

## Physiological Effects of Shinrin-yoku (Taking in the Atmosphere of the Forest)—Using Salivary Cortisol and Cerebral Activity as Indicators—

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**Abstract** The purpose of this study is to examine the physiological effects of Shinrin-yoku (taking in the atmosphere of the forest). The subjects were 12 male students ( $22.8 \pm 1.4$  yr). On the first day of the experiments, one group of 6 subjects was sent to a forest area, and the other group of 6 subjects was sent to a city area. On the second day, each group was sent to the opposite area for a cross check. In the forenoon, the subjects were asked to walk around their given area for 20 minutes. In the afternoon, they were asked to sit on chairs and watch the landscapes of their given area for 20 minutes. Cerebral activity in the prefrontal area and salivary cortisol were measured as physiological indices in the morning at the place of accommodation, before and after walking in the forest or city areas during the forenoon, and before and after watching the landscapes in the afternoon in the forest and city areas, and in the evening at the place of accommodation. The results indicated that cerebral activity in the prefrontal area of the forest area group was significantly lower than that of the group in the city area after walking; the concentration of salivary cortisol in the forest area group was significantly lower than that of the group in the city area before and after watching each landscape. The results of the physiological measurements show that Shinrin-yoku can effectively relax both people's body and spirit. *J Physiol Anthropol* 26(2): 123–128, 2007 <http://www.jstage.jst.go.jp/browse/jpa2> [DOI: 10.2114/jpa2.26.123]

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### Introduction

Since ancient times, human beings have been communicating with the natural environment. Humans have

lived in the natural environment for most of the 5 million years of their existence. If the Industrial Revolution can be considered as urbanization, we have lived in the natural environment for nearly 99.99% of the past 5 million years. All human physiological functions have evolved in and adapted to the natural environment. Thus, it can be thought that the physiological functions of the human are made for the forest. That is one of the reasons why human beings can relax in a forest environment (Miyazaki et al, 2002).

Rapid technological changes have become a fact of life in offices in the 1990s. The use of visual display terminals has increased every year. This has brought about a new keyword, called 'technostress,' which is used to describe the modern stresses of city life (Brod, 1984). People living in urban settings are generally exposed to increases in workloads and mental stresses. So there are increasing levels of social interest in the therapeutic effects of forest environments. In particular, the role that urban forests can play in better human health has been brought to the public's attention through accessibility.

Shinrin-yoku can be defined as making contact with nature and taking in the atmosphere of the forest. It is widely believed that coming into contact with nature is somehow beneficial to human health (Kellert and Wilson, 1993). The term "Shinrin-yoku" was coined by the Ministry of Agriculture, Forestry and Fisheries in Japan in 1982. Shinrin-yoku is a process in which activities in forest environments are used to improve the mental and physical health of people. Shinrin-yoku is an effective and beneficial treatment for people of all ages and backgrounds.

Ulrich (1981) investigated the physiological changes related to recovery from stress. His study showed that lower blood pressure, higher alpha brain wave amplitudes, and reduced muscle tension are observed when subjects are shown slides or videotapes of nature rather than when they are shown urban scenes. Ulrich (1984) showed that people recovered more quickly from surgery if they had a view of trees rather than a

empty wall in their hospital rooms. Miyazaki and Motohashi (1996) investigated the physiological effect of Taiwan Hinoki (*Chamaecyparis taiwanensis*) essential oil for the odoriferous stimulus of forest environments. They found that systolic blood pressure decreased after inhalation of Taiwan Hinoki wood oil. Lohr et al. (1996) studied the benefits of plants in the work places. They found that their subjects' systolic blood pressures rose higher when they performed computer tasks in a room where there were no plants present rather than in a room filled with plants. Additionally, they found that the systolic blood pressures of their subjects in the room with plants returned to pre-task levels more quickly. Ohtsuka et al. (1998) showed that blood glucose levels in diabetic patients decreased when they walked in the forest for 3 km or 6 km, depending on their individual physical ability.

