SILVA FENNICA

Silva Fennica 43(2) research articles

www.metla.fi/silvafennica · ISSN 0037-5330
The Finnish Society of Forest Science · The Finnish Forest Research Institute

# Physiological Effects of Forest Recreation in a Young Conifer Forest in Hinokage Town, Japan

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**Park, B.J., Tsunetsugu, Y., Kasetani, T., Morikawa, T., Kagawa, T. & Miyazaki, Y.** 2009. Physiological effects of forest recreation in a young conifer forest in Hinokage Town, Japan. Silva Fennica 43(2): 291–301.

It is widely believed that coming into contact with forest environments is somehow beneficial to human well-being and comfort. In Japan, "*Shinrin-yoku*" (taking in the atmosphere of a forest) has been proposed to be a relaxation activity associated with forest recreation. The purpose of this study was to examine the physiological effects of forest recreation on the autonomic nervous activity. The subjects were twelve male university students (21.8 ± 0.8 years old). On the first day of the experiment, six subjects were sent to a forest area, and the other six to a city area. On the second day, each subject was sent to the area he did not visit on the first day as a cross check. The subjects walked (15 minutes) around their assigned areas before noon, and sat on chairs viewing (15 minutes) the landscapes of their assigned areas in the afternoon. Heart rate variability (HRV), blood pressure, and pulse rate were measured as physiological indices. Measurements were taken at the place of accommodation in the morning, before and after walking, and before and after viewing at their assigned field areas. Pulse rate, diastolic blood pressure and LF/(LF+HF) (LF – low frequency, HF – high frequency) components of HRV were significantly lower in the forest area than in the city area. HF components of HRV tended to be higher in the forest than in the city. In conclusion, the results of the physiological measurements show that forest recreation enabled effective relaxation in people, both of the mind and body.

**Keywords** blood pressure, heart rate variability, pulse rate, relaxation, *Shinrin-yoku*, therapeutic effects of forest, well-being
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**Received** 26 June 2008 **Revised** 22 December 2008 **Accepted** 6 April 2009
**Available at** http://www.metla.fi/silvafennica/full/sf43/sf432291.pdf

# 1 Introduction

The growing interest in environmental stress has been accompanied by a rapid accumulation of evidence indicating that environmental stress (e.g. crowding, community noise, air pollution) can exert substantial stress on people living in urban environments (Ulrich et al. 1991). Furthermore, there is the broad perception that the natural environment can enhance human health (Frumkin 2001). There have also been other studies showing that contact with trees and plants in gardens or urban parks makes people calmer and more relaxed (Ulrich 1984, Ulrich et al. 1991, Honeyman 1992, Kellert and Wilson 1993).

According to E.O Wilson's hypothesis of 'biophilia' (1984), humans are innately attracted to other living organisms. Furthermore, the authors of 'The Biophilia Hypothesis' (1993) have expanded this concept, suggesting that humans have an innate bond with nature. This implies that certain kinds of contact with the natural world may benefit human health (Frumkin 2001). Physiological anthropology also suggests that humans have lived in the natural environment for most of the 5 million years of their existence. Therefore, human physiological functions are made for natural settings. This is the reason why a natural environment enhances the relaxation of human beings (Miyazaki et al. 2002).

"*Shinrin-yoku*" can be defined as making contact with and taking in the atmosphere of the forest. In Japan, forest bathing ("*Shinrin-yoku*" in Japanese) is now receiving increased attention for its effects of reducing stress and providing a feeling of relaxation. "*Shinrin-yoku*" is a word that was coined by the Forestry Agency of the Japanese government when it brought out the "*Shinrin-yoku* plan" in 1982. It is a compound word made up of two independent words meaning "forest" and "bathing." Most likely, the word "*Shinrin-yoku*" is intended to convey a concept like sea bathing, of being in a forest environment and taking in the atmosphere of the forest in expectation of a potential curative or therapeutic effect. Over the 25 years since then, interest in stress control and relaxation has increased in Japanese society. In addition to this, in the fields of medicine and nursing, there has been a trend towards evidence-based medicine or nursing, emphasizing scientific evidence in medical practice. Against this social background, in 2004 the Forest Agency came out with the "Therapeutic Effects of Forests plan." This may be thought of as an advanced version of the "*Shinrin-yoku* plan," the major difference being that it emphasizes the importance of scientific investigation. The aim of "Therapeutic Effects of Forests Plan" is to collect data on the relaxation effects of forest environments from the viewpoint of evidence based medicine (EBM). We have collected data to elucidate the effects of physiological relaxation provided by forests using 456 subjects and 38 forests studied over the period of 4 years. The other aim of this plan is to authorize restorative forest environments. One of the main criteria of restorative forest is the physiological effects attributable to the forest environments.

