afternoon (Figure 1). Conversation among participants was prohibited. Furthermore, the participants viewed the two areas at approximately the same time of day to eliminate the influence of diurnal changes on physiological rhythms.

After viewing, participants answered the questionnaires.

**Physiological indices**

Heart rate variability (HRV) and heart rate were measured to assess autonomic nervous activity. HRV and heart rate were measured using an electrocardiogram sensing system (myBeat; Union Tool Co., Tokyo, Japan). Frequency spectra were generated using a HRV software tool (MemCalc/Win; GMS, Tokyo, Japan). For real-time HRV analysis using the maximum entropy method, interbeat (R–R) intervals were continuously obtained. In this study, the following two broad HRV spectral components were calculated: low frequency (LF; 0.04–0.15 Hz) and high frequency (HF; 0.15–0.40 Hz). The HF component is an estimate of the parasympathetic nervous activity, whereas the LF/HF ratio is an estimate of the sympathetic nervous activity (Pagani et al., 1986; Task force of the European society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

Several studies have investigated the reliability of HRV measurement by calculating the intraclass correlation coefficient (ICC). Kowalewski and Urban (2004) reported the short- and long-term reproducibility of HRV parameters according to body position (supine or standing). The ICCs of the components HF and LF/HF were 0.71–0.89 and 0.54–0.85, respectively. Kobayashi (2009) reported that the ICCs of logarithmic transformed components (lnHF and lnLF) were 0.71–0.88 regardless of whether paced breathing was applied. Bertsch et al. (2012) demonstrated a value of 0.70–0.73 for the ICC of the parasympathetic indicator of HRV. Most of these studies concluded that the reliability of HRV measurement is good or excellent.
HRV and heart rate data were collected at 1-min intervals and averaged over the entire 10-min period. We then compared these average values between sites.

**Psychological indices**

The modified semantic differential (SD) method (Osgood et al., 1957) was used to evaluate the psychological responses of the participants. This method tests the subjective spatial impressions of participants through a questionnaire with three pairs of opposing adjectives, each of which is evaluated on 13 scales, including “comfortable to uncomfortable,” “relaxed to awakening,” and “natural to artificial.” The higher the score for each, the better the emotional condition.

**Statistical analyses**

Physiological data of 19 participants were used for analysis because of errors in data collection for one participant. We used the paired t-test to compare the mean HRV and heart rate between the two sites. Wilcoxon signed-rank test was used to analyze differences between the psychological indices. All statistical analyses were performed using SPSS, version 20.0 (IBM Corp., Armonk, NY, USA). In all comparisons, p < 0.05 was considered statistically significant. One-sided tests were used for both comparisons because our hypothesis was that middle-aged hypertensive men would be relaxed by viewing a forest environment than by viewing an urban environment.

**Results**

The participants showed significant differences in their physiological and psychological responses for the 10-min viewing of forest and urban areas.

Figure 2 shows the HF component, which is an estimate of parasympathetic nervous activity, to be enhanced in relaxing situations. In the 1-min segment analysis, all HF values were higher when participants viewed the forest area than when they viewed the urban area (Figure 2a). The mean HF over the entire viewing period was significantly higher in the forest area than in the urban area (forest, 142.4 ± 28.1 ms\(^2\); urban, 97.0 ± 17.4 ms\(^2\); p < 0.05, Figure 2b). However, there was no significant difference between the two environments for LF/HF, an estimate of sympathetic nervous activity that is enhanced in stressful situations (forest area, 5.8 ± 1.0; urban area, 6.0 ± 1.1; p > 0.05).

Heart rates were lower in the forest area than in the urban area in all 10-min periods (Figure 3a). The mean heart rate was significantly lower when participants viewed the forest area than when they viewed the urban area (forest, 69.8 ± 1.6 bpm; urban, 72.3 ± 1.2 bpm; p < 0.01, Figure 3b).
Our analysis of the participant responses to the SD method revealed differences in psychological responses between the two environments. Participants felt more “comfortable,” “relaxed,” and “natural” when they viewed the forest area than when they viewed the urban area (p < 0.01, Figure 4).