The purpose of this study is to examine the physiological effects of basic Shinrin-yoku activities (specifically, walking in the forest and watching forest landscapes) to clarify the role of Shinrin-yoku's availability in the forest.

## Method

### Experimental areas

The study area was located in "Seiwa Prefectural Forest Park," in Chiba Prefecture (Fig. 1). Seiwa Prefectural Forest

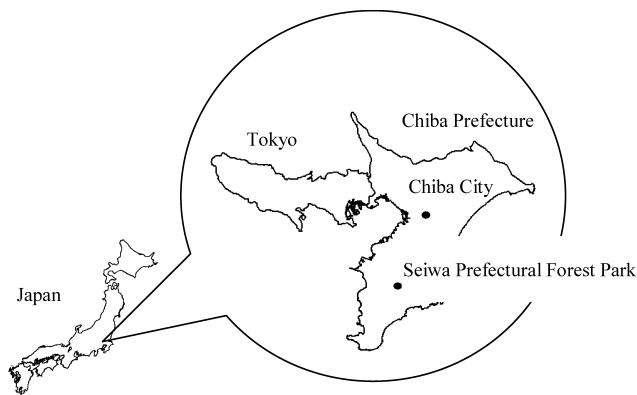


Fig. 1 The study area

Park is a famous urban forest of the Tokyo area because it is no more than 60 km away from Tokyo.

The predominant species in the Seiwa Prefectural Forest Park is the Oak tree (*Quercus acutissima* Carruth., *Quercus serrata* Thunb.). The average age of the forest is approximately 30 years. The experiment was carried out in July, when the vitality of plants is at its highest.

### Subjects

Twelve normal male college students ( $22.8 \pm 1.4$  years old) participated in the study as subjects. None of the subjects reported having any physiological or psychiatric disorders in their personal histories. The study was performed under the regulations of the Institutional Review Committee of the Forestry and Forest Products Research Institute in Japan.

### Procedure

On the day before the experiments, all of the subjects arrived in a city area. Subjects were sufficiently informed of the aim and the procedure of the experiment. The subjects consented to the informed experiment. After an orientation for the experiment, all of the subjects moved to a place of accommodation. The same single rooms were prepared as lodgings for each subject and the same meals were offered during the experiments for environmental condition control.

Figure 2 shows the schedule of the experiments for this study. In the experiments the subjects were divided into two groups randomly. On the first day of the experiments, 6 subjects were sent to a forest area, and the other 6 subjects of the control group were sent to a city area. On the second day of the experiments, the subjects were sent to the opposite areas for a cross check.

In the forenoon of each day of the experiments, the subjects walked around their given area for 20 minutes. In the afternoon, they were seated on chairs watching the landscapes of their given area for 20 minutes. Walking in the forest and watching the forest landscape are considered to be elemental activities of Shinrin-yoku (Fig. 3).

The first measurements were taken in the morning (between 06:15 and 07:15) at the place of accommodation. After the first

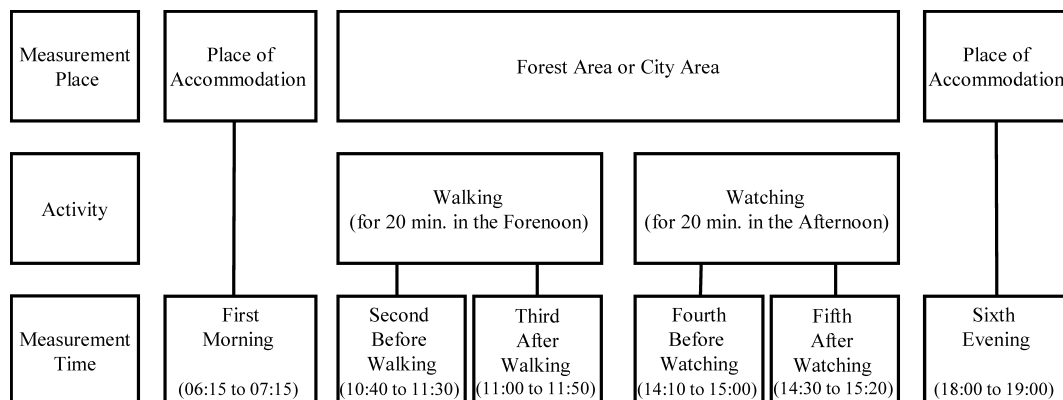
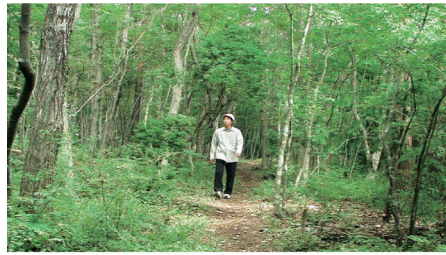