"*Shinrin-yoku*" is a process in which activities in forest environments are used to improve the mental and physical health of people (Park et al. 2007). Given this background, there have also been other reports on "*Shinrin-yoku*". We have reported the physiological relaxation effects of "*Shinrin-yoku*" from the perspective of the autonomic nervous activity and stress hormones (Park et al. 2007, Tsunetsugu et al. 2007, Park et al. 2008). Further, studies have reported that the mode of action of "*Shinrin-yoku*" can be recovery of the immune system as determined from the perspective of natural killer (NK) cells activity (Li et al. 2007, Li et al. 2008a, Li et al. 2008b). Furthermore, Ohtsuka et al. (1998) reported that forest walking effectively decreases blood glucose levels in diabetic patients. Therefore, the study performed by Morita et al. (2006) demonstrated the relaxation effects of "*Shinrin-yoku*" by employing a questionnaire.

The physiological effects of the natural environment have been studied indoors using natural stimuli (visual, odoriferous, etc.) (Ulrich 1981, Ulrich 1984, Miyazaki and Motohashi 1996). The lack of field experiments in the 1980s and 1990s was due to the limitations of physiological measurements in field conditions. Field experiments not only require the movement of the subjects to be restricted to the experiment site, but also require equipment that is difficult to transport and power. However, in the mid-2000s, the physiological measurement technology available for field experiments developed rapidly. Consequently, several studies on the physiological effects of the natural environment in field conditions have been performed recently (Hartig et al. 2003, Park et al. 2007, Tsunetsugu et al. 2007, Park et al. 2008).

In the Europe, COST Action E39 (Forest and Trees & Health and Human Well-being) performed various studies on forest and human health. With this background, studies on forests and human health have been performed extensively in Europe during the past few years (Korpela et al. 2001, Hartig et al. 2003, Herzog et al. 2003, Laumann et al. 2003, Van den Berg et al. 2003, Hartig and Staats 2006).

The autonomic nervous system is a suitable index for clarifying the physiological effects of forest recreation. The autonomic nervous system has been measured by using a variety of methods, such as heart rate variability (HRV), pulse rate, and blood pressure. It is a well-known fact that autonomic nervous activity is a good indicator of human body relaxation. Certain studies have reported that increase in pulse rate and blood pressure under the stress state was employed as relaxation indicators in indoor and field experiments (Ulrich 1981, Ulrich 1984, Miyazaki and Motohashi 1996, Tsunetsugu et al. 2007, Park et al. 2008). Furthermore, HRV can measure parasympathetic and sympathetic nervous activities, which comprise the 2 branches of autonomic nervous activity. Two major spectral components of HRV were calculated, the low frequency (LF: 0.04–0.15Hz) component and the high frequency (HF: 0.15–0.40 Hz) component (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). HF power spectrum of HRV reflects parasympathetic nervous activity (Cacioppo et al. 1994), which increases under the relaxation state, and LF/(LF+HF) of HRV reflects sympathetic nervous activity (Weise and Heydenreich 1989), which increases under the stress state. HRV was employed as a relaxation indicator in field experiments (Tsunetsugu et al. 2007, Park et al. 2008).

Tsunetsugu et al. (2007) reported that in forest areas blood pressure and pulse rate were significantly lower than in city areas. Moreover, the power of HF components of HRV tended to be higher and LF/(LF+HF) tended to be lower in forests than in city settings. Park et al. (2007) reported that cerebral activity in the prefrontal area was significantly lower among the group that stayed in the forest relative to the group that stayed in the city area. Moreover, the concentration of salivary cortisol was significantly lower in the forest than in the city area.

The purpose of this study is to examine the physiological and therapeutic effects of forest recreation by measuring autonomic nervous activity and subjective feelings under field conditions.

# 2 Materials and Methods

### 2.1 Design of the Experiment

The study areas were located in Hinokage Town and Hyuga City in Miyazaki Prefecture. Twelve male university students (21.8 ± 0.8 years of age) participated in the study as subjects. None of the subjects reported a history of physical or psychiatric disorders. The study was performed under the regulations of the Institutional Ethical Committee of the Forestry and Forest Products Research Institute in Japan. On the day prior to the experiments, subjects were fully informed of the aims and procedures of the experiment and their informed consent was obtained. After being given an orientation to the experiment, the subjects visited and previewed the experimental sites in the forest and city areas. Next, practice measurements of all of the physiological indices and subjective feelings were conducted at the place of accommodation. Identical single rooms were prepared as lodgings for each subject and identical meals and water were provided during the experiments in order to control these background environmental conditions.