**Discussion**

Viewing forest landscape can have significant physiological and psychological relaxation effects on middle-aged hypertensive men. Compared with the urban environment, a view of forest environment landscapes for 10 min significantly increased parasympathetic nervous activity and decreased heart rate. In the questionnaires, participants reported that they felt more “comfortable,” “relaxed,” and “natural” after viewing the forest. Our findings are consistent with those of previous studies that examined physiological and psychological responses to a forest environment (Tsunetsugu et al., 2007; Park et al., 2008; Park et al., 2009; Park et al., 2010; Park et al., 2011; Lee et al., 2011; Tsunetsugu et al., 2013; Lee et al., 2014). These results may support the possibility that just being in a forest environment for a short period of time can be relaxing both physically and mentally.

In a previous study, we examined the effects of walking in a forest area compared with walking in an urban area (Ohtsuka et al, 1998) using a similar experimental design and the same locations and participants as in this study. In the previous study, participants walked in both forest and urban areas for 17 min. The HF value was 107.1 ± 31.2 ms² during walking in the forest area and 56.0 ± 14.3 ms² during walking in an urban area. In present study, the HF value was 142.4 ± 28.1 ms² during viewing a forest area and 97.0 ± 17.4 ms² during viewing an urban area. HF values during both viewing and walking were higher in the forest area than in the urban area. In addition, they were higher when viewing landscape than when walking. Heart rate was 77.1 ± 2.0 bpm when walking in the forest area and 78.6 ± 1.8 bpm when walking in the urban area. In the present study, the heart rate was 69.8 ± 1.6 bpm while viewing the forest area and 72.3 ± 1.2 bpm while viewing the urban area. Heart rate while viewing and walking was lower in the forest area than in the urban area. In addition, it was lower while viewing landscape than while walking. The present study shows that the physiological effects of a forest environment alone without incorporating an element of exercise.
Regarding the differences in physiological effect in the forest environment, it may be influenced by various physical factors, such as temperature, humidity, atmospheric pressure, and wind speed, as well as by differences in the stimuli that affect the five senses in a forest environment. Lee et al. (2009) reported significant differences in temperature and humidity between forest and urban environments and discussed the relationship between temperature and human physiological responses. The heart rate is known to decrease at a low ambient temperature (Ishibashi and Yasukouchi, 1999); however, studies on the effect of ambient temperature changes on HRV are lacking. In the present study, the difference in average temperature and humidity between the two environments was 5.6°C and 18.5%, respectively. Future studies should evaluate the physiological effects with comparable temperature and humidity.

The reasons why these effects can be achieved in a forest environment have not been identified. However, some theories exist. Ulrich et al (1983; 1991) developed a “psycho-evolutionary theory,” which suggested that during evolution, there were definite advantages in acquiring a capacity for restoration in response to certain unthreatening natural conditions. Therefore, modern civilization may have an inherent preparedness to quickly and readily acquire restorative responses to many unthreatening natural environments.

According to Kaplan’s (1995) “Attention restoration theory,” an environment that possesses a restorative effect requires the following four properties: being distinct from the daily environment either physically or conceptually (being away), containing elements that effortlessly drive attention (fascination), having scope and coherence that allows one to remain engaged (extent), and fitting with and supporting what one wants or is inclined to do (compatibility). Consequently, Kaplan argued that the natural environment satisfies these elements.

Miyazaki et al (2011) promulgated a “back to nature” theory (O’Grady and Meinecke, 2015). Humans have spent more than 99.99% of their evolutionary history in the natural environment; thus, the human body is made to adapt to nature. Because physiological functions have adapted to the natural environment, we are unable to adjust to rapid environmental changes and may feel stressed. Thus, when we are exposed to the natural environment, our bodies revert to how they should be. In addition, they are targeting “nature” as safe and not a stressor. Recently, Song et al (2015) clarified that a physiological adjustment effect moved close to an appropriate level. Participants with high initial blood pressure and pulse rate showed a decrease in these values after walking in a forest environment, whereas those with low initial values showed an increase. However, there was
no physiological adjustment effect observed in those walking in an urban environment. Thus, it is clear that these effects are specific to a forest environment. These results support the “back to nature” theory.