Fig. 2 The experimental schedule



(a) Walking in the Forest Area



(b) Watching the Landscape in the Forest Area



(c) Walking in the City Area



(d) Watching the Landscape in the City Area

**Fig. 3** Walking and watching in the forest and city areas

measurement, subjects were sent to a forest or city area. It took an hour and a half to get to the forest area or city area from the point of departure. The second and third measurements were taken before (between 10:40 and 11:30) and after (between 11:00 and 11:50) walking at the given places. The fourth and fifth measurements were taken before (between 14:10 and 15:00) and after (between 14:30 and 15:20) watching at the given places. The sixth measurement was taken in the evening (between 18:00 and 19:00) at the place of accommodation on arrival. The measurements were taken one person at a time. Indoor waiting places for the subjects were prepared in both forest and urban areas. The temperature and humidity of the waiting places were properly controlled. The subjects were made to stay in the waiting places during the time when they were not involved in the field test. They were allowed to read a newspaper or a book to avoid becoming drowsy.

#### Measurements

Saliva was collected in a salivette (No. 51.1534, Sarstedt, Numbrecht, Germany) for 5 minutes. The collected saliva was frozen, and the samples were transported to SRL, Inc., for analysis of salivary cortisol concentrations.

Absolute hemoglobin concentrations of the prefrontal cortex were measured as an index of cerebral activity on the left side of the forehead (Hoshi et al., 2000). A Time-Resolved Spectroscopy (TRS) system (TRS-10; Hamamatsu Photonics K.K., Japan) was used to measure hemoglobin concentrations. Two 1-channel TRS systems were employed in this study (Ohmae et al., 2006). Absolute hemoglobin concentrations had never been measured in the field for any study before.

Sensory evaluation was conducted after physiological measurements at the place of accommodation in the morning

and in the evening, and after walking and watching the landscape in the given areas. The subjects were asked to evaluate the given areas and to graph their levels of “comfort” and “calm” on two 13-point scales.

Both physiological and psychological tests were used to compare the forest and city areas. A one-tailed t-test was used to analyze the physiological effect and a Wilcoxon signed-rank test was used to analyze the psychological effect.

In order to compare exercise load during forest and city walking, exercise load was estimated with an activity monitor (Lifecorder; Suzuken Co, Ltd, Japan). The subject wore an activity monitor during city and forest walking. There is no difference of exercise load between forest-area walking and city-area walking.

#### Results

The results of the psychological effect of Shinrin-yoku are shown in Figs. 4 and 5. Figure 4 shows the scores of “comfort” for the forest and city areas. Both areas were evaluated almost equivalently as “slightly comfortable” in the morning. The scores of “comfort” in the forest area were “moderately comfortable” after walking and watching. However, the scores of “comfort” in the city were “indifferent” and “slightly uncomfortable” after walking and watching. After walking and watching, the scores of “comfort” in the forest area were significantly higher than those for the city area. In the evening, the scores of “comfort” of the forest area tend to be higher than those for the city area. The results show that the city area was not so uncomfortable. However, the forest area was significantly more comfortable ( $p < 0.01$ ) than the city area. Fig. 5 shows the scores of “calm” for the forest and city areas.