The subjects were randomly divided into two groups. On the first day of the experiments, six subjects were sent to a forest area, and the other six subjects to a city area. On the second day of the experiments, each subject went to the area he had not visited on the first day in order to do a cross check. The first measurement was taken in the early morning at the place of accommodation before breakfast (Morning; 06:15–07:15). Follow-

**Fig. 1.** The scenery at the two experiment sites. Upper left: viewing the landscape in the forest area. Upper right: walking in the forest area. Lower left: viewing the landscape in the city area. Lower right: walking in the city area.

ing the first measurement, subjects were sent to either the forest or the city area using vehicles. It took an hour to get to both the forest and city areas from the place of accommodation. Upon arrival in the given area, the subjects walked around the given places for 15 minutes (Walking) before noon. The subjects then sat on chairs and viewed the landscapes for 15 minutes (Viewing) in the afternoon (Fig. 1). The second and third measurements were taken before 'Walking' (10:40–11:30) and after 'Walking' (11:00–11:50). The fourth and fifth measurements were taken before 'Viewing' (14:10–15:00) and after 'Viewing' (14:30–15:20). These measurements were taken one person at a time. In addition to these five measurements, the R-R interval was measured continuously during 'Walking' and 'Viewing' at the given place. HRV was calculated once per minute using the time duration between two consecutive R waves (R-R interval) data. The first 10 seconds of the first minute were removed because of the noise generated when starting measurements.

### 2.2 Measurements

R-R interval of the electrocardiogram was measured using a portable electrocardiograph (Activtracer AC-301A, GMS, Japan). Three disk electrodes were attached to the chest to measure the R-R interval. The R-R interval data were analyzed by the maximum entropy method (Memcalc/win; GMS, Japan). It is considered that HF power of HRV reflects parasympathetic nervous activity (Cacioppo et al. 1994) and that LF/(LF+HF) of HRV reflects sympathetic nervous activity (Weise and Heydenreich 1989).

Pulse rate and blood pressure were measured with a digital blood pressure monitor using the oscillometric method (HEM-1000, OMRON, Japan).

In order to compare exercise load during forest and city walking, exercise load was estimated with an activity monitor using 3-dimensional acceleration sensors (Activtracer AC-301A; GMS, Japan). There was no difference in exercise load between

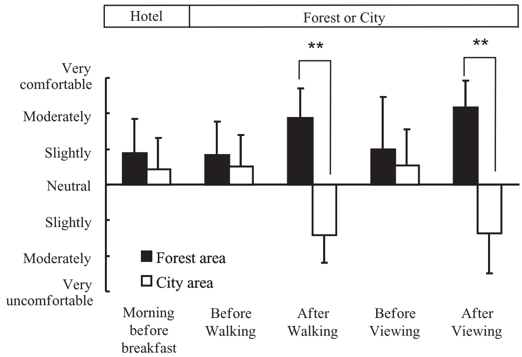


**Fig. 2.** Change in subjective feelings of comfort in forest and city areas. N = 11–12, Mean ± SD, **: $p < 0.01$, by Wilcoxon signed-rank test.

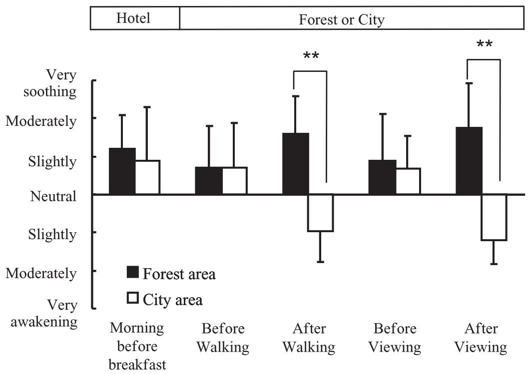


**Fig. 3.** Change in subjective feelings of calm in forest and city areas. N = 11–12, Mean ± SD, **: $p < 0.01$ by Wilcoxon signed-rank test.

forest-area walking and city-area walking.

Sensory evaluation was conducted after physiological measurements at the place of accommodation in the 'Morning', and before 'Walking' and after 'Walking' at the given areas and before 'Viewing' and after 'Viewing' the landscape at the given areas. The subjects were asked to evaluate the given area and to graph it on two 13-point scales along the following two dimensions: 'feeling of comfort' and 'feeling of calm.' The subjects were also asked to answer 30 questions to ascertain the degree to which they felt refreshed (Mackay et al. 1978). The questionnaire consists of 30 items asking, for instance, if the respondent feels sleepy or vigorous. The scale scores ranged from 1 (to a great extent) to 4 (not at all).