Regarding the effects of exposure to the forest environment for 10 min on middle-aged men with hypertension, our study findings revealed the following: (1) a significant increase in parasympathetic nervous activity, (2) a significant decrease in heart rate, and (3) a significant increase in feeling “comfortable,” “relaxed,” and “natural” assessed by the modified SD method. In conclusion, exposure to a forest environment induced physiological and psychological relaxation.

Currently, most people live in an urban, artificial environment and are constantly exposed to stressors through the five senses (Craig, 1984; Herbert and Cohen, 1993; Patz et al., 2005; Ge’mes et al., 2008; Lederbogen et al, 2011; McKenzie et al., 2013). Therefore, these physiological and psychological benefits of the forest environment are significant, and the forest environment is expected to play a very important role in shaping health promotion in the future.

However, this study had several limitations. To generalize the findings, it is necessary to consider the following. First, these results cannot be extrapolated to the female population and people of different age groups. Further studies on a large sample, including various participant groups, are required. Second, this study only used HRV and heart rate as variables for analysis. For the overall discussion, future studies should determine the effects of the forest environment using other physiological indices, such as brain and endocrine activities.

Conclusions

Regarding the effects of viewing forest landscape for a short period of time on middle-aged men with hypertension, our study findings revealed the following: (1) a significant increase in parasympathetic nervous activity, (2) a significant decrease in heart rate, and (3) a significant increase in feeling “comfortable,” “relaxed,” and “natural” assessed by the modified SD method. In conclusion, exposure to a forest environment induced physiological and psychological relaxation.

Author Contributions: Chorong Song contributed to the experimental design, data acquisition, statistical analysis, interpretation of results, and manuscript preparation. Harumi Ihei contributed to the experimental design, data acquisition, statistical analysis,
and interpretation of results. Maiko Kobayashi conducted data acquisition. Takashi Miura contributed to preparing the experimental sites and cooperated with data acquisition. Qing Li and Takahide Kagawa participated in data acquisition and contributed to the interpretation of results. Shigeyoshi Kumeda and Michiko Imai conceived the study and participated in the interpretation of results. Yoshifumi Miyazaki conceived and designed the study and contributed to the interpretation of results and manuscript preparation. All authors have read and approved the final version submitted for publication.

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

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Figure 1. Scenery as viewed in the forest and urban areas.

Figure 2. Comparison of HF value of heart rate variability between the forest and urban areas.

(a) Change in each 1-min average of HF value during 10-min viewing.
(b) Overall mean HF values.

N = 19, mean ± standard error. *P < 0.05, determined using the paired t-test (one-sided).
Figure 3. Comparison of heart rate between the forest and urban areas.
(a) Change in each 1-min average of heart rate during 10-min viewing.
(b) Overall mean heart rates.
N = 19, mean ± standard error. **P < 0.01, determined using the paired t-test (one-sided).

Figure 4. Comparison of subjective scoring for “comfortable,” “relaxed,” and “natural” feelings between the two environments according to the semantic differential method.
N = 20, mean ± standard error. **P < 0.01, determined using the Wilcoxon signed-rank test (one-sided).
Table 1. Participant demographics.

| Parameters       | Value                      |
|------------------|----------------------------|
|                  | (Mean ± Standard deviation) |
| Total sample number | 20                        |
| Sex              | Male                       |
| Age (years)      | 58.0 ± 10.6                |
| Height (cm)      | 167.9 ± 6.2                |
| Weight (kg)      | 66.1 ± 10.6                |
| BMI (kg/m²)      | 23.4 ± 3.3                 |
| SBP (mmHg)       | 151.2 ± 17.9               |
| DBP (mmHg)       | 90.7 ± 5.0                 |