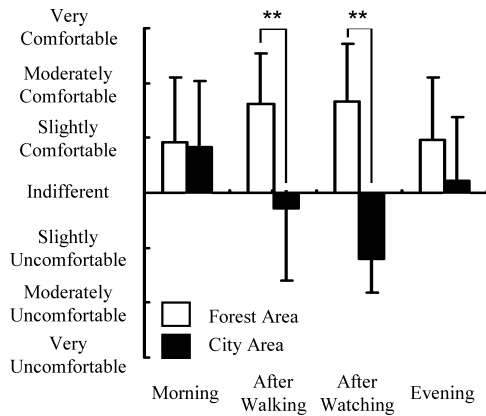


Fig. 4 Change in the subjective “comfort” feeling in forest and city areas, N=12, Mean±SD, \*\*:  $p < 0.01$ , by Wilcoxon signed-rank test

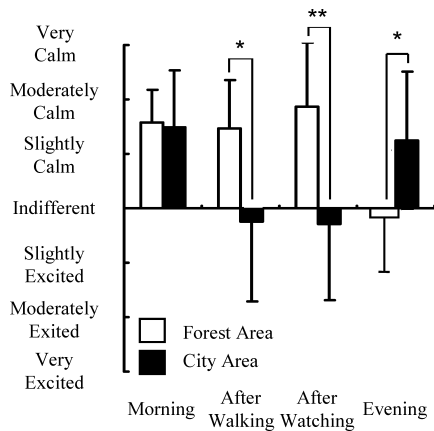


Fig. 5 Change in the subjective “calm” feeling in forest and city areas, N=12, Mean±SD, \*:  $p < 0.05$ , \*\*:  $p < 0.01$  by Wilcoxon signed-rank test

The result of the scores of “calm” shows the same tendency as the result of the “comfort” feelings in the morning, and after walking and watching. In the evening at the place of accommodation, the “calm” scores of the subjects that were sent to the forest area were almost all “indifferent” and the scores of the subjects that were sent to the city area were almost all “slightly calm.” This shows that in the evening, the subjects tended to feel that the place of accommodation was more exciting than the forest area and calmer than the city area.

The results of the physiological effect of Shinrin-yoku are shown in Figs. 6 and 7. Figure 6 shows the average value of the t-Hb (total hemoglobin concentration) in the left prefrontal area. Since t-Hb measurements cannot be taken under bright, sunshiny circumstances, there were several cases where the measurement data could not be obtained either in the city or the forest area. The number of obtained data sets was 5 to 12 depending on the brightness of the moment of measurement. In the morning at the place of accommodation, the t-Hb of the

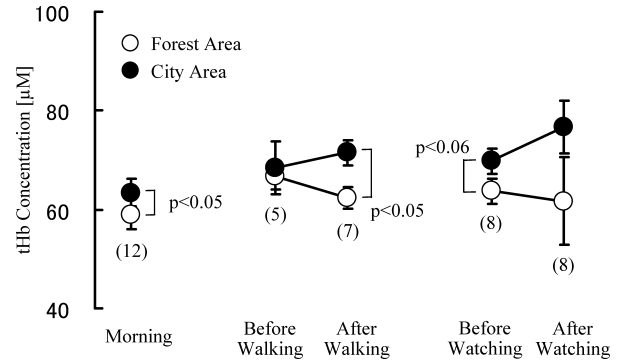


Fig. 6 Change in the average value of the absolute concentration of total hemoglobin in the left prefrontal area in forest and city areas, Mean±SD, The numbers in parentheses indicate the numbers of data,  $p$ -value by one-tailed  $t$ -test

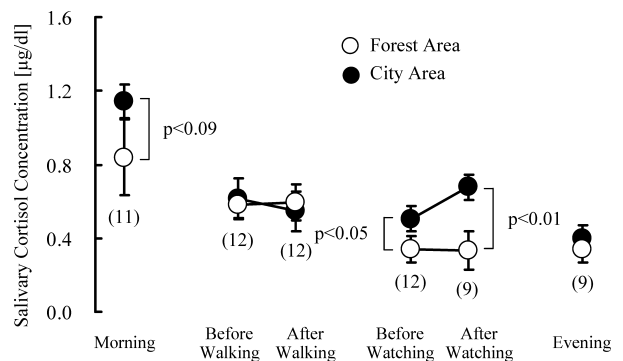


Fig. 7 Change in the average value of the salivary cortisol concentration in forest and city areas, Mean±SD, The numbers in parentheses indicate the numbers of data,  $p$ -value by one-tailed  $t$ -test