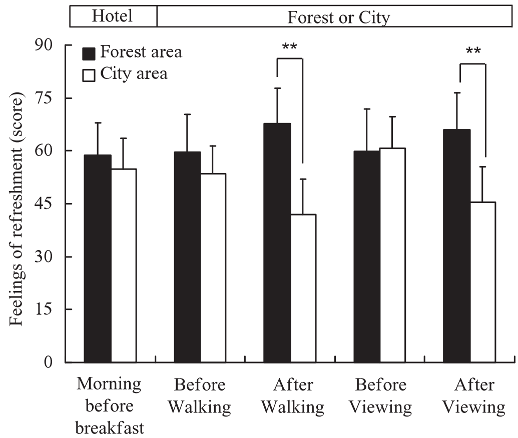


**Fig. 4.** Change in subjective feelings of refreshment in forest and city areas. N = 12, Mean ± SD, **: $p < 0.01$ by Wilcoxon signed-rank test.

A one-tailed t-test was used to compare the physiological responses to the forest and city areas. The Wilcoxon signed-rank test was used to analyze the psychological effect. Statistical analysis of physiological data was processed with EXCEL 2003 (Microsoft Inc.) and subjective data was processed with StatView version 5.5 (SAS Institute Inc.). Moreover, $p < 0.05$ was considered to be significant.

# 3 Results

Figs. 2, 3, and 4 show the results of the psychological assessment to ascertain the effects of forest recreation. Fig. 2 shows the scores for 'feeling of comfort' recorded in the forest and city areas. The score for 'feeling of comfort' in the forest area (Moderately comfortable) was significantly higher ($p < 0.01$) than in the city area (Moderately uncomfortable) at the stage after 'Walking.' At the stage after 'Viewing,' the score for 'feeling of comfort' in the forest setting (Moderately comfortable) was also significantly higher ($p < 0.01$) than in the city setting (Moderately uncomfortable).

Fig. 3 shows the scores for 'feeling of calm' recorded in the forest and city areas. At the stage after 'Walking,' the score for 'feeling of calm'

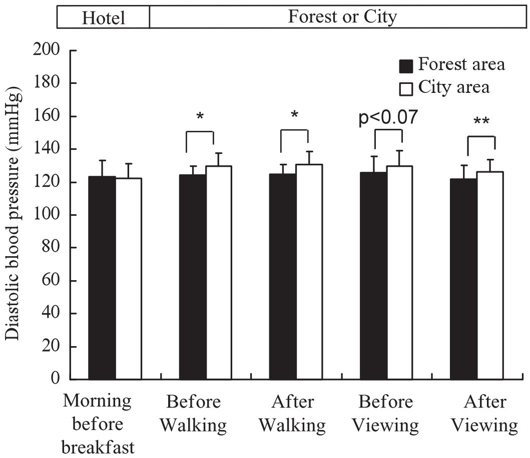


**Fig. 5.** Change in average diastolic blood pressure in forest and city areas. N = 12, Mean ± SD, **: $p < 0.01$, *: $p < 0.05$, p-value by paired t-test.

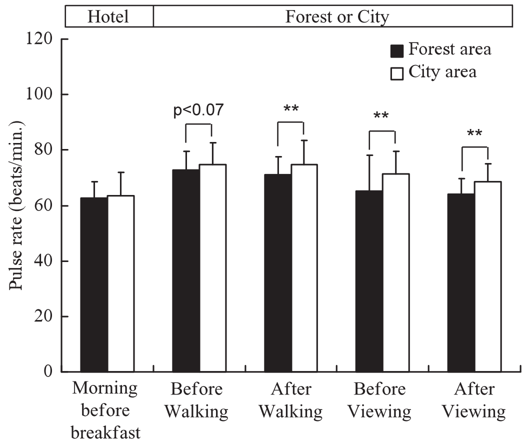


**Fig. 6.** Change in average pulse rate in forest and city areas. N = 12, Mean ± SD, **: $p < 0.01$, p-value by paired t-test.

in the forest area (Moderately soothing) was significantly higher ($p < 0.01$) than for the city area (Slightly awakening). Likewise, the score for 'feeling of calm' in the forest area (Moderately soothing) at the stage after 'Viewing' was significantly higher ($p < 0.01$) than in the city area (Slightly awakening).

Fig. 4 shows the scores for 'feeling of refreshment' recorded in the forest and city areas. The score for 'feeling of refreshment' in the forest area after 'Walking' was significantly higher ($p < 0.01$) than the score in the city area. At the stage after 'Viewing,' the score for 'feeling of refreshment' was also significantly higher ($p < 0.01$) in the forest than in the city area.

Figs. 5, 6, and 7 show the results of physiological assessments to ascertain the effects of forest recreation. Fig. 5 shows the average diastolic blood pressure in both forest and city settings. Diastolic blood pressure was significantly lower in the forest area before 'Walking' ($p < 0.05$), after 'Walking' ($p < 0.05$) and after 'Viewing' ($p < 0.01$) than in the city area. At the stage before 'Viewing,' diastolic blood pressure in the forest area tended to be lower ($p < 0.07$) than in the city area.

Fig. 6 shows the average pulse rate in the forest and city areas. Pulse rate was significantly lower ($p < 0.01$) in the forest area after 'Walking,' before 'Viewing' and after 'Viewing.' At the stage before 'Walking,' pulse rate in the forest area tended to be lower ($p < 0.07$) than in the city area.

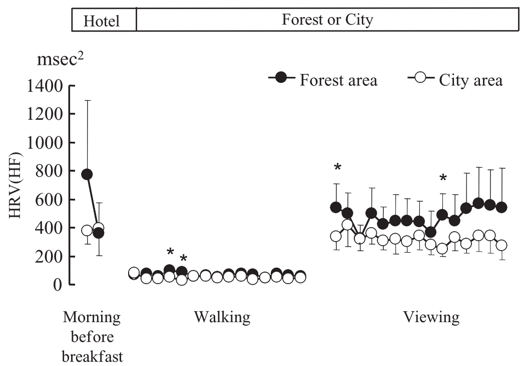


**Fig. 7.** Change in average HF power of HRV per minute in forest and city areas. N = 10–12, Mean ± SE, *: $p < 0.05$, p-value by paired t-test.

Fig. 7 shows the average HF component of HRV every minute. During 'Walking' around the assigned places, the HF component in forest areas tended to be higher than in city areas. Moreover, a significant difference was obtained at 4 minutes and 5 minutes ($p < 0.05$) after the starting point. The HF component tended to be higher than in city areas during 'Viewing' of the landscape, and a significant difference in the HF component between the two areas was obtained

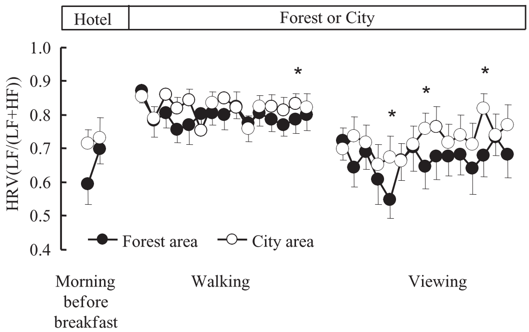


**Fig. 8.** Change in average LF/(LF+HF) of HRV per minute in forest and city areas. N = 10–12, Mean ± SE, *: $p < 0.05$, p-value by paired t-test.

at 1 minute and 10 minutes ($p < 0.05$) after the starting point.

Fig. 8 shows the average LF/(LF+HF) component of HRV every minute. For 'Walking' around the assigned places, the LF/(LF+HF) component in forest areas tended to be lower than in city areas. Moreover, a significant difference was obtained at 14 minutes ($p < 0.05$) after the starting point. The LF/(LF+HF) component was significantly lower in the forest area during 'Viewing' of the landscape, and a significant difference in the LF/(LF+HF) component between the two areas was obtained at 5 minutes, 8 minutes and 13 minutes ($p < 0.05$) after the starting point.

# 4 Discussion

The results of psychological measurements after 'Walking' and after 'Viewing' show that forest settings produced significantly more comfortable, calmer and more refreshed feelings in the subjects than the city setting. On the day prior to the experiments, subjects were fully informed about the aims and procedures of the experiment. If the subject participated without proper information on the aims of the study, especially when he is participating in the measurement for the first time, they could experience nervousness. This is why we informed the subjects about the aim of study prior to the start of the experiments. However, it can affect the results of the self-evaluation report.

The studies of Park et al. (2007), Tsunetsugu et al. (2007) and Park et al. (2008)'s field test have reached the same conclusion. Based on these studies, walking in a forest setting and viewing forest landscapes can be considered to be effective in providing relaxation to people as compared to a city setting. This result strongly supports the results of research about positive emotions among subjects who were shown pictures of natural environments (Blood et al. 1999, Buchanan et al. 2000, Goel and Dolan 2000, Iidaka et al. 2001). This result also supports the finding that forest environments improved the psychological wellness of people (Herzog et al. 1997, Kaplan 1984, 2001, Kaplan and Talbot 1983, Talbot and Kaplan 1986).

Pulse rate and diastolic blood pressure in the forest area were significantly lower than in the city area after 'Walking' and after 'Viewing.' This shows that the forest setting had a significant relaxing effect on the human body compared to city settings. At the stages before 'Walking' and before 'Viewing,' pulse rate and diastolic blood pressure in the forest area were significantly lower or tended to be lower than in the city area. This result suggests that forest settings and city settings already had different impacts on physiological conditions before the activities commenced (Park et al. 2007, Tsunetsugu et al. 2007). The subjects were exposed to given places before walking and viewing; therefore, this kind of exposure affects the difference in blood pressure and pulse rate in subjects before 'Walking,' and before 'Viewing.'