subjects who were scheduled to go to the forest area was significantly lower ( $p < 0.05$ ) than that of those of the group scheduled to go to the city area. However, the result of psychological measurements showed no difference between the two subject groups. The t-Hb after walking was significantly lower ( $p < 0.05$ ) in the forest area than that in the city area. Furthermore, t-Hb before watching tended to be lower ( $p < 0.06$ ) in the forest area than that in the city area.

Figure 7 shows the average value of the salivary cortisol concentration in forest and city areas. The results of salivary cortisol concentration showed that it is at its highest in the morning and gradually decreases toward the evening. This result shows the diurnal variation of cortisol. In the morning, at the place of accommodation, the concentration of the salivary cortisol of the subjects who were scheduled to go to the forest area tended to be lower ( $p < 0.09$ ) than that of those of the group scheduled to go to the city area. For reference, in the psychological measurements, the two subject groups stated no difference. The concentration of the salivary cortisol was significantly lower before ( $p < 0.05$ ) and after ( $p < 0.01$ ) watching the forest area compared to that in the city area.

## Discussion

The results of psychological evaluations shows that the subjective “comfort” feeling and “calm” feeling in the forest area were significantly higher than the city area after walking and after watching the landscapes in the given areas. The result of the psychological measurements after walking and watching shows that forest settings are significantly more comfortable and calmer than the city settings. According to Kaplan (1993), natural settings such as forests can serve a restorative function for people suffering from mental fatigue. From that point of view, Shinrin-yoku can be considered to be effective for recovery from the mental fatigue which people suffer.

The results for the absolute concentration of t-Hb showed that the t-Hb of the subjects was significantly decreased in a forest area. In addition, the t-Hb of the subjects who were scheduled to go to a forest area was significantly lower than that of the subjects scheduled to go to an urban area. The decrease in the t-Hb shows there is a reduction in the amount of oxygen delivered to tissues of the prefrontal cortex. This reduction to the prefrontal cortex suggests that cerebral activity at the points measured had subsided. This result implies that Shinrin-yoku has a relaxing effect.

The result showed that the cortisol concentration of the subjects in a forest area was significantly lower than that of the subjects in an urban area before and after watching the landscape. Many previous studies (Kirschbaum and Hellhammer, 1994) have showed that lower levels of stress result in lower concentrations of cortisol. In light of the result of this experiment, it can be presumed that Shinrin-yoku reduces levels of human stress.

## Conclusions

This study estimated the effects of Shinrin-yoku on humans with physiological and psychological indices. The findings were as follows: (1) In the psychological evaluation, walking in and watching the forest area produced significantly more comfortable and significantly calmer feelings than those of the city area. This shows that the forest is a restorative environment for human beings. Activities in the city area were evaluated as between “indifferent” and “moderately uncomfortable” and between “indifferent” and “slightly excited,” which can show that the city area was familiar to the subjects. (2) The t-Hb evaluation showed that Shinrin-yoku lowers the t-Hb of prefrontal areas. It shows that the activity in the cerebral area measured calms down. Even before Shinrin-yoku action, t-Hb was affected. In the morning, the cerebral activity of the subjects who were scheduled to go to the forest area was significantly lower than that of the subjects scheduled to go to the city area, although no significant differences of comfort and calm were observed in the subjective evaluation. (3) In the salivary cortisol concentration evaluation, it is thought that stress levels in the forest area were lower than those in the city area. Similar to t-Hb, salivary cortisol

concentration was affected even before Shinrin-yoku action.

The present study strongly indicates that Shinrin-yoku activities such as walking and watching forested environments can effectively relax people that live in urban surroundings. Shinrin-yoku has the capacity for human well-being and health improvement. Further work in the direction of this study will provide more evidence for this result.

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