The LF/(LF+HF) component of HRV measurements was significantly lower in the forest area than in the city area when 'Viewing' the landscape. The sympathetic nervous system predominates when a person is stressful. The value of the LF/(LF+HF) component increases when the sympathetic nervous system is activated. We did not know the reason why there is the difference between 1 and 10 minutes in HF and 5, 8 and 13 minutes in LF/(LF+HF). However, we were to show that there was the point showing significant difference and that there was tendency of difference during 15 minutes of walking and watching. In this field test, the result of LF/(LF+HF) components showed that it is easy to ease the human body in the forest setting in comparison to the city setting.

The relationship between respiration and heart rate variability (HRV) has been well-established. Researchers have been advocating the necessity for controlled breathing to avoid respiratory interference with HRV components (Brown et al. 1993, Kobayashi et al. 1999, Camman and Michel 2002). However, it is difficult to apply the technique of controlled breathing in field studies; in this case, HRV is frequently measured under spontaneous breathing conditions. Studies have been conducted on quantitative examinations of the effect of controlled breathing on reliability of HRV measurements. There have also been other studies that reported significant improvements in the reliability of the measurements by controlled breathing (e.g., Carrasco et al. 2003, Pinna et al. 2007); however, others have demonstrated that controlled breathing was not sufficiently effective. Further, in certain cases, controlled breathing decreased the reliability of the measurement (e.g., Reland et al. 2005, Tarkiainen et al. 2005). From the above findings, the necessity for controlled breathing appears to be inconclusive.

To minimize the exclusive effects of walking, we controlled the walking conditions. At first, we set up experimental roads that had no slope. Secondly, prior to the day of the first experiment day, the subjects walked on the forest and city experimental roads. Further, they were asked to maintain the same pace when they walked on forest and city experimental roads. Finally, we checked exercise loads in order to compare the exercise loads during forest and city walking. Exercise load was estimated with an activity monitor using 3-dimensional acceleration sensors (Activtracer AC-301A; GMS, Japan). There was no difference in exercise load between forest-area walking and city-area walking.

The results of physiological measurements strongly supports the result of the indoor research using heart rate and blood pressure on the effect of viewing a forest scene on recovery from stress (Ulrich 1981, Ulrich et al. 1991). The results were also consistent with the finding of Park et al. (2008), which reported physiological effects from "*Shinrin-yoku*" using salivary cortisol, pulse rate and HRV as indicators, Park et al. (2007), which reported physiological effects from forest settings using salivary cortisol and cerebral activity as indicators, and Tsunetsugu et al. (2007), which reported physiological effects from forest environments using salivary cortisol, pulse rate, blood pressure and HRV. Moreover, Yamaguchi et al. (2006), reported exercise effects from forestry using salivary amylase activity.

With respect to the visiting span, there have also been other reports on the relationship between length of visit and recovery of immune function (Li et al. 2007, Li et al. 2008a, Li et al. 2008b). The results of these papers showed that 3-day/2-night stay in the forest setting can aid the recovery of immune function. Furthermore, recovered immune function lasted for more than 7days following a 3-day/2-night stay in the forest.

In addition, the results of physiological measurements showed that the physiological responses of the autonomic nervous system (pulse rate, diastolic blood pressure and HRV) reflected the relaxing effects of forest environments.

During this study, effects from other factors were minimized to clarify the differences in the effect on physiological and psychological relaxation of humans from forestry and urban surroundings. Other surrounding factors such as accommodation, food, water intake or quantity of exercise etc. were controlled so as to be the same and thus to minimize their influence. The subject group was limited to 12 persons so that conditions could be controlled in detail during the study. Subjects were also narrowed down to male students in their early twenties, as the number of subjects was limited. Also, the forests used for field studies were limited to young conifer forests. To remove this limitation, we have conducted experiments of the same design in 38 different types of forest. We also have plans to collect data from 100 more fields with 1200 subjects in Japan. We expect to be able to clarify the differences between the relaxing effects of different forest types when we have finished collecting this data.

In summary, in the forest area, 1) pulse rates were significantly lower; 2) diastolic blood pressure was significantly lower; 3) the HF component tended to be higher; 4) the LF/(LF+HF) component was significantly lower; 5) the subjective 'feeling of comfort,' 'feeling of calm' and 'feeling of refreshment' were significantly higher than in the city area. Furthermore, the autonomic nervous activity measurements proved that the subjects felt more relaxed when viewing or walking in the forest setting than when viewing or walking in the city setting. Further, these values showed that forest recreation had a significant relaxing effect on the human body and mind.

## Acknowledgments

The authors wish to thank Dr. Eeva Karjalainen for her special advice. This study was partly supported by a Grant-in-Aid for Scientific Research (S: 16107007) from The Ministry of Education, Culture, Sports, Science and Technology (MEXT) – Japan.

## References

Blood, A.J., Zatorre, R.J., Bermudez, P. & Evans, A.C. 1999. Emotional responses to pleasant and unpleasant music correlate with activity in paralimbic brain regions. Nature Neuroscience 2: 382–387.

Brown, T.E., Beightol, L.A., Koh, J. & Eckberg, D.L. 1993. Important influence of respiration on human R-R interval power spectra is largely ignored. Journal of Applied Physiology 75(5): 2310–2317.

Buchanan, T.W., Lutz, K., Mirzazade, S., Specht, K., Shah, N.J., Zilles, K. & Jancke, L. 2000. Recognition of emotional prosody and verbal components of spoken language: an fMRI study. Cognitive Brain Research 9: 227–238.

Cacioppo, J.T., Berntson, G.G., Binkley, P.F., Quigley, K.S., Uchino, B.N. & Fieldstone, A. 1994. Autonomic cardiac control II Noninvasive indices and basal response as revealed by autonomic blockades. Psychophysiology 31(6): 586–598.

Cammann, H. & Michel, J. 2002. How to avoid misinterpretation of heart rate variability power spectra? Computer methods and Programs in Biomedicine 68(1): 15–23.

Carrasco, S., Gonzalez, R., Gaitan, M.J. & Yanez, O. 2003. Reproducibility of heart rate variability from short-term recordings during five manoeuvres in normal subjects. Journal of Medical Engineering & Technology 27(6): 241–248.

Frumkin, H. 2001. Beyond toxicity human health and the natural environment. American Journal of Preventive Medicine 20(3): 234–240.

Goel, V. & Dolan, R.J. 2001. The functional anatomy of humor: Segregating cognitive and affective components. Nature Neuroscience 4: 237–238.

Hartig, T., Evans, G.W., Jamner, L.D., Davis, D.S. & Gärling, T. 2003. Tracking restoration in natural and urban field settings. Journal of Environmental Psychology 23: 109–123.

— & Staats, H. 2006. The need for psychological restoration as a determinant of environmental preferences. Journal of Environmental Psychology 26: 215–226.

Herzog, A.M., Black, K.A., Fountaine., D.J. & Knotts, T.R. 1997. Reflection and attentional recovery as two distinctive benefits of restorative environments. Journal of Environmental Psychology 17: 165–170.

Herzog, T.R., Maguire, C.P. & Nebel, M.B. 2003. Assessing the restorative components of environments. Journal of Environmental Psychology 23: 159–170.

Honeyman, M.K. 1992. Vegetation and stress: a comparison study of varying amounts of vegetation in countryside and urban scenes. In: Relf, D. (ed.). The role of horticulture in human well-being and social development. A national symposium, Portland, OR, Timber Press. p. 143–145.

Iidaka, T., Omori, M., Murata, T. & Kosaka, H. 2001. Neural interaction of the amygdala with the prefrontal and temporal cortices in the processing of facial expressions as revealed by fMRI. Journal of Cognitive Neuroscience 13: 1035–1047.

Kaplan, R. 1984. Wilderness perception and psychological benefits: an analysis of a continuing program. Leisure Sciences 6(3): 271–290.

— 2001. The nature of the view from home: Psychological benefits. Environment & Behavior 33(4): 507–542.

Kaplan, S. & Talbot, J.F. 1983. Psychological benefits of a wilderness experience. In: Altman, I. & Wohlwill, J.F. (eds.). Human behavior and environment 6: 163–203. New York, NY: Plenum.

Kellert, S.R. & Wilson, E.O. (ed.). 1993. The biophilia hypothesis. Washington, D.C., Island press. 484 p.)

Kobayashi, H., Ishibashi, K. & Noguchi, H. 1999. Heart rate variability; an index for monitoring and analyzing human autonomic activities. Applied Human Science 18(2): 53–59.

Korpela, K.M., Hartig, T., Kaiser, F.G. & Fuhrer, U. 2001. Restorative experience and self-regulation in favorite places. Environment and Behavior 33(4): 572–589.

Laumann, K., Gärling, T. & Stormark, K.M. 2003. Selective attention and heart rate responses to natural and urban environments. Journal of Environmental Psychology 23: 125–134.

Li, Q., Morimoto, K., Nakadai, A., Inagaki, H., Katsumata, M., Shimizu, T., Hirata, Y., Hirata, K., Suzuki, H., Miyazaki, Y., Kagawa, T., Koyama, Y., Ohira, T., Takayama, N., Krensky, A. M. & Kawada, T. 2007. Forest bathing enhances human natural killer activity and expression of anti-cancer proteins. International Journal of Immunopathology and Pharmacology 20(2): 3–8.

— , Morimoto, K., Kobayashi, M., Inagaki, H., Katsumata, M., Hirata, Y., Hirata, K., Shimizu, T., Li, Y.J., Wakayama, Y., Kawada, T., Ohira, T., Takayama, N., Kagawa, T. & Miyazaki, Y. 2008a. A forest bathing trip increases human natural killer activity and expression of anti-cancer proteins in female subjects. Journal of Biological Regulators & Homeostatic Agents 22(1): 45–55.

— , Morimoto, K., Kobayashi, M., Inagaki, H., Katsumata, M., Hirata, Y., Hirata, K., Suzuki, H., Li, Y.J., Wakayama, Y., Kawada, T., Park, B.J., Ohira, T., Matsui, N., Kagawa, T., Miyazaki, Y. & Krensky, A.M. 2008b. Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins. International Journal of Immunopathology and Pharmacology 21(1): 117–127.

Mackay, C., Cox, T., Burrows, G. & Lazzerini, T. 1978. An inventory for the measurement of self-reported stress and arousal. British Journal of Social and Clinical Psychology 17(3): 283–284.

Miyazaki, Y. & Motohashi, Y. 1996. Forest environment and physiological response. In: New frontiers in health resort medicine. Sapporo, Kokoku Printing Co. Ltd. p. 67–77.

— , Morikawa, T. & Hatakeyama, E. 2002. Nature and comfort. Proceeding of 6th International Congress of Physiological Anthropology. p. 20.

Morita, E., Fukuda, S., Nagano, J., Hamajima, N., Yamamoto, H., Iwai, Y., Nakashima, T., Ohira, H. & Shirakawa, T. 2006. Psychological effects of forest environments on healthy adults: Shinrin-yoku (forest-air bathing, walking) as a possible method of stress reduction. Public Health 121(1): 54–63.

Ohtsuka, Y., Yabunaka, N. & Takayama, S. 1998. Shinrin-yoku (forest-air bathing and walking) effectively decreases blood glucose levels in diabetic patients. International Journal of Biometeorology 41: 125–127.

Park, B.J., Tsunetsugu, Y., Kasetani, T., Hirano, H., Kagawa, T., Sato, M. & Miyazaki, Y. 2007. Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) – using salivary cortisol and cerebral activity as indicators. Journal of Physiological Anthropology 26(2): 123–128.

— , Tsunetsugu, Y., Ishii, H., Furuhashi, S., Hirano, H., Kagawa, T. & Miyazaki, Y. 2008. Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) in a mixed forest in Shinano Town, Japan. Scandinavian Journal of Forest Research 23: 278–283.

Pinna, G.D., Maestri, R., Torunski, A., Danilowicz-Szymanowicz, L., Szwoch, M.La., Rovere, M.T. & Raczak, G. 2007. Heart rate variability measures: a fresh look at reliability. Clinical Science (Lond) 113(3): 131–140.

Reland, S., Ville, N.S., Wong, S., Carrault, G. & Carre, F. 2005. Reliability of heart rate variability in healthy older women at rest and during orthostatic testing. Aging Clinical and Experimental Research 17(4): 316–321.

Talbot, J.F. & Kaplan, S. 1986. Perspective on wilderness: reexamining the value of extended wilderness experiences. Journal of Environmental Psychology 6(3): 177–188.

Tarkiainen, T.H., Timonen, K.L., Tiittanen, P., Hartikainen, J.E., Pekkanen, J., Hoek, G., Ibald-Mulli, A. & Vanninen, E.J. 2005. Stability over time of short-term heart rate variability. Clinical Autonomic Research 15(6): 394–399.

Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. 1996. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Circulation 93(5): 1043–1065.

Tsunetsugu, Y., Park, B.J., Ishii, H., Hirano, H., Kagawa, T. & Miyazaki, Y. 2007. Physiological effects of Shinrin-yoku (taking in the atmosphere of the forest) in an old-growth broadleaf forest in Yamagata prefecture, Japan. Journal of Physiological Anthropology 26(2): 135–142.

Ulrich, R.S. 1981. Natural versus urban scenes: Some psycho-physiological effects. Environment and

Behavior 13: 523–556.
— 1984. View through a window may influence recovery from surgery. Science 224: 420–421.
— , Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A. & Zelson, M. 1991. Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology 11: 201–230.
Van den Berg, A.E., Koole, S.L. & Wulp, N.Y. 2003. Environmental preference and restoration: (how) are they related? Journal of Environmental Psychology 23: 135–146.
Weise, F. & Heydenreich, F. 1989. Effects of modified respiratory rhythm on heart rate variability during active orthostatic load. Biomedica Biochimica Acta 48(8): 549–56.
Wilson, E.O. 1984. Biophilia. Harvard University Press. 111 p.
Yamaguchi, M., Deguchi, M. & Miyazaki, Y. 2006. The effects of exercise in forest and urban environments on sympathetic nervous activity of normal young adults. The Journal of International Medical Research 34: 152–159.

*Total of 44 references*